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2) SOLICITANTE (71)	Nombre: NANOVENTIONS, INC. Dirección: 1050 Northfield Court, Suite 300, Roswell, GA 30076 USA Nacionalidad o domicilio: Roswell, GA, USA Lugar de constitución: GA, USA		IDENTIFICACIÓN C.C. ☐ NIT: ☒ C.E. ☐ OTRO ☐ Cual _____ NÚMERO _____
	Teléfono: _____ Fax: _____ E. Mail: _____		
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ANEXOS

- ☒ Comprobante de pago de la tasa de presentación de la solicitud
- ☐ Comprobante de pago por reivindicación de prioridad
- ☐ Documento que acredite la existencia y representación legal cuando el solicitante sea persona Jurídica
- ☐ Poderes, si fuera el caso
- ☐ Documento de cesión del inventor al solicitante o a su causante
- ☐ Declaraciones
- ☒ Copia de la solicitud Internacional. (Resumen, descripción, reivindicación, Dibujos).
- ☒ Traducción de la solicitud internacional al castellano. (Resumen, descripción, reivindicación, Dibujos)
- ☐ Copia del examen preliminar efectuado por la IPEA
- ☐ De ser el caso, copia del contrato de acceso
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- ☐ De ser el caso, certificado de depósito del material biológico
- ☐ Arte final 12 x 12 y 8 x 8 cm
- ☐ De ser el caso, información sobre otras solicitudes de patente o títulos obtenidos en el extranjero por el mismo titular o su causante, relacionados parcial o totalmente con la invención de esta solicitud.
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11) FIGURA CARACTERÍSTICA:

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(54) Title: MICRO-OPTIC SECURITY AND IMAGE PRESENTATION SYSTEM

(57) Abstract: A film material utilizing a regular two-dimensional array of non-cylindrical lenses to enlarge micro-images, called
icons, to form a synthetically magnified image through the united performance of a multiplicity of individual lens/icon image sys-
tems. The synthetic magnification micro-optic system includes one or more optical spacers (5), a micro-image formed of a periodic
planar array of a plurality of image icons (4) having an axis of symmetry about at least one of its planar axes and positioned on or
next to the optical spacer (5), and a periodic planar array of image icon focusing elements (1) having an axis of symmetry about at
least one of its planar axes, the axis of symmetry being the same planar axis as that of the micro-image planar array (4). A number
of distinctive visual effects, such as three-dimensional and motion effects, can be provided by the present system.

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MICRO-OPTIC SECURITY AND IMAGE PRESENTATION SYSTEM**CROSS-REFERENCE TO RELATED APPLICATIONS**

- This application claims benefit of and priority to US Provisional Patent Application No. 60/524,281 filed on November 21, 2003, US Provisional Patent
- 5 Application No. 60/538,392, filed on January 22, 2004, and US Provisional Patent Application No. 60/_____ filed on November 12, 2004, and where permissible, each of which is incorporated by reference in their entirety.

Field of the Invention

- The present invention relates to a synthetic magnification micro-optic system
- 10 that in an exemplary embodiment is formed as a polymer film. The unusual optical effects provided by the various embodiments of the disclosure can be used as a security device for overt and covert authentication of currency, documents, and products as well as visual enhancement of products, packaging, printed material, and consumer goods.

15 **Background**

- Various optical materials have been employed to provide authentication of currency and documents, to identify and distinguish authentic products from counterfeit products, and to provide visual enhancement of manufactured articles and packaging. Examples include holographic displays, and other image systems
- 20 involving lenticular structures and arrays of spherical micro-lenses. Holographic displays have become prevalent for use with credit cards, drivers' licenses, and clothing tags.

An example of a lenticular structure for document security is disclosed in U.S. Patent 4,892,336 to Kaulic, et al. directed to a security thread for embedding within a

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document to provide anti-falsification measures. The security thread is transparent having a printed pattern on one side, on the opposite side, a lenticular lens structure coordinated with the printed pattern. The lenticular lens structure is described as comprised of a plurality of parallel cylinder lenses, or alternatively spherical or
5 honeycomb lenses.

U.S. Patent 5,712,731 to Drinkwater, et al. discloses a security device that includes an array of micro-images coupled with an array of substantially spherical micro-lenses. The lenses may also be astigmatic lenses. The lenses are each typically 50-250 μm and with a focal length of typically 200 μm .

10 These approaches all suffer from similar drawbacks. They result in a relatively thick structure that is not particularly suitable for use with document authentication. Their use of cylindrical or spherical lenses provides a narrow field of view resulting in fuzzy images and requiring exact and difficult alignment of the focal point of the lenses with the associated images. Additionally, they have not proven
15 particularly effective as security or anti-counterfeiting measures.

In view of these and other deficiencies, a need exists in the industry for secure and visually unique optical materials that can facilitate overt authentication of currency, documents, manufactured articles, and products and for optical materials that provide visual enhancement of manufactured articles, products, and packaging.

20 Summary

The present disclosure relates to a film material that utilizes a regular two-dimensional array of non-cylindrical lenses to enlarge micro-images, called icons herein, and to form a synthetically magnified image through the united performance of a multiplicity of individual lens/icon image systems. The synthetically magnified

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images and the background surrounding them can be either colorless or colored, and either or both the images and the background surrounding them can be transparent, translucent, pigmented, fluorescent, phosphorescent, display optically variable color, metallized, or substantially retroreflective. The material displaying colored images on

5 a transparent or tinted background is particularly well suited for use in combination with underlying printed information. When a piece of such material is applied over printed information both the printed information and the images are seen at the same time in spatial or dynamic motion relationship to each other. Material of this kind can also be overprinted, i.e. have print applied to the uppermost (lens) surface of the

10 material. Alternatively, the material displaying colored images (of any color, including white and black) on a translucent or substantially opaque background of different color is particularly well suited for stand-alone use or with overprinted information, not in combination with underlying printed information.

The magnitude of the synthetic magnification achieved can be controlled by

15 the selection of a number of factors, including the degree of 'skew' between the axes of symmetry of the lens array and the axes of symmetry of the icon array. Regular periodic arrays possess axes of symmetry that define lines that the pattern could be reflected around without changing the basic geometry of the pattern, that in the ideal of arrays are infinite in extent. A square array, for example, can be reflected around

20 any diagonal of any square without changing the relative orientation of the array: if the sides of the squares are aligned with the x and y axes of the plane, then the sides of the squares will still be aligned with those axes after reflection, with the assumption that all sides are identical and indistinguishable.

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Instead of mirroring the square array the array can be rotated through an angle equal to the angle between the axes of symmetry of the same type. In the case of a square array the array can be rotated through an angle of 90 degrees, the angle between diagonals, to arrive at an array orientation which is indistinguishable from the original array. Similarly, an array of regular hexagons can be mirrored or rotated about a number of axes of symmetry, including the "diagonals" of the hexagon (the lines connecting opposite vertices) or "midpoint divisors" (lines that connect between the center points of faces on opposite sides of the hexagon). The angle between the axes of symmetry of either type is sixty degrees (60°) results in an array orientation that is indistinguishable from the original orientation.

If a lens array and an icon array are initially arranged with their planar dimensions defining their respective x-y plane, one of the axes of symmetry being chosen to represent the x axis of the first array, the corresponding type of axis of symmetry (for example, diagonal axis of symmetry) being chosen to represent the x axis of the second array, with the two arrays separated by a substantially uniform distance in the z axis direction, then the arrays are said to have zero skew if the x axes of the arrays appear to be parallel to each other when the arrays are viewed along the z axis direction. In the case of hexagonal arrays, rotation of one array through an angle of 60 degrees, or multiples thereof, puts the arrays in alignment again, so there is no skew, just as there is no skew for a rotation of 90 degrees, or multiples thereof, in the case of square arrays. Any angular misalignment between the x axes that is different from these "zero skew rotations" is called the skew. A small skew, such as 0.06 degree, can create a large magnification, in excess of 1,000x, and a large skew, such as 20 degrees produces a small magnification, potentially as small as 1x. Other

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factors, such as the relative scales of the two arrays and the $F\#$ of the lens, can affect both the magnification of the synthetic image as well as its rotation, orthoparallactic movement, and apparent visual depth.

There are a number of distinct visual effects that can be provided by the present material (subsequently referred to as "Unison" for the material in general, or by the names "Unison Motion", "Unison Deep", "Unison SuperDeep", "Unison Float", "Unison SuperFloat", "Unison Levitate", "Unison Morph", and "Unison 3-D" for Unison material presenting those respective effects), and their various embodiments producing each of these effects, generally described as follows:

Unison Motion presents images that show orthoparallactic movement (OPM) - when the material is tilted the images move in a direction of tilt that appears to be perpendicular to the direction anticipated by normal parallax. Unison Deep and SuperDeep present images that appear to rest on a spatial plane that is visually deeper than the thickness of the material. Unison Float and SuperFloat present images that appear to rest on a spatial plane that is a distance above the surface of the material; and Unison Levitate presents images that oscillate from Unison Deep (or SuperDeep) to Unison Float (or SuperFloat) as the material is rotated through a given angle (e.g. 90 degrees), then returning to Unison Deep (or SuperDeep) again as the material is further rotated by the same amount. Unison Morph presents synthetic images that change form, shape, or size as the material is rotated or viewed from different viewpoints. Unison 3-D presents images that show large scale three-dimensional structure, such as an image of a face.

Multiple Unison effects can be combined in one film, such as a film that incorporates multiple Unison Motion image planes that can be different in form,

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color, movement direction, and magnification. Another film can combine a Unison Deep image plane and a Unison Float image plane, while yet another film can be designed to combine Unison Deep, Unison Motion, and Unison Float layers, in the same color or in different colors, those images having the same or different graphical elements. The color, graphical design, optical effect, magnification, and other visual elements of multiple image planes are largely independent; with few exceptions, planes of these visual elements can be combined in arbitrary ways.

For many currency, document and product security applications it is desirable that the total thickness of the film be less than 50 microns, (also referred to herein as "μ", or "um"), for example less than about 45 microns, and as a further example in the range of about 10 microns to about 40 microns. This can be accomplished, for example, through the use of focusing elements having an effective base diameter of less than 50 microns, as a further example less than 30 microns, and as yet a further example, from about 10 microns to about 30 microns. As another example, a focusing element having a focal length of less than about 40 microns, and as a further example having a focal length of about 10 to less than about 30 microns, can be used. In a particular example focusing elements having a base diameter of 35 microns and a focal length of 30 microns can be used. An alternate, hybrid refractive/diffractive embodiment, can be made as thin as 8 microns.

The films herein are highly counterfeit resistant because of their complex multi-layer structure and their high aspect-ratio elements that are not amenable to reproduction by commonly available manufacturing systems.

of a polymer film having a thickness that when viewed by unaided eye(s) in reflective or transmitted light projects one or more images that:

- i. show orthoparallactic movement (Unison Motion);
- 5 ii. appear to lie on a spatial plane deeper than the thickness of the polymer film (Unison Deep and Unison SuperDeep);
- iii. appear to lie on a spatial plane above a surface of the polymer film (Unison Float and Unison SuperFloat);
- iv. oscillate between a spatial plane deeper than the thickness of
10 the polymer film and a spatial plane above a surface of the film as the film is azimuthally rotated (Unison Levitate);
- v. transform from one form, shape, size, color (or some combination of these properties) into a different form, shape, size, or color (or some combination of these properties) (Unison Morph); and/or
- 15 vi. appear to have realistic three-dimensionality (Unison 3-D).

The present disclosure more particularly provides a synthetic magnification micro-optic system and method of making the same comprising:

- (a) one or more optical spacers;
- (b) a micro image comprised of a periodic planar array of a plurality of image
20 icons having an axis of symmetry about at least one of its planar axes, and positioned on or next to the optical spacer, and
- (c) a periodic planar array of image icon focusing elements having an axis of symmetry about at least one of its planar axes, the axis of symmetry being the same planar axis as that of the micro image planar array, each focusing element being either

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Thus, the present system provides a micro-optic system preferably in the form

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a polygonal base multi-zonal focusing element, a lens providing an enlarged field of view over the width of the associated image icon so that the peripheral edges of the associated image icon do not drop out of view, or an aspheric focusing element having an effective diameter of less than 50 microns.

- 5 The system can include one or more of the aforementioned effects. A method is provided by which said effects can be selectively included within the system.

 The present disclosure further provides a security device suitable for at least partial incorporation in or on, and for use on or in association with, a security document, label, tear tape, tamper indicating device, sealing device, or other
10 authentication or security device, which comprises at least one micro-optic system, as defined above. More particularly the present disclosure provides a document security device and method of making the same comprising:

- (a) one or more optical spacers;
- (b) a micro image comprised of a periodic planar array of a plurality of image
15 icons having an axis of symmetry about at least one of its planar axes, and positioned on or next to the optical spacer; and
- (c) a periodic planar array of image icon focusing elements having an axis of symmetry about at least one of its planar axes, the axis of symmetry being the same planar axis as that of the micro image planar array, each focusing element being either
20 a polygonal base multi-zonal focusing element, a lens providing an enlarged field of view over the width of the associated image icon so that the peripheral edges of the associated image icon do not drop out of view, or an aspheric focusing element having an effective diameter of less than 50 microns.

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Additionally, the present disclosure provides a visual enhancement device which comprises at least one micro-optic system, as defined above and having the above described effects, for visual enhancement of clothing, skin products, documents, printed matter, manufactured goods, packaging, point of purchase displays, publications, advertising devices, sporting goods, financial documents and transaction cards, and all other goods.

Also provided is a security document or label having at least one security device, as defined above, at least partially embedded therein and/or mounted thereon.

Other features and advantages of the present disclosure will be apparent to one of ordinary skill from the following detailed description and accompanying drawings.

Other systems, devices, methods, features, and advantages will be or become apparent to one with skill in the art upon examination of the following drawings and detailed description. It is intended that all such additional systems, methods, features, and advantages be included within this description, be within the scope of the present disclosure, and be protected by the accompanying claims.

Unless otherwise defined, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this invention belongs. All publications, patent applications, patents and other references mentioned herein are incorporated by reference in their entirety. In case of conflict, the present specification, including definitions, will control. In addition, the materials, methods, and examples are illustrative only and not intended to be limiting.

Brief Description of the Figures:

Many aspects of the disclosure can be better understood with reference to the drawings. The components in the drawings are not necessarily to scale, emphasis

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instead being placed upon clearly illustrating the principles of the present disclosure. Moreover, in the drawings, like reference numerals designate corresponding parts throughout the several views.

Fig. 1a is a cross-section of a micro-optic system exemplifying one
5 embodiment of the present disclosure providing orthoparallactic movement of the images of the system.

Fig. 1b is an isometric cutaway view of the embodiment of Fig. 1a.

Fig. 2a illustrates an orthoparallactic synthetic image motion effect of the
embodiment of Figs. 1a-b.

10 Figs. 2 b-c illustrate the visual effects of the Deep and Float embodiments of the present system.

Figs. 2 d-f illustrate the visual effects obtained by rotation of a Levitate
embodiment of the present system.

Figs. 3 a-i are plan views showing various embodiments and fill-factors of
15 different patterns of symmetric two dimensional arrays of lenses of the present system.

Fig. 4 is a graph illustrating different combinations of Deep, Unison, Float,
and Levitate embodiment effects produced by variation of the icon element
period/lens period ratio.

20 Figs. 5 a-c are plan views illustrating how the synthetic magnification of the icon images can be controlled by the relative angle between the lens array and icon array axes of the present system.

Figs. 6 a-c are plan views illustrating an embodiment accomplishing a
morphing effect of synthetically magnified images of the present system.

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Figs. 7 a-c are cross-sections showing various embodiments of the icon layer of the present system.

Figs. 8 a-b are plan views illustrating both 'positive' and 'negative' icon element embodiments.

5 Fig. 9 is a cross-section view illustrating an embodiment of a multi-level material for creating regions of a synthetically magnified image having different properties.

10 Fig. 10 is a cross-section view illustrating another embodiment of a multi-level material for creating regions of a synthetically magnified image having different properties.

Figs. 11 a-b are cross-section views showing reflective optics and pinhole optics embodiments of the present system.

15 Figs. 12 a-b are cross-section views comparing the structures of an all-refractive material embodiment with a hybrid refractive/reflective material embodiment.

Fig. 13 is a cross-section view showing a 'peel-to-reveal' tamper-indicating material embodiment.

Fig. 14 is a cross-section view illustrating a 'peel-to-change' tamper-indicating material embodiment.

20 Figs. 15 a-d are cross-section views showing various embodiments of two-sided systems.

Figs. 16 a-f are cross-section views and corresponding plan views illustrating three different methods for creating grayscale or tonal icon element patterns and subsequent synthetically magnified images by the present system.

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Figs. 17 a-d are cross-section views showing the use of the present system in conjunction with printed information.

Figs. 18 a-f are cross-section views illustrating the application of the present system to, or incorporation into, various substrates and in combination with printed
5 information.

Figs. 19 a-b are cross-section views comparing the in-focus field of view of a spherical lens with that of a flat field aspheric lens when each are incorporated into the present system.

Figs. 20 a-c are cross-section views illustrating two benefits of utility which
10 result from the use of a thick icon layer in the present system.

Fig. 21 is a plan view that shows the application of the present system to currency as a "windowed" security thread.

Fig. 22 illustrates the orthoparallactic motion embodiment of the present system of images in connection with a "windowed" security thread.

15 Fig. 23 illustrates half-toning a synthetic image of the present system.

Fig. 24a illustrates use of the present system to create combined synthetic images that are smaller in dimension than the smallest feature of the individual synthetic images.

Fig. 24b illustrates use of the present system to create narrow patterns of gaps
20 between icon image elements.

Fig. 25 illustrates incorporation of covert, hidden information into icon images of the present system.

Fig. 26 illustrates creating fully three-dimensional images with the present system.

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Fig. 27 illustrates the method for designing icon images for the three-dimensional embodiment of Fig. 26.

Fig. 28 illustrates the icon image resulting from the method of Fig. 27.

Fig. 29 illustrates how the method of Fig. 27 can be applied to a complex
5 three-dimensional synthetic image.

Fig. 30 illustrates the central zone focal properties of an exemplary hexagonal base multi-zonal lens having an effective diameter of 28 microns.

Fig. 31 illustrates the central zone focal properties of a spherical lens having a diameter of 28 microns.

Fig. 32 illustrates the performance of the side zones of the hexagonal lens of
10 Fig. 30.

Fig. 33 illustrates the performance of the outer zones of the spherical lens of Fig. 31.

Detailed Description of the Embodiments

15 Reference is now made in detail to the description of the embodiments as illustrated in the figures. While several embodiments are described in connection with these figures, there is no intent to limit the invention to the embodiment or embodiments disclosed herein. On the contrary, the intent is to cover all alternatives, modifications, and equivalents.

20 Fig. 1a illustrates one embodiment of the present micro-optic system 12 providing orthoparallactic movement of the images of the system.

The system 12 micro-lenses 1 that have at least two substantially equal axes of symmetry and that are arranged in a two-dimensional periodic array. Lens diameter 2 is preferably less than 50 μ and the interstitial space between lenses 3 is preferably 5 μ

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or less. (We use the terms " μ " and " μm " interchangeably to mean the same measurement). Micro-lens 1 focuses an image of icon element 4 and projects this image 10 toward a viewer. The system is commonly used in situations having normal levels of ambient lighting, so the illumination of the icon images arises from reflected or transmitted ambient light. Icon element 4 is one element of a periodic array of icon elements having periods and dimensions substantially similar to those of the lens array including lens 1. Between the lens 1 and the icon element 4 is an optical spacer 5, which may be contiguous with the lens 1 material or may optionally be a separate substrate 8 – in this embodiment the lenses 9 are separate from the substrate. The icon elements 4 may be optionally protected by a sealing layer 6, preferably of a polymer material. Sealing layer 6 may be transparent, translucent, tinted, pigmented, opaque, metallic, magnetic, optically variable, or any combination of these that provide desirable optical effects and/or additional functionality for security and authentication purposes, including support of automated currency authentication, verification, tracking, counting and detection systems, that rely on optical effects, electrical conductivity or electrical capacitance, magnetic field detection.

The total thickness 7 of the system is typically less than 50μ ; the actual thickness depends on the P# of the lenses 1 and the diameter of the lenses 2, and the thickness of additional security feature or visual effect layers. The repeat period 11 of the icon elements 4 is substantially identical to the repeat period of the lenses 1; the "scale ratio", the ratio of the repeat period of the icons to the repeat period of the lenses, is used to create many different visual effects. Axially symmetric values of the scale ratio substantially equal to 1.0000 result in Unison Motion orthoparallactic effects when the symmetry axes of the lenses and the icons are misaligned, axially

29%

symmetric values of the scale ratio less than 1.0000 result in Unison Deep and Unison SuperDeep effects when the symmetry axes of the lenses and the icons are substantially aligned, and axially symmetric values of the scale ratio greater than 1.0000 result in Unison Float and Unison SuperFloat effects when the symmetry axes of the lenses and the icons are substantially aligned. Axially asymmetric values of the scale ratio, such as 0.995 in the X direction and 1.005 in the Y direction, result in Unison Levitate effects.

Unison Morph effects can be obtained by scale distortions of either or both the lens repeat period and the icon repeat period, or by incorporating spatially varying information into the icon pattern. Unison 3-D effects are also created by incorporating spatially varying information into the icon pattern, but in this embodiment the information represents different viewpoints of a three dimensional object as seen from specific locations substantially corresponding to the locations of the icons.

Fig. 1b presents an isometric view of the present system, as depicted in cross-section in Fig. 1a, having square array patterns of lenses 1 and icons 4 of repeat period 11 and optical spacer thickness 5 (Fig. 1a is not specific to a square array pattern, but is a representative cross-section of all regular periodic array patterns). The icon elements 4 are shown as "S" images, clearly seen in the cut-away section at the front. While there is substantially a one-to-one correspondence between lenses 1 and icon elements 4, the axes of symmetry of the lens array will not, in general, be exactly aligned with the axes of symmetry of the icon array.

In the case of the Unison (orthoparallactic motion) material embodiment of Figs. 1a-b with a scale ratio of 1.0000, when the lens 1 axes and icon elements 4 axes

are substantially aligned, the resulting synthetic images of the icon elements (in this example, a giant "\$") "blow-up" and are magnified by a factor that theoretically approaches infinity. Slight angular misalignment of the lens 1 axes and icon elements 4 axes reduces the magnification factor of the synthetic images of the icon elements and causes the magnified synthetic images to rotate.

The synthetic magnification factor of Unison Deep, Unison Float, and Unison Levitate embodiments depends on the angular alignment of the lens 1 axes and the icon elements 4 axes as well as the scale ratio of the system. When the scale ratio is not equal to 1.0000 the maximum magnification obtained from substantial alignment of these axes is equal to the absolute value of $1/(1.0000 - (\text{scale ratio}))$. Thus a Unison Deep material having a scale ratio of 0.995 would exhibit a maximum magnification of $|1/(1.000 - 0.995)| = 200x$. Similarly, a Unison Float material having a scale ratio of 1.005 would also exhibit a maximum magnification of $|1/(1.000 - 1.005)| = 200x$. In a manner similar to the Unison Motion material embodiment, slight angular misalignment of the lens 1 axes and icon elements 4 axes of the Unison Deep, Unison Float, and Unison Levitate embodiments reduces the magnification factor of the synthetic images of the icon elements and causes the magnified synthetic images to rotate.

The synthetic image produced by a Unison Deep or SuperDeep icon pattern is upright with respect to the orientation of the Unison Deep or SuperDeep icon pattern, while the synthetic image produced by a Unison Float or SuperFloat icon pattern is upside down, rotated one hundred and eighty degrees (180°) with respect to the orientation of the Unison Float or Super Float icon pattern.

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Fig. 2a schematically depicts the counter-intuitive orthoparallactic image motion effects seen in the Unison Motion embodiment. The left side of Fig. 2a depicts a piece of Unison Motion material 12 in plan view being oscillated 18 about horizontal axis 16. If the synthetically magnified image 14 moved according to parallax, it would appear to be displaced up and down (as shown in Fig. 2a) as the material 12 was oscillated around the horizontal axis 16. Such apparent parallax motion would be typical of real objects, conventional print, and holographic images. Instead of exhibiting parallax motion, synthetically magnified image 14 shows orthoparallactic motion 20 – motion which is perpendicular to the normally expected parallax motion direction. The right side of Fig. 2a depicts a perspective view of a piece of material 12 exhibiting the orthoparallactic motion of a single synthetically magnified image 14 as it is oscillated 18 about horizontal rotational axis 16. The dotted outline 22 shows the position of the synthetically magnified image 14 after it has moved to the right by orthoparallax and the dotted outline 24 shows the position of the synthetically magnified image 14 after it has moved to the left by orthoparallax.

The visual effects of the Unison Deep and Unison Float embodiments are isometrically depicted in Figs. 2 b,c. In Fig. 2b, a piece of Unison Deep material 26 presents synthetically magnified images 28 that stereoscopically appear to lie beneath the plane of the Unison Deep material 26 when viewed by the eyes of the observer 30. In Fig. 2c, a piece of Unison Float material 32 presents synthetically magnified images 34 that stereoscopically appear to lie above the plane of the Unison Float material 34 when viewed by the eyes of the observer 30. The Unison Deep and Unison Float effects are visible from all azimuthal viewing positions and over a wide

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range of elevation positions, from vertical elevation (such that the line of sight from the eyes of the observer 30 to the Unison Deep material 26 or Unison Float material 32 is perpendicular to the surface of the materials) down to a shallow elevation angle which is typically less than 45 degrees. The visibility of the Unison Deep and Unison
5 Float effects over a wide range of viewing angles and orientations provides a simple and convenient method of differentiating Unison Deep and Unison Float materials from simulations utilizing cylindrical lenticular optics or holography.

The Unison Levitate embodiment effect is illustrated in Figs. 2 d-f by isometric views showing the stereoscopically perceived depth position of a
10 synthetically magnified image 38 in three different azimuthal rotations of the Unison Levitate material 36 and the corresponding plan view of the Unison Levitate material 36 and synthetically magnified image 38 as seen by the eyes of the observer 30. Fig. 2d depicts the synthetically magnified image 38 (hereafter referred to as 'the image') as stereoscopically appearing to lie in a plane beneath the Unison Levitate material 36
15 when said material is oriented as shown in the plan view. The heavy dark line in the plan view serves as an azimuthal orientation reference 37 for the sake of explanation. Note that in Fig. 2d the orientation reference 37 is aligned in a vertical direction and the image 38 is aligned in a horizontal direction. The image 38 appears in the Unison Deep position because the scale ratio is less than 1.000 along a first axis of the Unison
20 Levitate material 36 that is aligned substantially parallel to a line connecting the pupils of the observer's two eyes (this will be hereafter called the 'stereoscopic scale ratio'). The stereoscopic scale ratio of the Unison Levitate material 36 is greater than 1.000 along a second axis perpendicular to this first axis, thereby producing a Unison Float effect of the image 38 when the second axis is aligned substantially parallel to a

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line connecting the pupils of the observer's eyes, as shown in Fig. 2f. Note that the orientation reference 37 is in a horizontal position in this figure. Fig. 2e depicts an intermediate azimuthal orientation of the Unison Levitate material 36 that produces a Unison Motion orthoparallactic image effect because the stereoscopic scale ratio in this azimuthal orientation is substantially 1.000.

The visual effect of a Unison Levitate image 38 moving from beneath the Unison Levitate material 36 (Fig. 2d) up to the level of the Unison Levitate material 36 (Fig. 2e) and further up above the level of the Unison Levitate material 36 (Fig. 2f) as the material is azimuthally rotated can be enhanced by combining the Unison Levitate material 36 with conventionally printed information. The unchanging stereoscopic depth of the conventional print serves as a reference plane to better perceive the stereoscopic depth movement of the images 38.

When a Unison material is illuminated by a strongly directional light source such as a 'point' light source (ex: a spotlight or an LED flashlight) or a collimated source (ex: sunlight), "shadow images" of the icons may be seen. These shadow images are unusual in many ways. While the synthetic image presented by Unison does not move as the direction of illumination is moved, the shadow images produced do move. Furthermore, while the Unison synthetic images may lie in different visual planes than the plane of the material, the shadow images always lie in the plane of the material. The color of the shadow image is the color of the icon. So black icons create black shadow images, green icons create green shadow images, and white icons create white shadow images.

The movement of the shadow image as the angle of illumination moves is tied to the specific depth or motion Unison effect in a way that parallels the visual effect

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present in the synthetic image. Thus the movement of a shadow image as the angle of the light is altered parallels the movement that the synthetic image shows when the angle of view is altered. In particular:

Motion shadow images move orthoparallactically as the light source is moved.

5 Deep shadow images move in the same direction as the light source.

Float shadow images move opposite to the direction of the light source.

Levitate shadow images move in directions that are a combination of the above:

10 Levitate Deep shadow images move in the same direction as the light in the left-right direction, but opposite from the direction of the light in the up-down direction; Levitate Float shadow images move opposite to the light in the left right direction but in the same direction as the light in the up-down direction; Levitate Motion shadow images show orthoparallactic motion with respect to the light movement.

15 Unison Morph shadow images show morphing effects as the light source is moved.

Additional unusual shadow image effects are seen when a diverging point light source, such as an LED light, is moved toward and away from a Unison film. When the light source is further away its diverging rays more closely approximate
20 collimated light, and the shadow images produced by Deep, SuperDeep, Float, or SuperFloat Unison synthetic images appear approximately the same size as the synthetic images. When the light is brought closer to the surface the shadow images of Deep and SuperDeep materials shrink because the illumination is strongly divergent, while the shadow images of Float and SuperFloat materials expand.

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Illuminating these materials with converging illumination causes Deep and SuperDeep shadow images to enlarge to a size greater than the synthetic images, while Float and SuperFloat shadow images shrink.

The shadow images of Unison motion material do not change scale significantly as the convergence or divergence of illumination is changed, rather, the shadow images rotate about the center of illumination. Unison Levitate shadow images shrink in one direction and enlarge in the perpendicular direction when the convergence or divergence of the illumination is changed. Unison Morph shadow images change in ways specific to the particular Morph pattern as the convergence or divergence of the illumination is changed.

All of these shadow image effects can be used as additional authentication methods for Unison materials utilized for security, anti-counterfeiting, brand protection applications, and other similar applications.

Figs. 3 a-i are plan views showing various embodiments and fill-factors of different patterns of symmetric two-dimensional arrays of micro-lenses. Figs. 3a, d and g depict micro-lenses 46, 52, and 60, respectively, that are arranged in regular hexagonal array pattern 40. (The dashed array pattern lines 40, 42, and 44 indicate the symmetry of the pattern of lenses but do not necessarily represent any physical element of the lens array.) The lenses of Fig. 3a have substantially circular base geometry 46, the lenses of Fig. 3g have substantially hexagonal base geometries 60, and the lenses of Fig. 3d have intermediate base geometries which are rounded-off hexagons 52. A similar progression of lens geometries applies to the square array 42 of lenses 48, 54, and 62, wherein these lenses have base geometries which range from substantially circular 48, to rounded-off square 54, to substantially square 62, as seen

in Figs. 3b, e, and h. Correspondingly, the equilateral triangular array 44 holds lenses having base geometries that range from substantially circular 50, to rounded-off triangle 58, to substantially triangular 64, as seen in Figs. 3c, f and i.

The lens patterns of Figs. 3 a-i are representative of lenses that can be used
5 for the present system. The interstitial space between the lenses does not directly contribute to the synthetic magnification of the images. A material created using one of these lens patterns will also include an array of icon elements that is arranged in the same geometry and at approximately the same scale, allowing for differences in scale utilized to produce Unison Motion, Unison Deep, Unison Float, and Unison Levitate
10 effects. If the interstitial space is large, such as is shown in Fig. 3c, the lenses are said to have a low fill-factor and the contrast between the image and the background will be reduced by light scattered from icon elements. If the interstitial spaces are small the lenses are said to have a high fill-factor and the contrast between the image and the background will be high, providing the lenses themselves have good focal
15 properties and icon elements are in the lenses' focal planes. It is generally easier to form high optical quality micro-lenses with a circular or nearly circular base than with a square or triangular base. A good balance of lens performance and minimizing of interstitial space is shown in Fig. 3d; a hexagonal array of lenses having base geometries that are rounded hexagons.

20 Lenses having a low F# are particularly suitable for use in the present system. By low F# we mean less than 4, and in particular for Unison Motion approximately 2 or lower. Low F# lenses have high curvature and a correspondingly large sag, or center thickness, as a proportion of their diameter. A typical Unison lens, with an F# of 0.8, has a hexagonal base 28 microns wide and a center thickness of 10.9 microns.

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A typical Drinkwater lens, with a diameter of 50 microns and a focal length of 200 microns, has an F# of 4 and a center thickness of 3.1 microns. If scaled to the same base size, the Unison lens has a sag almost six times larger than the Drinkwater lens.

We have discovered that polygonal base multi-zonal lenses, for example

5 hexagonal base multi-zonal lenses, have important and unexpected advantages over circular base spherical lenses. As explained above, hexagonal base multi-zonal lenses significantly improve manufacturability by virtue of their stress-relieving geometry, but there are additional unexpected optical benefits obtained through the use of hexagonal base multi-zonal lenses.

10 We refer to these lenses as multi-zonal because they possess three optical zones that each provide a different and unique benefit to the subject invention. The three zones are the central zone (constituting approximately half of the area of the lens), the side zones, and the corner zones. These polygonal lenses have an effective diameter that is the diameter of a circle drawn inside the corner zones around the
15 central zone and including the side zones.

The central zone of the hexagonal base multi-zonal lens of the subject invention has an aspheric form (for example, having the form defined by [$y = (5.1316E)X^4 - (0.01679)X^3 + (0.124931)X + 11.24824$] for a 28 micron diameter lens with a nominal 28 micron focal length) that brings light to a focus at
20 least as well as a spherical surface having the same diameter and focal length. Figure 30 illustrates the central zone 780 focal properties 782 of a nominal 28 micron diameter hexagonal base multi-zonal lens 784 with a nominal 28 micron focal length in a polymer substrate 786 (lens and substrate $n=1.51$) and Figure 31 illustrates the central zone 788 focal properties 790 of a 28 micron diameter spherical lens 792 with

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a nominal 30 micron focal length in a polymer substrate 794 (lens and substrate $n=1.51$). Comparison of these two figures clearly demonstrates that the hexagonal base multi-zonal lens 784 of the subject disclosure performs at least as well as the spherical lens 792. The central zone 789 of the hexagonal base multi-zonal lens 784 provides high image resolution and shallow depth of field from a wide variety of viewing angles.

Each of the six side zones 796 of the hexagonal base multi-zonal lens 784 of the subject invention have focal lengths that depend on the location with the zone in a complex way, but the effect is to cause the focus of the side zones 796 to be spread over a range of values 798 spanning approximately ± 10 percent of the central zone focus, as illustrated in Figure 32. This vertical blurring 798 of the focal point effectively increases the depth of field of the lens in these zones 796, and provides a benefit that is equivalent to having a flat-field lens. The performance of the outer zones 800 of spherical lens 792 can be seen in Figure 33. The vertical blurring of the focal point 802 is significantly less for the spherical lens 792 than it is for the hexagonal base multi-zonal lens 784.

This is particularly important for off-normal viewing: the increased depth of field, and effectively flatter field, mitigates the abrupt image defocus that can occur with a spherical lens when its curved focal surface separates from the icon plane. Consequently, a Unison material using hexagonal base multi-zonal lenses displays synthetic images that fade from focus more softly at higher viewing angles than the equivalent Unison material using spherical lenses. This is desirable because it increases the effective viewing angle of the material and therefore increases its usefulness as a security device or an image presentation device.

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The corner zones 806 of the hexagonal base multi-zonal lens 784 of Figure 32 possess diverging focal properties that provide the unexpected benefit of scattering 808 ambient illumination onto the icon plane and thereby reducing the sensitivity of the Unison material to illumination conditions. The spherical lens 792 of Figure 33
5 does not scatter the ambient illumination over as wide an area (as seen by the absence of rays scattered into the icon plane regions 804), so Unison materials made using spherical lenses have greater synthetic image brightness variations when viewed from a variety of angles than Unison materials made using hexagonal base multi-zonal lenses.

10 The benefit obtained from the exemplary hexagonal base multi-zonal lenses is further magnified because hexagonal base multi-zonal lenses have a higher fill factor (ability to cover the plane) than spherical lenses. The interstitial space between spherical lenses provides virtually no scattering of ambient light, while this non-scattering area is much smaller in the case of hexagonal base multi-zonal lenses.

15 Thus it is seen that even though the focal properties of a hexagonal base multi-zonal lens are inferior to those of a spherical lens as evaluated by conventional optical standards, in the context of the subject invention hexagonal base multi-zonal lenses provide unexpected benefits and advantages over spherical lenses.

20 Either type of lens can benefit from the addition of scattering microstructures or scattering materials introduced into, or incorporated into, the lens interstitial spaces to enhance the scattering of ambient illumination onto the icon plane. Furthermore, the lens interstitial spaces can be filled with a material that will form a small radius meniscus, with either converging or diverging focal properties, to direct ambient illumination onto the icon plane. These methods may be combined, for example, by

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incorporating light scattering particles into a lens interstitial meniscus fill material.

Alternatively, the lens interstitial zones can be originally manufactured with suitably scattering lens interstitial zones.

A spherical lens having these proportions is very difficult to manufacture
5 because the high contact angle between the surface of the film and the edge of the lens acts as a stress concentrator for the forces applied to separate the lens from the tool during manufacture. These high stresses tend to cause the adhesion of the lens to the film to fail and to failure of removal of the lens from the tool. Furthermore, the optical performance of a low F# spherical lens is progressively compromised for
10 radial zones away from the center of the lens: low F# spherical lenses do not focus well except near their central zone.

Hexagonal base lenses have an unexpected and significant benefit over lenses that have a more substantially circular base: hexagonal lenses release from their tools with lower peeling force than the optically equivalent lenses with substantially
15 circular bases. Hexagonal lenses have a shape that blends from substantially axially symmetric near their center to hexagonally symmetric, with corners that act as stress concentrators, at their bases. The stress concentrations caused by the sharp base corners reduce the overall peeling force required to separate the lenses from their molds during manufacturing. The magnitude of this effect is substantial – the peeling
20 forces can be reduced during manufacturing by a factor of two or more for hexagonal base lenses as compared to substantially circular base lenses.

The image contrast of the material can be enhanced by filling the lens interstitial spaces with a light absorbing (dark colored) opaque pigmented material, effectively forming a mask for the lenses. This eliminates the contrast reduction that

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arises from light scattered from the icon layer through the lens interstitial spaces. An additional effect of this interstitial fill is that the overall image becomes darker because incoming ambient illumination is blocked from passing through the interstitial spaces to the icon plane. The image clarity produced by lenses having aberrant focusing at their periphery can also be improved by an opaque pigmented interstitial fill, providing that this fill occludes the aberrant peripheral lens zone.

A different effect can be obtained by filling the lens interstitial spaces with a white or light colored material, or a material color matched to a substrate to be used with the Unison material. If the light colored lens interstitial fill is dense enough and the icon plane incorporates a strong contrast between the icon elements and the background, the Unison synthetic image will be substantially invisible when viewed with reflected light, yet will be distinctly visible when viewed in transmitted light from the lens side, but not visible when viewed from the icon side. This provides the novel security effect of having a one-way transmission image that is visible only in transmitted light and visible only from one side.

Fluorescing materials can be utilized in a lens interstitial coating instead of, or in addition to, visible light pigments to provide additional means of authentication.

Fig. 4 graphs the effects of changing the stereoscopic scale ratio, SSR (the icon element repeat period/ the lens array repeat period), along an axis of the present material. Zones of the system having an SSR greater than 1.0000 will produce Unison Float and SuperFloat effects, zones having an SSR of substantially 1.0000 will produce Unison Motion orthoparallactic motion (OPM) effects, and zones having an SSR less than 1.0000 will produce Unison Deep and Unison SuperDeep effects. All of these effects can be produced and transitioned from one to another in a variety of

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ways along an axis of system film. This figure illustrates one of an infinite variety of such combinations. The dashed line 66 indicates the SSR value corresponding substantially to 1.0000, the dividing line between Unison Deep and Unison SuperDeep and Unison Float and Unison SuperFloat, and the SSR value which demonstrates OPM. In zone 68 the SSR of the Unison material is 0.995, creating a Unison Deep effect.

Adjacent to this is zone 70 in which the SSR is ramped from 0.995 up to 1.005, producing a spatial transition from a Unison Deep to a Unison Float effect. The SSR in the next zone 72 is 1.005 creating a Unison Float effect. The next zone 74 creates a smooth transition down from a Unison Float effect to a Unison Deep effect. Zone 76 proceeds stepwise up from a Unison Deep effect, to OPM, to a Unison Float effect, and zone 78 steps it back down to OPM. The variations in repeat period needed to accomplish these effects are generally most easily implemented in the icon element layer. In addition to varying the SSR in each zone, it may be desirable to vary the rotational angle of each zone of the arrays, preferably within the icon element array, to keep the synthetically magnified images substantially similar in size.

The easiest way to interpret this graph is to see it as a cross-section of the stereoscopic depth that will be perceived across this axis of a piece of system material. It is therefore possible to create a stereoscopically sculpted field of images, a contoured visual surface, by local control of the SSR and optionally by corresponding local control of the array rotational angle. This stereoscopically sculpted surface can be used to represent an unlimited range of shapes, including human faces. A pattern of icon elements that create the effect of a stereoscopically

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sculpted grid, or periodic dots, can be a particularly effective way to visually display a complex surface.

Fig. 5 a-c are plan views depicting the effect of rotating one array pattern with respect to the other in the production of material of the present system. Fig. 5a shows a lens array 80 having a regular periodic array spacing 82, without substantial change in the angle of the array axes. Fig. 5b shows an icon element array 84 with a progressively changing array axis orientation angle 86. If the lens array 80 is combined with the icon element array 84 by translating the lens array over the icon array, as drawn, then the approximate visual effect that results is shown in Fig. 5c. In Fig. 5c the material 88 created by combining lens array 80 and icon array 84 creates a pattern of synthetically magnified images 89, 90, 91 that vary in scale and rotation across the material. Towards the lower left edge of the material 88 image 89 is large and shows no rotation. Image 90, toward the upper middle section of material 88 is smaller and is rotated through a significant angle with respect to image 89. The different scales and rotations between images 89 and 90 are the result of the differences in the angular misalignment of the lens pattern 82 and the icon element pattern 86.

Fig. 6 a-c illustrate a method for causing one synthetically magnified OPM image 98 to morph into another synthetically magnified image 102 as the first image moves across a boundary 104 in the icon element patterns 92 and 94. Icon element pattern 92 bears circle-shaped icon elements 98, shown in the magnified inset 96. Icon element pattern 94 bears star-shaped icon elements 102, shown in the magnified inset 100. Icon element patterns 92 and 94 are not separate objects, but are joined at their boundary 104. When the material is assembled using this combined pattern of

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icon elements the resulting OPM images will show the morphing effects depicted in Figs. 6b and c. Fig. 6b shows OPM circle images 98 moving to the right 107 across the boundary 104 and emerging from the boundary as star images 102 also moving to the right. Image 106 is in transition, part circle and part star, as it crosses the

5 boundary. Fig. 6c of the figure shows the images after they have moved further to the right: image 98 is now closer to the boundary 104 and image 106 has almost completely crossed the boundary to complete its morphing from circle to star. The morphing effect can be accomplished in a less abrupt manner by creating a transition zone from one icon element pattern to the other, instead of having a hard boundary

10 104. In the transition zone the icons would gradually change from circle to star through a series of stages. The smoothness of the visual morphing of the resulting OPM images will depend on the number of stages used for the transition. The range of graphical possibilities is endless. For example: the transition zone could be designed to make the circle appear to shrink while sharp star points protruded up

15 through it, or alternatively the sides of the circle could appear to dent inward to create a stubby star that progressively became sharper until it reached its final design.

Figs. 7 a-c are cross-sections of materials of the present system that illustrate alternative embodiments of the icon elements. Fig. 7a depicts a material having lenses 1 separated from icon elements 108 by optical spacer 5. Icon elements 108 are

20 formed by patterns of colorless, colored, tinted, or dyed material applied to the lower surface of optical spacer 5. Any of the multitude of common printing methods, such as ink jet, laserjet, letterpress, flexo, gravure, and intaglio, can be used to deposit icon elements 108 of this kind so long as the print resolution is fine enough.

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Fig. 7b depicts a similar material system with a different embodiment of icon elements 112. In this embodiment the icon elements are formed from pigments, dyes, or particles embedded in a supporting material 110. Examples of this embodiment of icon elements 112 in supporting material 110 include: silver particles in gelatin, as a
5 photographic emulsion, pigmented or dyed ink absorbed into an ink receptor coating, dye sublimation transfer into a dye receptor coating, and photochromic or thermochromic images in an imaging film.

Fig. 7c depicts a microstructure approach to forming icon elements 114. This method has the benefit of almost unlimited spatial resolution. The icon elements 114
10 can be formed from the voids in the microstructure 113 or the solid regions 115, singly or in combination. The voids 113 can optionally be filled or coated with another material such as evaporated metal material having a different refractive index, or dyed or pigmented material.

Figs. 8 a,b depict positive and negative embodiments of icon elements. Fig. 8a shows positive icon elements 116 that are colored, dyed, or pigmented 120 against
15 a transparent background 118. Fig. 8b shows negative icon elements 122 that are transparent 118 against a colored, dyed, or pigmented background 120. A material of the present system may optionally incorporate both positive and negative icon elements. This method of creating positive and negative icon elements is particularly
20 well adapted to the microstructure icon elements 114 of Fig. 7c.

Fig. 9 shows a cross-section of one embodiment of a pixel-zone material of the present system. This embodiment includes zones with lenses 124 having a short focus and other zones with lenses having a long focus 136. The short focus lenses 124 project images 123 of icon elements 129 in icon plane 128 disposed at the focal plane

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of lenses 124. The long focus lenses 136 project images 134 of icon elements 137 in icon plane 132 disposed at the focal plane of lenses 136. Optical separator 126 separates short focus lenses 124 from their associated icon plane 128. Long focus lenses 136 are separated from their associated icon plane 132 by the sum of the

5 thicknesses of optical separator 126, icon plane 128, and second optical separator 130. Icon elements 137 in the second icon plane 132 are outside the depth of focus of short focus lenses 124 and therefore do not form distinct synthetically magnified images in the short focus lens zones. In a similar manner, icon elements 129 are too close to long focus lenses 136 to form distinct synthetically magnified images. Accordingly,

10 zones of material bearing short focus lenses 124 will display images 123 of the icon elements 129, while zones of material bearing long focus lenses 136 will display images 134 of icon elements 137. The images 123 and 134 that are projected can differ in design, color, OPM direction, synthetic magnification factor, and effect, including the Deep, Unison, Float, and Levitate effects described above.

15 Fig. 10 is a cross-section of an alternate embodiment of a pixel-zone material of the present system. This embodiment includes zones with lenses 140 elevated by a lens support mesa 144 above the bases of the non-elevated lenses 148. The focal length of the elevated lenses 140 is the distance 158, placing the focus of these lenses in the first icon plane 152. The focal length of the non-elevated lenses 148 is the

20 distance 160, placing the focus of these lenses in the second icon plane 156. These two focal lengths, 158 and 160, may be chosen to be similar or dissimilar. The elevated lenses 140 project images 138 of icon elements 162 in icon plane 152 disposed at the focal plane of lenses 140. The non-elevated lenses 148 project images 146 of icon elements 164 in icon plane 156 disposed at the focal plane of lenses 148.

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The elevated lenses 140 are separated from their associated icon elements 162 by the sum of the thickness of the lens support mesa 144 and the optical separation 150. The non-elevated lenses 148 are separated from their associated icon elements 164 by the sum of the thickness of the optical separation 150, the icon layer 152, and the icon separator 154. Icon elements 164 in the second icon plane 156 are outside the depth of focus of the elevated lenses 140 and therefore do not form distinct synthetically magnified images in the elevated lens zones. In a similar manner, icon elements 152 are too close to non-elevated lenses 148 to form distinct synthetically magnified images. Accordingly, zones of material bearing elevated lenses 140 will display images 138 of the icon elements 162, while zones of material bearing non-elevated lenses 136 will display images 146 of icon elements 156. The images 138 and 146 that are projected can differ in design, color, OPM direction, synthetic magnification factor, and effect, including Deep, Unison, Float, and Levitate effects.

Figs. 11 a,b are cross-sections illustrating non-refractive embodiments of the present system. Fig. 11a illustrates an embodiment that utilizes a focusing reflector 166 instead of a refractive lens to project images 174 of icon elements 172. The icon layer 170 lies between the viewer's eyes and the focusing optics. Focusing reflectors 166 can be metallized 167 to obtain high focusing efficiency. The icon layer 170 is maintained at a distance equal to the focal length of the reflectors by optical separator 168. Fig. 11b discloses a pinhole optics embodiment of this material. Opaque upper layer 176, preferably black in color for contrast enhancement, is pierced by apertures 178. Optical separator element 180 controls the field of view of the system. Icon elements 184 in icon layer 182 are imaged through apertures 178 in a manner similar to the pinhole optics of a pinhole camera. Because of the small amount of light

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passed through the apertures, this embodiment is most effective when it is back-illuminated, with light passing through the icon plane 182 first, then through the apertures 178. Effects of each of the above-described embodiments, OPM, Deep, Float, and Levitate, can be created using either the reflective system design or the

5 pinhole optics system design.

Figs. 12 a,b are cross-sections comparing the structures of an all-refractive material 188 with a hybrid refractive/reflective material 199. Fig. 12a depicts an exemplary structure, with micro-lenses 192 separated from the icon plane 194 by optical separator 198. Optional sealing layer 195 contributes to the total refractive

10 system thickness 196. Lenses 192 project icon images 190 toward the viewer (not shown). Hybrid refractive/reflective material 199 includes micro-lenses 210 with icon plane 208 directly beneath them. Optical spacer 200 separates the lenses 210 and the icon plane 208 from reflective layer 202. Reflective layer 202 can be metallized, such as by evaporated or sputtered aluminum, gold, rhodium, chromium, osmium,

15 depleted uranium or silver, by chemically deposited silver, or by multi-layer interference films. Light scattered from icon layer 208 reflects from reflective layer 202, passes through icon layer 208 and into lenses 210 which project images 206 toward the viewer (not shown). Both of these figures are drawn to approximately the same scale: by visual comparison it can be seen that the total system thickness 212 of

20 the hybrid refractive/reflective system 199 is about half the total system thickness 196 of the all-refractive system 188. Exemplary dimensions for equivalent systems are 29μ total refractive system 188 thickness 196 and 17μ for total hybrid refractive/reflective system 199 thickness 212. The thickness of a refractive/reflective system can be further reduced by scaling. Thus, a hybrid system having lenses 15μ in

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diameter can be made with a total thickness of about 8μ . Effects of each of the above described embodiments, OPM, Deep, Float, Levitate, Morph, and 3-D can be created using the hybrid refractive/diffractive design.

Fig. 13 is a cross-section showing a 'peel-to-reveal' tamper-indicating material
5 embodiment of the present system. This embodiment does not display an image until it is tampered with. The untampered structure is shown in region 224, where a refractive system 214 is optically buried under a top layer 216 consisting of an optional substrate 218 and a peelable layer 220 which is conformal to the lenses 215. Peelable layer 220 effectively forms negative lens structures 220 that fit over positive
10 lenses 215 and negate their optical power. Lenses 215 cannot form images of the icon layer in the untampered region, and the light scattered 222 from the icon plane is unfocused. Top layer 216 may include an optional film substrate 218. Tampering, shown in region 226, causes the release of top layer 216 from the refractive system 214, exposing the lenses 215 so that they can form images 228. Effects of each of the
15 above described embodiments, OPM, Deep, Float, and Levitate, can be included in a tamper indicating 'peel-to-reveal' system of the type of Fig. 13.

Fig. 14 is a cross-section illustrating a 'peel-to-change' tamper-indicating material embodiment of the present system. This embodiment displays a first image
248 of a first icon plane 242 prior to tampering 252, then displays a second image 258
20 at region 254 after it has been tampered with. The untampered structure is shown in region 252, where two refractive systems, 232 and 230, are stacked. The first icon plane 242 is located beneath the lenses 240 of the second system. Prior to tampering in region 252 the first, or upper, system 232 presents images of the first icon plane 242. The second icon plane 246 is too far outside the depth of focus of lenses 234 to

41 31

form distinct images. The first lenses 234 are separated from the second lenses 240 by an optional substrate 236 and a peelable layer 238 which is conformal to the second lenses 240. Peelable layer 232 effectively forms negative lens structures 238 that fit over positive lenses 240 and negate their optical power. Top layer 232 may
5 include optional film substrate 236. Tampering results in the peeling 256 of the top layer 232, shown in region 254, from the second refractive system 230, exposing the second lenses 240 so that they can form images 258 of the second icon layer 246. Second lenses 240 do not form images of the first icon layer 242 because the icon layer is too close to the lenses 240.

10 This embodiment of a tamper indicating material is well suited to application as a tape or label applied to an article. Tampering releases the top layer 232, leaving the second system 230 attached to the article. Prior to tampering, this embodiment presents a first image 248. After tampering 254 the second system 230, still attached to the article, presents a second image 258 while the peeled layer 256 presents no
15 image at all. Effects of each of the above described embodiments, OPM, Deep, Float, and Levitate, can be included in either the first system 232 or the second system 230.

Note that an alternative embodiment accomplishing a similar effect to that of Fig. 14 is to have two separate systems laminated to each other. In this embodiment when the upper layer is peeled it takes the first icon plane and its image(s) with it,
20 revealing the second system and its image(s).

Figs. 15 a-d are cross-sections showing various two-sided embodiments of the present system. Fig. 15a depicts a two-sided material 260 that includes a single icon plane 264 that is imaged 268 by lenses 262 on one side and imaged 270 by a second set of lenses 266 on the opposite side. The image 268 seen from the left side (as



"ANA T. BARRETO"
<abarreto@propi.es>
19/05/2006 08:03 a.m.

Para <tlopez@clarkmodet.com>

cc

cco

Asunto: Procesos de Nulidad y Reestablecimiento de Derecho

Estimada Sra. López:

Acusamos recibo de su carta de fecha 10 de mayo de 2006 en la que nos adjunta los escritos de refuerzo de alegatos presentados en los Procesos indicados en los Expedientes No. 2003-0227 y 2003-0028, que corresponden a las marcas No.10923 "BBVA BANCORER" en clase 36 y No.10928 "BBVA BANCORER" en clase 36.

No obstante lo anterior la factura que nos remite conjuntamente con dichos escritos, la No. 9346 por € 419.92 hace mención a los expedientes 2003-0227 y 2003-0226.

En Enero pasado nos enviaron la factura No. 8878 de 22 de noviembre de 2005 por los gastos de la presentación del escrito en el expediente No. 2003-0226 que corresponde a la marca No. 10917 "ENVÍOS DE DINERO BBVA BANCORER" en clase 36, el día 12 de enero de 2006 Iñigo Sánchez les envió un email en el que les solicitaba el escrito presentado en el expediente antes mencionado y les devolvía la factura No. 8878 para la emisión de una nueva con fecha 2006.

Por todo ello le agradeceré los siguiente:

- Nos confirme que la factura No. 8878 ha sido cancelada
- Nos remita la factura correspondiente al expediente no 2003-0228
- Nos envíe el escrito del expediente No. 2003-0226

Una vez tengamos las facturas por la presentación del escrito en los tres expediente y los 3 escritos podremos proceder en consecuencia.

Agradeceré nos adelantara los documentos por fax.

Por último les agradeceré tomar nota que Iñigo Sánchez ya no trabaja con nosotros por lo que cualquier comunicación la deberán dirigir a mi atención o a la de Estrella Zamora, Directora del Departamento.

Un cordial saludo

Ana Barreto Guinea
Departamento Internacional
International Department

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"Meilman, Edward"
<MeilmanE@demo.com>
18/05/2006 02:38 p.m.

Para: TLopez@clarkemodet.com.co
cc
cco

Asunto: RE: Sun Chemical Case 299 - ENERGY CURABLE
COATING COMPOSITIONS - National phase filing -
URGENT

Dear Ms. Lopez:

Is there a specific due date for the assignment?

Would it be acceptable to have a US notary certify that an assignment document is a true copy and then have the certification legalized?

Regards,

Edward Meilman

From: TLopez@clarkemodet.com.co [mailto:TLopez@clarkemodet.com.co]
Sent: Monday, May 15, 2006 5:45 PM
To: Meilman, Edward
Subject: RE: Sun Chemical Case 299 - ENERGY CURABLE COATING COMPOSITIONS - National phase filing - URGENT

Dear Mr. Meilman,

Please see attachments.

Best regards,

Tatiana López- Romero
Intellectual Property Advisor
Clarke Modet & Co. Colombia
Carrera 11 No.86-53 Piso 6
TEL (571) 6181088
FAX (571) 6350824

ESPAÑA - PORTUGAL - ARGENTINA - BRASIL - CHILE - MEXICO - PERU - VENEZUELA

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Tatiana
Lopez/Colombia/Clarkmod
et
18/05/2006 04:16 p.m.

Para "Meilman, Edward" <MeilmanE@damo.com>
cc
cco

Asunto RE: Sun Chemical Case 299 - ENERGY CURABLE
COATING COMPOSITIONS - National phase filing -
URGENT

Dear Mr. Meilman,

Please be informed that there is no term fixed to file the assignment document so far. We consider the PO will fix this term within the next three or four months after filing the application.
Kindly be advised that a copy of the assignment certified by the USPTO's certifying officer legalized by Apostille will fulfill the Colombian PO requirements.

Best regards,

Tatiana López- Romero
Intellectual Property Advisor
Clarke Modet & Co.Colombia
Carrera 11 No.86-53 Piso 6
TEL (571) 6181088
FAX (571) 6350824

ESPAÑA - PORTUGAL - ARGENTINA - BRASIL - CHILE - MEXICO - PERU - VENEZUELA

Este mensaje es confidencial y pertenece sólo a la(s) persona(s) a quien(es) está dirigido. Puede contener información privilegiada y confidencial. Si usted no es la persona a quien está dirigido, no debe leer, copiar, distribuir, discutir o tomar acción alguna con respecto al mismo. Si usted ha recibido esta información por error, por favor notifique a Clarke, Modet & C^a Colombia tan pronto como sea posible a los teléfonos o números de fax arriba mencionados o por e-mail.

Gracias.

This message is confidential and intended solely for the person(s) to whom it is addressed. It may contain privileged and confidential information. If you are not the intended recipient(s), you must not read, copy, distribute, discuss or take any action related to it. If you have received this information in error, please notify Clarke, Modet & C^a Colombia as soon as possible to the above telephone or facsimile numbers or by return mail.

Thank you

"Meilman, Edward" <MeilmanE@damo.com> escribió el 18/05/2006 02:36:08 p.m.:

> Dear Ms. Lopez:
>
> Is there a specific due date for the assignment?
>
> Would it be acceptable to have a US notary certify that an
> assignment document is a true copy and then have the certification
legalized?

45

drawn) is the mirror image of the image 270 seen from the right side. Icon plane 264 may contain icon elements that are symbols or images which appear similar in mirror image, or icon elements which appear different in mirror image, or combinations of icon elements wherein a portion of the icon elements are correct-reading when viewed from one side and the other icon elements are correct-reading when viewed from the other side. Effects of each of the above described embodiments, OPM, Deep, Float, and Levitate, can be displayed from either side of a two-sided material according to this embodiment.

Fig. 15b illustrates another two-sided embodiment 272 having two icon planes 276 and 278 that are imaged, 282 and 286 respectively, by two sets of lenses, 274 and 280 respectively. This embodiment is essentially two separate systems, 287 and 289, such as illustrated in Fig. 1a, that have been joined together with an icon layer spacer 277 in between them. The thickness of this icon layer spacer 277 will determine the degree that the 'wrong' icon layer is imaged 284 and 288 by a set of lenses. For example, if the thickness of icon layer spacer 277 is zero, such that icon layers 276 and 278 are in contact, then both icon layers will be imaged by both sets of lenses 274 and 280. In another example, if the thickness of icon layer spacer 277 is substantially larger than the depth of focus of lenses 274 and 280, then the 'wrong' icon layers will not be imaged by the lenses 274 and 280. In yet another example, if the depth of focus of one set of lenses 274 is large, but the depth of focus of the other set of lenses is small (because the lenses 274 and 280 have different F#s), then both icon planes 276 and 278 will be imaged 282 through lenses 274 but only one icon plane 278 will be imaged through lenses 280, so a material of this type would show two images from one side but only one of those images, mirrored, from the opposite side. Effects of

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each of the above described embodiments, OPM, Deep, Float, and Levitate, can be displayed from either side of a two-sided material according to this embodiment, and the projected images 282 and 286 can be of the same or different colors.

Fig. 15c shows yet another two-sided material 290 having a pigmented icon layer spacer 298 that blocks the lenses on one side of the material from seeing the 'wrong' set of icons. Lenses 292 image 294 icon layer 296 but cannot image icon layer 300 because of the presence of pigmented icon layer 298. Similarly, lenses 302 image 304 icon layer 300, but cannot image icon layer 296 because of the presence of pigmented icon layer 298. Effects of each of the above described embodiments, OPM, Deep, Float, and Levitate, can be displayed from either side of a two-sided material according to this embodiment, and the projected images 294 and 304 can be of the same or different colors.

Fig. 15d discloses a further two-sided material 306 embodiment having lenses 308 that image 318 icon layer 314 and lenses 316 on the opposite side that image 322 icon layer 310. Icon layer 310 is close to, or substantially in contact with, the bases of lenses 308 and icon layer 314 is close to, or substantially in contact with, the bases of lenses 316. Icons 310 are too close to lenses 308 to form an image, so their light scatters 320 instead of focusing. Icons 314 are too close to lenses 316 to form an image, so their light scatters 324 instead of focusing. Effects of each of the above described embodiments, OPM, Deep, Float, and Levitate, can be displayed from either side of a two-sided material according to this embodiment, and the projected images 318 and 322 can be of the same or different colors.

Figs. 16 a-f are cross-sections and corresponding plan views illustrating three different methods for creating grayscale or tonal icon element patterns and subsequent

47 30

synthetically magnified images with the present system. Figs. 16 a-c are cross-section details of the icon side of a material 307, including part of optical separator 309 and a transparent micro structured icon layer 311. The icon elements are formed as bas-relief surfaces 313, 315, 317 that are then filled with a pigmented or dyed material 323, 325, 327 respectively. The underside of the icon layer may be optionally sealed by a sealing layer 321 that can be transparent, tinted, colored, dyed, or pigmented, or opaque. The bas-relief micro structures of icon elements 313, 315, and 317 provide thickness variations in the dyed or pigmented fill material, 323, 325, and 327 respectively, that create variations in the optical density of the icon element as seen in plan view. The plan views corresponding to icon elements 323, 325, and 327 are plan views 337, 339, and 341. The use of this method to create grayscale or tonal synthetically magnified images is not limited to the specifics of the examples disclosed here, but may be generally applied to create an unlimited variety of grayscale images.

Fig. 16 a includes icon element 313, dyed or pigmented icon element fill 323, and corresponding plan view 337. The cross section view of the icon plane at the top of this figure can only show one cutting plane through the icon elements. The location of the cutting plane is indicated by the dashed line 319 through the plane views 337, 339, and 341. Accordingly, the cross-section of icon element 313 is one plane through a substantially hemispherical-shaped icon element. By suitably limiting the overall dye or pigment density of the fill 323, thickness variations of the dyed or pigmented fill 323 create a tonal, or grayscale, optical density variations represented in the plan view 337. An array of icon elements of this type can be

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synthetically magnified within the present material system to produce images that show equivalent grayscale variations.

Fig. 16 b includes icon element 315, dyed or pigmented icon element fill 325, and corresponding plan view 339. Plan view 339 shows that the icon element 315 is a
5 bas-relief representation of a face. The tonal variations in an image of a face are complex, as shown by the complex thickness variations 325 in the cross-section view. As disclosed with regard to icon element 313, an array of icon elements of this type, as shown by 315, 325, and 339, can be synthetically magnified within the present material system to produce images that show equivalent grayscale variations
10 representing, in this example, the image of a face.

Fig. 16 c includes icon element 317, dyed or pigmented fill 327, and corresponding plan view 341. In a manner similar to the discussion of Figs. 16 a,b, above, the bas-relief shape of this icon element structure produces a tonal variation in the appearance of the dyed and pigmented fill 327 and in the synthetically magnified
15 image produced by the present material system. Icon element 317 illustrates a method for creating a bright center in a rounded surface, as compared to the effect of icon element 313 which creates a dark center in a rounded surface.

Figs. 16 d,e disclose another embodiment 326 of transparent bas-relief micro structured icon layer 311 including icon elements 329 and 331 that are coated with a
20 high refractive index material 328. The icon layer 311 can be sealed with an optional sealing layer 321 that fills the icon elements 329 and 331, 330 and 332, respectively. The high refractive index layer 328 enhances the visibility of sloping surfaces by creating reflections from them by total internal reflection. Plan views 342 and 344 present representative images of the appearance of icon elements 329 and 331 and

49-2

their synthetically magnified images. This high refractive index coating embodiment provides a kind of edge-enhancement effect without adding pigment or dye to make the icons and their images visible.

Fig. 16 f discloses yet another embodiment 333 of transparent bas-relief micro structured icon 335 utilizing an air, gas, or liquid volume 336 to provide visual definition for this phase interface 334 microstructure. Optional scaling layer 340 may be added with or without optional adhesive 338 to entrap the air, gas, or liquid volume 336. The visual effect of a phase interface icon element is similar to that of a high refractive index coated icon element 329 and 331.

10 Figs. 17 a-d are cross-sections showing the use of the present system as a laminating film in conjunction with printed information, such as may be utilized in the manufacture of I.D. cards and driver's licenses, wherein the material 348 (consisting of the coordinated micro-array of lenses and images described above) covers a substantial proportion of the surface. Fig. 17a depicts an embodiment of Unison used as a laminate over print 347. Material 348 having at least some optical transparency in the icon layer is laminated to fibrous substrate 354, such as paper or paper substitute, with lamination adhesive 350, covering or partly covering print element 352 that had previously been applied to the fibrous substrate 354. Because the material 348 is at least partially transparent, the print element 352 can be seen through 15 it and the effect of this combination is to provide the dynamic image effect of the present system in combination with the static print.

Fig. 17b shows an embodiment of the system material used as a laminate over a print element 352 applied to a nonfibrous substrate 358, such as a polymer film. As in Fig 17a, material 348 having at least some optical transparency in the icon layer is

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laminated to nonfibrous substrate 358, such as polymer, metal, glass, or ceramic substitute, with lamination adhesive 350, covering or partly covering print element 352 that had previously been applied to the nonfibrous substrate 354. Because the material 348 is at least partially transparent, the print element 352 can be seen through
5 it and the effect of this combination is to provide the dynamic image effect in combination with the static print.

Fig. 17c depicts the use of a print element directly on the lens side of material 360. In this embodiment material 348 has print element 352 directly applied to the upper lens surface. This embodiment does not require that the material be at least
10 partly transparent: the print element 352 lies on top of the material and the dynamic image effects can be seen around the print element. In this embodiment the material 348 is used as the substrate for the final product, such as currency, ID cards, and other articles requiring authentication or providing authentication to another article.

Fig. 17d depicts the use of a print element directly on the icon side of an at-
15 least partially transparent material 362. Print element 352 is applied directly to the icon layer or sealing layer of an at-least partially transparent system material 348. Because the system material 348 is at least partially transparent, the print element 352 can be seen through it and the effect of this combination is to provide the dynamic image effect in combination with the static print. In this embodiment the system
20 material 348 is used as the substrate for the final product, such as currency, ID cards, and other articles requiring authentication or providing authentication to another article.

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Each of the embodiments of Figs. 17 a-d can be used singly or in combination. Thus, for example, a system material 348 can be both overprinted (Fig. 17c) and backside printed (Fig. 17d), then optionally laminated over print on a substrate (Figs. 17 a,b). Combinations such as these can further increase the counterfeiting, simulation, and tampering resistance of the material of the present system.

Figs. 18 a-f are cross-sections illustrating the application of the present system to, or incorporation into, various substrates and in combination with printed information. The embodiments of Figs. 18 a-f differ from those of Figs. 17 a-d in that the former figures disclose system material 348 that covers most or all of an article, whereas the present figures disclose embodiments wherein the system material or its optical effect do not substantially cover a whole surface, but rather cover only a portion of a surface. Fig. 18a depicts a piece of at-least partially transparent system material 364 adhered to a fibrous or non-fibrous substrate 368 with adhesive element 366. Optional print element 370 has been directly applied to the upper, lens, surface of material 364. Print element 370 may be part of a larger pattern that extends beyond the piece of material 364. The piece of material 364 is optionally laminated over print element 372 that was applied to the fibrous or non-fibrous substrate prior to the application of the material 364.

Fig. 18b illustrates an embodiment of single-sided system material 364 incorporated into an non-optical substrate 378 as a window, wherein at least some of the edges of the system material 364 are captured, covered, or enclosed by the non-optical substrate 378. Print elements 380 may be optionally applied on top of the system material lens surface and these print elements may be aligned with, or correspond to, print elements 382 applied to the non-optical substrate 378 in the area

52 57

adjacent to print element 380. Similarly, print elements 384 can applied to the opposite side of the non-optical substrate aligned with, or corresponding to, print elements 386 applied to the icon or scaling layer 388 of the system material 364. The effect of a window of this kind will be to present distinct images when the material is viewed from the lens side and no images when viewed from the icon side, providing a one-way image effect.

Fig. 18c shows a similar embodiment to that of Fig. 18b, except that the system material 306 is double-sided material 306 (or other double-sided embodiment described above). Print elements 390, 392, 394, and 396 substantially correspond in function to print elements 380, 382, 384, 386, previously described. The effect of a material window of this kind will be to present different distinct images when the material is viewed from opposite sides. For example, a window incorporated into a currency paper could display the numerical denomination of the bill, such as "10" when viewed from the face side of the bill, but when viewed from the back side of the bill the Unison window could display different information, such as "USA", that may be in the same color as the first image or a different color.

Fig. 18d illustrates a transparent substrate 373 acting as the optical spacer for a material formed by a zone of lenses 374 of limited extent and an icon layer 376 extending substantially beyond the periphery of the zone of lenses 374. In this embodiment the present effects will only be visible in that zone that includes both lenses and icons (corresponding to lens zone 374 in this figure). Both the lenses 374 and the adjacent substrate may optionally be printed 375, and print elements may also be applied to the icon layer 376 or to an optional scaling layer covering the icons (not indicated in this figure – see Fig. 1). Multiple lens zones can be used on an article

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after the manner of this embodiment; wherever a lens zone is placed the Unison effects will be seen; the size, rotation, stereoscopic depth position, and OPM properties of the images can be different for each lens zone. This embodiment is well suited for application to ID cards, credit cards, drivers' licenses, and similar applications.

Fig. 18e shows an embodiment that is similar to that of Fig. 18d, except that the icon plane 402 does not extend substantially beyond the extent of the lens zone 400. Optical spacer 398 separates the lenses 400 from the icons 402. Print elements 404 and 406 correspond to print elements 375 and 377 in Fig. 18d. Multiple zones 400 can be used on an article after the manner of this embodiment; each zone can have separate effects. This embodiment is well suited for application to ID cards, credit cards, drivers' licenses, and similar applications.

Fig. 18f depicts an embodiment that is similar to Fig. 18d except that the present embodiment incorporates optical spacer 408 that separates lenses 413 from icon plane 410. Lenses 413 extend substantially beyond the periphery of the icon zone 412. Print elements 414 and 416 correspond to print elements 375 and 377 in Fig. 18d. Multiple lens zones can be used on an article after the manner of this embodiment; wherever a lens zone is placed the present effects will be seen; the size, rotation, stereoscopic depth position, and OPM properties of the images can be different for each lens zone. This embodiment is well suited for application to ID cards, credit cards, drivers' licenses, and similar applications.

Figs. 19 a,b illustrate cross-sectional views comparing the in-focus field of view of a spherical lens with that of a flat field aspheric lens when each are incorporated into a structure of the type described above. Fig. 19a illustrates a

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substantially spherical lens as applied in a system as described above. Substantially spherical lens 418 is separated from icon plane 422 by optical spacer 420. Image 424 projected out perpendicular to the surface of the material originates at focal point 426 within the icon layer 422. The image 424 is in sharp focus because the focal point 426 is within the icon layer 422. When the lens is viewed from an oblique angle, then image 428 is blurry and out of focus because the corresponding focal point 430 is no longer in the icon plane, but is above it a substantial distance. Arrow 432 shows the field curvature of this lens, equivalent to the sweep of the focal point from 426 to 430. The focal point is within the icon plane throughout the zone 434, then moves outside of the icon plane in zone 436. Lenses which are well suited to application in coordination with a plane of printed images or icons typically have a low F#, typically less than 1, resulting in a very shallow depth of focus – higher F# lenses can be used effectively with Deep and Float effects, but cause proportionate vertical binocular disparity with effects described herein when used with Unison Motion effects. As soon as the lower limit of the depth of focus moves outside of the icon plane the image clarity degrades rapidly. From this figure it can be seen that the field curvature of a substantially spherical lens limits the field of view of the image: the image is distinct only within the in-focus zone 434, rapidly going out of focus for more oblique viewing angles. Substantially spherical lenses are not flat-field lenses, and the field curvature of these lenses is amplified for low F# lenses.

Fig. 19b illustrates an aspheric lens as applied to the present system. As an aspheric lens, its curvature is not approximated by a sphere. Aspheric lens 438 is separated from icon layer 442 by optical spacer 440. Aspheric lens 438 projects image 444 of icon plane 442 normal to the plane of the material. The image

55

originates at focal point 446. The focal length of aspheric lens 438 lies within the icon plane 442 for a wide range of viewing angles, from normal 444 to oblique 448, because it has a flat-field 452. The focal length of the lens varies according to the angle of view through it. The focal length is shortest for normal viewing 444 and
5 increases as the viewing angle becomes more oblique. At the oblique viewing angle 448 the focal point 450 is still within the thickness of the icon plane, and the oblique image is therefore still in focus for this oblique viewing angle 448. The in-focus zone 454 is much larger for the aspheric lens 438 than the in-focus zone 434 of the substantially spherical lens 418. The aspheric lens 438 thus provides an enlarged field
10 of view over the width of the associated image icon so that the peripheral edges of the associated image icon do not drop out of view compared to that of the spherical lens 418. Aspheric lenses are preferred for the present system because of the larger field of view they provide and the resulting increase in visibility of the associated images.

Figs. 20 a-c are cross-sections illustrating two benefits of utility which result
15 from the use of a thick icon layer. These benefits apply whether the lens 456 used to view them is substantially spherical 418 or aspheric 438, but the benefits are greatest in combination with aspheric lenses 438. Fig. 20a illustrates a thin icon layer 460 system material including lenses 456 separated from icon layer 460 by optical spacer 458. Icon elements 462 are thin 461 in comparison to the field curvature of the lens
20 463, limiting the in-focus zone to a small angle, the angle between the image projected in the normal direction 464 and the highest oblique angle image 468 that has a focal point 470 within the icon layer 460. The greatest field of view is obtained by designing the normal image focus 466 to lie at the bottom of the icon plane, thereby maximizing the oblique field of view angle, limited by the point at which the focal

56 15

point 470 lies at the top of the icon plane. The field of view of the system in Fig. 20a is limited to 30 degrees.

Fig. 20b illustrates the benefits obtained from the incorporation of an icon plane 471 that is thick 472 in comparison to the field curvature of lens 456. Lenses 456 are separated from thick icon elements 474 by optical spacer 458. Thick icon elements 474 remain in focus 475 over a larger field of view, 55 degrees, than the thin icon elements 462 of Fig. 20a. The normal image 476 projected through lenses 456 from focal point 478 is in clear focus, and the focus remains clear while the angle of view increases all the way up to 55 degrees, where oblique image 480 focal point 482 lies at the top of the thick icon plane 471. The increased field of view is greatest for a flat-field lens, such as the aspheric lens 438 of Fig. 19b.

Fig. 20c illustrates yet another advantage of a thick icon plane 492; reducing the sensitivity of the present system material to variations in thickness S that may result from manufacturing variations. Lens 484 is spaced a distance S from the bottom surface of icon layer of thickness i . Lens 484 projects image 496 from focal point 498 disposed at the bottom of icon layer 492. This figure is drawn to demonstrate that variations in the optical space S between the lenses and the icon layer can vary over a range equal to the thickness of the icon layer i without loss of image 496, 500, 504 focus. At lens 486 the optical spacer thickness is about $(S + i / 2)$ and the focal point 502 of image 500 is still within the thickness i of icon layer 492. At lens 488 the thickness of the optical spacer has increased to $(S + i)$ 490 and the focal point 506 of image 504 lies at the top of thick icon element 494. The optical spacer thickness can therefore vary over a range corresponding to the thickness of the icon layer i ; a thin icon layer therefore provides a small tolerance for optical spacer

57 125

thickness variations and a thick icon layer provides a larger tolerance for optical spacer thickness variations.

An additional benefit is provided by a thick icon layer 492. Imperfect lenses, such as substantially spherical lenses, may have a shorter focal length 493 towards their edges than at their center 496. This is one aspect of the common spherical aberration defect of substantially spherical lenses. A thick icon layer provides an icon element that can be clearly focused over a range of focal lengths, 498 to 495, thereby improving the overall clarity and contrast of an image produced by a lens 484 having focal length variations.

Fig. 21 is a plan view that shows the application of the present system to currency and other security documents as a 'windowed' security thread. Fig. 21 shows a windowed thread structure including system material 508 that has been slit into a ribbon, referred to as a "thread", that is typically in the range of 0.5 mm to 10 mm in width. Thread 508 is incorporated into the fibrous document substrate 510 and provides windowed zones 514. The thread 508 may optionally incorporate a pigmented, dyed, filled, or coated sealing layer 516 to increase image contrast and/or to provide additional security and authentication features, such as electrical conductivity, magnetic properties, nuclear magnetic resonance detection and authentication, or to hide the material from view in reflected illumination when viewed from the back side of the substrate (the side opposite the side presenting the Union synthetic images and an adhesive layer 517 to strengthen the bond between the thread 508 and the fibrous substrate 510. The thread 508 is maintained in an orientation to keep the lenses uppermost so that the image effects are visible in the windowed zones 514. Both the fibrous substrate 510 and the thread may be

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overprinted by print elements 518 and the fibrous substrate may be printed 520 on its opposite face.

Fig. 21 illustrates that thread 508 and its image effects 522 are only visible from the upper surface 521 of the substrate 510 in the windowed zones 514. Thread 508 is covered by fibrous substrate material at the inside zones 512 and the image effects 522 are not substantially visible in these zones. OPM effects are particularly dramatic when incorporated into thread 508. (See Fig. 22) As the fibrous substrate 510 is tilted in various directions the OPM image can be made to scan across the width 524 of the thread, producing a startling and dramatic visual effect. This scanning feature of an OPM image makes it possible to present image 522 which is larger than the width of the thread 508. The user examining the document containing a windowed thread 508 can then tilt the document to scan the whole image across the thread, scrolling it like a marquee sign. The effects of the Deep, Float, and Levitate embodiments can also be used to advantage in a windowed thread format.

The thread 508 may be at least partially incorporated in security papers during manufacture by techniques commonly employed in the paper-making industry. For example, thread 508 may be pressed within wet papers while the fibers are unconsolidated and pliable, as taught by U.S. Patent 4,534,398 which is incorporated herein by reference.

The windowed thread of the present system is particularly well suited for application to currency. A typical total thickness for the thread material is in the range of 22 μ to 34 μ , while the total thickness of currency paper may range as high as 88 μ . It is possible to incorporate a windowed security thread of the present system into currency paper without substantially altering the total thickness of the paper by

59 8

locally reducing the thickness of the paper by an amount equivalent to the thickness of the thread.

In an exemplary embodiment, thread 508 comprises:

- (a) one or more optical spacers;
- 5 (b) one or more optionally periodic planar arrays of micro-images or icons positioned within, on, or next to an optical spacer; and
- (c) one or more optionally periodic planar arrays of non-cylindrical micro lenses positioned on or next to either an optical spacer or a planar icon array, with each micro-lens having a base diameter of less than 50 microns.

- 10 In another embodiment, the micro-images or icons constitute filled voids or recesses that are formed on a surface of the one or more optical spacers, while the non-cylindrical micro-lenses are aspheric micro-lenses, with each aspheric micro-lens having a base diameter ranging from about 15 to about 35 microns. At least one pigmented sealing or obscuring layer 516 may be positioned on the planar array(s) of
- 15 micro-images or icons for increasing contrast and thus visual acuity of the icons and also for masking the presence of thread 508 when the thread is at least partially embedded in a security document.

In yet another embodiment of the present invention, thread 508 comprises:

- (a) an optical spacer having opposing upper and lower planar
- 20 surfaces;
- (b) a periodic array of micro-images or icons comprising filled recesses formed on the lower planar surface of the optical spacer;
- (c) a periodic array of non-cylindrical, flat field, aspheric or polygonal base multi-zonal micro-lenses positioned on the upper planar surface of the

60 7

optical spacer, wherein each micro-lens have a base diameter ranging from about 20 to about 30 microns; and

(d) a pigmented sealing or obscuring layer 516 positioned on the icon array.

5 The optical spacer(s) may be formed using one or more essentially colorless polymers including, but not limited to, polyester, polypropylene, polyethylene, polyethylene terephthalate, polyvinylidene chloride, and the like. In an exemplary embodiment, the optical spacer(s) is formed using polyester or polyethylene terephthalate and has a thickness ranging from about 8 to about 25 microns.

10 The icon and micro-lens arrays can be formed using substantially transparent or clear radiation curable material including, but not limited to acrylics, polyesters, epoxies, urethanes and the like. Preferably, the arrays are formed using acrylated urethane which is available from Lord Chemicals under the product designation U107.

15 The icon recesses formed on the lower planar surface of the optical spacer each measures from about 0.5 to about 8 microns in depth and typically 30 microns in micro-image or icon width. The recesses can be filled with any suitable material such as pigmented resins, inks, dyes, metals, or magnetic materials. In an exemplary embodiment, the recesses are filled with a pigmented resin comprising a sub-micron
20 pigment which is available from Sun Chemical Corporation under the product designation Spectra Pac.

The pigmented sealing or obscuring layer 516 can be formed using one or more of a variety of opacifying coatings or inks including, but not limited to, pigmented coatings comprising a pigment, such as titanium dioxide, dispersed within

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a binder or carrier of curable polymeric material. Preferably, the sealing or obscuring layer 516 is formed using radiation curable polymers and has a thickness ranging from about 0.5 to about 3 microns.

Thread 508, which is described above, may be prepared in accordance with the following method:

- (a) applying a substantially transparent or clear radiation curable resin to the upper and lower surfaces of the optical spacer;
- (b) forming a micro-lens array on the upper surface and an icon array in the form of recesses on the lower surface of the optical spacer;
- (c) curing the substantially transparent or clear resin using a source of radiation;
- (d) filling the icon array recesses with a pigmented resin or ink;
- (e) removing excess resin or ink from the lower surface of the optical spacer; and
- (f) applying a pigmented sealing or obscuring coating or layer to the lower surface of the optical spacer.

In many cases, it is desirable that security threads used in currency and in other high value financial and identification documents be detected and authenticated by high-speed non-contact sensors, such as capacitance sensors, magnetic field sensors, optical transmission and opacity sensors, fluorescence, and/or nuclear magnetic resonance.

Incorporation of fluorescent materials into the lens, substrate, icon matrix, or icon fill elements of a Unison film can enable covert or forensic authentication of the

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Unison material by observation of the presence and spectral characteristics of the fluorescence. A fluorescing Unison film can be designed to have its fluorescent properties visible from both sides of the material or from only one side of the material. Without an optical isolation layer in the material beneath the icon layer, the fluorescence of any part of a Unison material will be visible from either of its sides. Incorporation of an optical isolation layer makes it possible to separate the visibility of the fluorescence from its two sides. Thus a Unison material incorporating an optical isolation layer beneath the icon plane may be designed to exhibit fluorescence in a number of different ways: fluorescent color A visible from the lens side, no fluorescence visible from the optical isolation layer side, fluorescent color A or B visible from the optical isolation layer side but not from the lens side, and fluorescent color A visible from the lens side and fluorescent color A or B visible from the optical isolation layer side. The uniqueness provided by the variety of fluorescent signatures possible can be used to further enhance the security of the Unison material. The optical isolation layer can be a layer of pigmented or dyed material, a layer of metal, or a combination of pigmented layers and metal layers, that absorbs or reflects the fluorescent emission from one side of the material and prevents it from being seen from the other side.

Icons formed from shaped voids and their inverse, icons formed from shaped posts, are particularly enabling for adding machine-readable authentication features to a Unison material security thread for currency and other high value documents. The icon matrix, the icon fill, and any number of back coats (scaling coats) can all, separately and/or in all combinations, incorporate non-fluorescing pigments, non-fluorescing dyes, fluorescing pigments, fluorescing dyes, metal particles, magnetic

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particles, nuclear magnetic resonance signature materials, lasing particles, organic
LED materials, optically variable materials, evaporated metal, thin film interference
materials, liquid crystal polymers, optical upconversion and downconversion
materials, dichroic materials, optically active materials (possessing optical rotary
5 power), optically polarizing materials, and other allied materials.

In some circumstances, such as when a dark or colored coating (such as a
magnetic material or conductive layer) has been added to a Unison material or when
the color of the icon plane is objectionable when seen through the back side of a
substrate, it may be desirable to mask or hide the appearance of an embedded,
10 partially embedded, or windowed Unison material security thread from one side of a
paper substrate as seen in reflected light, while the thread is visible from the opposite
side of the substrate. Other types of currency security threads commonly incorporate
a metal layer, typically aluminum, to reflect light that filters through the surface
substrate, thereby providing similar brightness to the surrounding substrate.
15 Aluminum or other color neutral reflecting metal can be used in similar manner to
mask the appearance of a Unison thread from the back side of a paper substrate by
applying the metal layer on the back surface of the Unison material and then
optionally sealing it in place. A pigmented layer can be utilized for the same
purpose, that of hiding or obscuring the visibility of the security thread from the
20 "back" side of the document, in place of a metallized layer, or in conjunction with it.
The pigmented layer can be of any color, including white, but the most effective color
is one that matches the color and intensity of the light internally scattered within, and
outside of, the fibrous substrate.

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The addition of a metallized layer to a Unison material can be accomplished in a number of ways, including direct metallization of the icon or sealing layer of the Unison material by evaporation, sputtering, chemical deposition, or other suitable means, or lamination of the icon or sealing layer of the Unison material to the metallized surface of a second polymer film. It is common practice to create currency security threads by metallizing a film, pattern demetallizing this film to leave narrow 'ribbons' of metallized area, laminating the metallized surface to a second polymer film, then slitting the laminated material such that the metal ribbons are isolated from the edges of the slit threads by the laminating adhesive, thereby protecting the metal from chemical attack at the edges of the thread. This method can also be applied in the case of the subject invention: the Unison material can simply replace the second laminating film. Thus a Unison material can be segmented by the addition of patterned or unpatterned metallized layers.

Synthetic images can be designed as binary patterns, having one color (or absence of color) defining the icons and a different color (or absence of color) defining the background; in this case each icon zone includes a complete single-tone image that utilizes image 'pixels' that are either full on or full off. More sophisticated synthetic images can be produced by providing tonal variations of the selected icon color. The synthetic image tonal variation can be created by controlling the density of the color in each icon image or by effectively 'half-toning' the synthetic image by including or excluding design elements in selected groups of icons.

The first method, controlling the density of the color in each icon image, may be accomplished by controlling the optical density of the material creating the

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microprinted icon image. One convenient method to do this utilizes the filled void icon embodiment, already described previously.

The second method, 'half-toning' the synthetic image by including or excluding design elements in selected groups of icons, illustrated in Figure 23, accomplished by including image design elements in a proportion of icon zones that is equal to the color density desired. Figure 23 illustrates this with an example using a hexagonal repeat pattern for the icon zones 570 that would be coordinated with a similar hexagonal repeat pattern of lenses. Each of the icon zones 570 do not contain identical information. All of the icon image elements, 572, 574, 576, and 578 are present at substantially the same color density. Icon image elements 572 and 574 are present in some of the icon zones and different icon image elements are present in other icon zones. Some icon zones contain the single icon image element 570. Specifically, the icon image element 572 is present in half of the icon zones, icon image element 574 is present in three-fourths of the icon zones, icon image element 578 is present in half of the icon zones, and icon image element 576 is present in one-third of the icon zones. The information present in each icon zone determines whether its associated lens will show the color of the icon image pattern or the color of the icon image background from a particular viewing orientation. Either image elements 572 or 578 will be visible in all of the lenses associated with this icon pattern, but the synthetic image space of icon image element 572 overlaps the synthetic image space of icon image element 578. This means that the overlap zone 582 of the synthetic images of icons 572 and 578 will appear at 100% color density, because every lens will project icon image color in this zone. The non-overlapping part of these two synthetic images, 588, is only visible in 50% of the lenses, so it

66 75

appears at 50% color density. The synthetic image 586 of icon element 576 is visible in only one third of the lenses, so it appears at 33.3...% density. The synthetic image 584 of icon image element 576 correspondingly appears at 75% color density. It is clear within the scope of this teaching that a tremendous range of tonal variations can be obtained in the synthetic image through selective omission of icon image elements in selected percentages of icon zones. For greatest effectiveness the distributions of the icon image elements across the icon image zones should be relatively uniform.

A related icon image design method, illustrated in Figure 24a, can be used to create combined synthetic image elements that are smaller in dimension than the smallest feature of the individual synthetic image elements. This is possible in the common circumstance where the smallest feature size of an icon image is larger than the placement accuracy of the feature. Thus an icon image may have minimum features on the order of two microns in dimension, but those features may be placed accurately on any point on a grid of 0.25 micron spacing. In this case the smallest feature of the icon image is eight times larger than the placement accuracy of that feature. As with the previous diagram this method is illustrated using a hexagonal icon pattern 594, but it applies equally well to any other usable pattern symmetry. In similar fashion to the method of Figure 23, this method relies on the use of different information in at least one icon zone. In the example of Figure 24a two different icon patterns, 596 and 598, are each present in half of the icon zones (for clarity only one of each pattern is shown in this figure). These icon images produce a composite synthetic image 600 that incorporates synthetic image 602 created by icon image elements 596, and synthetic image 604, created by icon image elements 598. The two synthetic images, 602 and 604, are designed to have overlapped areas, 606 and 608,

67 68

that appear to have 100% color density while the non-overlapped areas 605 have 50% color density. The minimum dimension of the overlapped areas in the composite synthetic image may be as small as the synthetic magnification-scaled positioning accuracy of the icon image elements, and therefore may be smaller than the minimum
5 feature size of the two constituent synthetic images that are designed to overlap in a small region. In the example of Figure 23, the overlap regions are used to create the characters for the number "10" with narrower lines than would otherwise be possible.

This method can also be used to create narrow patterns of gaps between icon image elements, as shown in Figure 24b. Hexagonal icon zones 609 could be square
10 or any other suitable shape to make a space-filling array, but hexagonal is preferred. In this example, half the icon patterns the icon image 610, and half of them are the icon image 611. Ideally these two patterns would be relatively uniformly distributed among the icon zones. All of the elements of these patterns are depicted as being of substantially equal and uniform color density. In isolation these two patterns do not
15 clearly suggest the form of the final image, and this can be used as a security element – the image is not obvious until it is formed by the overlying lens array. One instance of the synthetic image 612 formed by the combination of the synthetic images of icon elements 610 with the synthetic image of icon elements 611 is shown, whereby the gaps that remain between the separate synthetic images form the numeral "10". In
20 this case, two synthetic images are combined to form the final synthetic image, so the colored parts of this image 613 show 50% color density. This method is not limited by the details of this example: three icons could have been used instead of two, the gaps defining the desired element in the composite synthetic images can have variable widths and unlimited shape variety, and this method can be combined with either the

b6 b7c

methods of Figures 23, 24a,b or 25, or an other icon image design method we have taught.

Covert, hidden information can be incorporated into the icon images that cannot be seen in the resulting synthetic images. Having such covert information hidden in the icon images can be used, for example, for covert authentication of an object. Two methods for accomplishing this are illustrated by Figure 25. The first method is illustrated by the use of matched icon images 616 and 618. Icon image 616 shows a solid border pattern and the number "42" contained inside of the border. Icon image 618 shows a solid shape with the number "42" as a graphical hole in that shape. In this example, the perimeter shapes of icon images 616 and 618 are substantially identical and their relative position within their respective icon zones, 634 and 636, are also substantially identical. When a composite synthetic image 620 is created from these icon images, the border of the composite synthetic image 622 will show 100% color density because all icon images have a pattern in that corresponding area, so there is full overlap in the synthetic images created from icon images 616 and 618. The color density of the interior 624 of the composite synthetic image 620 will be 50%, since the image of the space surrounding the "42" comes from icon images 618 that only fill half the icon zones, and the image of the colored "42" comes from icon images 616 that also fill half the icon zones. Consequently, there is no tonal differentiation between the "42" and its background, so the observed composite synthetic image 626 will show an image having a 100% color density border 628 and a 50% color density interior 630. The "42" covertly present in all of the icon images 616 and 618 is thereby "neutralized" and will not be seen in the observed composite synthetic image 626.

6A *

A second method for incorporating covert information into icon images is illustrated by triangles 632 in Figure 25. Triangles 632 may be randomly placed within the icon zones (not shown in this figure) or they can be placed in an array or other pattern that does not substantially match the period of the icon zones 634, 632.

5 Synthetic images are created from a multiplicity of regularly arrayed icon images that are imaged by a corresponding regular array of micro-lenses. Patterns in the icon plane that do not substantially correspond to the period of the micro-lens array will not form complete synthetic images. The pattern of triangles 632 therefore will not create a coherent synthetic image and will not be visible in the observed synthetic

10 image 626. This method is not limited to simple geometric designs, such as triangles 632: other covert information, such as alpha-numeric information, bar codes, data bits, and large-scale patterns can be incorporated into the icon plane with this method.

Figure 26 illustrates a general approach to creating fully three dimensional integral images in a Unison material (Unison 3-D). A single icon zone 640 contains

15 icon image 642 that represents a scale-distorted view of an object to be displayed in 3-D as seen from the vantage point of that icon zone 640. In this case the icon image 642 is designed to form a synthetic image 670 of a hollow cube 674. Icon image 642 has a foreground frame 644 that represents the nearest side 674 of hollow cube 672,

20 tapered gap patterns 646 that represent the corners 676 of the hollow cube 672, and a background frame 648 that represents the farthest side 678 of the hollow cube 672. It can be seen that the relative proportions of the foreground frame 644 and the background frame 648 in the icon image 642 do not correspond to the proportions of the nearest side 674 and the farthest side 678 of the synthetic image hollow cube 672.

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The reason for the difference in scale is that images that are to appear further from the plane of the Unison material experience greater magnification, so their size in the icon image must be reduced in order to provide the correct scale upon magnification to form the synthetic image 672.

5 At a different location on the Unison 3-D material we find icon zone 650 that includes a different icon image 652. As with icon image 642, icon image 652 represents a scale-distorted view of the synthetic image 672 as seen from the different vantage point of this icon zone 650. The relative scaling of foreground frame 654 and background frame 658 are similar to the corresponding elements of icon image 642
10 (although this will not be true, in general), but the position of the background frame 658 has shifted, along with the size and orientation of the corner patterns 656. Icon zone 660 is located a further distance away on the Unison 3-D material and it presents yet another scale-distorted icon image 662, including icon image 662 with foreground frame 664, tapered gap patterns 667, and background frame 668.

15 In general, the icon image in each icon zone in a Unison 3-D material will be slightly different from its nearby neighbors and may be significantly different from its distant neighbors. It can be seen that icon image 652 represents a transitional stage between icon images 642 and 662. In general, each icon image in a Unison 3-D material may be unique, but each will represent a transitional stage between the icon
20 images to either side of it.

Synthetic image 670 is formed from a multiplicity of icon images like icon images 640, 650, and 660 as synthetically imaged through an associated lens array. The synthetic image of the hollow cube 674 shows the effects of the different synthetic magnification factors that result from the effective repeat periods of the

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different elements of each of the icon images. Let us assume that the hollow cube image 674 is intended to be viewed as a SuperDeep image. In this case if icon zone 640 was disposed some distance to the lower left of icon zone 650, and icon zone 660 was disposed some distance to the upper right of icon zone 650, it can be seen that the effective period of the foreground frames 644, 654, and 664 will be less than that of the background frames 648, 658, and 668, thereby causing the closest face 676 of the cube (corresponding to the foreground frames 644, 654, and 664) to lie closer to the plane of the Unison material and the farthest face 678 of the cube to lie deeper and farther from the plane of the Unison material, and to be magnified by a greater factor.

10 The corner elements 646, 656, and 667 coordinate with both the foreground and background elements to create the effect of smoothly changing depth between them.

The method of designing icon images for Unison 3-D is more fully described in Figure 27. This figure isolates the method for a single image projector 680. As previously described, a single image projector includes a lens, an optical spacer, and an icon image; the icon image having substantially the same dimensions as the repeat period of the lens (allowing for the small differences in scale that create the Unison visual effects). The field of view for the lens and its associated icon is shown as the cone 682: this also corresponds to an inversion of the focal cone of the lens, so the proportions of the field of view cone 682 are determined by the F# of the lens.

15 Although the figure shows this cone as having a circular base, the base shape will actually be the same as the shape of an icon zone, such as a hexagon.

In this example we wish to create a Unison 3-D synthetic image that incorporates three copies of the word "UNISON", 686, 690 and 694, at the same visual size at three different SuperDeep image planes 684, 690, and 692. The

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diameter of the image planes 684, 688, and 692 expands with the field of view cone; in other words, as the depth of image increases, area covered by the field of view cone increases. Thus the field of view at the shallowest depth plane 684 only encompasses portions of "NIS" of the word UNISON, while the middle depth plane 688 encompasses all of "NIS" and portions of "U" and "O" and the deepest depth plane 692 encompasses almost all of "UNISON", lacking only part of the final "N".

The information they presented (UNISONs 686, 690, and 694) by each of these synthetic image planes 684, 688, and 692, must ultimately be incorporated into a single icon image in image projector 680. This is accomplished by capturing the information in the field of view cone 686 at each depth plane 684, 688, and 692, then scaling the resulting icon image patterns to the same dimensions. Icon image 696 represents the field of view of UNISON image 686 as seen at depth plane 684, icon image 704 represents the field of view of UNISON image 690 as seen at depth plane 688, and icon image 716 represents the field of view of UNISON image 694 as seen at depth plane 692.

Within icon image 696 icon image elements 698 originate from a portion of the first "N" of UNISON image 686, icon image element 700 originates from a portion of the "T" of UNISON image 686, and icon image elements 702 originate from portions of the "S" of UNISON image 686. Within icon image 704 icon image element 706 originates from a portion of the "U" of UNISON image 690, icon image element 708 originates from the first "N" of UNISON image 690, icon image element 710 originates from the "S" of UNISON image 690, and icon image element 714 originates from a portion of the "O" of UNISON image 690. Note that although the synthetic images 686, 690, and 694 are presented at similar scale, icon image 704 for

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the middle depth plane 688 presents its UNISON letters at a smaller scale than those of icon image 696. This accounts for the higher synthetic magnification that icon image 704 will experience (when synthetically combined with a multiplicity of surrounding icon images for the same depth plane). In similar manner, icon image 5 716 incorporates icon image elements 718 that originate from the UNISON image 694 and the UNISON letters incorporated in its icon image are at a further reduced scale.

The final icon image for this image projector is created by combining these three icon images 696, 704, and 716 into a single icon image 730, shown in Figure 28. The combined icon elements 732 incorporate all of the graphical and depth 10 information necessary for the image projector 680 to make its contribution to the synthetic image formed from a multiplicity of image projectors, each incorporating the specific icon image information that results from the intersection of its own field of view cone, centered on the image projector, with the levels and elements of the synthetic image to be produced. Since each image projector is displaced by at least 15 one lens repeat period from every other image projector, each image projector will carry different information resulting from the intersection of its field of view cone with the synthetic image space.

Each of the icon images required to present a chosen 3-D image can be computed from knowledge of the three-dimensional digital model of the synthetic 20 image, desired depth position and depth span to be presented in the synthetic image, the lens repeat period, the lens field of view, and the ultimate graphical resolution of the icon images. This latter factor puts an upper limit on the level of detail that can be presented at each depth plane. Since depth planes that lie farther from the plane of the Unison material carry a larger amount of information (because of the increased

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field of view) the graphical resolution limit of the icons has the greatest impact on the resolution of these synthetic image depth planes.

Figure 29 illustrates how the method of Figure 27 can be applied to a complex three-dimensional synthetic image, such as an image of the priceless ice-age carved mammoth ivory artifact, the Lady of Brassenpouy 742. Individual image projector 738, incorporating at least a lens, an optical spacing element, and an icon image (not shown in this figure), lies in the plane 740 of a Unison material that separate the float synthetic image space from the deep synthetic image space. In this example the synthetic image space spans the Unison material such that a portion of the image lies in the float synthetic image space and a portion lies in the deep synthetic image space. The image projector 738 has a substantially conical field of view that extends both into the deep synthetic image space 744 and into the float synthetic image space 746. A chosen number of deep image planes are selected, 748 and 752-762, at whatever spacing is required to obtain the deep synthetic image space resolution desired. Similarly, a chosen number of float image planes are selected, 750 and 764-774, at whatever spacing is required to obtain the float synthetic image space resolution desired. Some of these planes, such as deep planes 748 and float planes 750 will extend beyond the synthetic image and will not contribute to the final information in the icon image. For clarity, the number of image planes shown in Figure 29 is limited to a small number but the actual number of image planes selected may be high, such as 50 or 100 planes, or more, to obtain the desired synthetic image depth resolution.

The method of Figures 27 and 28 is then applied to obtain the icon image at each depth plane by determining the shape of the intersection of the surface of the object 742 with the selected depth plane 756-774. The resulting separate icon images

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are scaled to the final size of the combined icon image. All of the float icon images are first rotated 180 degrees (because they undergo that rotation again when they are projected, thereby returning them to their correct orientation in the synthetic image) then they are combined with the deep icon images to form the final icon image for this
5 image projector 738. This process is repeated for each of the positions of the image projectors to obtain the complete pattern of icon images required to form the full synthetic image 742.

The resolution of the synthetic image depends on the resolution of the optical projectors and the graphical resolution of the icon images. We have obtained icon
10 image graphical resolutions, less than 0.1 micron, that exceed the theoretical optical resolution limit of magnifying optics (0.2 micron). A typical icon image is created with a resolution of 0.25 micron.

Unison materials can be manufactured by sheet or web processing utilizing tools that separately incorporate the lens and icon microstructures. Both the lens tools
15 and the icon tools are originated using photomasks and photoresist methods.

Lens tools are initially designed as semiconductor-type masks, typically black chrome on glass. Masks having sufficient resolution can be created by photoreduction, electron beam writing, or laser writing. A typical mask for a lens tool will incorporate a repeating pattern of opaque hexagons at a chosen period such as 30
20 microns, with clear lines separating the hexagons that are less than 2 microns wide. This mask is then used to expose photoresist on a glass plate using a conventional semiconductor UV exposure system. The thickness of the resist is selected to obtain the desired sag of the lens. For example, a thickness of 5 microns of AZ 4620 positive photoresist is coated onto a glass plate by suitable means, such as by spin

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coating, dip coating, meniscus coating, or spraying, to form lenses having a nominal 30 micron repeat and a nominal 35 micron focal length. The photoresist is exposed with the mask pattern, and developed down to the glass in a conventional manner, then dried and degassed at 100 C for 30 minutes. The lenses are formed by thermal
5 reflow according to standard methods that are known in the art. The resulting photoresist micro-lenses are coated with a conductive metal, such as gold or silver, and a negative nickel tool is created by electroforming.

Icon tools are created in a similar manner. An icon pattern is typically designed with the aid of CAD software and this design is transmitted to a
10 semiconductor mask manufacturer. This mask is used in similar manner to the lens mask, except the thickness of the resist to be exposed is typically in the range of 0.5 micron to 8 microns, depending on the optical density of the desired synthetic image. The photoresist is exposed with the mask pattern, developed down to glass in a conventional manner, coated with a conductive metal, and a negative nickel tool is
15 created by electroforming. According the choice of original mask design and in the choice of resist type used (positive or negative), the icons can be created in the form of voids in the resist pattern or they can be created in the form of "mesas" or posts in the resist pattern, or both.

Unison materials can be manufactured from a variety of materials and a
20 multiplicity of methods that are known in the art of micro-optic and microstructure replication, including extrusion embossing, radiation cured casting, soft embossing, and injection molding, reaction injection molding, and reaction casting. An exemplary method of manufacture is to form the icons as voids in a radiation cured liquid polymer that is cast against a base film, such as 75 gage adhesion-promoted

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PET film, then to form the lenses from radiation cured polymer on the opposite face of the base film in correct alignment or skew with respect to the icons, then to fill the icon voids with a submicron particle pigmented coloring material by gravure-like doctor blading against the film surface, solidify the fill by suitable means (ex: solvent removal, radiation curing, or chemical reaction), and finally apply an optional sealing layer that may be either clear, dyed, pigmented, or incorporate covert security materials.

The manufacture of Unison Motion material requires that the icon tool and the lens tool incorporate a chosen degree of misalignment of the axes of symmetry of the two arrays. This misalignment of the icon and lens patterns axes of symmetry controls the synthetic image size and synthetic image rotation in the produced material. It is often desirable to provide the synthetic images substantially aligned with either the web direction or the cross-web direction, and in these cases the total angular misalignment of the icons and the lenses is divided equally between the lens pattern and the icon pattern. The degree of angular misalignment required is usually quite small. For example, a total angular misalignment on the order of 0.3 degree is suitable to magnify 30 micron icon images to a size of 5.7 mm in a Unison Motion material. In this example, the total angular misalignment is divided equally between the two tools, so each tool is skewed through an angle of 0.15 degree in the same direction for both tools. The skew is in the same direction because the tools form microstructures on opposite faces of a base film, so the skews of the tools add to each other, instead of canceling each other.

Skew can be incorporated into the tools at the time of the original design of the masks by rotating the whole pattern through the desired angle before writing it.

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Skew can also be mechanically incorporated into a flat nickel tool by cutting it at the appropriate angle with a numerically controlled mill. The skewed tool is then formed into a cylindrical tool using the skew-cut edge to align the tool to the rotational axis of an impression cylinder.

- 5 The synthetic magnification micro-optic system herein can be combined with additional features including but not limited to these embodiments as single elements or in various combinations, such as icon fill materials, back coatings, top coatings, both patterned and non-patterned, fill or inclusions in the lens, optical spacer or icon materials, as a laminate or coating, inks and or adhesives including aqueous, solvent
- 10 or radiation curable, optically transparent, translucent or opaque, pigmented or dyed Indicia in the form of positive or negative material, coatings, or print including but not limited to inks, metals, fluorescent, or magnetic materials, X-ray, infrared, or ultra-violet absorbent or emitting materials, metals both magnetic and non-magnetic including aluminum, nickel, chrome, silver, and gold; magnetic coatings and particles
- 15 for detection or information storage; fluorescent dye and pigments as coatings and particles; IR fluorescent coatings, fill, dyes or particles; UV fluorescent coatings, fill, dyes or particles; phosphorescent dye and pigments as coatings and particles, planchettes, DNA, RNA or other macro-molecule taggants, dichroic fibers, radioisotopes, print receptive coatings, sizing, or primers, chemically reactive
- 20 materials, micro-encapsulated ingredients, field affected materials, conductive particles and coatings both metallic and non-metallic, micro-perforated holes, colored threads or fibers, patches of Unison embedded in the surface of a document, label, or materials surface, bonded to paper or polymer as a carrier to adhere to paper during manufacture, fluorescent Dichroic threads or particles, raman scattering coatings or

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- particles, color shifting coatings or particles, Unison laminated to paper, paper board, card board, plastic, ceramic, fabric, or metal substrate, Unison as a thread, patch, label, over wrap, hot stamp foil, or tear tape, holographic, diffractive, diffractive kinegram, isograms, photographic or refractive optical elements, liquid crystal materials, Up Conversion and Down Conversion materials.

The synthetic magnification micro-optic system herein has many fields of use and applications. Examples include:

- Government and defense applications – whether Federal, State or Foreign (such as Passports, ID Cards, Driver's Licenses, Visas, Birth Certificates, Vital Records, Voter Registration Cards, Voting Ballots, Social Security Cards, Bonds, Food Stamps, Postage Stamps, and Tax Stamps);
- currency – whether Federal, State or Foreign (such as security threads in paper currency, features in polymer currency, and features on paper currency);
- documents (such as Titles, Deeds, Licenses, Diplomas, and Certificates);
- financial and negotiable instruments (such as Certified Bank Checks, Corporate Checks, Personal Checks, Bank Vouchers, Stock Certificates, Travelers' Checks, Money Orders, Credit cards, Debit cards, ATM cards, Affinity cards, Prepaid Phone cards, and Gift Cards);
- confidential information (such as Movie Scripts, Legal Documents, Intellectual Property, Medical Records/Hospital Records, Prescription Forms/Pads, and "Secret Recipes");
- product and brand protection, including Fabric & Home Care (such as Laundry Detergents, fabric conditioners, dish care, household cleaners, surface coatings, fabric refreshers, bleach, and care for special fabrics);

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beauty care (such as Hair care, hair color, skin care & cleansing, cosmetics, fragrances, antiperspirants & deodorants, feminine protection pads, tampons and pantliners);

- 5 baby and family care (such as Baby diapers, baby and toddler wipes, baby bibs, baby change & bed mats, paper towels, toilet tissue, and facial tissue);

- health care (such as Oral care, pet health and nutrition, prescription pharmaceuticals, over-the counter pharmaceuticals, drug delivery and personal health care, prescription vitamins and sports and nutritional supplements; prescription and non-prescription eyewear; Medical devices and equipment sold to Hospitals, Medical
10 Professionals, and Wholesale Medical Distributors (ie: bandages, equipment, implantable devices, surgical supplies);

food and beverage packaging;

dry goods packaging;

electronic equipment, parts & components;

- 15 apparel and footwear, including sportswear clothing, footwear, licensed and non-licensed upscale, sports and luxury apparel items, fabric;

biotech pharmaceuticals;

aerospace components and parts;

automotive components and parts;

- 20 sporting goods;

tobacco Products;

software;

compact disks and DVD's;

explosives;

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- novelty items (such as gift wrap and ribbon)
- books and magazines;
- school products and office supplies;
- business cards;
- 5 shipping documentation and packaging;
- notebook covers;
- book covers;
- book marks;
- event and transportation tickets;
- 10 gambling and gaming applications (such as Lottery tickets, game cards, casino chips and items for use at or with casinos, raffle and sweepstakes);
- home furnishing (such as towels, linens, and furniture);
- flooring and wallcoverings;
- jewelry & watches;
- 15 handbags;
- art, collectibles and memorabilia;
- toys;
- displays (such as Point of Purchase and Merchandising displays);
- product marking and labeling (such as labels, hangtags, tags, threads, tear strips,
- 20 over-wraps, securing a tamperproof image applied to a branded product or document for authentication or enhancement, as camouflage, and as asset tracking.

Suitable materials for the embodiments described above include a wide range of polymers. Acrylics, acrylated polyesters, acrylated urethanes, polypropylenes, *epoxies*, urethanes, and polyesters have suitable optical and mechanical properties for both the

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microlenses and the microstructured icon elements. Suitable materials for the optional substrate film include most of the commercially available polymer films, including acrylic, cellophane, Saran, nylon, polycarbonate, polyester, polypropylene, polyethylene, and polyvinyl. Microstructured icon fill materials can include any of the materials listed above as suitable for making microstructured icon elements, as well as solvent based inks and other commonly available pigment or dye vehicles. Dyes or pigments incorporated into these materials should be compatible with the chemical makeup of the vehicle. Pigments must have a particle size that is substantially smaller than the smallest dimensions of any component of an icon element. Optional sealing layer materials can include any of the materials listed above as suitable for making microstructured icon elements, plus many different commercially available paints, inks, overcoats, varnishes, laquers, and clear coats used in the printing and paper and film converting industries. There is no preferred combination of materials – the choice of materials depends on the details of the material geometry, on the optical properties of the system, and on the optical effect that is desired.

Although exemplary embodiments have been shown and described, it will be clear to those of ordinary skill in the art that a number of changes, modifications, or alterations to the invention as described can be made. All such changes, modifications, and alterations should therefore be seen as within the scope of the disclosure.

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We claim:

1. A synthetic magnification micro-optic system comprising:
 - (a) one or more optical spacers;
 - (b) a micro image comprised of a periodic planar array of a plurality of image
5 icons having an axis of symmetry about at least one of its planar axes, and positioned
on or next to the optical spacer; and
 - (c) a periodic planar array of image icon focusing elements having an axis of
symmetry about at least one of its planar axes, the axis of symmetry being the same
planar axis as that of the micro image planar array, each focusing element having an
10 effective diameter of less than 50 microns and being associated with an image icon
and providing an enlarged field of view over the width of the associated image icon so
that the peripheral edges of the associated image icon do not drop out of view.
2. The synthetic magnification micro-optic system of claim 1, wherein
the focusing elements are selected from the group consisting of non-cylindrical lenses
15 and non-cylindrical focusing reflectors.
3. The synthetic magnification micro-optic system of claim 2, wherein
the focusing elements are aspheric focusing elements.
4. The synthetic magnification micro-optic system of claim 3, wherein
the focusing elements have base geometries in the plane of their planar array selected
20 from the group consisting of a circular base, a hexagonal base, a rounded off
hexagonal base, a square base, a triangular base, a rounded off triangular base, and
mixtures thereof.
5. The synthetic magnification micro-optic system of claim 2, wherein
the focusing elements have an F number equivalent to 4 or less.

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6. The synthetic magnification micro-optic system of claim 3, wherein the focusing elements have an F number equivalent to 4 or less.

7. The synthetic magnification micro-optic system of claim 1, wherein the scale ratio of the repeat period of the image icons to the repeat period of the focusing elements is substantially equal to 1 and the axes of symmetry of the periodic planar array of the micro image and the periodic planar array of image icon focusing elements are misaligned.

8. The synthetic magnification micro-optic system of claim 7, wherein orthoparallactic motion effects are provided.

9. The synthetic magnification micro-optic system of claim 1, wherein the scale ratio of the repeat period of the image icons to the repeat period of the focusing elements is greater than 1 and the axes of symmetry of the periodic planar array of the micro image and the periodic planar array of image icon focusing elements are aligned.

10. The synthetic magnification micro-optic system of claim 1, wherein the scale ratio of the repeat period of the image icons to the repeat period of the focusing elements is less than 1 and the axes of symmetry of the periodic planar array of the micro image and the periodic planar array of image icon focusing elements are aligned.

11. The synthetic magnification micro-optic system of claim 1, wherein the scale ratio of the repeat period of the image icons to the repeat period of the focusing elements is axially asymmetric in the planes of the image icons and the focusing elements, the scale ratio being less than 1 in one axis of symmetry and being greater than 1 in the other axis of symmetry, and the axes of symmetry of the periodic

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planar array of the micro image and the periodic planar array of image icon focusing elements are aligned.

12. The synthetic magnification micro-optic system of claim 1, each focusing element having an effective diameter of from about 15 to about 30 microns.
- 5 13. The synthetic magnification micro-optic system of claim 1, each focusing element having an effective diameter of less than 30 microns.
14. The synthetic magnification micro-optic system of claim 1, having a total thickness of less than about 45 microns.
15. The synthetic magnification micro-optic system of claim 1, having a
10 total thickness of about 10 to about 40 microns.
16. The synthetic magnification micro-optic system of claim 1, each focusing element having a focal length of less than about 40 microns.
17. The synthetic magnification micro-optic system of claim 1, each focusing element having a focal length of about 10 to less than about 30 microns.
- 15 18. The synthetic magnification micro-optic system of claim 1, wherein a morphing effect is provided for causing one synthetically magnified image to morph into another synthetically magnified image.
19. The synthetic magnification micro-optic system of claim 1, each image icon being formed from a printing method selected from the group consisting of ink
20 jet, laserjet, letterpress, flexo, gravure, and intaglio printing methods.
20. The synthetic magnification micro-optic system of claim 1, wherein the image icons are formed as recesses in a substrate, the voids in the recesses being filled with an evaporated metal material, a dyed material, a pigmented material and combinations thereof.

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21. The synthetic magnification micro-optic system of claim 1, having two layers of image icons at different depths in the system and a combination of focusing elements some having a focal length for focusing on one of the two layers of image icons and some having a focal length for focusing on the other of the two layers of image icons.

22. The synthetic magnification micro-optic system of claim 1, wherein the focusing elements are non-cylindrical lenses and a reflective layer is positioned on the side of the micro image opposite the focusing elements.

23. The synthetic magnification micro-optic system of claim 1, including a transparent tamper indicating material is placed over the focusing elements.

24. The synthetic magnification micro-optic system of claim 1, including a second periodic planar array of focusing elements placed on the side of the micro image opposite the focusing elements.

25. The synthetic magnification micro-optic system of claim 24, having a second planar array of image icons in between the two planar arrays of focusing elements.

26. A document security device comprising:

- (a) one or more optical spacers;
- (b) a micro image comprised of a periodic planar array of a plurality of image icons having an axis of symmetry about at least one of its planar axes, and positioned on or next to the optical spacer; and
- (c) a periodic planar array of image icon focusing elements having an axis of symmetry about at least one of its planar axes, the axis of symmetry being the same planar axis as that of the micro image planar array, each focusing element having an

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effective diameter of less than 50 microns and being associated with an image icon and providing an enlarged field of view over the width of the associated image icon so that the peripheral edges of the associated image icon do not drop out of view.

27. The document security device of claim 26, the device operating as a
5 laminating film on a document.

28. The document security device of claim 26, the document being selected from the group consisting of I.D. cards, credit cards, drivers' licenses, financial documents, bank notes, bank checks and currency.

29. The document security device of claim 26, wherein the device is in the
10 form of a security thread for incorporation into currency paper.

30. The synthetic magnification micro-optic system of claim 1, wherein the focusing elements are selected from the group consisting of non-cylindrical lenses and non-cylindrical focusing reflectors.

31. The synthetic magnification micro-optic system of claim 30, wherein
15 the focusing elements are aspheric focusing elements.

32. The synthetic magnification micro-optic system of claim 31, wherein the focusing elements have base geometries in the plane of their planar array selected from the group consisting of a circular base, a hexagonal base, a rounded off hexagonal base, a square base, a triangular base, a rounded off triangular base, and
20 truxtures thereof.

33. The synthetic magnification micro-optic system of claim 30, wherein the focusing elements have an F number equivalent to 4 or less.

34. The synthetic magnification micro-optic system of claim 31, wherein the focusing elements have an F number equivalent to 4 or less.



35. The synthetic magnification micro-optic system of claim 26, wherein the scale ratio of the repeat period of the image icons to the repeat period of the focusing elements is substantially equal to 1 and the axes of symmetry of the periodic planar array of the micro image and the periodic planar array of image icon focusing elements are misaligned.

36. The synthetic magnification micro-optic system of claim 35, wherein orthoparallactic motion effects are provided.

37. The synthetic magnification micro-optic system of claim 26, wherein the scale ratio of the repeat period of the image icons to the repeat period of the focusing elements is greater than 1 and the axes of symmetry of the periodic planar array of the micro image and the periodic planar array of image icon focusing elements are aligned.

38. The synthetic magnification micro-optic system of claim 26, wherein the scale ratio of the repeat period of the image icons to the repeat period of the focusing elements is less than 1 and the axes of symmetry of the periodic planar array of the micro image and the periodic planar array of image icon focusing elements are aligned.

39. The synthetic magnification micro-optic system of claim 26, wherein the scale ratio of the repeat period of the image icons to the repeat period of the focusing elements is axially asymmetric in the planes of the image icons and the focusing elements, the scale ratio being less than 1 in one axis of symmetry and being greater than 1 in the other axis of symmetry, and the axes of symmetry of the periodic planar array of the micro image and the periodic planar array of image icon focusing elements are aligned.

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40. The synthetic magnification micro-optic system of claim 26, each focusing element having an effective diameter of from about 15 to about 30 microns.
41. The synthetic magnification micro-optic system of claim 26, each focusing element having an effective diameter of less than 30 microns.
- 5 42. The synthetic magnification micro-optic system of claim 26, having a total thickness of less than about 45 microns.
43. The synthetic magnification micro-optic system of claim 26, having a total thickness of about 10 to about 40 microns.
44. The synthetic magnification micro-optic system of claim 26, each
10 focusing element having a focal length of less than about 40 microns.
45. The synthetic magnification micro-optic system of claim 26, each focusing element having a focal length of about 10 to less than about 30 microns.
46. The synthetic magnification micro-optic system of claim 26, wherein a morphing effect is provided for causing one synthetically magnified image to morph
15 into another synthetically magnified image.
47. The synthetic magnification micro-optic system of claim 26, each image icon being formed from a printing method selected from the group consisting of ink jet, laserjet, letterpress, flexo, gravure, and intaglio printing methods.
48. The synthetic magnification micro-optic system of claim 26, wherein
20 the image icons are formed as recesses in a substrate, the voids in the recesses being filled with an evaporated metal material, a dyed material, a pigmented material and combinations thereof.
49. A synthetic magnification micro-optic system comprising:
- (a) one or more optical spacers;

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(b) a micro image comprised of a periodic planar array of a plurality of image icons having an axis of symmetry about at least one of its planar axes, and positioned on or next to the optical spacer; and

(c) a periodic planar array of image icon focusing elements having an axis of symmetry about at least one of its planar axes, the axis of symmetry being the same planar axis as that of the micro image planar array, each focusing element being an aspheric focusing element having an effective diameter of less than 50 microns and being associated with an image icon.

50. The synthetic magnification micro-optic system of claim 49, wherein the focusing elements have base geometries in the plane of their planar array selected from the group consisting of a circular base, a hexagonal base, a rounded off hexagonal base, a square base, a triangular base, a rounded off triangular base, and mixtures thereof.

51. The synthetic magnification micro-optic system of claim 49, wherein the focusing elements have an F number equivalent to 4 or less.

52. The synthetic magnification micro-optic system of claim 50, wherein the focusing elements have an F number equivalent to 4 or less.

53. The synthetic magnification micro-optic system of claim 49, wherein the scale ratio of the repeat period of the image icons to the repeat period of the focusing elements is substantially equal to 1 and the axes of symmetry of the periodic planar array of the micro image and the periodic planar array of image icon focusing elements are misaligned.

54. The synthetic magnification micro-optic system of claim 53, wherein orthoparallactic motion effects are provided.

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55. The synthetic magnification micro-optic system of claim 49, wherein the scale ratio of the repeat period of the image icons to the repeat period of the focusing elements is greater than 1 and the axes of symmetry of the periodic planar array of the micro image and the periodic planar array of image icon focusing elements are aligned.

56. The synthetic magnification micro-optic system of claim 49, wherein the scale ratio of the repeat period of the image icons to the repeat period of the focusing elements is less than 1 and the axes of symmetry of the periodic planar array of the micro image and the periodic planar array of image icon focusing elements are aligned.

57. The synthetic magnification micro-optic system of claim 49, wherein the scale ratio of the repeat period of the image icons to the repeat period of the focusing elements is axially asymmetric in the planes of the image icons and the focusing elements, the scale ratio being less than 1 in one axis of symmetry and being greater than 1 in the other axis of symmetry, and the axes of symmetry of the periodic planar array of the micro image and the periodic planar array of image icon focusing elements are aligned.

58. The synthetic magnification micro-optic system of claim 49, each focusing element having an effective diameter of from about 15 to about 30 microns.

59. The synthetic magnification micro-optic system of claim 49, each focusing element having an effective diameter of less than 30 microns.

60. The synthetic magnification micro-optic system of claim 49, having a total thickness of less than about 45 microns.

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61. The synthetic magnification micro-optic system of claim 49, having a total thickness of about 10 to about 40 microns.

62. The synthetic magnification micro-optic system of claim 49, each focusing element having a focal length of less than about 40 microns.

5 63. The synthetic magnification micro-optic system of claim 49, each focusing element having a focal length of about 10 to less than about 30 microns.

64. The synthetic magnification micro-optic system of claim 49, wherein a morphing effect is provided for causing one synthetically magnified image to morph into another synthetically magnified image.

10 65. The synthetic magnification micro-optic system of claim 49, each image icon being formed from a printing method selected from the group consisting of ink jet, laserjet, letterpress, flexo, gravure, and intaglio printing methods.

66. The synthetic magnification micro-optic system of claim 49, wherein the image icons are formed as recesses in a substrate, the voids in the recesses being
15 filled with an evaporated metal material, a dyed material, a pigmented material and combinations thereof.

67. A document security device comprising:

(a) one or more optical spacers;

(b) a micro image comprised of a periodic planar array of a plurality of image
20 icons having an axis of symmetry about at least one of its planar axes, and positioned on or next to the optical spacer; and

(c) a periodic planar array of image icon focusing elements having an axis of symmetry about at least one of its planar axes, the axis of symmetry being the same planar axis as that of the micro image planar array, each focusing element being an

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aspheric focusing element having an effective diameter of less than 50 microns and being associated with an image icon.

68. A method of producing a synthetic magnification micro-optic system, comprising the steps of:

- 5 (a) providing one or more optical spacers;
- (b) providing a micro image comprised of a periodic planar array of a plurality of image icons having an axis of symmetry about at least one of its planar axes, and positioned on or next to the optical spacer; and
- (c) providing a periodic planar array of image icon focusing elements having
- 10 an axis of symmetry about at least one of its planar axes, the axis of symmetry being the same planar axis as that of the micro image planar array, each focusing element having an effective diameter of less than 50 microns and being associated with an image icon and providing an enlarged field of view over the width of the associated image icon so that the peripheral edges of the associated image icon do not drop out
- 15 of view.

69. A method of producing a synthetic magnification micro-optic system, comprising the steps of:

- (a) providing one or more optical spacers;
- (b) providing a micro image comprised of a periodic planar array of a
- 20 plurality of image icons having an axis of symmetry about at least one of its planar axes, and positioned on or next to the optical spacer; and
- (c) providing a periodic planar array of image icon focusing elements having an axis of symmetry about at least one of its planar axes, the axis of symmetry being the same planar axis as that of the micro image planar array, each focusing element

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being an aspheric focusing element having an effective diameter of less than 50 microns and being associated with an image icon.

70. A method for producing a document security device, comprising the steps of:

- 5 (a) providing one or more optical spacers;
- (b) providing a micro image comprised of a periodic planar array of a plurality of image icons having an axis of symmetry about at least one of its planar axes, and positioned on or next to the optical spacer; and
- (c) providing a periodic planar array of image icon focusing elements having
- 10 an axis of symmetry about at least one of its planar axes, the axis of symmetry being the same planar axis as that of the micro image planar array, each focusing element having an effective diameter of less than 50 microns and being associated with an image icon and providing an enlarged field of view over the width of the associated image icon so that the peripheral edges of the associated image icon do not drop out
- 15 of view.

71. A method of producing a document security device, comprising the steps of:

- (a) providing one or more optical spacers;
- (b) providing a micro image comprised of a periodic planar array of a
- 20 plurality of image icons having an axis of symmetry about at least one of its planar axes, and positioned on or next to the optical spacer; and
- (c) providing a periodic planar array of image icon focusing elements having an axis of symmetry about at least one of its planar axes, the axis of symmetry being the same planar axis as that of the micro image planar array, each focusing element

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being an aspheric focusing element having an effective diameter of less than 50 microns and being associated with an image icon.

72. A method of controlling motion effects in a synthetic magnification micro-optic system, comprising the steps of:

- 5 (a) providing one or more optical spacers;
- (b) providing a micro image comprised of a periodic planar array of a plurality of image icons having an axis of symmetry about at least one of its planar axes, and positioned on or next to the optical spacer;
- (c) providing a periodic planar array of image icon focusing elements having
10 an axis of symmetry about at least one of its planar axes, the axis of symmetry being the same planar axis as that of the micro image planar array, each focusing element having an effective diameter of less than 50 microns and being associated with an image icon and providing an enlarged field of view over the width of the associated image icon so that the peripheral edges of the associated image icon do not drop out
15 of view; and
- (d) selecting the scale ratio of the repeat period of the image icons to the repeat period of the focusing elements from the group consisting of less than 1, substantially equal to 1, and greater than 1, and selecting whether the axes of symmetry of the periodic planar array of the micro image and the periodic planar
20 array of image icon focusing elements are aligned or misaligned.

73. A method of controlling motion effects in a synthetic magnification micro-optic system, comprising the steps of:

- (a) providing one or more optical spacers;

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(b) providing a micro image comprised of a periodic planar array of a plurality of image icons having an axis of symmetry about at least one of its planar axes, and positioned on or next to the optical spacer;

(c) providing a periodic planar array of image icon focusing elements having
5 an axis of symmetry about at least one of its planar axes, the axis of symmetry being the same planar axis as that of the micro image planar array, each focusing element being an aspheric focusing element having an effective diameter of less than 50 microns and being associated with an image icon; and

(d) selecting the scale ratio of the repeat period of the image icons to the
10 repeat period of the focusing elements from the group consisting of less than 1, substantially equal to 1, and greater than 1, and selecting whether the axes of symmetry of the periodic planar array of the micro image and the periodic planar array of image icon focusing elements are aligned or misaligned.

74. A method of controlling motion effects in a document security device,
15 comprising the steps of:

(a) providing one or more optical spacers;

(b) providing a micro image comprised of a periodic planar array of a plurality of image icons having an axis of symmetry about at least one of its planar axes, and positioned on or next to the optical spacer;

20 (c) providing a periodic planar array of image icon focusing elements having an axis of symmetry about at least one of its planar axes, the axis of symmetry being the same planar axis as that of the micro image planar array, each focusing element having an effective diameter of less than 50 microns and being associated with an image icon and providing an enlarged field of view over the width of the associated

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image icon so that the peripheral edges of the associated image icon do not drop out of view; and

- (d) selecting the scale ratio of the repeat period of the image icons to the repeat period of the focusing elements from the group consisting of less than 1, substantially equal to 1, and greater than 1, and selecting whether the axes of symmetry of the periodic planar array of the micro image and the periodic planar array of image icon focusing elements are aligned or misaligned.

75. A method of controlling motion effects in a document security device, comprising the steps of:

- 10 (a) providing one or more optical spacers;
- (b) providing a micro image comprised of a periodic planar array of a plurality of image icons having an axis of symmetry about at least one of its planar axes, and positioned on or next to the optical spacer;
- (c) providing a periodic planar array of image icon focusing elements having
- 15 an axis of symmetry about at least one of its planar axes, the axis of symmetry being the same planar axis as that of the micro image planar array, each focusing element being an aspheric focusing element having an effective diameter of less than 50 microns and being associated with an image icon; and
- (d) selecting the scale ratio of the repeat period of the image icons to the
- 20 repeat period of the focusing elements from the group consisting of less than 1, substantially equal to 1, and greater than 1, and selecting whether the axes of symmetry of the periodic planar array of the micro image and the periodic planar array of image icon focusing elements are aligned or misaligned.

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76. An image icon for use in a synthetic magnification micro-optic system, the synthetic magnification micro-optic system including:

(a) one or more optical spacers;

5 (b) a micro image comprised of a periodic planar array of a plurality of image icons having an axis of symmetry about at least one of its planar axes, and positioned on or next to the optical spacer; and

(c) a periodic planar array of image icon focusing elements having an axis of symmetry about at least one of its planar axes, the axis of symmetry being the same planar axis as that of the micro image planar array, each focusing element being
10 associated with an image icon; and

the image icons being formed as recesses in a substrate, the voids in the recesses being filled with an evaporated metal material, a dyed material, a pigmented material and combinations thereof.

77. An image icon for use in a document security device, the synthetic
15 magnification micro-optic system including:

(a) one or more optical spacers;

(b) a micro image comprised of a periodic planar array of a plurality of image icons having an axis of symmetry about at least one of its planar axes, and positioned on or next to the optical spacer; and

20 (c) a periodic planar array of image icon focusing elements having an axis of symmetry about at least one of its planar axes, the axis of symmetry being the same planar axis as that of the micro image planar array, each focusing element being associated with an image icon; and

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the image icons being formed as recesses in a substrate, the voids in the recesses being filled with an evaporated metal material, a dyed material, a pigmented material and combinations thereof.

78. A synthetic magnification micro-optic system comprising:

5 (a) one or more optical spacers;

(b) a micro image comprised of a periodic planar array of a plurality of image icons having an axis of symmetry about at least one of its planar axes, and positioned on or next to the optical spacer; and

10 (c) a periodic planar array of image icon focusing elements having an axis of symmetry about at least one of its planar axes, the axis of symmetry being the same planar axis as that of the micro image planar array, each focusing element being a polygonal base multi-zonal lens.

79. A document security device comprising:

(a) one or more optical spacers;

15 (b) a micro image comprised of a periodic planar array of a plurality of image icons having an axis of symmetry about at least one of its planar axes, and positioned on or next to the optical spacer; and

(c) a periodic planar array of image icon focusing elements having an axis of symmetry about at least one of its planar axes, the axis of symmetry being the same planar axis as that of the micro image planar array, each focusing element being a polygonal base multi-zonal lens.

80. A method of making a synthetic magnification micro-optic system, comprising the steps of:

(a) providing one or more optical spacers;

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(b) providing a micro image comprised of a periodic planar array of a plurality of image icons having an axis of symmetry about at least one of its planar axes, and positioned on or next to the optical spacer; and

(c) providing a periodic planar array of image icon focusing elements having an axis of symmetry about at least one of its planar axes, the axis of symmetry being the same planar axis as that of the micro image planar array, each focusing element being a polygonal base multi-zonal lens.

81. A method of making document security device, comprising the steps of

(a) providing one or more optical spacers;

(b) providing a micro image comprised of a periodic planar array of a plurality of image icons having an axis of symmetry about at least one of its planar axes, and positioned on or next to the optical spacer; and

(c) providing a periodic planar array of image icon focusing elements having an axis of symmetry about at least one of its planar axes, the axis of symmetry being the same planar axis as that of the micro image planar array, each focusing element being a polygonal base multi-zonal lens.

82. A security thread comprising:

(a) one or more optical spacers;

(b) one or more optionally periodic planar arrays of micro-images or icons positioned within, on, or next to an optical spacer; and

(c) one or more optionally periodic planar arrays of non-cylindrical micro lenses positioned on or next to either an optical spacer or a planar icon array, with each micro-lens having a base diameter of less than 50 microns.

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83. A security thread, comprising:

- (a) an optical spacer having opposing upper and lower planar surfaces;
- (b) a periodic array of micro-images or icons comprising filled recesses

formed on the lower planar surface of the optical spacer;

- 5 (c) a periodic array of non-cylindrical, flat field, aspheric or polygonal base multi-zonal micro-lenses positioned on the upper planar surface of the optical spacer, wherein each micro-lens have a base diameter ranging from about 20 to about 30 microns; and

- (d) a pigmented sealing or obscuring layer 516 positioned on the icon array.

10 84. A method of making a security thread, comprising the steps of:

- (a) applying a substantially transparent or clear radiation curable resin to the upper and lower surfaces of the optical spacer;

- (b) forming a micro-lens array on the upper surface and an icon array in the form of recesses on the lower surface of the optical spacer;

- 15 (c) curing the substantially transparent or clear resin using a source of radiation;

- (d) filling the icon array recesses with a pigmented resin or ink;

- (e) removing excess resin or ink from the lower surface of the optical spacer; and

- 20 (f) applying a pigmented sealing or obscuring coating or layer to the lower surface of the optical spacer.

102 ⁹⁷/₁₀

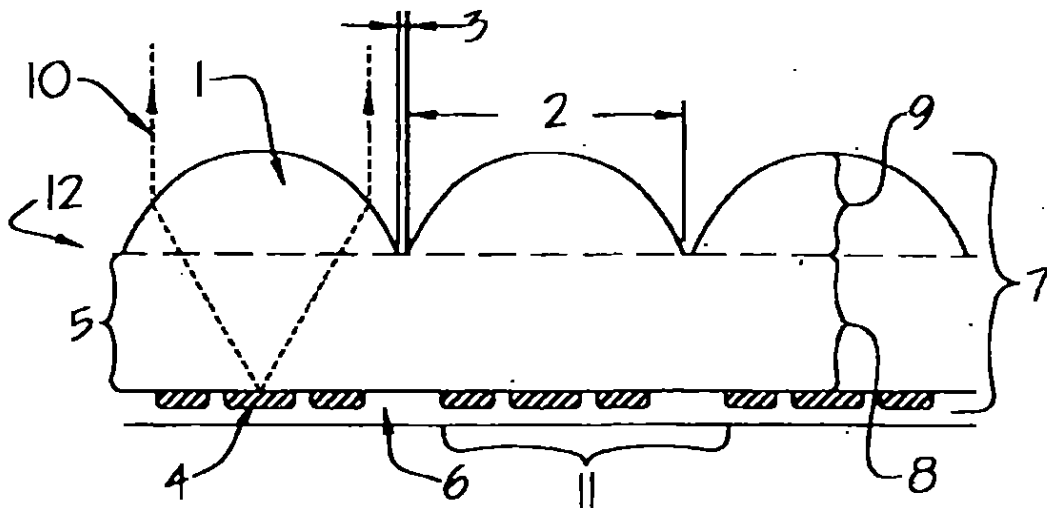


Fig. 1a

103 \$

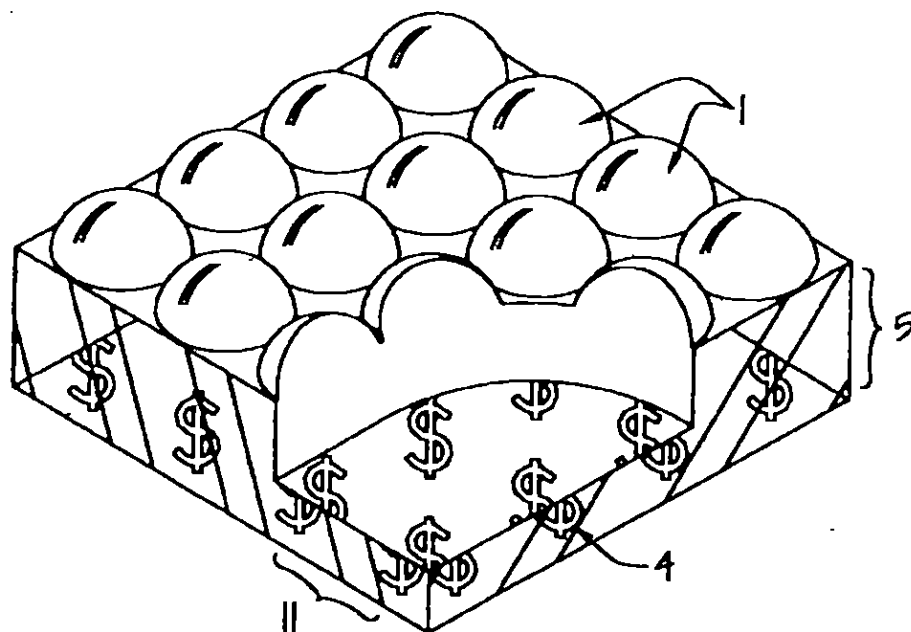


Fig. 1b

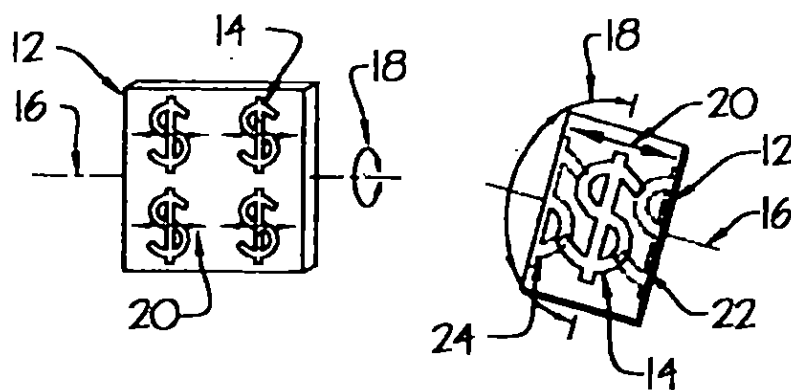
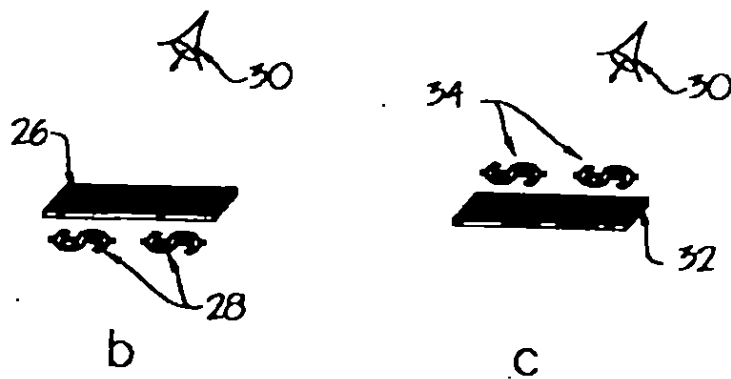


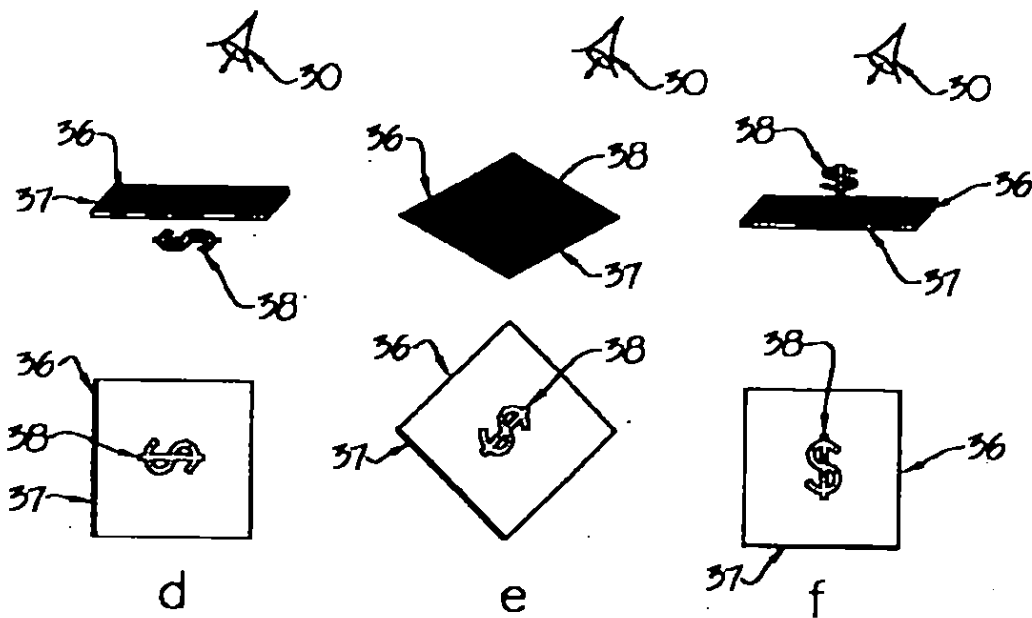
Fig 2a

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104 \$

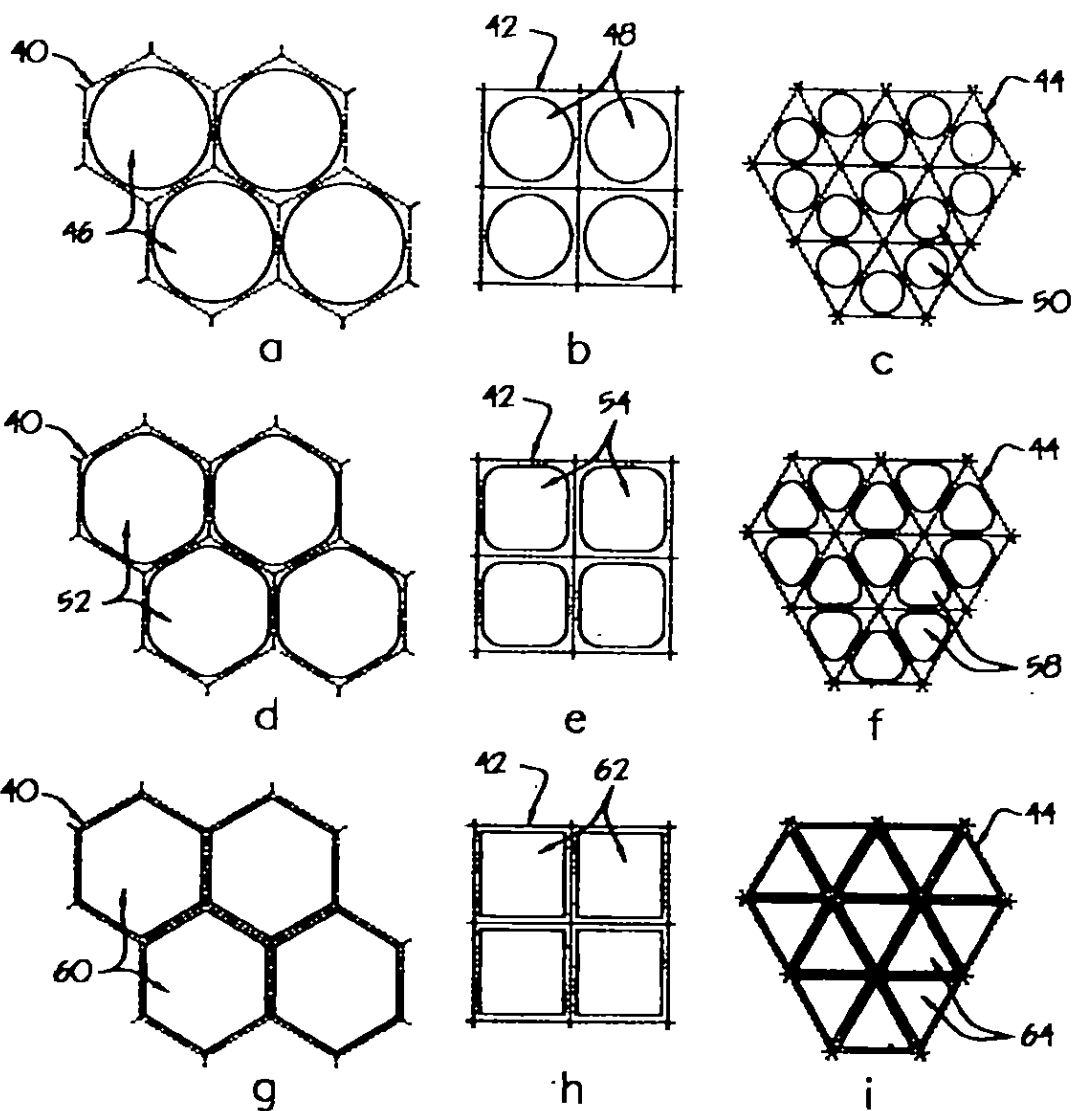


Figs 2b,c



Figs 2d,e,f

105 *fe*



Figs 3a-i

106 ⁹/₂

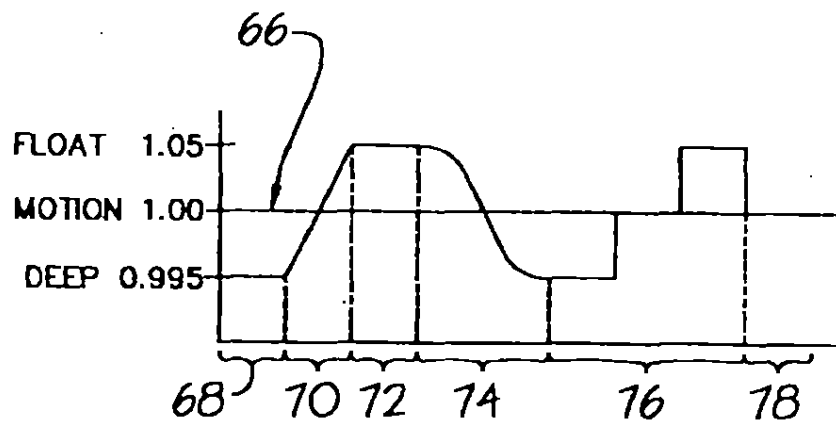
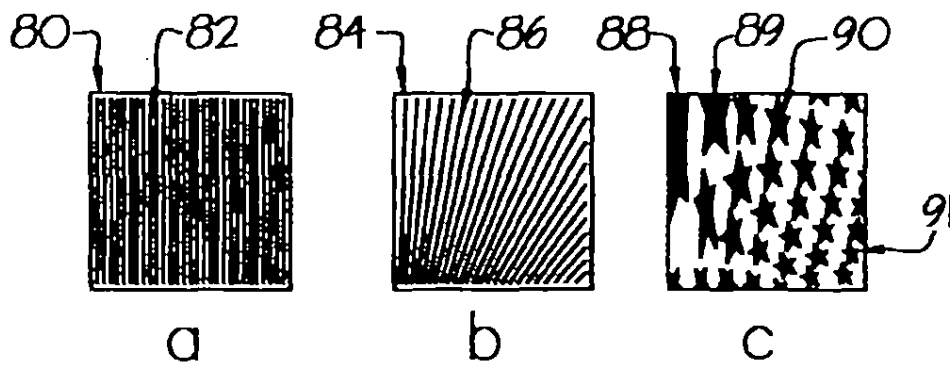
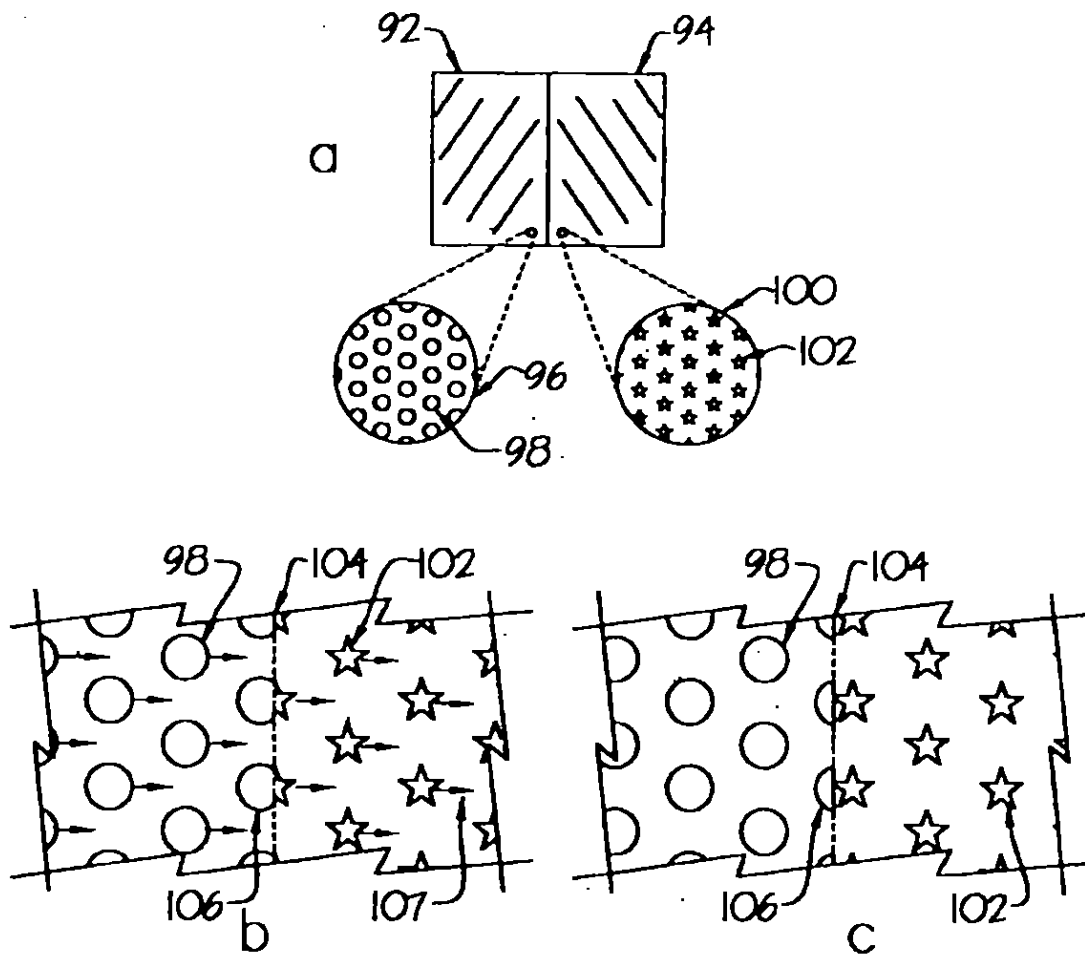


Fig. 4



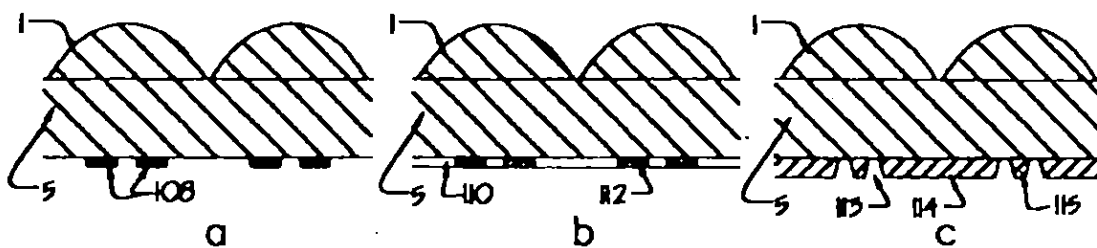
Figs. 5a-c

107
102

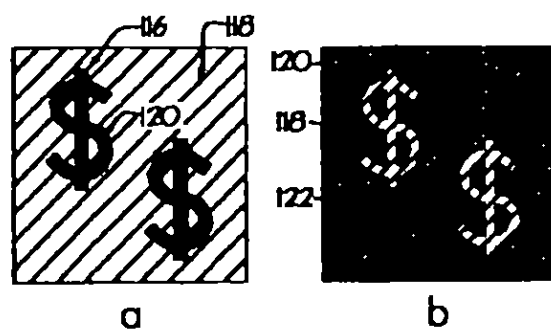


Figs. 6a-c

108



Figs. 7a-c



Figs. 8a-b

109 27

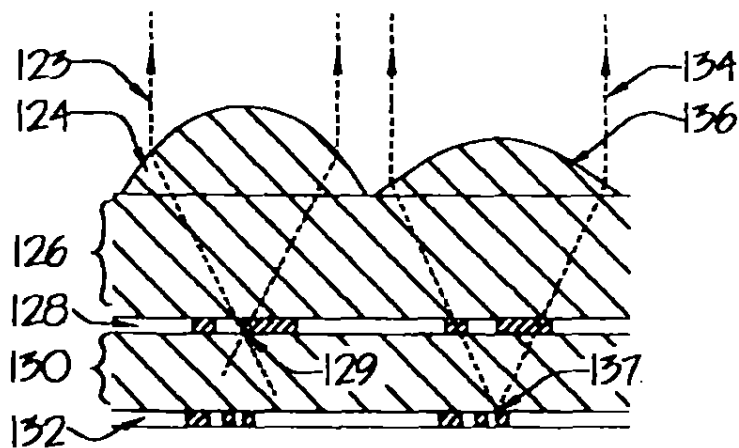


Fig. 9

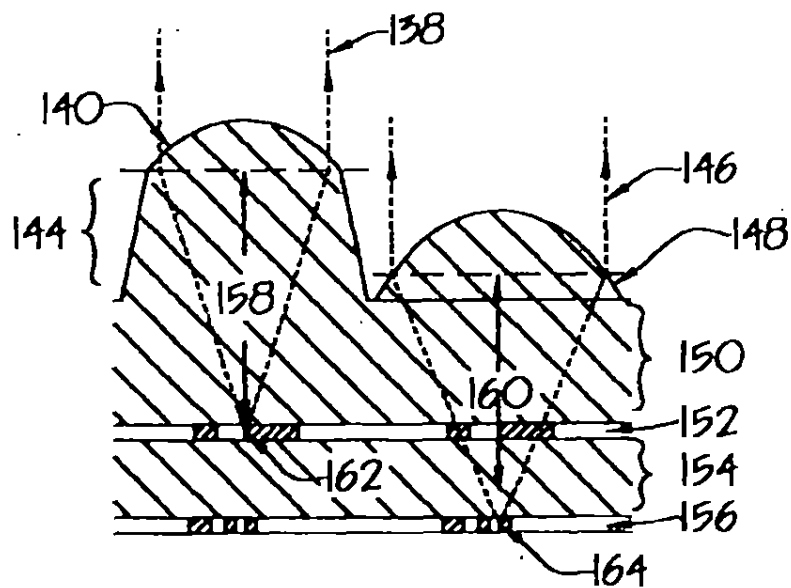
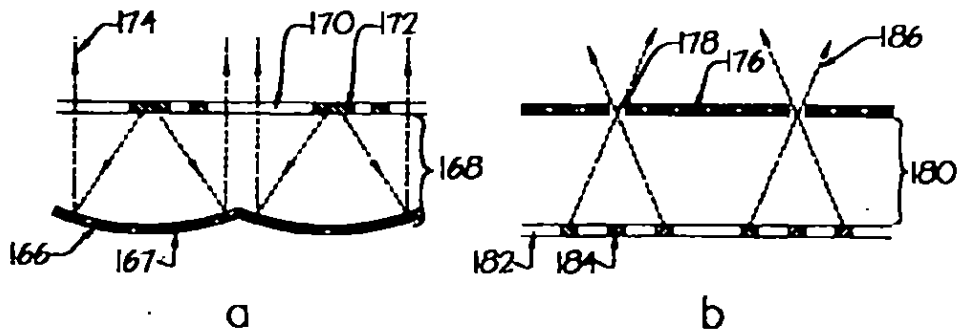


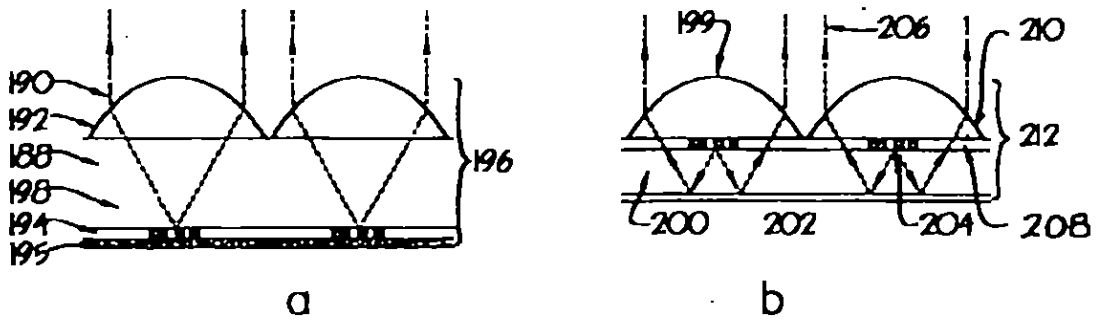
Fig. 10

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110



Figs. 11a-b



Figs. 12a-b

111 2

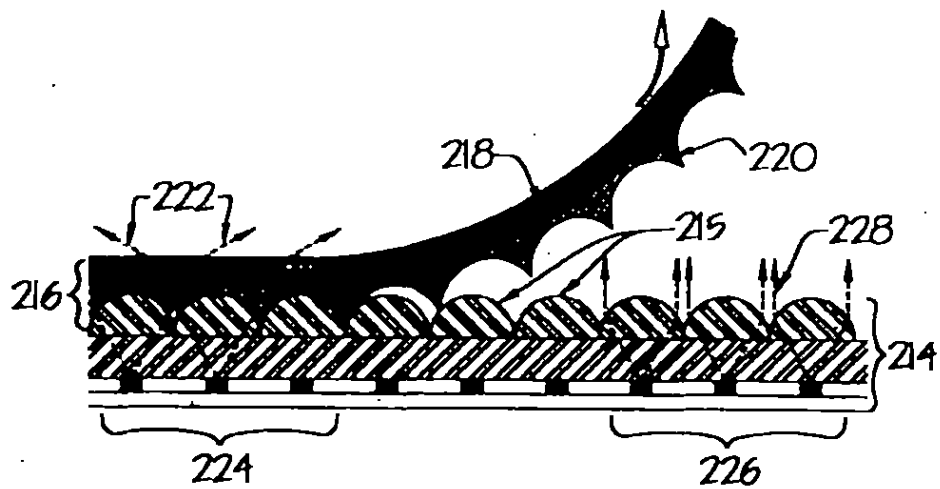


Fig. 13

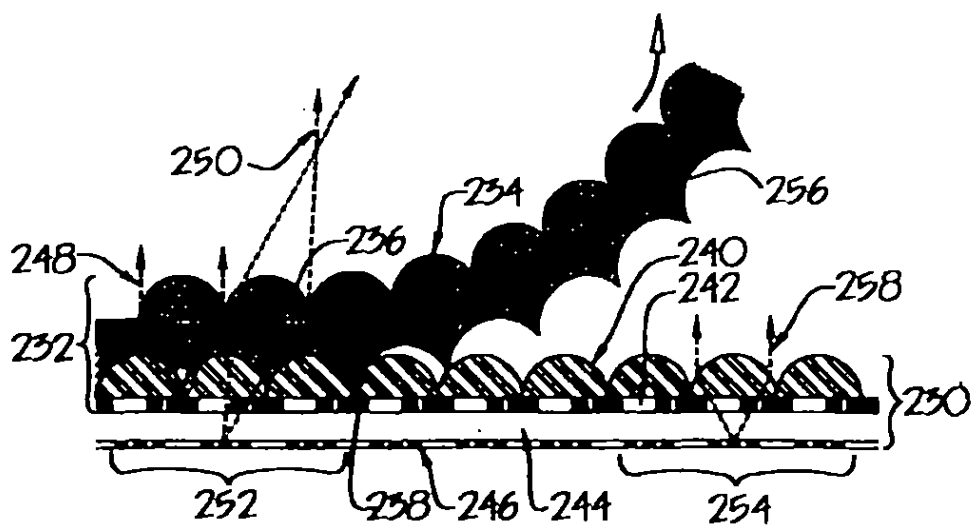
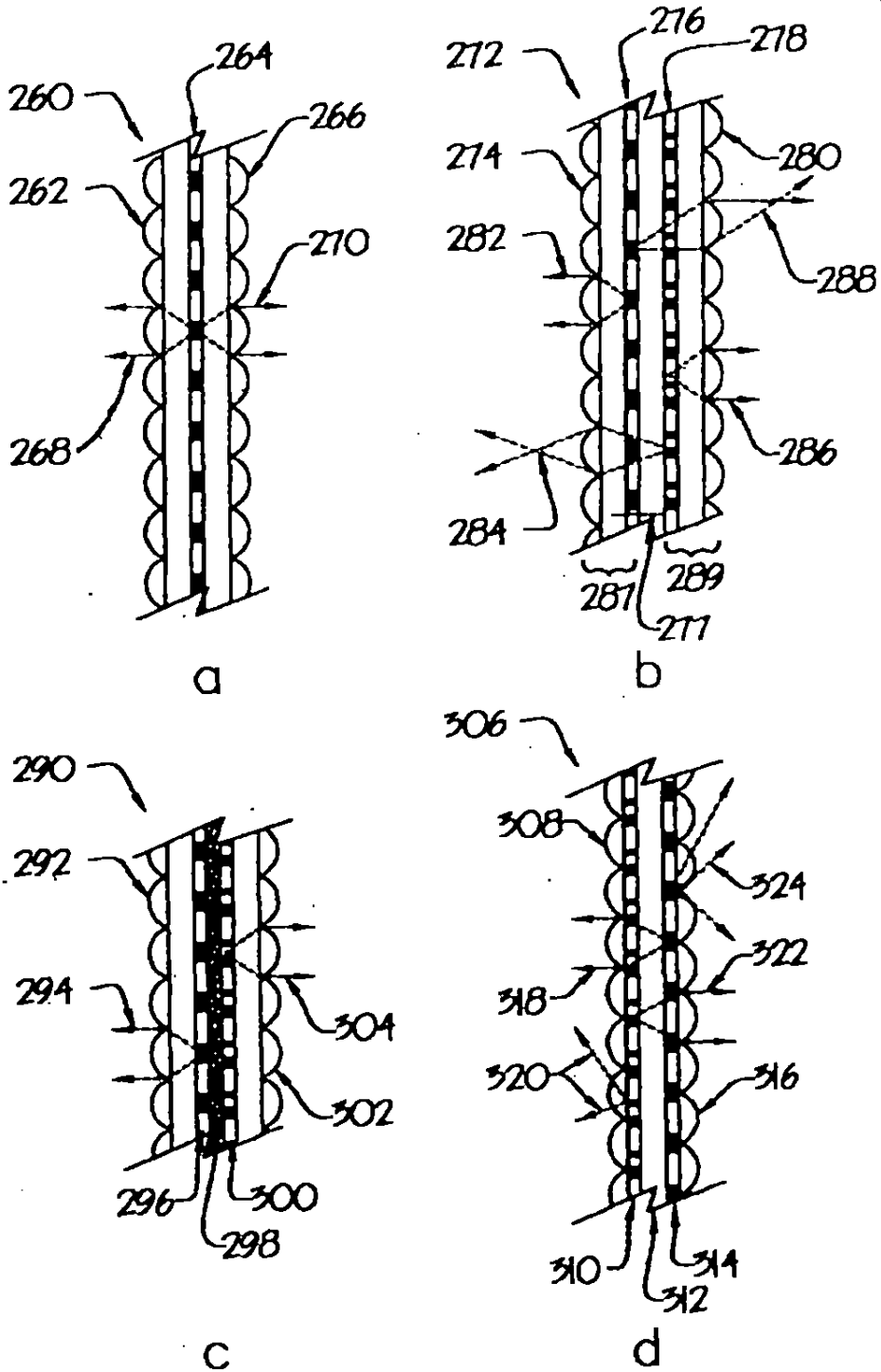


Fig. 14

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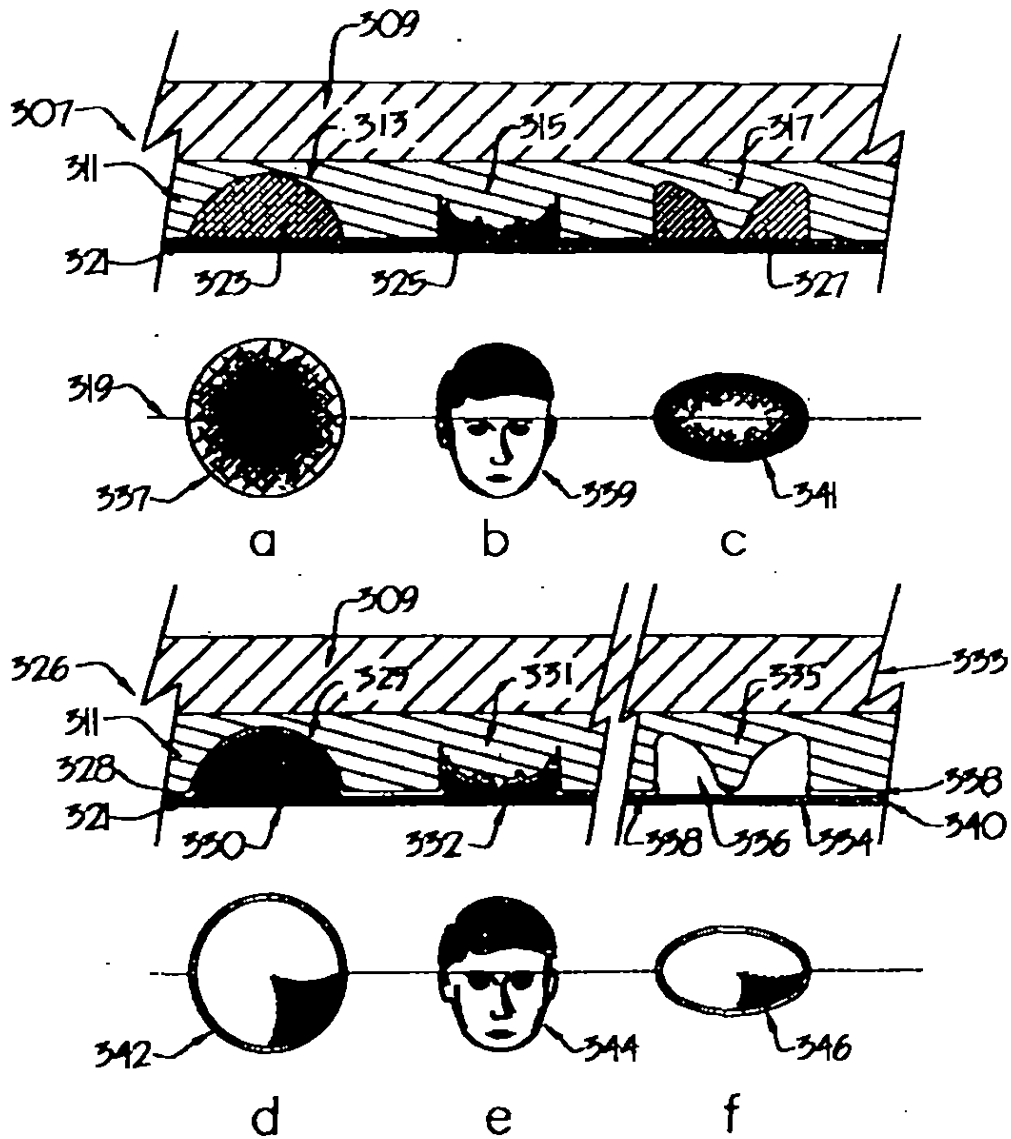
112 11



Figs. 15a-d

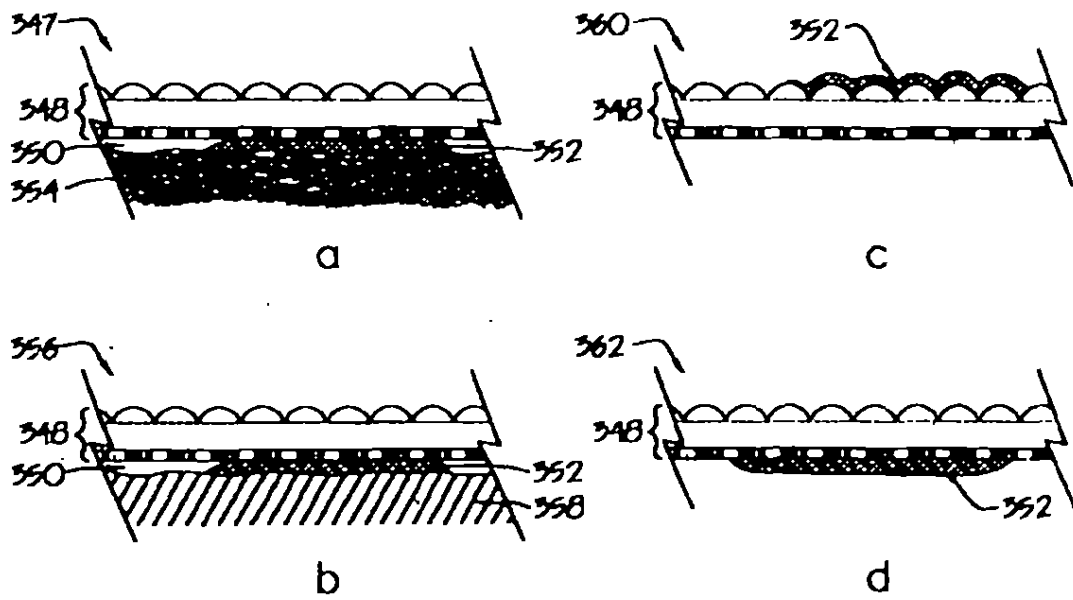
SUBSTITUTE SHEET (RULE 26)

113



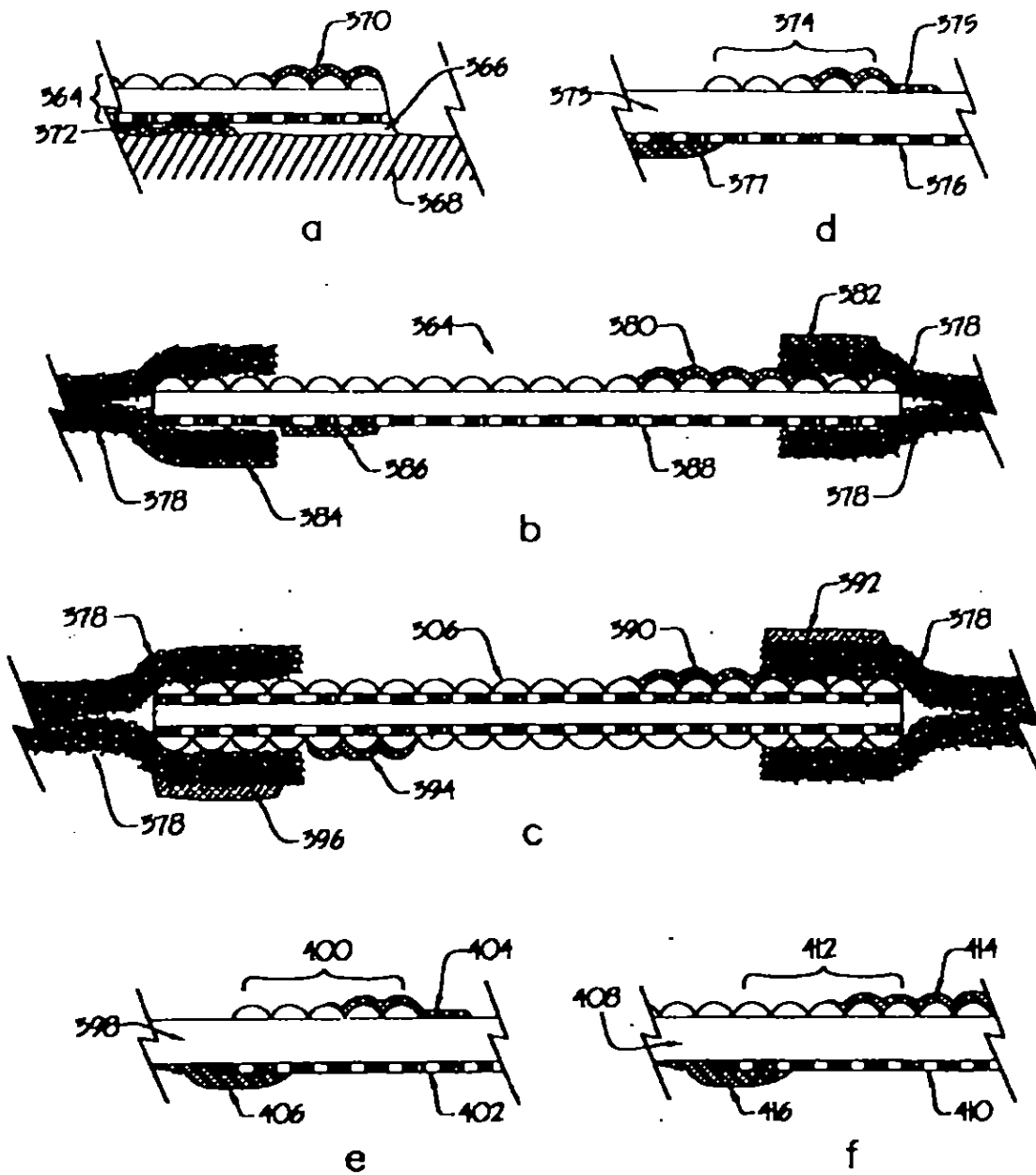
Figs. 16a-f

114-32



Figs. 17a-d

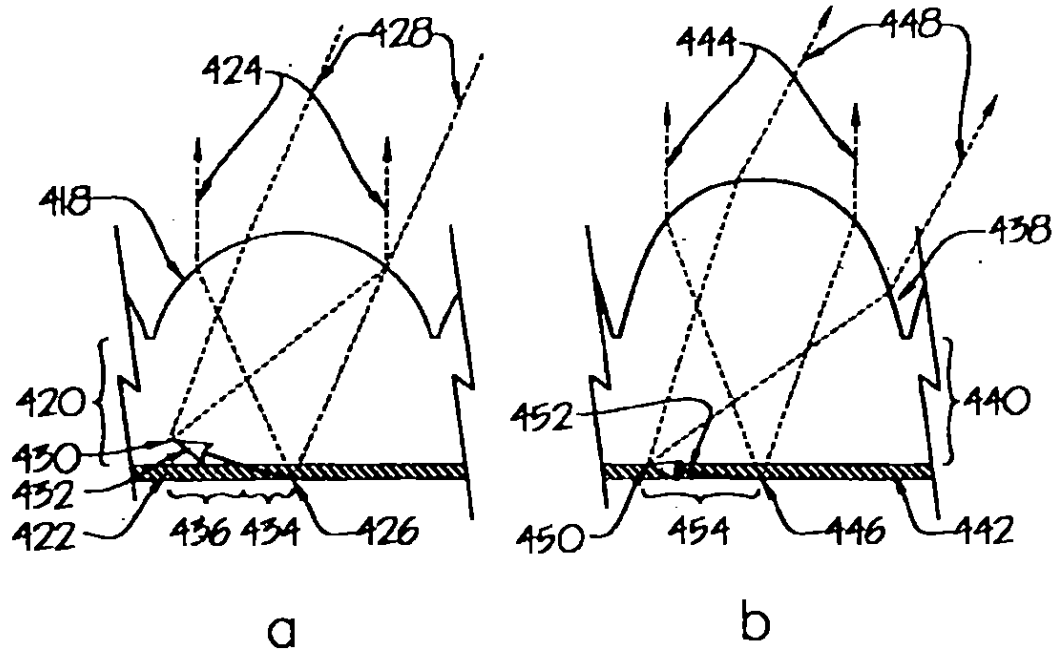
115 9/11



Figs. 18a-f

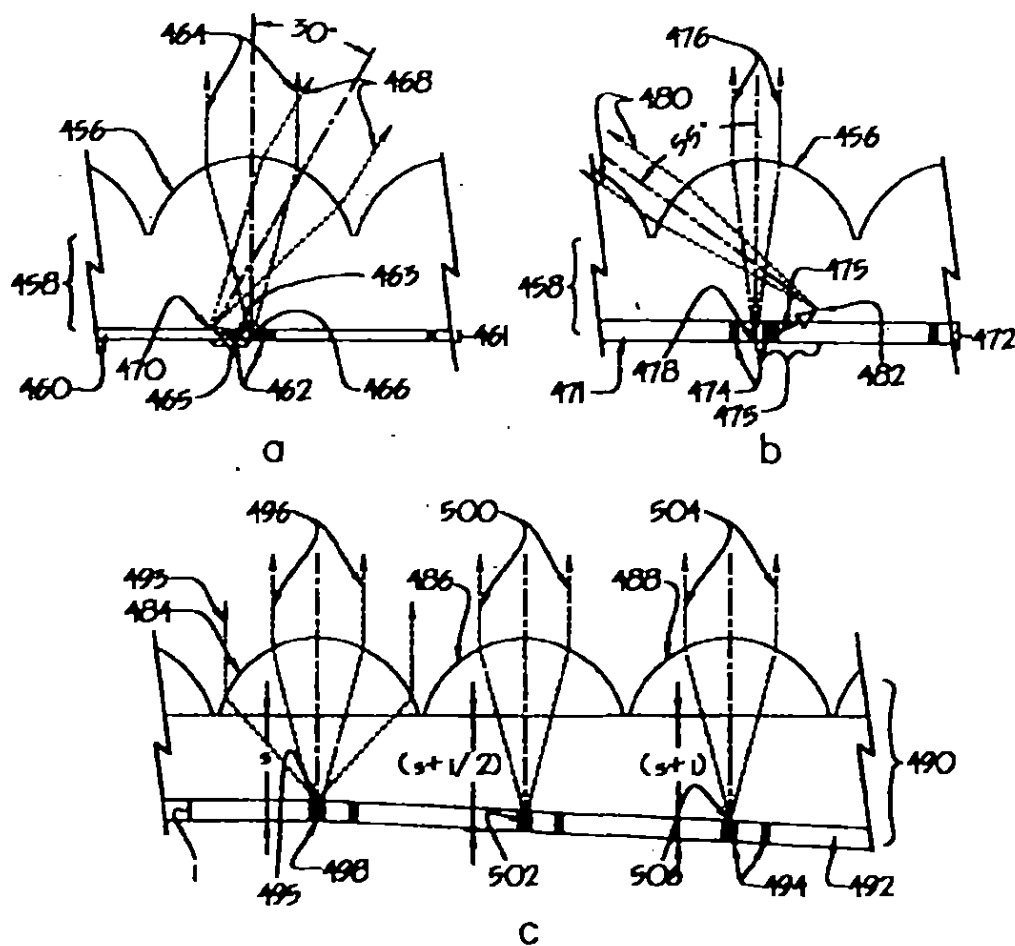
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116 *



Figs. 19a-b

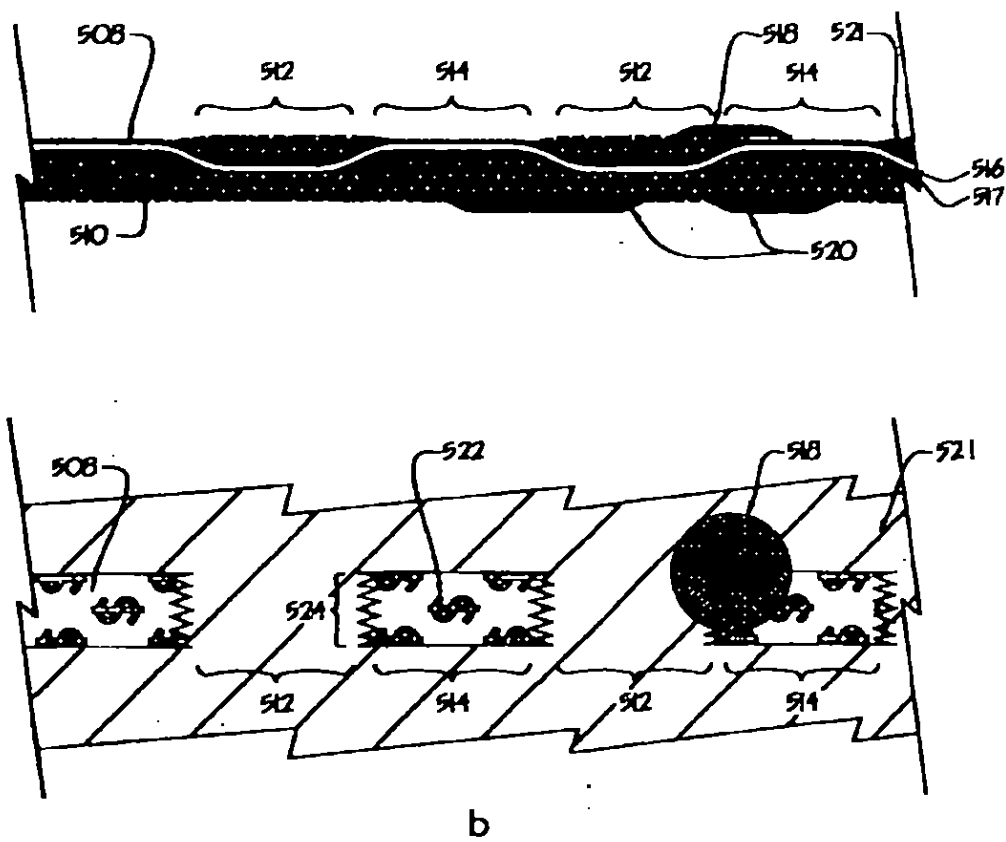
117.00



Figs. 20a-c

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118 3



Figs. 21a,b

117 70

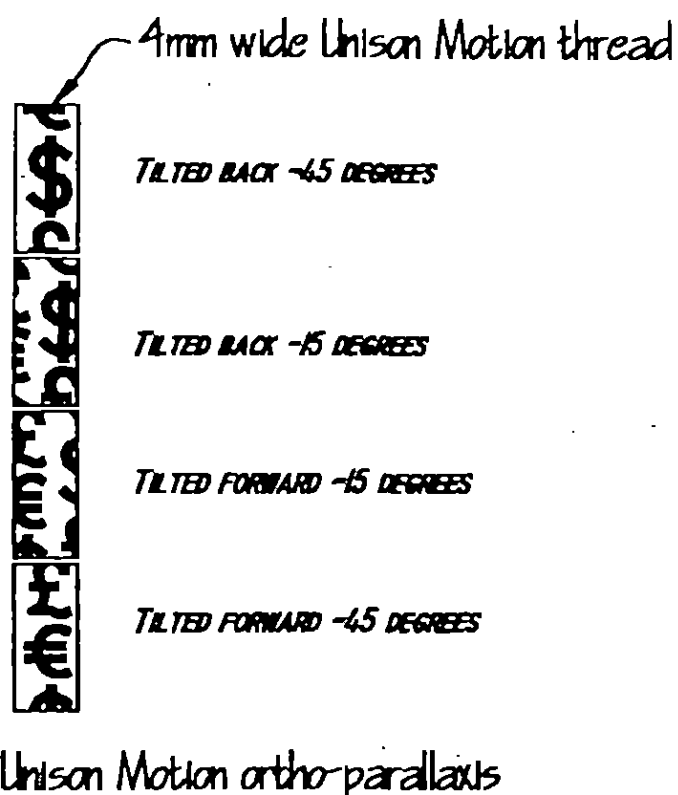


Fig. 22

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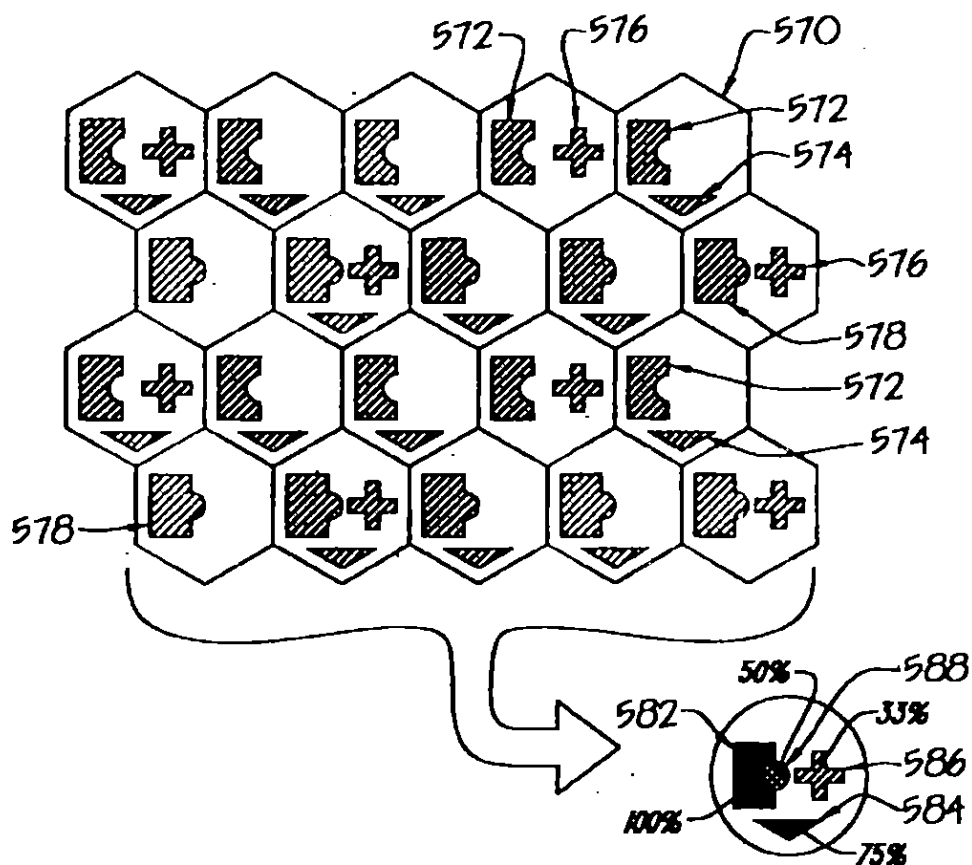


Fig. 23

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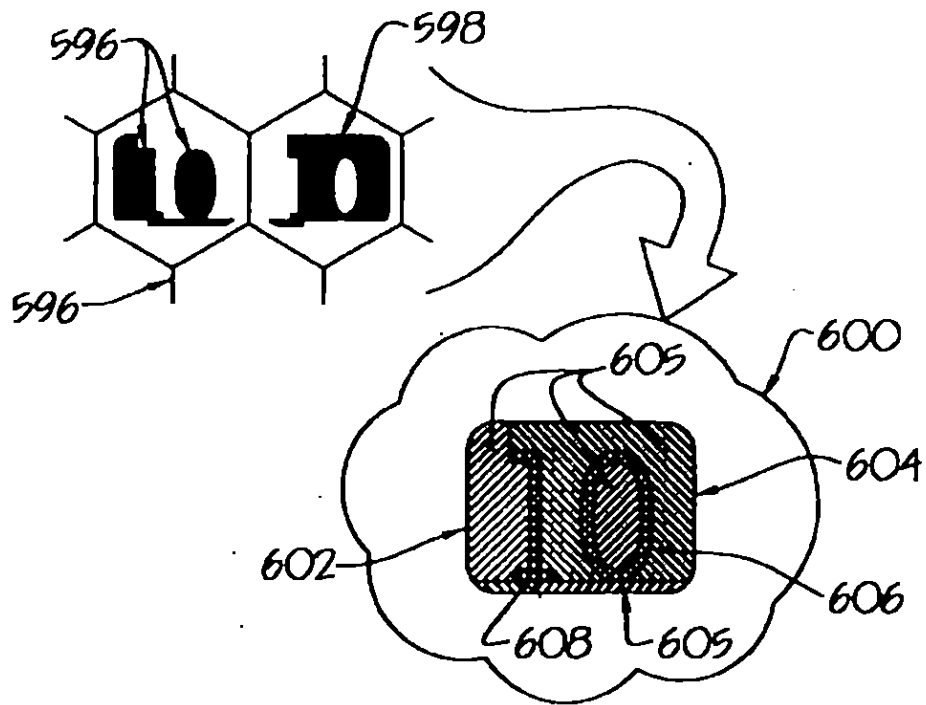


Fig. 24a

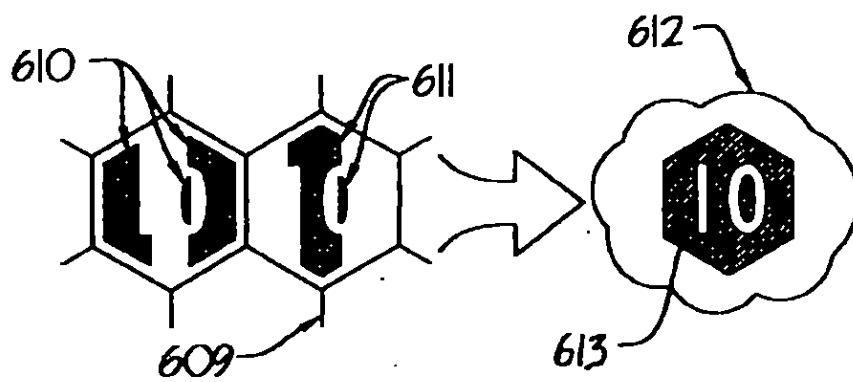


Fig. 24b

122

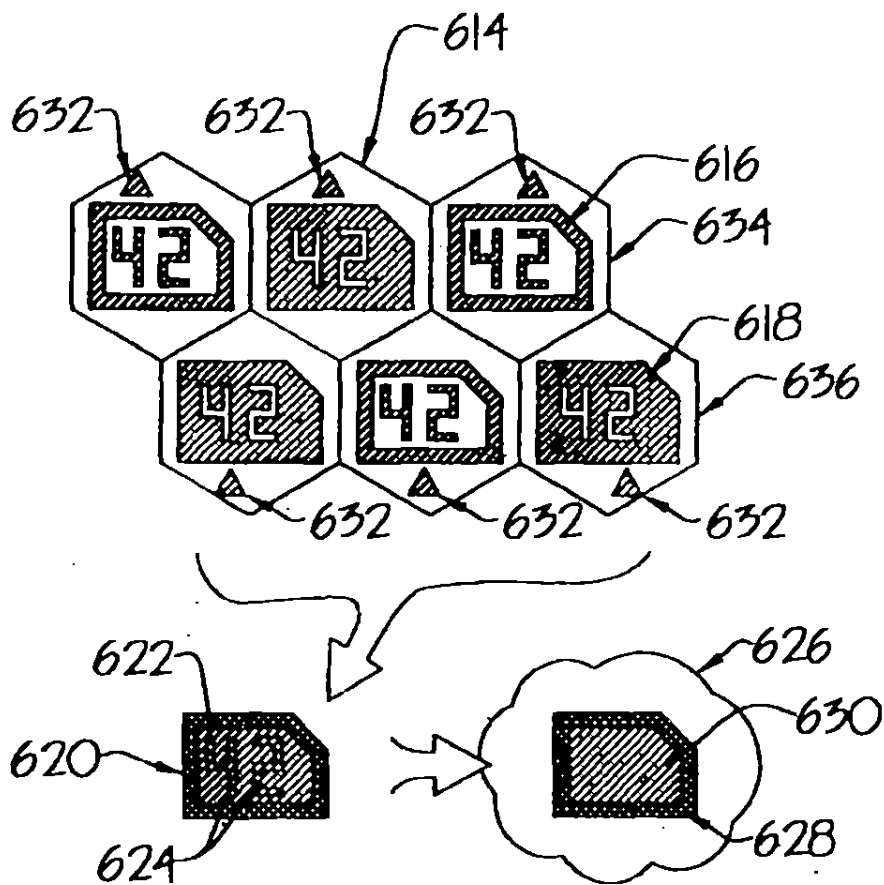


Fig. 25

128 27

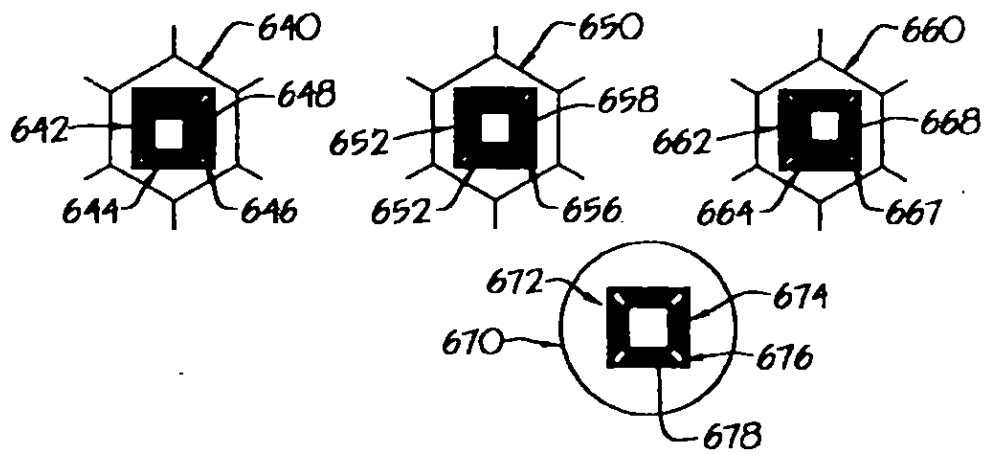


Fig. 26

124-5

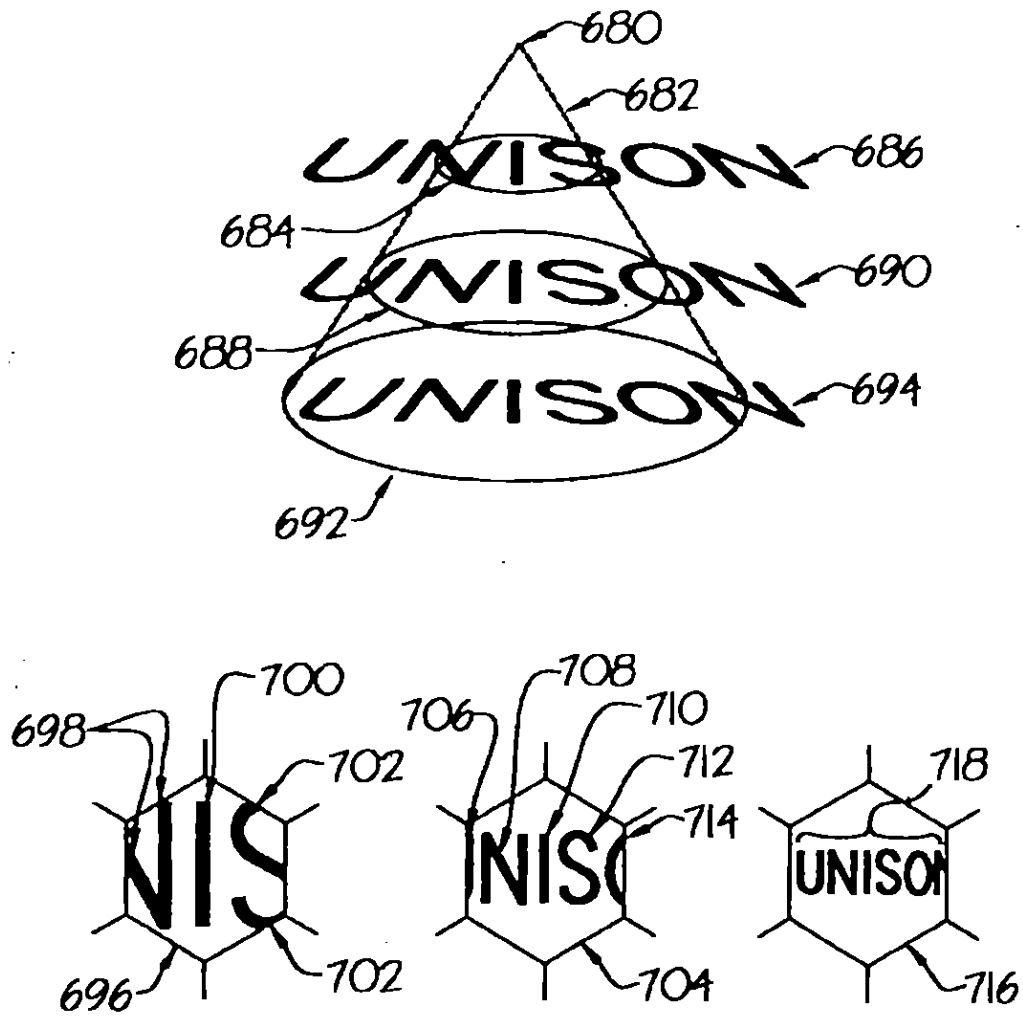


Fig. 27

125

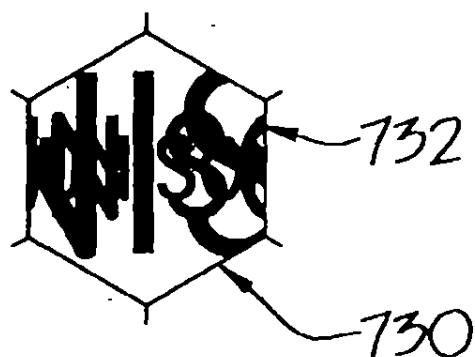


Fig. 28

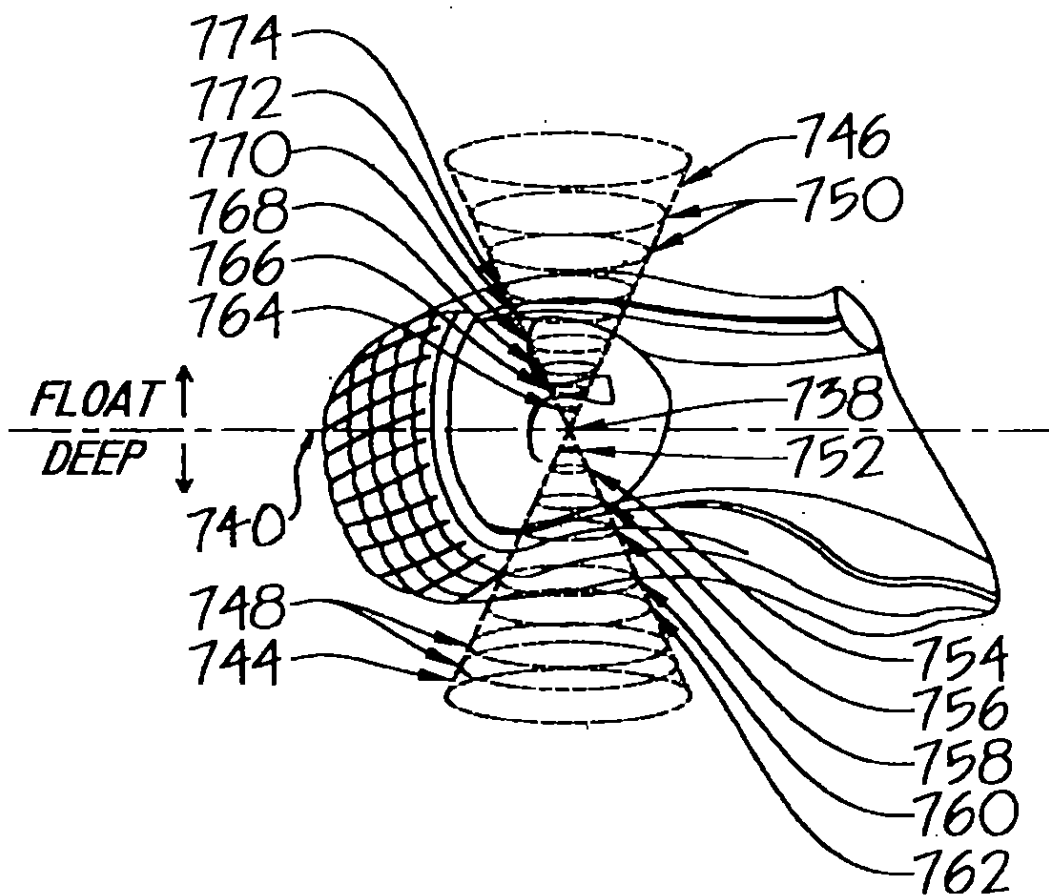
126 ~~21~~

Fig. 29

129 93

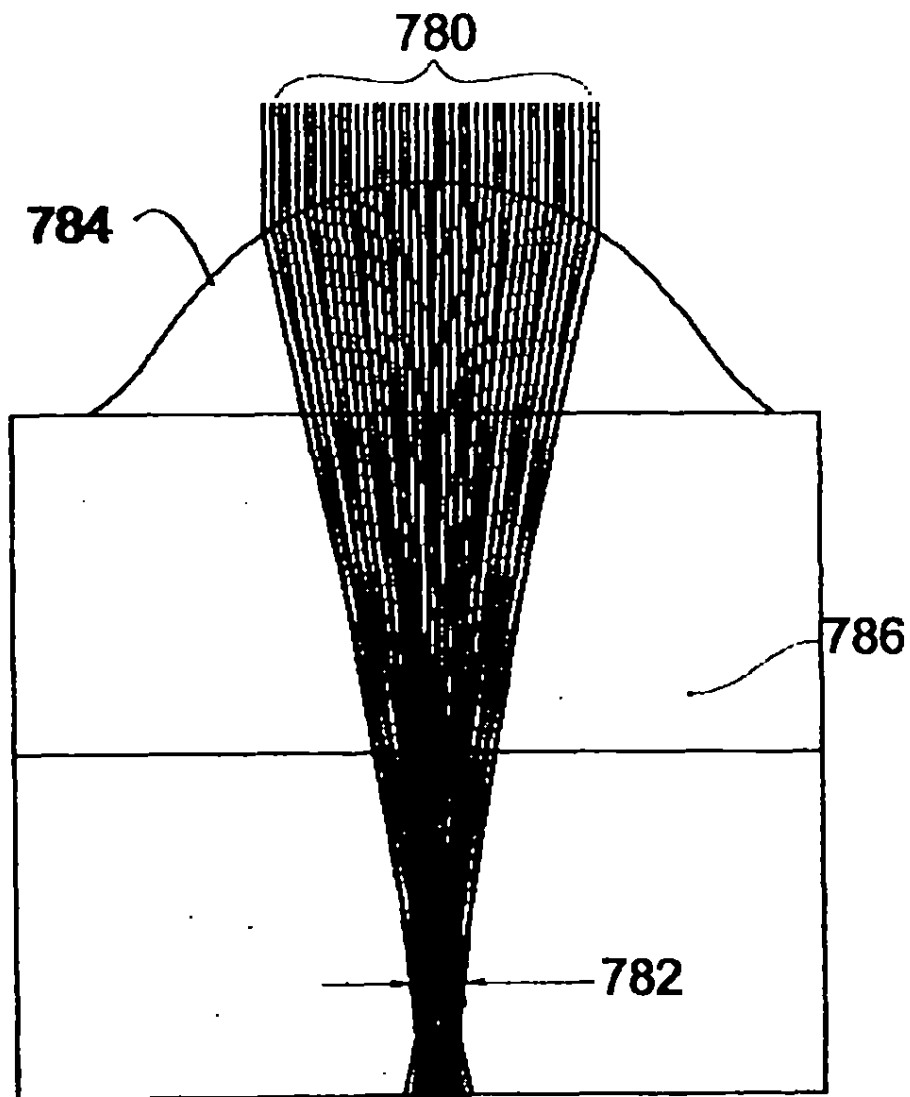


Fig. 30

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128

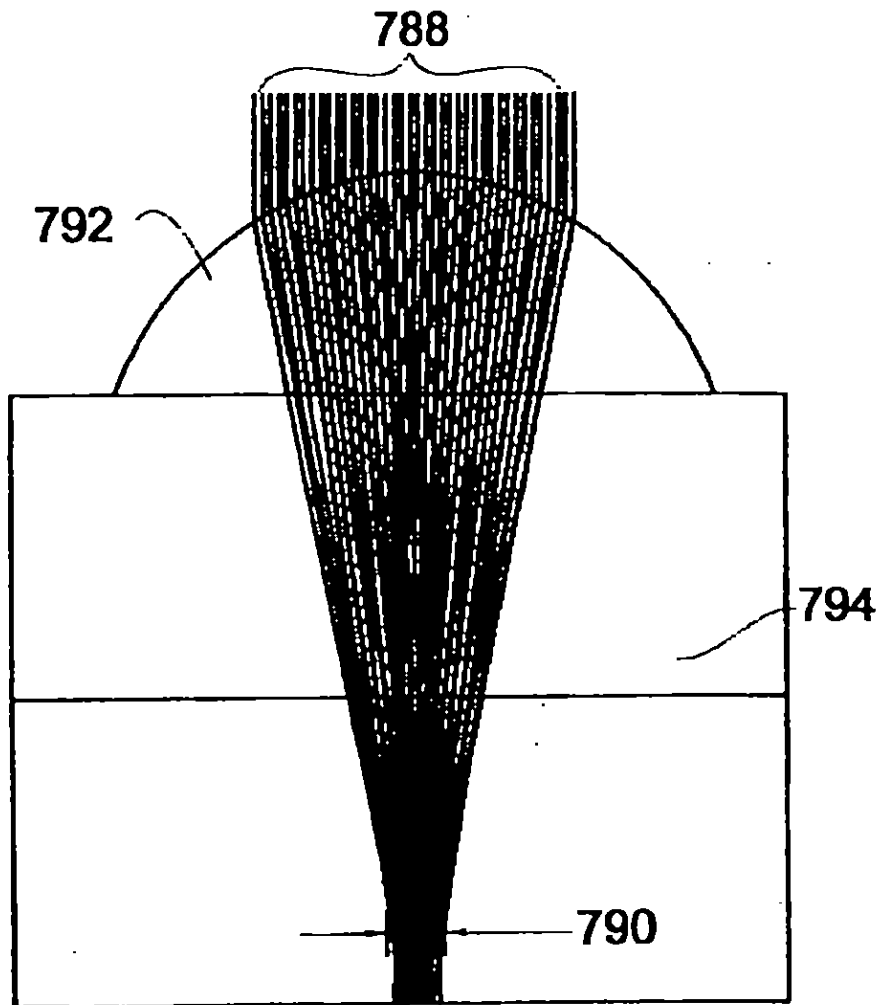


Fig. 31

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129 8

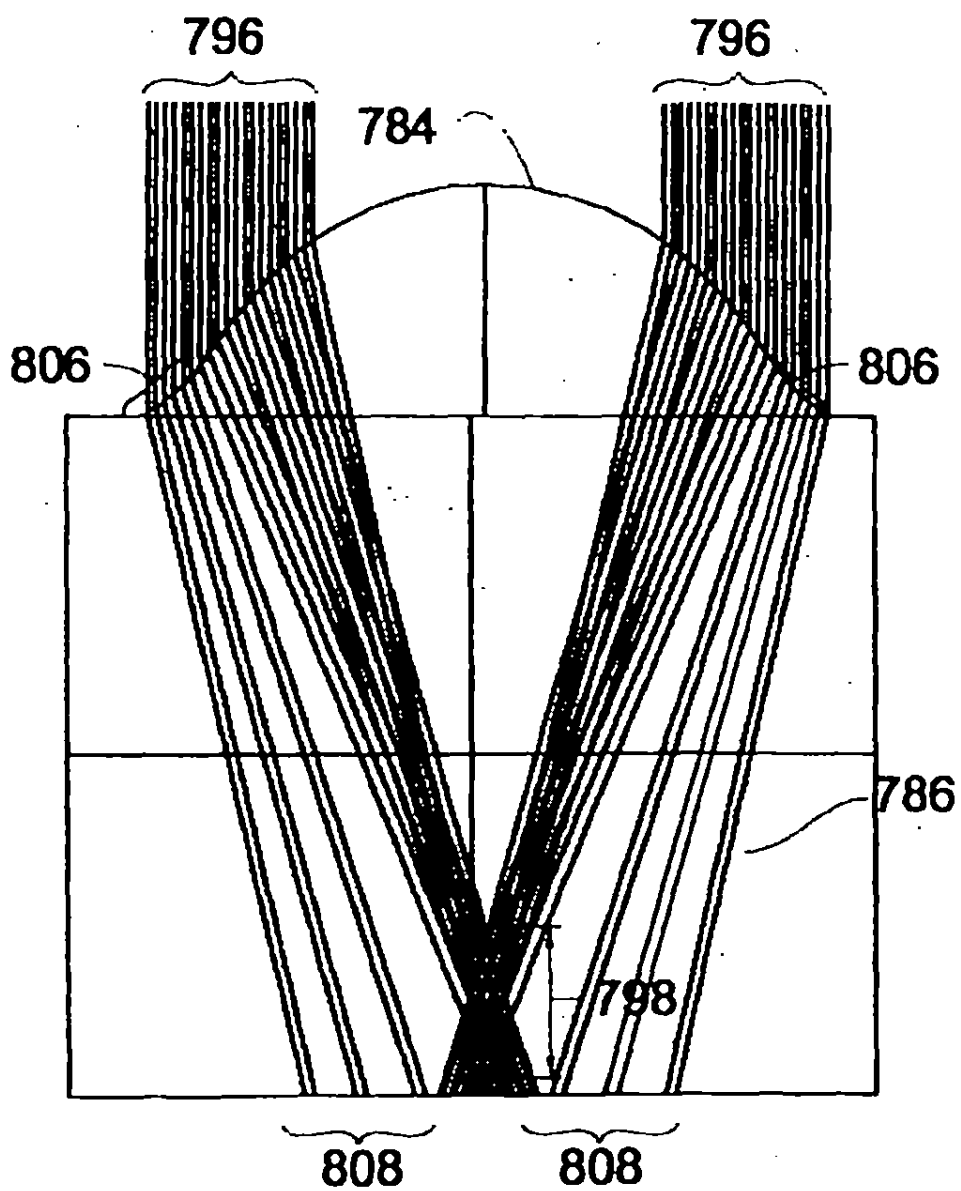


Fig. 32

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139 F

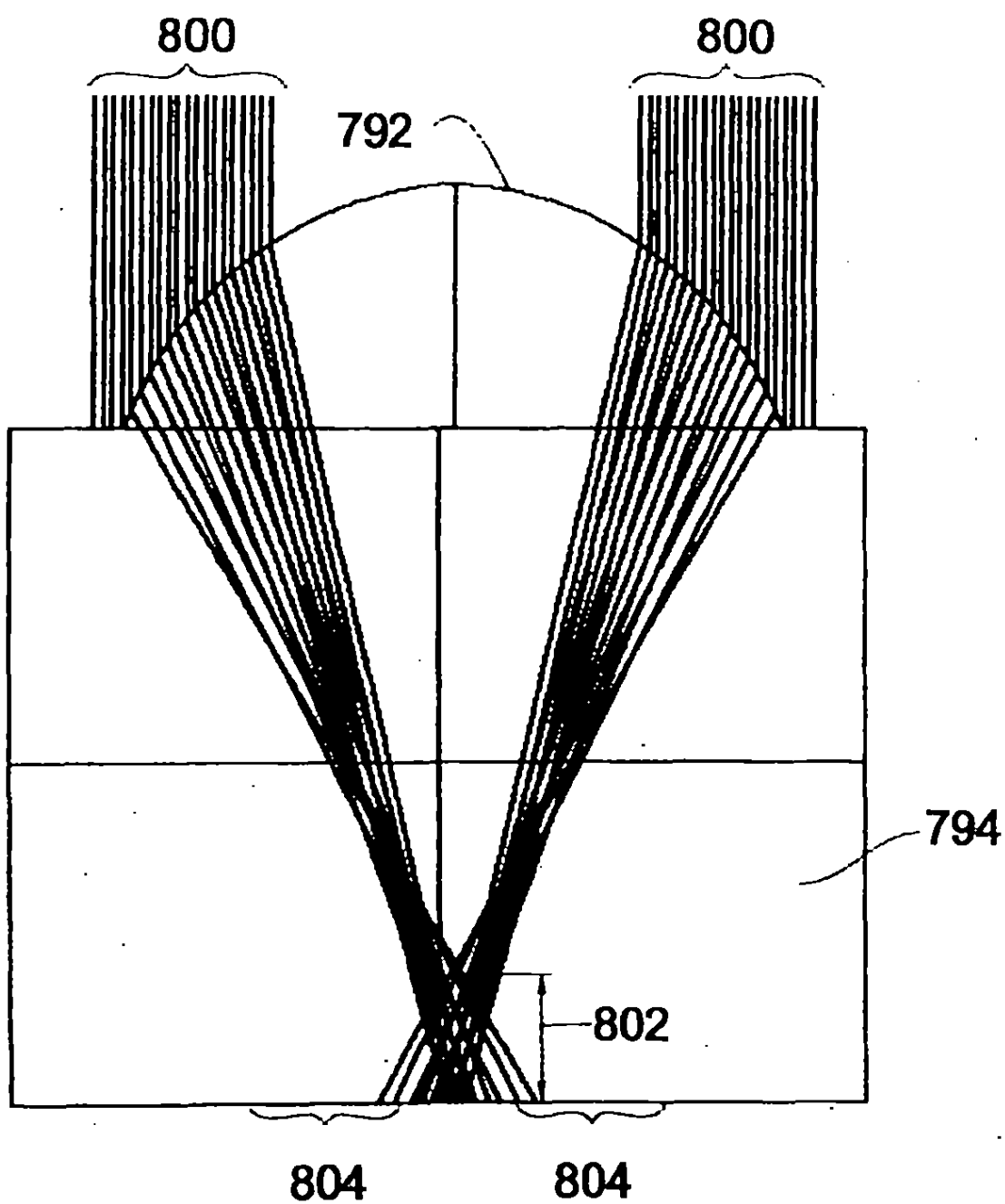


Fig. 33

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SISTEMA DE PRESENTACION DE IMAGENES Y SEGURIDAD MICRO-

OPTICA

CAMPO DE LA INVENCION

5

La presente invención se refiere a un sistema micro-óptico de magnificación sintético que en una modalidad ejemplar se forma como una película de polímero. Los efectos ópticos inusuales provistos por las diversas modalidades de la descripción se pueden utilizar como un dispositivo de seguridad para autenticación abierta y encubierta de moneda corriente, documentos y productos así como una mejora visual de productos, empaques, material impreso y bienes para el consumidor.

15

ANTECEDENTES DE LA INVENCION

Se han empleado varios materiales ópticos para proveer la autenticación de moneda corriente y documentos, para identificar y distinguir productos auténticos de productos falsificados, y para proveer una mejora visual de artículos fabricados y empaques. Ejemplos incluyen despliegues holográficos, y otros sistemas de imagen que involucran estructuras lenticulares y disposiciones de micro-lentes esféricos. Los despliegues holográficos han

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prevalecido para uso con tarjetas de crédito, licencias de conducir y etiquetas de ropa.

Un ejemplo de una estructura lenticular para la seguridad de documentos se describe en la Patente EUA 4,892,336 a Kaule, et al. que se enfoca en un hilo de seguridad para incorporación dentro de un documento para proveer medidas anti-falsificación. El hilo de seguridad es transparente y tiene un patrón impreso en un lado, en el lado opuesto, una estructura de lente lenticular coordinada con el patrón impreso. La estructura de lente lenticular se describe como compuesta de una pluralidad de lentes cilíndricos paralelos, o alternativamente lentes en panal o esféricos.

La Patente EUA 5,712,731 a Drinkwater, et al. describe un dispositivo de seguridad que incluye una disposición de micro-imágenes acopladas con una disposición de micro-lentes sustancialmente esféricos. Los lentes también pueden ser lentes astigmáticos. Cada uno de los lentes típicamente tiene 50-250 μm y una longitud focal de 200 μm .

Todos estos enfoques sufren de inconvenientes similares. Como resultado se obtiene una estructura relativamente gruesa que no es particularmente conveniente para uso con autenticación de documentos. Su uso de lentes cilíndricos o esféricos provee un campo angosto de visión,

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dando como resultado imágenes borrosas y requiriendo una alineación exacta y difícil del punto focal de los lentes con las imágenes asociadas. Adicionalmente, no han probado ser particularmente efectivos como medidas de seguridad o anti-falsificación.

En virtud de estas y otras deficiencias, existe una necesidad en la industria de materiales ópticos visualmente únicos y seguros que puedan facilitar la autenticación abierta de moneda corriente, documentos, artículos fabricados, y productos y para materiales ópticos que provean una mejora visual de artículos fabricados, productos y empaques.

SUMARIO DE LA INVENCION

15

La presente descripción se refiere a un material de película que utiliza una disposición bidimensional regular de lentes no cilíndricos para agrandar micro-imágenes, denominadas íconos en la presente invención, y para formar una imagen sintéticamente magnificada a través del desempeño unificado de una multiplicidad de sistemas de imágenes de íconos/lentes individuales. Las imágenes sintéticamente magnificadas y el fondo que las rodea puede ser a color o sin color, y cualquiera o ambas imágenes y el fondo que las rodea puede ser transparente, traslúcido,

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pigmentado, fluorescente, fosforescente, color ópticamente variable de despliegue, metalizado, o sustancialmente retrorreflectivo. El material que despliega imágenes a color en un fondo transparente o teñido es particularmente muy conveniente para uso en combinación con información impresa subyacente. Cuando una pieza de dicho material se aplica sobre información impresa, tanto la información impresa como las imágenes son vistas al mismo tiempo en relación de movimiento espacial o dinámico entre sí. El material de este tipo también puede estar sobreimpreso, es decir, puede tener un grabado aplicado en la superficie superior (lente) del material. Alternativamente, el material que despliega imágenes a color (de cualquier color, incluyendo blanco y negro) en un fondo sustancialmente opaco o traslúcido de diferente color es particularmente muy conveniente para uso independiente o con información sobreimpresa, no en combinación con información impresa subyacente.

La magnitud de la magnificación sintética lograda se puede controlar a través de la selección de un número de factores, incluyendo el grado de "sesgo" entre los ejes de simetría de la disposición del lente y los ejes de simetría de la disposición del icono. Disposiciones periódicas regulares tienen ejes de simetría que definen líneas que el patrón podría reflejar alrededor sin cambiar la geometría

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básica del patrón, que en el ideal de las disposiciones son infinitas en extensión. Una disposición cuadrada, por ejemplo, se puede reflejar alrededor de cualquier diagonal de cualquier cuadrado sin cambiar la orientación relativa de la disposición: si los lados de los cuadrados están alineados con los ejes x y y del plano, entonces los lados de los cuadrados seguirán estando alineados con aquellos ejes después de la reflexión, suponiendo que todos los lados son idénticos e indistinguibles.

10 En lugar de reflejar la disposición cuadrada, la disposición se puede girar a través de un ángulo igual al ángulo entre los ejes de simetría del mismo tipo. En el caso de una disposición cuadrada, la disposición se puede girar a través de un ángulo de 90 grados, el ángulo entre diagonales, para llegar a una orientación de disposición que sea indistinguible de la disposición original. De manera similar, se puede reflejar o girar una disposición de hexágonos regulares alrededor de un número de ejes de simetría, incluyendo las "diagonales" del hexágono (las líneas que conectan los vértices opuestos) o "divisores de punto medio" (líneas que se conectan entre los puntos centrales de las caras en los lados opuestos del hexágono). El ángulo entre los ejes de simetría de cualquier tipo es sesenta grados (60°), dando como resultado una orientación de disposición que es indistinguible de la orientación

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original.

Si una disposición de lentes y una disposición de iconos inicialmente se colocan con sus dimensiones planas definiendo su plano respectivo x-y, uno de los ejes de simetría se elige para representar el eje x de la primera disposición, el tipo correspondiente de eje de simetría (por ejemplo, eje diagonal de simetría) se elige para representar el eje x de la segunda disposición, en donde las dos disposiciones están separadas por una distancia sustancialmente uniforme en la dirección del eje z, después se dice que las disposiciones tienen cero sesgo si los ejes x de las disposiciones parecen ser paralelas entre sí cuando las disposiciones son vistas a lo largo de la dirección del eje z. En el caso de disposiciones hexagonales, la rotación de una disposición a través de un ángulo de 60 grados, o múltiplos de las mismas, coloca a las disposiciones nuevamente en alineación, por lo que no existe sesgo, tal como tampoco existe sesgo para una rotación de 90 grados, o múltiplos de las mismas, en el caso de disposiciones cuadradas. Cualquier desalineación angular entre los ejes x que sea diferente de estas "rotaciones con cero sesgo" se denomina el sesgo. Un pequeño sesgo, tal como 0.06 grados, puede crear una gran magnificación, en exceso de 1,000x, y un gran sesgo, tal como 20 grados, produce una pequeña magnificación,

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potencialmente tan pequeña como 1x. Otros factores, tal como las escalas relativas de las dos disposiciones y el F# del lente, pueden afectar tanto la magnificación de la imagen sintética como su rotación, el movimiento
5 ortoparaláctico y la aparente profundidad visual.

Existe un número de diferentes efectos visuales que pueden ser provistos por el presente material (posteriormente denominado como un "Unísono" para el material en general, o por los nombres de "Movimiento
10 Unísono", "Profundidad Unísona", "Súper Profundidad Unísona", "Flotador Unísono", "Súper Flotador Unísono", "Levitado Unísono", "Morfo Unísono", y "3-D Unísona" para material Unísono que presenta esos efectos respectivos), y sus diversas modalidades que producen cada uno de estos
15 efectos, generalmente descritos de la siguiente forma:

El Movimiento Unísono presenta imágenes que muestran el movimiento ortoparaláctico (OPM), cuando el material es inclinado, las imágenes se mueven en una dirección de inclinación que parece ser perpendicular a la
20 dirección anticipada por el paralaje normal. La Profundidad y la Súper Profundidad Unísona presentan imágenes que parecen yacer sobre un plano espacial que es visualmente más profundo que el grosor del material. El Flotador y el Súper Flotador Unísono presentan imágenes que parecen yacer
25 sobre un plano espacial que está a una distancia por encima

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de la superficie del material; y el Levitado Unísono presenta imágenes que oscilan de la Profundidad Unísona (o Súper Profundidad) a Flotador Unísono (o Súper Flotados) conforme el material es girado a través de un ángulo determinado (por ejemplo, 90 grados), volviendo después a la Profundidad Unísona (o Súper Profundidad) nuevamente conforme el material es girado adicionalmente por la misma cantidad. El Morfo Unísono presenta imágenes sintéticas que cambian de forma, configuración o tamaño conforme el material es girado o visto desde diferentes puntos de visión. La 3-D Unísona presenta imágenes que muestran estructuras tridimensionales a gran escala, tal como una imagen de un rostro.

Se pueden combinar múltiples efectos Unísonos en una película, tal como una película que incorpora múltiples planos de imágenes en Movimiento Unísono que pueden ser diferentes en forma, color, dirección de movimiento, y magnificación. Otra película puede combinar un plano de imagen de Profundidad Unísona y un plano de imagen de Flotador Unísono, mientras que se puede diseñar otra película para combinar las capas de Profundidad Unísona, Movimiento Unísono y Flotador Unísono, en el mismo color o en diferentes colores, esas imágenes tienen los mismos elementos gráficos o diferentes. El color, el diseño gráfico, el efecto óptico, la magnificación, y otros

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elementos visuales de múltiples planos de imagen son bastante independientes; con pocas excepciones, planos de estos elementos visuales se pueden combinar en formas arbitrarias.

5 Para muchas aplicaciones de seguridad de moneda corriente, documentos y productos, es deseable que el grosor total de la película sea menos de 50 micras (también denominado en la presente invención como " μ " o " μm "), por ejemplo menos de aproximadamente 45 micras, y como un
10 ejemplo adicional en el rango de alrededor de 10 micras a aproximadamente 40 micras. Esto se puede lograr, por ejemplo, a través del uso de elementos de enfoque que tienen un diámetro base efectivo de menos de 50 micras, como un ejemplo adicional menos de 30 micras, y aún como un
15 ejemplo adicional, de alrededor de 10 micras a aproximadamente 30 micras. Como otro ejemplo, se puede utilizar un elemento de enfoque que tenga una longitud focal de menos de alrededor de 40 micras, y como un ejemplo adicional, un elemento que tenga una longitud focal de
20 alrededor de 10 a menos de aproximadamente 30 micras. En un ejemplo particular, se pueden utilizar elementos de enfoque que tengan un diámetro base de 35 micras y una longitud focal de 30 micras. Una modalidad alterna refractiva/difractiva híbrida puede ser tan delgada como 8
25 micras.

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Las películas de la presente invención son muy resistentes a las falsificaciones debido a su estructura compleja de múltiples capas y sus elementos de aspecto de radio elevado que no son dóciles a la reproducción por sistemas de fabricación comúnmente disponibles.

Por lo tanto, el presente sistema provee un sistema micro-óptico de preferencia en la forma de una película de polímero que tiene un grosor que cuando es visto por ojos sin ayuda en luz transmitida o reflectiva proyecta una o más imágenes que:

- i. muestran movimiento ortoparaláctico (Movimiento Unísono);
- ii. parecen yacer sobre un plano espacial más profundo que el grosor de la película de polímero (Profundidad Unísona y Súper Profundidad Unísona);
- iii. parecen yacer sobre un plano espacial por encima de una superficie de la película de polímero (Flotador Unísono o Súper Flotador Unísono);
- iv. oscilan entre un plano espacial más profundo que el grosor de la película de polímero y una plano espacial por encima de una superficie de la película conforme la película es girada azimutalmente (Levitado Unísono);
- v. se transforman de una forma, configuración, tamaño, color (o alguna combinación de estas propiedades)

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cul

en una forma, configuración, tamaño, o color diferente (o alguna combinación de estas propiedades) (Morfo Unísono); y/o

vi. parecen tener una tridimensionalidad realista
5 (3-D Unísona).

La presente descripción provee, muy particularmente, un sistema micro-óptico de magnificación sintética y método para elaborar el mismo que comprende:

- a) uno o más separadores ópticos;
- 10 b) una micro imagen compuesta de una disposición plana periódica de una pluralidad de iconos de imagen que tienen un eje de simetría por lo menos alrededor de sus ejes planos, y colocados en o junto al separador óptico; y
- c) una disposición plana periódica de elementos
15 de enfoque de iconos de imagen que tienen un eje de simetría por lo menos alrededor de sus ejes planos, el eje de simetría es el mismo eje plano que aquel de la disposición plana de micro imágenes, cada elemento de enfoque es un elemento de enfoque de multi-zonas de base
20 poligonal, un lente que provee un campo de visión agrandado sobre la anchura del icono de imagen asociado para que los bordes periféricos del icono de imagen asociado no se salgan de la vista, o un elemento de enfoque esférico que tiene un diámetro efectivo de menos de 50 micras.

25 El sistema puede incluir uno o más de los efectos

antes mencionados. Se provee un método por medio del cual dichos efectos pueden ser incluidos selectivamente dentro del sistema.

La presente descripción además provee un
5 dispositivo de seguridad conveniente por lo menos para la incorporación parcial en o sobre, y para uso sobre o en asociación con, un documento de seguridad, etiqueta, cinta de desgarre, dispositivo de indicación de alteración, dispositivo de sellado, u otro dispositivo de seguridad o
10 autenticación, el cual comprende por lo menos un sistema micro-óptico, tal como se definió anteriormente. De manera muy particular, la presente descripción provee un dispositivo de seguridad de documentos y método para elaborar el mismo que comprende:

15 a) uno o más separadores ópticos;

b) una micro imagen compuesta de una disposición plana periódica de una pluralidad de iconos de imagen que tienen un eje de simetría por lo menos alrededor de sus ejes planos, y colocados en o junto al separador óptico; y

20 c) una disposición plana periódica de elementos de enfoque de iconos de imagen que tienen un eje de simetría por lo menos alrededor de sus ejes planos, el eje de simetría es el mismo eje plano que aquel de la disposición plana de micro imágenes, cada elemento de
25 enfoque es un elemento de enfoque de multi-zonas de base

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poligonal, un lente que provee un campo de visión agrandado sobre la anchura del icono de imagen asociado para que los bordes periféricos del icono de imagen asociado no se salgan de la vista, o un elemento de enfoque esférico que

5 tiene un diámetro efectivo de menos de 50 micras.

Adicionalmente, la presente descripción provee un dispositivo de mejora visual que comprende por lo menos un sistema micro-óptico, tal como se definió anteriormente y que tiene los efectos anteriormente descritos, para la

10 mejora visual de vestimenta, productos para la piel, documentos, material impreso, productos manufacturados, empaque, aparadores de puntos de compra, publicaciones, dispositivos de publicidad, productos deportivos, documentos financieros y tarjetas para transacciones y

15 otros bienes.

También se provee un documento o etiqueta de seguridad que tiene por lo menos un dispositivo de seguridad, tal como se definió anteriormente, por lo menos parcialmente incorporado en el mismo y/o montado en el

20 mismo.

Otras características y ventajas de la presente descripción serán aparentes para aquellos expertos en la técnica a partir de la siguiente descripción detallada y figuras anexas.

25 Otros sistemas, dispositivos, métodos,

características y ventajas serán o se volverán aparentes para aquellos expertos en la técnica al momento de examinar las siguientes figuras y descripción detallada. Se pretende que dichos sistemas, métodos, características, y ventajas adicionales queden incluidos dentro de la presente descripción, dentro del alcance de la presente descripción, y que además queden protegidos por las reivindicaciones anexas.

A menos que se defina lo contrario, todos los términos técnicos y científicos aquí empleados tienen el mismo significado tal como comúnmente lo entienden aquellos expertos en la técnica a quienes pertenece esta invención. Todas las publicaciones, solicitudes de patente, patentes y otras referencias mencionadas aquí quedan incorporadas por referencia en su totalidad. En caso de conflicto, regulará la presente descripción, incluyendo las definiciones. Además, los materiales, métodos y ejemplos son ilustrativos únicamente y no pretenden ser una limitación.

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BREVE DESCRIPCION DE LAS FIGURAS

Muchos aspectos de la descripción se pueden entender mejor con referencia a las figuras. Los componentes en las figuras no necesariamente están a escala; sin embargo, se hace énfasis para ilustrar con toda

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claridad los principios de la presente descripción. Además, en las figuras, números de referencia similares designan partes correspondientes a través de varias vistas.

La figura 1a es una vista transversal de un sistema micro-óptico que ejemplifica una modalidad de la presente descripción que provee movimiento ortoparaláctico de las imágenes del sistema.

La figura 1b es una vista en corte isométrico de la modalidad de la figura 1a.

La figura 2a ilustra un efecto de movimiento de imagen sintética ortoparaláctico de la modalidad de las figuras 1a-b.

Las figuras 2 b-c ilustran los efectos visuales de las modalidades de Profundidad y Flotador de la presente invención.

Las figuras 2 d-f ilustran los efectos visuales obtenidos a través de la rotación de una modalidad de Levitado de la presente invención.

Las figuras 3 a-i son vistas planas que muestran varias modalidades y factores de relleno de diferentes patrones de disposiciones bidimensionales simétricas de lentes del presente sistema.

La figura 4 es una gráfica que ilustra diferentes combinaciones de los efectos de la modalidad de Profundidad, Unísona, Flotador, y Levitado producidos por

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la variación de la relación del periodo del elemento de icono/periodo de lente.

Las figuras 5 a-c son vistas planas que ilustran cómo se puede controlar la magnificación sintética de las imágenes de iconos a través del ángulo relativo entre la disposición de lentes y los ejes de la disposición de iconos del presente sistema.

Las figuras 6 a-c son vistas planas que ilustran una modalidad que logra un efecto morfo de imágenes sintéticamente magnificadas del presente sistema.

Las figuras 7 a-c son secciones transversales que muestran varias modalidades de la capa de iconos de la presente invención.

Las figuras 8 a-b son vistas planas que ilustran modalidades de elementos de iconos "positivos" y "negativos".

La figura 9 es una vista transversal que ilustra una modalidad de un material de múltiples niveles para crear regiones de una imagen sintéticamente magnificada que tiene diferentes propiedades.

La figura 10 es una vista transversal que ilustra otra modalidad de un material de múltiples niveles para crear regiones de una imagen sintéticamente magnificada que tiene diferentes propiedades.

Las figuras 11 a-b son vistas transversales que

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muestran modalidades ópticas puntiformes y ópticas reflectivas del presente sistema.

Las figuras 12 a-b son vistas transversales que comparan las estructuras de una modalidad de material
5 totalmente refractivo con una modalidad de material reflectivo/refractivo híbrido.

La figura 13 es una vista transversal que muestra una modalidad de material que indica alteración de "despegue-para-revelar"

10 La figura 14 es una vista transversal que muestra una modalidad de material que indica alteración de "despegue-para-cambiar"

Las figuras 15 a-d son vistas transversales que muestran varias modalidades de sistemas de dos lados.

15 Las figuras 16 a-f son vistas transversales y vistas planas correspondientes que ilustran tres métodos diferentes para crear patrones de elementos de iconos con tono o en escala de grises e imágenes sintéticamente magnificadas posteriores a través del presente sistema.

20 Las figuras 17 a-d son vistas transversales que muestran el uso del presente sistema junto con información impresa.

Las figuras 18 a-f son vistas transversales que ilustran la aplicación del presente sistema para, o
25 incorporación en varios sustratos y en combinación con

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información impresa.

Las figuras 19 a-b son vistas transversales que comparan el campo de visión en-foco de un lente esférico con aquel de un lente asférico cuando cada uno está
5 incorporado en el presente sistema.

Las figuras 20 a-c son vistas transversales que ilustran dos beneficios de utilidad que dan como resultado el uso de una capa de iconos gruesa en el presente sistema.

Las figuras 21 a-b son vistas planas que muestran
10 la aplicación del presente sistema a moneda corriente tal como un hilo de seguridad "con ventanas".

La figura 22 ilustra la modalidad de movimiento ortoparaláctico del presente sistema de imágenes en relación con un hilo de seguridad "con ventanas".

La figura 23 ilustra un fotograbado a media tinta
15 de una imagen sintética del presente sistema.

La figura 24a ilustra el uso del presente sistema para crear imágenes sintéticas combinadas que son más pequeñas en dimensión que la característica más pequeña de
20 las imágenes sintéticas individuales.

La figura 24b ilustra el uso del presente sistema para crear patrones angostos de espacios entre elementos de imágenes de iconos.

La figura 25 ilustra la incorporación de
25 información escondida encubierta en imágenes de iconos del

presente sistema.

La figura 26 ilustra la creación de imágenes completamente tridimensionales con el presente sistema.

La figura 27 ilustra el método para diseñar
5 imágenes de iconos para la modalidad tridimensional de la figura 26.

La figura 28 ilustra la imagen de iconos que resulta del método de la figura 27.

La figura 29 ilustra cómo el método de la figura
10 27 se puede aplicar a una imagen sintética tridimensional compleja.

La figura 30 ilustra las propiedades focales de la zona central de un lente multi-zonas de base hexagonal ejemplar que tiene un diámetro efectivo de 28 micras.

15 La figura 31 ilustra las propiedades focales de la zona central de un lente esférico que tiene un diámetro de 28 micras.

La figura 32 ilustra el rendimiento de las zonas laterales del lente hexagonal de la figura 30.

20 La figura 33 ilustra el rendimiento de las zonas exteriores del lente hexagonal de la figura 31.

DESCRIPCION DETALLADA DE LAS MODALIDADES

25 Ahora se hará referencia con mayor detalle a la

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descripción de las modalidades tal como se ilustran en las figuras. Aunque se describen varias modalidades en relación con estas figuras, no se pretende limitar la invención a la modalidad o modalidades aquí descritas. Por el contrario, el intento es abarcar todas las alternativas, modificaciones y equivalentes.

La figura 1a ilustra una modalidad del presente sistema micro-óptico 12 que provee movimiento ortoparaláctico de las imágenes del sistema.

Los lentes 1 del sistema 12 tienen por lo menos dos ejes de simetría sustancialmente iguales y están acomodados en una disposición periódica bidimensional. El diámetro de los lentes 2 de preferencia es menor que 50μ y el espacio intersticial entre lentes 3 de preferencia es 5μ o menos. (Se utilizan los términos " μ " y " μm " de manera intercambiable para decir la misma medición). El micro-lente 1 enfoca una imagen del elemento de icono 4 y proyecta esta imagen 10 hacia un telespectador. Por lo regular, el sistema se utiliza en situaciones que tienen niveles normales de iluminación ambiental, de forma que la iluminación de las imágenes de iconos surge de la luz ambiental reflejada o transmitida. El elemento de icono 4 es un elemento de una disposición periódica de elementos de icono que tienen periodos y dimensiones sustancialmente similares a aquellos de la disposición de lentes que

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incluye el lente 1. Entre el lente 1 y el elemento de icono 4 hay un separador óptico 5 el cual puede estar contiguo al material del lente 1 u opcionalmente puede ser un sustrato separado 8, en esta modalidad los lentes 9 están separados 5 del sustrato. Los elementos de icono 4 opcionalmente pueden ser protegidos por una capa de sellado 6, de preferencia de un material de polímero. La capa de sellado 6 puede ser transparente, traslúcida, teñida, pigmentada, opaca, metálica, magnética, ópticamente variable, o 10 cualquier combinación de éstos que provea los efectos ópticos deseables y/o la funcionalidad adicional para propósitos de seguridad y autenticación, incluyendo soporte de autenticación automatizada de moneda corriente, verificación, rastreo, sistemas de conteo y detección, que 15 se basan en los efectos ópticos, la conductividad eléctrica o capacitancia eléctrica, y la detección del campo magnético.

El grosor total 7 del sistema típicamente es menos que 50μ ; el grosor real depende del $F\#$ de los lentes 20 1 y del diámetro de los lentes 2, y el grosor de la característica de seguridad adicional o capas de efecto visual. El periodo de repetición 11 de los elementos de icono 4 es sustancialmente idéntico al periodo de repetición de los lentes 1; la "relación de escala", la 25 relación del periodo de repetición de los iconos al periodo

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de repetición de los lentes, se utiliza para crear muchos efectos visuales diferentes. Valores axialmente simétricos de la relación de escala sustancialmente iguales a 1.0000 dan como resultado efectos ortoparalácticos de Movimiento Unísono cuando los ejes de simetría de los lentes y los iconos están desalineados, valores axialmente simétricos de la relación de escala menor que 1.0000 dan como resultado efectos de Profundidad Unísona y de Súper Profundidad Unísona cuando los ejes de simetría de los lentes y los iconos están sustancialmente alineados, y valores axialmente simétricos de la relación de escala mayores que 1.0000 dan como resultado efectos de Flotador Unísono y Súper Flotador Unísono cuando los ejes de simetría de los lentes y los iconos están sustancialmente alineados. Los valores axialmente simétricos de la relación de escala, tal como 0.995 en la dirección X y 1.005 en la dirección Y, dan como resultado efectos de Levitado Unísono.

Los efectos Morfo Unísono se pueden obtener a través de distorsiones de escala de cualquiera o ambos del periodo de repetición de lente y el periodo de repetición de icono, o incorporando información espacialmente variable en el patrón de iconos. Los efectos 3-D Unísonos también son creados a través de la incorporación de información espacialmente variable en el patrón de iconos, pero en esta modalidad, la información representa diferentes puntos de

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vista de un objeto tridimensional tal como se puede apreciar desde ubicaciones específicas sustancialmente correspondientes a las ubicaciones de los iconos.

La figura 1b presenta una vista isométrica del presente sistema, tal como se muestra en la sección transversal de la figura 1a, que tiene patrones de disposición cuadrados de lentes 1 e iconos 4 de periodo de repetición 11 y grosor de separador óptico 5 (la figura 1a no es específica de un patrón cuadrado de disposición, pero es una sección transversal representativa de todos los patrones regulares de disposición periódica. Los elementos de icono 4 se muestran como imágenes "\$", claramente vistas en la sección cortada en la parte frontal. Aunque sustancialmente existe una correspondencia uno a uno entre los lentes 1 y los elementos de icono 4, los ejes de simetría de la disposición de lentes, por lo general, no estarán alineados exactamente con los ejes de simetría de la disposición de iconos.

En el caso de la modalidad de material Unísono (movimiento ortoparaláctico) de las figuras 1 a-b con una relación de escala de 1.0000, cuando los ejes del lente 1 y los ejes de los elementos de icono 4 están sustancialmente alineados, las imágenes sintéticas resultantes de los elementos de icono (en este ejemplo un "\$" gigante) se amplían y son agrandadas por un factor que teóricamente se

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aproxima a infinito. Una ligera desalineación angular de los ejes del lente 1 y los ejes de los elementos de icono 4 reduce el factor de magnificación de las imágenes sintéticas de los elementos de icono y ocasiona que las
5 imágenes sintéticas magnificadas giren.

El factor de magnificación sintética de las modalidades de Profundidad Unísona, Flotador Unísono y Levitado Unísono depende de la alineación angular de los ejes del lente 1 y los ejes de los elementos de icono 4 así
10 como de la relación de escala del sistema. Cuando la relación de escala no es igual a 1.0000, la magnificación máxima obtenida de la alineación sustancial de estos ejes es igual al valor absoluto de $1/(1.0000 - (\text{relación de escala}))$. Por lo tanto un material de Profundidad Unísona
15 que tiene una relación de escala de 0.995 mostraría una magnificación máxima de $|1/(1.000 - 0.995)| = 200x$. De manera similar, un material de Flotador Unísono que tiene una relación de escala de 1.005 también mostraría una magnificación máxima de $|1/(1.000 - 1.005)| = 200x$. De
20 manera similar a la modalidad de material de Movimiento Unísono, una ligera desalineación angular de los ejes del lente 1 y los ejes de los elementos de icono 4 de las modalidades de Profundidad Unísona, Flotador Unísono, y Levitado Unísono reduce el factor de magnificación de las
25 imágenes sintéticas de los elementos de icono y ocasiona

SP
(95)

que las imágenes sintéticas magnificadas giren.

La imagen sintética producida por un patrón de iconos de Profundidad o Súper Profundidad Unísona es vertical con respecto a la orientación del patrón de iconos de Profundidad o Súper Profundidad Unísona, mientras que la imagen sintética producida por un patrón de iconos de Flotador o Súper Flotador Unísono está al revés, girada ciento ochenta grados (180°) con respecto a la orientación del patrón de iconos de Flotador o Súper Flotador Unísono.

La figura 2a muestra esquemáticamente los efectos de movimiento de la imagen ortoparaláctica contra-intuitiva vistos en la modalidad del Movimiento Unísono. El lado izquierdo de la figura 2a muestra una pieza de un material de Movimiento Unísono 12 en una vista plana que oscila 180 grados alrededor del eje horizontal 16. Si la imagen sintéticamente magnificada 14 se movió de acuerdo con el paralaje, ésta parecería desplazarse hacia arriba y hacia abajo (como se muestra en la figura 2a) conforme el material 12 oscilaba alrededor del eje horizontal 16. Dicho movimiento paraláctico aparente sería típico de objetos reales, imágenes holográficas y de impresión convencional. En lugar de mostrar un movimiento paraláctico, la imagen sintéticamente magnificada 14 muestra movimiento ortoparaláctica 20, movimiento que es perpendicular a la dirección del movimiento paraláctico normalmente esperado.

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El lado derecho de la figura 2a muestra una vista en perspectiva de una pieza de material 12 que muestra el movimiento ortoparaláctica de una sola imagen sintéticamente magnificada 14 conforme ésta es oscilada 18
5 alrededor del eje de rotación horizontal 16. El contorno punteado 22 muestra la posición de la imagen sintéticamente magnificada 14 después que ésta se ha movido a la derecha por el eje de ortoparalaje y el contorno punteado 24 muestra la posición de la imagen sintéticamente magnificada
10 14 después que ésta se ha movido a la izquierda por el eje de ortoparalaje.

Los efectos visuales de las modalidades de Profundidad Unísona y Flotador Unísono se muestran isométricamente en las figuras 2 b, c. En la figura 2b, una
15 pieza de material de Profundidad Unísona 26 presenta imágenes sintéticamente magnificadas 28 que estereoscópicamente parecen yacer debajo del plano del material de Profundidad Unísona 26 cuando son vistas por los ojos del observador 30. En la figura 2c, una pieza de
20 material de Flotador Unísono 32 presenta imágenes sintéticamente magnificadas que estereoscópicamente parecen yacer encima del plano del material de Flotador Unísono 34 cuando son vistas por los ojos del observador 30. Los efectos de Profundidad Unísona y de Flotador Unísono son
25 visibles a partir de todas las posiciones de visualización

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azimutales y sobre un amplio rango de posiciones de elevación, desde una elevación vertical (de forma que la línea de visión desde los ojos del observador 30 al material de Profundidad Unísona 26 o material de Flotador Unísono 32 sea perpendicular a la superficie de los materiales) hasta abajo a un ángulo de elevación plana que típicamente es menor de 45 grados. La visibilidad de los efectos de Profundidad Unísona o Flotador Unísono sobre un amplio rango de ángulos de visualización y orientaciones provee un método simple y conveniente para diferenciar los materiales de Profundidad Unísona y Flotador Unísono a partir de simulaciones que utilizan óptica lenticular cilíndrica u holografía.

El efecto de la modalidad de Levitado Unísono se ilustra en las figuras 2 d-f por medio de vistas isométricas que muestran la posición profunda estereoscópicamente percibida de una imagen sintéticamente magnificada 38 en tres diferentes rotaciones azimutales del material de Levitado Unísono 36 y la vista plana correspondiente del material de Levitado Unísono 36 y la imagen sintéticamente magnificada 38 tal como es vista por los ojos del observador 30. La figura 2d muestra la imagen sintéticamente magnificada 38 (en lo sucesivo "la imagen") como si estereoscópicamente estuviera colocada en un plano por debajo del material de Levitado Unísono 36 cuando dicho

material es orientado como se muestra en la vista plana. La línea oscura remarcada en la vista plana sirve como una referencia de orientación azimutal 37 para propósitos de explicación. Se puede apreciar que en la figura 2d, la referencia de orientación 37 está alineada en una dirección vertical y la imagen 38 está alineada en una dirección horizontal. La imagen 38 aparece en la posición de Profundidad Unísona debido a que la relación de escala es menor que 1.000 a lo largo de un primer eje del material de Levitado Unísono 36 que está alineado sustancialmente paralelo a una línea que conecta las pupilas de los dos ojos del observador (esto se denominará en lo sucesivo la "relación de escala estereoscópica"). La relación de escala estereoscópica del material de Levitado Unísono 36 es mayor que 1.000 a lo largo de un segundo eje perpendicular a este primer eje, produciendo así un efecto de Flotador Unísono de la imagen 38 cuando el segundo eje está alineado sustancialmente paralelo a una línea que conecta las pupilas de los ojos del observador, como se muestra en la figura 2f. Se puede apreciar que la referencia de orientación 37 es en una posición horizontal en esta figura. La figura 2e muestra una orientación azimutal intermedia del material de Levitado Unísono 36 que produce un efecto de imagen ortoparaláctica de Movimiento Unísono debido a que la relación de escala estereoscópica en esta

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orientación azimutal es sustancialmente 1.000.

El efecto visual de una imagen de Levitado Unísono 38 que se mueve desde la parte inferior del material de Levitado Unísono 36 (figura 2d) hacia arriba al nivel del material de Levitado Unísono 36 (figura 2e) y todavía más hacia arriba por encima del nivel del material de Levitado Unísono 36 (figura 2f) conforme el material es girado azimutalmente, se puede mejorar combinando el material de Levitado Unísono 36 con información convencionalmente impresa. Esta profundidad estereoscópica sin cambios de la impresión convencional sirve como un plano de referencia para percibir mejor el movimiento profundo estereoscópico de las imágenes 38.

Cuando un material Unísono es iluminado por una fuente de luz intensamente direccional, tal como una fuente "puntual" de luz (por ejemplo, un reflector o una linterna LED) o una fuente colimada (por ejemplo, luz solar), se pueden apreciar "imágenes sombreadas" de los iconos. Estas imágenes sombreadas son inusuales en muchas formas. Aunque la imagen sintética presentada por Unísono no se mueve conforme se desplaza la dirección de iluminación, las imágenes sombreadas producidas sí se mueven. Además, aunque las imágenes sintéticas Unísonas pueden yacer en planos visuales diferentes al plano del material, las imágenes sombreadas siempre yacen en el plano del material. El color

de la imagen sombreada es el color del icono. Por lo tanto, iconos negros crean imágenes sombreadas negras, iconos verdes crean imágenes sombreadas verdes, e iconos blancos crean imágenes sombreadas blancas.

5 El movimiento de la imagen sombreada, conforme el ángulo de iluminación se mueve, está unido a la profundidad específica o efecto Unísono de movimiento en una forma que pone en paralelo el efecto visual presente en la imagen sintética. Por lo tanto, el movimiento de una imagen
10 sombreada, conforme el ángulo de la luz es alterado, se ubica en paralelo al movimiento que la imagen sintética muestra cuando el ángulo de visión es alterado. En particular:

Las imágenes sombreadas de movimiento se mueven
15 ortoparalácticamente conforme se mueve la fuente de luz.

Las imágenes sombreadas de profundidad se mueven en la misma dirección que la fuente de luz.

Las imágenes sombreadas de flotamiento se mueven en dirección opuesta a la dirección de la fuente de luz.

20 Las imágenes sombreadas de levitado se mueven en direcciones que son una combinación de las anteriores:

Las imágenes sombreadas de Profundidad en Levitado se mueven en la misma dirección que la luz en la dirección de izquierda a derecha, pero en oposición a la
25 dirección de la luz en la dirección de arriba hacia abajo;

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las imágenes sombreadas de Flotamiento en Levitado se mueven en la dirección opuesta a la luz en la dirección de izquierda a derecha, pero en la misma dirección que la luz en la dirección de arriba hacia abajo; las imágenes sombreadas de Movimiento en Levitado muestran movimiento ortoparaláctico con respecto al movimiento de la luz.

Las imágenes sombreadas Morfo Unísonas muestran efectos morfos conforme se mueve la fuente de luz.

Efectos de imágenes sombreadas inusuales adicionales se observan cuando una fuente puntual de luz divergente, tal como una luz LED, se mueve hacia y lejos de una película Unísona. Cuando la fuente de luz está más alejada todavía, sus rayos divergentes se aproximan de forma más estrecha a la luz colimada, y las imágenes sombreadas producidas por las imágenes sintéticas Unísonas de Profundidad, Súper Profundidad, Flotador o Súper Flotador aparecen aproximadamente del mismo tamaño que las imágenes sintéticas. Cuando la luz es aproximada a la superficie, las imágenes sombreadas de materiales de Profundidad y Súper Profundidad se encogen debido a que la iluminación es fuertemente divergente, mientras que las imágenes sombreadas de materiales de Flotador y Súper Flotador se expanden. La iluminación de estos materiales con iluminación convergente ocasiona que las imágenes sombreadas de Profundidad y Súper Profundidad se agranden a

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un tamaño mayor que las imágenes sintéticas, mientras que las imágenes sombreadas de Flotador y Súper Flotador se encogen.

Las imágenes sombreadas del material de movimiento Unísono no cambian de escala significativamente conforme cambia la convergencia o divergencia de la iluminación, más bien, las imágenes sombreadas giran alrededor del centro de iluminación. Las imágenes sombreadas de Levitado Unísono se encogen en una dirección y se agrandan en la dirección perpendicular cuando se cambia la convergencia o divergencia de la iluminación. Las imágenes sombreadas de Morfo Unísono cambian en formas específicas al patrón Morfo particular conforme cambia la convergencia o divergencia de la iluminación.

Todos estos efectos de imágenes sombreadas se pueden utilizar como métodos de autenticación adicionales para materiales Unísonos utilizados para seguridad, anti-falsificación, aplicaciones de protección de marcas, y otras aplicaciones similares.

Las figuras 3 a-i son vistas planas que muestran varias modalidades y factores de relleno de diferentes patrones de disposiciones bidimensionales simétricas de micro-lentes. Las figuras 3a, d y g muestran los micro-lentes 46, 52 y 60, respectivamente, que están acomodados en un patrón de disposición hexagonal regular 40. (Las

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[63]

líneas punteadas del patrón de disposición 40, 42 y 44 indican la simetría del patrón de lentes pero no necesariamente representan un elemento físico de la disposición de lentes). Los lentes de la figura 3a tienen una geometría base sustancialmente circular 46, los lentes de la figura 3g tienen geometrías base sustancialmente hexagonales 60, y los lentes de la figura 3d tienen geometrías base intermedias que son hexágonos redondeados 52. Una evolución similar de las geometrías de lentes aplica a la disposición cuadrada 42 de lentes 48, 54 y 62, en donde estos lentes tienen geometrías base que van desde sustancialmente circulares 48, a cuadrados redondeados 54, a sustancialmente cuadrados 62, como se observa en la figura 3b, e y h. De manera correspondiente, la disposición de triángulo equilátero 44 sostiene los lentes que tienen geometrías base que van desde sustancialmente circular 50, a triángulo redondeado 58, a sustancialmente triangular 64, como se aprecia en las figuras 3c, f é i.

Los patrones de lentes de las figuras 3 a-i son representativos de los lentes que se pueden utilizar para el presente sistema. El espacio intersticial entre los lentes no contribuye directamente a la magnificación sintética de las imágenes. Un material creado por medio del uso de uno de estos patrones de lente, también incluirá una disposición de elementos de icono que está acomodada en la

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misma geometría y a aproximadamente la misma escala, permitiendo diferencias en escala utilizadas para producir efectos de Movimiento Unísono, Profundidad Unísona, Flotador Unísono, y Levitado Unísono. Si el espacio intersticial es grande, tal como se muestra en la figura 3c, se dice que los lentes tienen un factor de relleno bajo y el contraste entre la imagen y el fondo se verá reducido por la luz esparcida desde los elementos de icono. Si los espacios intersticiales son pequeños, se dice que los lentes tienen un factor de relleno alto y el contraste entre la imagen y el fondo será elevado, siempre y cuando los lentes tengan buenas propiedades focales y los elementos de icono estén en los planos focales de los lentes. Generalmente es más sencillo formar micro-lentes de alta calidad óptica con una base circular o casi circular que con una base cuadrada o triangular. Un buen equilibrio del rendimiento de los lentes así como una reducción al mínimo del espacio intersticial se muestra en la figura 3d; una disposición hexagonal de lentes que tiene geometrías base que son hexágonos redondeados.

Los lentes que tienen un $F\#$ bajo son particularmente convenientes para uso en el presente sistema. Por $F\#$ bajo se entiende menos de 4, y en particular para Movimiento Unísono aproximadamente 2 o menos. Los lentes de $F\#$ bajo tienen una gran curvatura y

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una combadura correspondientemente grande, o grosor central, en proporción a su diámetro. Un lente Unisono típico, con un F# de 0.8, tiene una base hexagonal de 28 micras de ancho y un grosor central de 10.9 micras. Un
5 lente Drinkwater típico, con un diámetro de 50 micras y una longitud focal de 200 micras, tiene un F# de 4 y un grosor central de 3.1 micras. Si se escala al mismo tamaño base, el lente Unisono tiene una combadura casi seis veces mayor que el lente Drinkwater.

10 Se ha descubierto que los lentes multi-zonas de base poligonal, por ejemplo, los lentes multi-zonas de base hexagonal, tienen ventajas importantes e inesperadas sobre los lentes esféricos de base circular. Como se explicó anteriormente, los lentes multi-zonas de base hexagonal
15 mejoran significativamente la capacidad de manufactura en virtud de su geometría de liberación de tensión, pero existen beneficios ópticos inesperados adicionales que se obtienen a través del uso de lentes multi-zonas de base hexagonal.

20 Se hace referencia a estos lentes como multi-zonas debido a que tienen tres zonas ópticas donde cada una provee un beneficio diferente y único a la presente invención. Las tres zonas son la zona central (que constituye aproximadamente la mitad del área del lente),
25 las zonas laterales y las zonas de las esquinas. Estos

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lentes poligonales tienen un diámetro efectivo que es el diámetro de un círculo dibujado dentro de las zonas de esquina alrededor de la zona central e incluyendo las zonas laterales.

5 La zona central del lente multi-zonas de base hexagonal de la presente invención tiene una forma asférica (por ejemplo, que tiene la forma definida por $y = (5.1316E)X^4 - (0.01679)X^3 + (0.124931)X + 11.24824$) para un lente con un diámetro de 28 micras con una longitud
10 focal nominal de 28 micras) que lleva luz a un foco por lo menos tan bien como una superficie esférica que tiene el mismo diámetro y longitud focal. La figura 30 ilustra las propiedades focales 782 de la zona central 780 de un lente multi-zonas de base hexagonal con un diámetro nominal de 28
15 micras 784 con una longitud focal nominal de 28 micras en un sustrato de polímero 786 (lente y sustrato $n = 1.51$) y la figura 31 ilustra las propiedades focales 790 de la zona central 788 de un lente esférico con un diámetro de 28 micras 792 con una longitud focal nominal de 30 micras en
20 un sustrato de polímero 794 (lente y sustrato $n = 1.51$). La comparación de estas dos figuras demuestra claramente que el lente multi-zonas de base hexagonal 784 de la presente descripción funciona por lo menos tan bien como el lente esférico 792. La zona central 789 del lente multi-
25 zonas de base hexagonal 784 provee una alta resolución de

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imagen y una profundidad de campo superficial desde una amplia variedad de ángulos de visualización.

Cada una de las seis zonas laterales 796 del lente multi-zonas de base hexagonal 784 de la presente invención tiene longitudes focales que dependen de la ubicación con la zona en una forma compleja, pero el efecto es ocasionar que el foco de las zonas laterales 796 se difunda sobre un rango de valores 798 que abarquen aproximadamente +/- 10 por ciento del foco de la zona central, como se ilustra en la figura 32. Este desenfoque vertical 798 del punto focal aumenta de manera efectiva la profundidad de campo del lente en estas zonas 796, y provee un beneficio que es equivalente a tener un lente de campo plano. El rendimiento de las zonas exteriores 800 del lente esférico 792 se puede apreciar en la figura 33. El desenfoque vertical del punto focal 802 es significativamente menor para el lente esférico 792 que para el lente multi-zonas de base hexagonal 784.

Esto es particularmente importante para visualización fuera de lo normal: la profundidad incrementada del campo, y el campo efectivamente más plano, mitigan el desenfoque abrupto de la imagen que puede ocurrir con un lente esférico cuando su superficie focal curvada se separa del plano del icono. En consecuencia, un material Unísono que utiliza lentes multi-zonas de base

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hexagonal despliega imágenes sintéticas que se desvían del foco de manera más suave a ángulos superiores de visualización que el material Unísono equivalente que utiliza lentes esféricos. Esto es deseable debido a que
5 incrementa el ángulo de visualización efectivo del material y, por lo tanto, aumenta su utilidad como un dispositivo de seguridad o un dispositivo de presentación de imágenes.

Las zonas de esquina 806 del lente multi-zonas de base hexagonal 784 de la figura 32 poseen propiedades
10 focales divergentes que proveen el beneficio inesperado de esparcir 808 iluminación ambiental sobre el plano de iconos y así reducir la sensibilidad del material Unísono a las condiciones de iluminación. El lente esférico 792 de la figura 33 no esparce la iluminación ambiental sobre un área
15 tan amplia (como se observa por la ausencia de rayos esparcidos en las regiones planas de iconos 804), por lo tanto, los materiales Unísonos que se elaboran utilizando lentes esféricos tienen mayores variaciones de brillantez de imagen sintética cuando son vistos desde una variedad de
20 ángulos que los materiales Unísonos que son hechos utilizando lentes multi-zonas de base hexagonal.

El beneficio obtenido de los lentes multi-zonas de base hexagonal es aún mayor debido a que los lentes multi-zonas de base hexagonal tienen un factor de relleno
25 superior (capacidad para cubrir el plano) que los lentes

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esféricos. El espacio intersticial entre los lentes esféricos virtualmente no provee esparcimiento de la luz ambiental, mientras que esta área sin esparcimiento es mucho más pequeña en el caso de lentes multi-zonas de base hexagonal.

Por lo tanto, se puede apreciar que aún cuando las propiedades focales de un lente multi-zonas de base hexagonal son inferiores a aquellas de un lente esférico conforme a lo evaluado por los estándares ópticos convencionales, en el contexto de la presente invención, los lentes multi-zonas de base hexagonal proveen beneficios y ventajas inesperadas sobre los lentes esféricos.

Cualquier tipo de lente se puede beneficiar de la adición de micro-estructuras de esparcimiento o materiales de esparcimiento introducidos o incorporados en los espacios intersticiales del lente para mejorar el esparcimiento de la iluminación ambiental sobre el plano de iconos. Además, los espacios intersticiales del lente se pueden rellenar con un material que formará un menisco de radio pequeño, ya sea con propiedades focales convergentes o divergentes, para dirigir la iluminación ambiental sobre el plano de iconos. Estos métodos se pueden combinar, por ejemplo, incorporando partículas de esparcimiento de luz en un material de relleno de menisco intersticial de lente. Alternativamente, las zonas intersticiales del lente se

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pueden fabricar originalmente con zonas intersticiales de lente de esparcimiento adecuado.

Un lente esférico que tiene esas propiedades es muy difícil de fabricar debido a que el elevado ángulo de contacto entre la superficie de la película y el borde del lente actúa como un concentrador de tensión para las fuerzas aplicadas para separar el lente de la herramienta durante la fabricación. Estas altas tensiones tienden a ocasionar que falle la adhesión del lente a la película y que falle la remoción del lente de la herramienta. Además, el rendimiento óptico de un lente esférico de bajo $F\#$ se ve progresivamente comprometido para las zonas radiales alejadas del centro del lente: los lentes esféricos de bajo $F\#$ no enfocan bien, excepto cerca de su zona central.

Los lentes de base hexagonal tienen un beneficio inesperado e importante sobre los lentes que tienen una base sustancialmente más circular: los lentes hexagonales se liberan de sus herramientas con una fuerza de desconchadura menor que los lentes ópticamente equivalentes con bases sustancialmente circulares. Los lentes hexagonales tienen una forma que se combina desde una simétrica sustancialmente axial cerca de su centro a una simétrica hexagonal, en donde las esquinas actúan como concentradores de tensión, en sus bases. Las concentraciones de tensión provocadas por las esquinas de

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base angulosa reducen la fuerza de desconchadura general que se requiere para separar los lentes de sus moldes durante la fabricación. La magnitud de este efecto es sustancial, las fuerzas de desconchadura se pueden reducir durante la fabricación por un factor de dos o más para los lentes de base hexagonal en comparación con los lentes de base sustancialmente circular.

El contraste de imagen del material se puede mejorar rellenando los espacios intersticiales del lente con un material pigmentado opaco de absorción de luz (en color oscuro), formando de manera efectiva una máscara para los lentes. Esto elimina la reducción de contraste que surge de la luz esparcida desde la capa de iconos a través de los espacios intersticiales del lente. Un efecto adicional de este relleno intersticial es que la imagen global se vuelve más oscura debido a que la iluminación ambiental entrante es bloqueada para que no pase a través de los espacios intersticiales al plano de iconos. La claridad de imagen producida por los lentes que tienen enfoque aberrante en su periferia también se puede mejorar por medio de un relleno intersticial pigmentado opaco, siempre y cuando este relleno ocluya la zona de lente periférica aberrante.

Se puede obtener un efecto diferente rellenando los espacios intersticiales del lente con un material

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coloreado blanco o claro o un color de material que compagine con un substrato que se va a utilizar con el material Unísono. Si el relleno intersticial de lente de color claro es lo suficientemente denso y el plano de iconos incorpora un fuerte contraste entre los elementos de icono y el fondo, la imagen sintética Unísona será sustancialmente invisible cuando sea vista con luz reflejada, sin embargo será claramente visible cuando sea vista en luz transmitida desde el lado del lente, pero no será visible cuando sea vista desde el lado del icono. Esto provee el efecto de seguridad novedoso de tener una imagen de transmisión de una vía que es visible únicamente en luz transmitida y visible únicamente desde un lado.

Se pueden utilizar materiales fluorescentes en un recubrimiento intersticial de lente en lugar de, o además de los pigmentos de luz visible para proveer medios adicionales de autenticación.

La figura 4 grafica los efectos del cambio de la relación de escala estereoscópica, SSR (el periodo de repetición del elemento de icono/ el periodo de repetición de la disposición del lente), a lo largo de un eje del presente material. Las zonas del sistema que tienen una SSR mayor que 1.0000 producirán efectos de Flotador y Súper Flotador Unísono, las zonas que tienen una SSR sustancialmente de 1.0000 producirán efectos de movimiento

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ortoparaláctico (OPM) de Movimiento Unísono, y las zonas que tienen una SSR menor que 1.0000 producirán efectos de Profundidad Unísona y Súper Profundidad Unísona. Todos estos efectos se pueden producir y cambiar de uno a otro en una variedad de formas a lo largo de un eje de película de sistema. Esta figura ilustra una de una variedad infinita de dichas combinaciones. La línea punteada 66 indica el valor SSR que sustancialmente corresponde a 1.0000, la línea de división entre la Profundidad Unísona y la Súper Profundidad Unísona y el Flotador Unísono y el Súper Flotador Unísono, y el valor SSR que demuestra OPM. En la zona 68, la SSR del material Unísono es 0.995, creando un efecto de Profundidad Unísona.

Adyacente a ésta se encuentra la zona 70 en donde la SSR es rampeada de 0.995 a 1.005, produciendo una transición espacial de un efecto de Profundidad Unísona a un efecto de Flotador Unísono. La SSR en la siguiente zona 72 es 1.005, creando un efecto de Flotador Unísono. La siguiente zona 74 crea una suave transición hacia debajo de un efecto de Flotador Unísono a un efecto de Profundidad Unísona. La zona 76 avanza gradualmente hacia arriba desde un efecto de Profundidad Unísona, a OPM, a un efecto de Flotador Unísono, y la zona 78 lo regresa gradualmente a OPM. Las variaciones necesarias en un periodo de repetición para lograr estos efectos generalmente se pueden ejecutar

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de manera más fácil en la capa de elementos de icono. Además de variar la SSR en cada zona, puede ser deseable variar el ángulo de rotación de cada zona de las disposiciones, de preferencia dentro de la disposición de los elementos de icono, para mantener las imágenes sintéticamente magnificadas similares de manera sustancial en cuanto al tamaño.

La forma más fácil de interpretar esta gráfica es verla como una sección transversal de la profundidad estereoscópica que será percibida a través de este eje de una pieza de material del sistema. Por lo tanto, es posible crear un campo de imágenes estereoscópicamente esculpido, una superficie visual moldeada, por medio del control local de la SSR y, opcionalmente, a través del control local correspondiente del ángulo de rotación de la disposición. Esta superficie estereoscópicamente esculpida se puede utilizar para representar un rango ilimitado de formas, incluyendo rostros humanos. Un patrón de elementos de icono que crea el efecto de una rejilla estereoscópicamente esculpida, o puntos periódicos, puede ser una forma particularmente efectiva para desplegar de manera visual una superficie compleja.

Las figuras 5 a-c son vistas planas que muestran el efecto de girar un patrón de disposición con respecto al otro en la producción del material del presente sistema. La

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figura 5a muestra una disposición de lente 80 que tiene una separación de disposición periódica regular 82, sin un cambio sustancial en el ángulo de los ejes de la disposición. La figura 5b muestra una disposición de elementos de icono 84 con un ángulo de orientación de eje de disposición progresivamente cambiante 86. Si la disposición de lente 80 se combina con la disposición de elementos de icono 84 trasladando la disposición de lente sobre la disposición de icono, como se muestra, entonces el efecto visual aproximado que resulta se muestra en la figura 5c. En la figura 5c, el material 88 creado por la combinación de la disposición de lente 80 y la disposición de icono 84 crea un patrón de imágenes sintéticamente magnificada 89, 90, 91 que varían en escala y rotación a través del material. Hacia el borde izquierdo inferior del material 88, la imagen 89 es grande y no muestra rotación. La imagen 90, hacia la sección media superior del material 88, es más pequeña y es girada a través de un ángulo importante con respecto a la imagen 89. Las diferentes escalas y rotaciones entre las imágenes 89 y 90 son el resultado de las diferencias en la desalineación angular del patrón de lente 82 y el patrón de elementos de icono 86.

Las figuras 6 a-c ilustran un método para provocar que una imagen sintéticamente magnificada OPM 98

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se transforme en otra imagen sintéticamente magnificada 102 conforme la primera imagen se mueve a través de un límite 104 en los patrones de elementos de icono 92 y 94. El patrón de elementos de icono 92 porta elementos de icono en forma de círculo 98, que se muestran en el recuadro agrandado 96. El patrón de elementos de icono 94 porta elementos de icono en forma de estrella 102, que se muestran en el recuadro agrandado 100. El patrón de elementos de icono 92 y 94 no son objetos separados, sino que están unidos en su límite 104. Cuando el material es ensamblado utilizando este patrón combinado de elementos de icono, las imágenes OPM resultantes mostrarán los efectos de morfismo que se muestran en las figuras 6b y c. La figura 6b muestra imágenes circulares OPM 98 moviéndose hacia la derecha 107 a través del límite 104 y que surgen desde el límite como imágenes de estrellas 102 que también se mueven hacia la derecha. La imagen 106 está en transición, parte círculo y parte estrella, conforme ésta cruza el límite. La figura 6c muestra las imágenes después que se han movido más aún hacia la derecha: la imagen 98 ahora está más cerca del límite 104 y la imagen 106 casi ha cruzado por completo el límite para completar su morfismo de círculo a estrella. El efecto de morfismo se puede lograr en una forma menos abrupta mediante la creación de una zona de transición de un patrón de elementos de icono

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al otro, en lugar de tener un límite difícil 104. En la zona de transición los iconos cambiarían gradualmente de círculo a estrella a través de una serie de etapas. La suavidad del morfismo visual de las imágenes OPM resultantes dependerá del número de etapas empleadas para la transición. El rango de posibilidades gráficas es infinito. Por ejemplo: la zona de transición podría ser diseñada para hacer que el círculo pareciera encogerse mientras que las puntas de la estrella se hacen resaltar a través de éste, o alternativamente los lados del círculo podrían aparecer como abollados hacia dentro para crear una estrella gruesa que progresivamente se va definiendo hasta alcanzar su diseño final.

Las figuras 7 a-c son secciones transversales de materiales del presente sistema que ilustran modalidades alternativas de los elementos de icono. La figura 7a muestra un material que tiene lentes 1 separados de los elementos de icono 108 por un separador óptico 5. Los elementos de icono 108 están formados por patrones de material sin color, con color, teñido o pintado aplicado a la superficie inferior del separador óptico 5. Se puede utilizar cualquiera de la multitud de métodos de impresión comunes, tal como chorro de tinta, láser, impresión tipográfica, flexo, fotograbado e intaglio para depositar los elementos de icono 108 de este tipo, siempre y cuando

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la resolución de la impresión sea lo suficientemente fina.

La figura 7b muestra un sistema de material similar con una modalidad diferente de elementos de icono 112. En esta modalidad, los elementos de icono son formados a partir de pigmentos, tintes, o partículas incorporadas en un material de soporte 110. Ejemplos de esta modalidad de elementos de icono 112 en el material de soporte 110 incluyen: partículas de plata en gelatina, tal como una emulsión fotográfica, tinta pigmentada o teñida absorbida en un recubrimiento receptor de tinte, transferencia de sublimación de tinte a un recubrimiento receptor de tinte, e imágenes fotocrómicas o termocrómicas en una película de creación de imágenes.

La figura 7c muestra un enfoque de micro-estructura para formar elementos de icono 114. Este método tiene el beneficio de una resolución espacial casi ilimitada. Los elementos de icono 114 se pueden formar a partir de huecos en la micro-estructura 113 o las regiones sólidas 115, individualmente o en combinación. Los huecos 113 opcionalmente se pueden rellenar o recubrir con otro material tal como material de metal evaporado que tiene un índice refractivo diferente o material teñido o pigmentado.

Las figuras 8 a, b muestran modalidades positivas y negativas de los elementos de icono. La figura 8a muestra los elementos de icono positivos 116 que están coloreados,

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teñidos o pigmentados 120 contra un fondo transparente 118.

La figura 8b muestra los elementos de icono negativos 122 que son transparentes 118 contra un fondo coloreado, teñido o pigmentado 120. Un material del presente sistema 5 opcionalmente puede incorporar elementos de icono tanto positivos como negativos. Este método para crear elementos de icono positivos y negativos se adapta particularmente bien a los elementos de icono de micro-estructura 114 de la figura 7c.

10 La figura 9 muestra una sección transversal de una modalidad de un material de zona de píxeles del presente sistema. Esta modalidad incluye zonas con lentes 124 que tienen un foco corto y otras zonas con lentes que tienen un foco largo 136. Los lentes de foco corto 124 15 proyectan imágenes 123 de elementos de icono 129 en el plano de iconos 128 colocado en el plano focal de los lentes 124. Los lentes de foco largo 136 proyectan imágenes 134 de elementos de icono 137 en el plano de iconos 132 colocado en el plano focal de los lentes 136. El separador 20 óptico 126 separa los lentes de foco corto 124 de su plano de iconos asociado 128. Los lentes de foco largo 136 están separados de su plano de iconos asociado 132 por medio de la suma del grosor del separador óptico 126, el plano de iconos 128, y el segundo separador óptico 130. Los 25 elementos de icono 137 en el segundo plano de iconos 132

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están fuera de la profundidad de foco de los lentes de foco corto 124 y, por lo tanto, no forman imágenes sintéticamente magnificadas distintas en las zonas de lente de foco corto. En una forma similar, los elementos de icono 129 están demasiado cerca de los lentes de foco largo 136 para formar imágenes sintéticamente magnificadas distintas. Por consiguiente, las zonas de material que portan lentes de foco corto 124 desplegarán imágenes 123 de elementos de icono 129, mientras que las zonas de material que portan lentes de foco largo 136 desplegarán imágenes 134 de elementos de icono 137. Las imágenes 123 y 134 proyectadas pueden diferir en diseño, color, dirección OPM, factor de magnificación sintética, y efecto, incluyendo los efectos de Profundidad, Unísono, Flotador y Levitado descritos anteriormente.

La figura 10 es una sección transversal de una modalidad alterna de un material de zona de píxeles del presente sistema. Esta modalidad incluye las zonas con los lentes 140 elevados por una mesa de soporte de lente 144 por encima de las bases de los lentes no elevados 148. La longitud focal de los lentes elevados 140 es la distancia 158, colocando el foco de estos lentes en el primer plano de iconos 152. La longitud focal de los lentes no elevados 148 es la distancia 160, colocando el foco de estos lentes en el primer plano de iconos 156. Estas dos longitudes

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focales, 158 y 160, se pueden elegir para que sean similares o diferentes. Los lentes elevados 140 proyectan imágenes 138 de elementos de icono 162 en el plano de iconos 152 colocado en el plano focal de los lentes 140.

5 Los lentes no elevados 148 proyectan imágenes 146 de elementos de icono 164 en el plano de iconos 156 colocado en el plano focal de los lentes 148. Los lentes elevados 140 están separados de sus elementos de icono asociados 162 por la suma del grosor de la mesa de soporte de lente 144 y

10 la separación óptica 150. Los lentes no elevados 148 están separados de sus elementos de icono asociados 164 por la suma del grosor de la separación óptica 150, la capa de icono 152, y el separador de iconos 154. Los elementos de icono 164 en el segundo plano de iconos 156 están fuera de

15 la profundidad de foco de los lentes elevados 140 y, por lo tanto, no forman imágenes sintéticamente magnificadas distintas en las zonas de lentes elevados. De manera similar, los elementos de icono 152 están demasiado cerca de los lentes no elevados 148 para formar imágenes

20 sintéticamente magnificadas distintas. Por consiguiente, las zonas de material que portan lentes elevados 140 desplegarán imágenes 138 de los elementos de icono 162, mientras que las zonas de material que portan lentes no elevados 136 desplegarán imágenes 146 de elementos de icono

25 156. Las imágenes 138 y 146 proyectadas pueden diferir en

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diseño, color, dirección OPM, factor de magnificación sintética, y efecto, incluyendo los efectos de Profundidad, Unísono, Flotador y Levitado.

Las figuras 11, a, b son secciones transversales que ilustran modalidades no refractivas del presente sistema. La figura 11a ilustra una modalidad que utiliza un reflector de enfoque 166 en lugar de un lente refractivo para proyectar imágenes 174 de elementos de icono 172. La capa de iconos 170 yace entre los ojos del observador y la óptica de enfoque. Los reflectores de enfoque 166 pueden ser metalizados 167 para obtener una alta eficiencia de enfoque. La capa de iconos 170 es mantenida a una distancia igual a la longitud focal de los reflectores por el separador óptico 168. La figura 11b describe una modalidad de óptica puntiforme de este material. La capa superior opaca 176, de preferencia en color negro para una mejora del contraste, está perforada por aperturas 178. El elemento separador óptico 180 controla el campo de visión del sistema. Los elementos de icono 184 en la capa de iconos 182 son reflejados a través de las aperturas 178 en una forma similar a la óptica puntiforme de una cámara puntiforme. Debido a la pequeña cantidad de luz que pasa a través de las aperturas, esta modalidad es más efectiva cuando es iluminada por atrás, con luz que pasa a través del plano de iconos 182 primero, después a través de las

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aperturas 178. Los efectos de cada una de las modalidades anteriormente descritas, OPM, Profundidad, Flotador, y Levitado, se pueden crear utilizando ya sea el diseño del sistema reflector o el diseño del sistema de óptica puntiforme.

Las figuras 12 a, b son secciones transversales que comparan las estructuras de un material completamente refractivo 188 con un material refractivo/reflector híbrido 199. La figura 12a muestra una estructura ejemplar, con micro-lentes 192 separados del plano de iconos 194 por el separador óptico 198. La capa de sellado óptico 195 contribuye al grosor del sistema refractivo total 196. Los lentes 192 proyectan imágenes de icono 190 hacia el observador (que no se muestra). El material refractivo/reflector híbrido 199 incluye micro-lentes 210 con el plano de iconos 208 directamente debajo de éstos. El separador óptico 200 separa los lentes 210 y el plano de iconos 208 de la capa reflectora 202. La capa reflectora 202 puede ser metalizada, tal como por aluminio evaporado o pulverizado, oro, rodio, cromo, osmio, uranio agotado o plata, por plata químicamente depositada, o por películas de interferencia de múltiples capas. La luz esparcida desde la capa de iconos 208 se refleja desde la capa reflectora 202, pasa a través de la capa de iconos 208 y dentro de los lentes 210 los cuales proyectan las imágenes 206 hacia el

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observador (que no se muestra). Estas dos figuras están dibujadas aproximadamente a la misma escala: por comparación visual, se puede apreciar que el grosor del sistema total 212 del sistema refractivo/reflector híbrido 5 199 es aproximadamente la mitad del grosor del sistema total 196 del sistema completamente refractivo 188. Las dimensiones ejemplares para sistemas equivalentes son 29μ de grosor 196 del sistema refractivo total 188 y 17μ de grosor 212 para el sistema refractivo/reflector total 10 híbrido 199. El grosor de un sistema refractivo/reflector se puede reducir adicionalmente por escala. Por lo tanto, un sistema híbrido que tiene lentes con un diámetro de 15μ se puede hacer con un grosor total de aproximadamente 8μ . Los efectos de cada una de las modalidades anteriores, OPM, 15 Profundidad, Flotador, Levitado, Morfo, y 3-D se pueden crear utilizando el diseño refractivo/difractivo híbrido.

La figura 13 es una sección transversal que muestra una modalidad de un material que indica alteración "despegue-para-revelar" del presente sistema. Esta 20 modalidad no despliega una imagen hasta que se trata de forzar. La estructura no alterada se muestra en la región 224, en donde un sistema refractivo 214 está ópticamente enterrado bajo una capa superior 216 que consta de un sustrato opcional 218 y una capa que se puede despegar 220 25 la cual se ajusta a los lentes 215. La capa que se puede

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despegar 220 forma de manera efectiva estructuras de lentes negativos 220 que se ajustan sobre los lentes positivos 215 y niegan su potencia óptica. Los lentes 215 no pueden formar imágenes de la capa de iconos en la región no alterada, y la luz esparcida 222 desde el plano de iconos es desenfocada. La capa superior 216 puede incluir un sustrato de película opcional 218. La alteración, que se muestra en la región 226, ocasiona la liberación de la capa superior 216 del sistema refractivo 214, exponiendo los lentes 215 para que puedan formar imágenes 228. Los efectos de cada una de las modalidades anteriormente descritas, OPM, Profundidad, Flotador y Levitado, se pueden incluir en un sistema de "despegue-para-revelar" que indique alteración del tipo de la figura 13.

La figura 14 es una sección transversal que ilustra una modalidad de un material que indica alteración "despegue-para-cambiar" del presente sistema. Esta modalidad despliega una primera imagen 248 de un primer plano de iconos 242 antes de la alteración 252, después despliega una segunda imagen 258 en la región 254 después que se ha tratado de forzar. La estructura no alterada se muestra en la región 252, en donde dos sistemas refractivos, 232 y 230, están apilados. El primer plano de iconos 242 se ubica debajo de los lentes 240 del segundo sistema. Antes de alterar la región 252, el primer sistema

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o sistema superior 232 presenta imágenes del primer plano de iconos 242. El segundo plano de iconos 246 está demasiado alejado de la profundidad de foco de los lentes 234 para formar imágenes distintas. Los primeros lentes 234 están separados de los segundos lentes 240 por medio de un substrato opcional 236 y una capa que se puede despegar 238 la cual se ajusta a los segundos lentes 240. La capa que se puede despegar 232 forma de manera efectiva estructuras de lentes negativos 238 que se ajustan sobre los lentes positivos 240 y rechazan su potencia óptica. La capa superior 232 puede incluir substrato de película opcional 236. La alteración produce como resultado el despegue 256 de la capa superior 232, que se muestra en la región 254, del segundo sistema refractivo 230, exponiendo los segundos lentes 240 para que puedan formar las imágenes 258 de la segunda capa de iconos 246. Los segundos lentes 240 no forman imágenes de la primera capa de iconos 242 debido a que la capa de iconos está demasiado cerca de los lentes 240.

Esta modalidad de un material que indica alteración es muy conveniente para aplicación como una cinta o etiqueta aplicada a un artículo. La alteración libera la capa superior 232, dejando el segundo sistema 230 unido al artículo. Antes de la alteración, esta modalidad presenta una primera imagen 248. Después de la alteración

254, el segundo sistema 230, aún fijo al artículo, presenta una segunda imagen 258 mientras que la capa despegada 256 no presenta imagen alguna. Los efectos de cada una de las modalidades anteriormente descritas, OPM, Profundidad, 5 Flotador, y Levitado, se pueden incluir en el primer sistema 232 o en el segundo sistema 230.

Se puede apreciar que una modalidad alternativa que logra un efecto similar a aquel de la figura 14 tendrá dos sistemas separados laminados entre sí. En esta 10 modalidad, cuando la capa superior es despegada, ésta toma el primer plano de iconos y sus imágenes junto con la misma, revelando el segundo sistema y sus imágenes.

Las figuras 15 a-d son secciones transversales que muestran varias modalidades de doble lado del presente 15 sistema. La figura 15a muestra un material de doble lado 260 que incluye un solo plano de iconos 264 que es reflejado 268 por los lentes 262 en un lado y reflejado 270 por un segundo conjunto de lentes 266 en el lado opuesto. La imagen 268 vista desde el lado izquierdo (tal como está 20 dibujada) es la imagen espejo de la imagen 270 vista desde el lado derecho. El plano de iconos 264 puede contener elementos de icono que son símbolos o imágenes que parecen similares en la imagen de espejo, o elementos de icono que parecen diferentes en la imagen de espejo, o combinaciones 25 de los elementos de icono, en donde una porción de los



elementos de icono están en lectura correcta cuando son vistos desde un lado y los otros elementos de icono están en lectura correcta cuando son vistos desde el otro lado. Los efectos de cada una de las modalidades antes descritas

5 OPM, Profundidad, Flotador, y Levitado, se pueden desplegar desde cualquier lado de un material de doble lado de acuerdo con esta modalidad.

La figura 15b ilustra otra modalidad de doble lado 272 que incluye dos planos de iconos 276 y 278 que son

10 reflejados, 282 y 286 respectivamente, por dos conjuntos de lentes 274 y 280 respectivamente. Esta modalidad esencialmente consta de dos sistemas separados 287 y 289, tal como se ilustra en la figura 1a, que han sido unidos entre sí con un separador de capa de iconos 277 en medio de

15 los mismos. El grosor de este separador de capa de iconos 277 determinará el grado que la capa de iconos "equivocada" es reflejada 284 y 288 por un conjunto de lentes. Por ejemplo, si el grosor del separador de capa de iconos 277 es cero, de forma que las capas de iconos 276 y 278 están

20 en contacto, entonces ambas capas de iconos serán reflejadas por ambos conjuntos de lentes 274 y 280. En otro ejemplo, si el grosor del separador de capa de iconos 277 es sustancialmente más grande que la profundidad de foco de los lentes 274 y 280, entonces las capas de iconos

25 "equivocadas" no serán reflejadas por los lentes 274 y 280.

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En otro ejemplo todavía, si la profundidad de foco de un conjunto de lentes 274 es grande, pero la profundidad de foco del otro conjunto de lentes es pequeño (debido a que los lentes 274 y 280 tienen diferentes $F\#$), entonces ambos
5 planos de iconos 276 y 278 serán reflejados 282 a través de los lentes 274, pero solo un plano de iconos 278 será reflejado a través de los lentes 280, de forma que un material de este tipo mostraría dos imágenes desde un lado pero solo una de estas imágenes, reflejadas, desde el lado
10 opuesto. Los efectos de cada una de las modalidades antes descritas OPM, Profundidad, Flotador, y Levitado, se pueden desplegar desde cualquier lado de un material de doble lado de acuerdo con esta modalidad, y las imágenes proyectadas 282 y 286 pueden ser del mismo color o de un color
15 diferente.

La figura 15c muestra otra modalidad todavía de un material de doble lado 290 que tiene un separador de capa de iconos pigmentada 298 que bloquea los lentes en un lado del material contra la visualización del conjunto
20 "equivocado" de iconos. Los lentes 292 reflejan 294 la capa de iconos 296 pero no pueden reflejar la capa de iconos 300 debido a la presencia de la capa de iconos pigmentada 298. De manera similar, los lentes 302 reflejan 304 la capa de iconos 300, pero no pueden reflejar la capa de iconos 296
25 debido a la presencia de la capa de iconos pigmentada 298.

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Los efectos de cada una de las modalidades antes descritas OPM, Profundidad, Flotador, y Levitado, se pueden desplegar desde cualquier lado de un material de doble lado de acuerdo con esta modalidad, y las imágenes proyectadas 294 y 304 pueden ser del mismo color o de un color diferente.

La figura 15d describe una modalidad de un material de doble lado 306 adicional que tiene lentes 308 que reflejan 318 la capa de iconos 314 y, lentes 316 en el lado opuesto que reflejan 322 la capa de iconos 310. La capa de iconos 310 está cerca de, o sustancialmente en contacto con las bases de los lentes 308 y la capa de iconos 314 está cerca de, o sustancialmente en contacto con las bases de los lentes 316. Los iconos 310 están demasiado cerca de los lentes 308 para formar una imagen, de forma que su luz se esparce 320 en lugar de enfocar. Los iconos 314 están demasiado cerca de los lentes 316 para formar una imagen, de forma que su luz se esparce 324 en lugar de enfocar. Los efectos de cada una de las modalidades antes descritas OPM, Profundidad, Flotador, y Levitado, se pueden desplegar desde cualquier lado de un material de doble lado de acuerdo con esta modalidad, y las imágenes proyectadas 318 y 322 pueden ser del mismo color o de un color diferente.

Las figuras 16 a-f son secciones transversales y vistas planas correspondientes que ilustran tres métodos

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diferentes para crear patrones de elementos de icono con tono o en escala de grises e imágenes sintéticamente magnificadas posteriores con el presente sistema. Las figuras 16 a-c son detalles en sección transversal del lado de los iconos de un material 307, incluyendo parte del separador óptico 309 y una capa de iconos micro-estructurada transparente 311. Los elementos de icono se forman como superficies de bajo relieve 313, 315, 317 que después se rellenan con un material pigmentado o teñido 323, 325, 327, respectivamente. La parte inferior de la capa de iconos opcionalmente se puede sellar por medio de una capa de sellado 321 que puede ser transparente, entintada, coloreada, teñida, pigmentada u opaca. Las micro-estructuras de bajo relieve de elementos de icono 313, 315, y 317 proveen variaciones de grosor en el material de relleno teñido o pigmentado 323, 325, y 327 respectivamente, que crean variaciones en la densidad óptica del elemento de icono como se puede apreciar en la vista plana. Las vistas planas correspondientes a los elementos de icono 323, 325, y 327 son vistas planas 337, 339, y 341. El uso de este método para crear imágenes sintéticamente magnificadas con tono o en escala de grises no se limita a los puntos específicos de los ejemplos aquí descritos, sino que en general se pueden aplicar para crear una variedad ilimitada de imágenes en escala de grises.

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La figura 16a incluye el elemento de icono 313, el relleno del elemento de icono teñido o pigmentado 323, y la vista plana correspondiente 337. La vista transversal del plano de iconos en la parte superior de esta figura solo puede mostrar un plano en corte a través de los elementos de icono. La ubicación del plano en corte queda indicada por la línea punteada 319 a través de las vistas planas 337, 339 y 341. Por consiguiente, la sección transversal del elemento de icono 313 es un plano a través de un elemento de icono en forma sustancialmente hemisférica. Al limitar de manera conveniente la densidad global del tinte o pigmento del relleno 323, las variaciones en grosor del relleno teñido o pigmentado 323 crea variaciones de densidad óptica, de tonos, o de escala de grises representadas en la vista plana 337. Una disposición de elementos de icono de este tipo se puede magnificar sintéticamente dentro del sistema del material presente para producir imágenes que muestren variaciones equivalentes en escala de grises.

La figura 16b incluye el elemento de icono 315, el relleno del elemento de icono teñido o pigmentado 325, y la vista plana correspondiente 339. La vista plana 339 muestra que el elemento de icono 315 es una representación en bajorrelieve de un rostro. Las variaciones de tono en una imagen de un rostro son complejas, tal como se muestra

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a través de las variaciones de grosor complejas 325 en la vista transversal. Como se describe con respecto al elemento de icono 313, una disposición de elementos de icono de este tipo, como se muestra por medio de 315, 325 y 5 339, se puede magnificar sintéticamente dentro del sistema del material presente para producir imágenes que muestren variaciones equivalentes en escala de grises que, en este ejemplo, representan la imagen de un rostro.

La figura 16c incluye el elemento de icono 317, 10 el relleno teñido o pigmentado 327, y la vista plana correspondiente 341. En una manera similar al análisis de las figuras 16 a, b, anteriores, la forma en bajorrelieve de esta estructura de elemento de icono produce una variación en tono en la apariencia del relleno teñido y 15 pigmentado 327 y en la imagen sintéticamente magnificada producida por el sistema del material presente. El elemento de icono 317 ilustra un método para crear un centro brillante en una superficie redondeada, en comparación con el efecto del elemento de icono 313 el cual crea un centro 20 oscuro en una superficie redondeada.

Las figuras 16 d, e describen otra modalidad 326 de capa de iconos micro-estructurada de bajorrelieve 311 que incluye elementos de icono 329 y 331 que están recubiertos con un material de alto índice refractivo 328. 25 La capa de iconos 311 se puede sellar con una capa de

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sellado opcional 321 que rellena los elementos de icono 329 y 331, 330 y 332, respectivamente. La capa de alto índice refractivo 328 mejora la visibilidad de las superficies inclinadas mediante la creación de reflexiones a partir de las mismas por medio de reflexión interna total. Las vistas planas 342 y 344 presentan imágenes representativas de la apariencia de los elementos de icono 329 y 331 y sus imágenes sintéticamente magnificadas. Esta modalidad de recubrimiento con alto índice refractivo provee un tipo de efecto de mejoramiento de borde sin agregar pigmento o tinte para hacer que los iconos o sus imágenes sean visibles.

La figura 16 f describe otra modalidad todavía 333 de un icono micro-estructurado de bajorrelieve transparente 335 que utiliza un volumen de aire, gas o líquido 336 para proveer la definición visual para esta micro-estructura de interfaz de fase 334. La capa de sellado opcional 340 se puede agregar con o sin adhesivo opcional 338 para atrapar el volumen de aire, gas o líquido 336. El efecto visual de un elemento de icono de interfaz de fase es similar a aquel de un elemento de icono recubierto con un alto índice refractivo 329 y 331.

Las figuras 17 a-d son secciones transversales que muestran el uso del presente sistema como una película de laminado junto con información impresa, tal como puede

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ser utilizada en la fabricación de tarjetas de identificación o licencias de conducir, en donde el material 348 (que consta de la micro-disposición coordinada de lentes e imágenes descritos anteriormente) cubre una

5 proporción sustancial de la superficie. La figura 17a muestra una modalidad de Unísono empleado como una lámina sobre impresión 347. El material 348 que tiene por lo menos cierta transparencia óptica en la capa de iconos es laminado a substrato fibroso 354, tal como papel o

10 sustituto de papel, con adhesivo de laminación 350, cubriendo por completo o cubriendo parcialmente el elemento de impresión 352 que previamente había sido aplicado al substrato fibroso 354. Debido a que el material 348 es por lo menos parcialmente transparente, el elemento de

15 impresión 352 puede ser visto a través del mismo y el efecto de esta combinación es proveer el efecto de imagen dinámica del sistema presente en combinación con la impresión estática.

La figura 17b muestra una modalidad del material

20 del sistema empleado como un laminado sobre un elemento de impresión 352 aplicado a un substrato no fibroso 358, tal como una película de polímero. Como se aprecia en la figura 17a, el material 348 que tiene por lo menos cierta transparencia óptica en la capa de iconos es laminado al

25 substrato no fibroso 358, tal como polímero, metal, vidrio

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o sustituto de cerámica, con adhesivo de laminación 350, cubriendo por completo o cubriendo parcialmente el elemento de impresión 352 que previamente había sido aplicado al sustrato no fibroso 354. Debido a que el material 348 es
5 por lo menos parcialmente transparente, el elemento de impresión 352 puede ser visto a través del mismo y el efecto de esta combinación es proveer el efecto de imagen dinámica en combinación con la impresión estática.

La figura 17c muestra el uso de un elemento de
10 impresión directamente sobre el lado del lente del material 360. En esta modalidad, el material 348 tiene el elemento de impresión 352 directamente aplicado a la superficie de lente superior. Esta modalidad no requiere que el material sea por lo menos parcialmente transparente: el elemento de
15 impresión 352 yace en la parte superior del material y los efectos de imagen dinámica se pueden observar alrededor del elemento de impresión. En esta modalidad, el material 348 se utiliza como el sustrato para el producto final, tal como moneda corriente, tarjetas de identificación, y otros
20 artículos que requieren autenticación o que proveen autenticación a otro artículo.

La figura 17d muestra el uso de un elemento de impresión directamente sobre el lado del icono de un material por lo menos parcialmente transparente 362. El
25 elemento de impresión 352 se aplica directamente a la capa

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de iconos o capa de sellado de un material del sistema por lo menos parcialmente transparente 348. Debido a que el material del sistema 348 es por lo menos parcialmente transparente, el elemento de impresión 352 puede ser visto a través del mismo y el efecto de esta combinación es proveer el efecto de imagen dinámica en combinación con la impresión estática. En esta modalidad, el material del sistema 348 se utiliza como el substrato para el producto final, tal como moneda corriente, tarjetas de identificación, y otros artículos que requieren autenticación o que proveen autenticación a otro artículo.

Cada una de las modalidades de las figuras 17 a-d se puede utilizar por separado o en combinación. Por lo tanto, por ejemplo, un material del sistema 348 puede ser sobreimpreso (figura 17c) e impreso en la parte posterior (figura 17d), después opcionalmente laminado sobre impresión en un substrato (figuras 17 a, b). Combinaciones como éstas además pueden incrementar la resistencia a la falsificación, simulación y alteración del material del presente sistema.

Las figuras 18 a-f son secciones transversales que ilustran la aplicación del presente sistema a, o su incorporación en varios substratos y en combinación con información impresa. Las modalidades de las figuras 18 a-f difieren de aquellas de las figuras 17 a-d en que las

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primeras figuras describen el material del sistema 348 que cubre la mayor parte o todo un artículo, mientras que las presentes figuras describen modalidades en donde el material del sistema o su efecto óptico no cubre sustancialmente una superficie completa, sino más bien cubre solo una porción de una superficie. La figura 18a muestra una pieza del material del sistema por lo menos parcialmente transparente 364 adherida a un substrato fibroso o no fibroso 368 con elemento adhesivo 366. El elemento de impresión opcional 370 se ha aplicado directamente a la superficie superior de lente del material 364. El elemento de impresión 370 puede ser parte de un patrón más grande que se extienda más allá de la pieza de material 364. La pieza de material 364 es opcionalmente laminada sobre el elemento de impresión 372 que se aplicó al substrato fibroso o no fibroso antes de la aplicación del material 364.

La figura 18b ilustra una modalidad de un material del sistema de un solo lado 364 incorporado en un substrato no óptico 378 tal como una ventana, en donde por lo menos algunos de los bordes del material del sistema 364 son capturados, cubiertos o encerrados por el substrato no óptico 378. Los elementos de impresión 380 opcionalmente se pueden aplicar en la parte superior de la superficie de lente del material del sistema y estos elementos de

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impresión se pueden alinear con, o pueden corresponder a los elementos de impresión 382 aplicados al substrato no óptico 378 en el área adyacente al elemento de impresión 380. De manera similar, los elementos de impresión 384 se
5 pueden aplicar al lado opuesto del substrato no óptico alineados con, o en correspondencia a los elementos de impresión 386 aplicados a la capa de iconos o de sellado 388 del material del sistema 364. El efecto de una ventana de este tipo será presentar distintas imágenes cuando el
10 material sea visto desde el lado del lente y ninguna imagen cuando sea visto desde el lado del icono, proporcionando un efecto de imagen de un solo lado.

La figura 18c muestra una modalidad similar a aquella de la figura 18b, excepto que el material del
15 sistema 306 es un material de doble lado 306 (u otra modalidad de doble lado descrita anteriormente). Los elementos de impresión 390, 392, 394 y 396 corresponden sustancialmente en función a los elementos de impresión 380, 382, 384, 386, previamente descritos. El efecto de una
20 ventana de material de este tipo será presentar diferentes imágenes distintas cuando el material sea visto desde lados opuestos. Por ejemplo, una ventana incorporada en un papel moneda podría mostrar la denominación numérica del billete, tal como "10" cuando sea vista desde el lado frontal del
25 billete, pero cuando sea vista desde el lado posterior del

billete la ventana Unísona podría mostrar diferente información, tal como "EUA", que puede estar en el mismo color que la primera imagen o en un color diferente.

La figura 18d ilustra un substrato transparente 373 que actúa como el separador óptico para el material formado por una zona de lentes 374 de extensión limitada y una capa de iconos 376 que se extiende sustancialmente más allá de la periferia de la zona de lentes 374. En esta modalidad, los efectos presentes solo serán visibles en esa zona que incluye tanto los lentes como los iconos (correspondiente a la zona de lentes 374 en esta figura). Tanto los lentes 374 como el substrato adyacente opcionalmente pueden ser impresos 375, y los elementos de impresión también se pueden aplicar a la capa de iconos 376 o a una capa de sellado opcional que cubra los iconos (que no se indican en esta figura, ver figura 1). Se pueden utilizar múltiples zonas de lente en un artículo conforme a la manera de esta modalidad; en cualquier lado en donde se coloque una zona de lentes, se podrán apreciar los efectos Unísonos; el tamaño, la rotación, la posición de profundidad estereoscópica, y las propiedades OPM de las imágenes pueden ser diferentes para cada zona de lentes. Esta modalidad es muy conveniente para aplicación a tarjetas de identificación, tarjetas de crédito, licencias para conducir, y aplicaciones similares.

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La figura 18e muestra una modalidad que es similar a aquella de la figura 18d, excepto que el plano de iconos 402 no se extiende sustancialmente más allá de la extensión de la zona de lentes 400. El separador óptico 398
5 separa los lentes 400 de los iconos 402. Los elementos de impresión 404 y 406 corresponden a los elementos de impresión 375 y 377 en la figura 18d. Se pueden utilizar múltiples zonas 400 en un artículo conforme a la manera de esta modalidad; cada zona puede tener efectos separados.
10 Esta modalidad es muy conveniente para aplicación a tarjetas de identificación, tarjetas de crédito, licencias para conducir, y aplicaciones similares.

La figura 18f muestra una modalidad que es similar a aquella de la figura 18d, excepto que la presente
15 modalidad incorpora el separador óptico 408 que separa los lentes 413 del plano de iconos 410. Los lentes 413 se extienden sustancialmente más allá de la periferia de la zona de iconos 412. Los elementos de impresión 414 y 416 corresponden a los elementos de impresión 375 y 377 en la
20 figura 18d. Múltiples zonas de lentes se pueden utilizar en un artículo conforme a la manera de esta modalidad; en cualquier lado en donde se coloque una zona de lentes, se podrán apreciar los presentes efectos; el tamaño, la rotación, la posición de profundidad estereoscópica, y las
25 propiedades OPM de las imágenes pueden ser diferentes para

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cada zona de lentes. Esta modalidad es muy conveniente para aplicación a tarjetas de identificación, tarjetas de crédito, licencias para conducir, y aplicaciones similares.

Las figuras 19 a, b ilustran vistas transversales que comparan el campo en-foco de la vista de un lente esférico con aquella de un lente asférico de campo plano cuando cada uno está incorporado en una estructura del tipo descrito anteriormente. La figura 19a ilustra un lente sustancialmente esférico conforme se aplica en un sistema como se describió anteriormente. El lente sustancialmente esférico 418 está separado del plano de iconos 422 por el separador óptico 420. La imagen 424 proyectada hacia fuera, perpendicular a la superficie del material, se origina en el punto focal 426 dentro de la capa de iconos 422. La imagen 424 está en foco nítido debido a que el punto focal 426 está dentro de la capa de iconos 422. Cuando el lente es visto desde un ángulo oblicuo, entonces la imagen 428 queda borrosa y fuera de foco debido a que el punto focal correspondiente 430 ya no está en el plano de iconos, sino que está por arriba de éste por una distancia sustancial. La flecha 432 muestra la curvatura de campo de este lente, equivalente al barrido del punto focal desde 426 a 430. El punto focal está dentro del plano de iconos a través de la zona 434, después se mueve fuera del plano de iconos en la zona 436. Los lentes que son muy convenientes para

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aplicación en coordinación con un plano de imágenes impresas o iconos típicamente tienen un bajo $F\#$, típicamente menos de 1, dando como resultado una profundidad de foco muy superficial; de manera efectiva se pueden utilizar lentes con $F\#$ superior con efectos de Profundidad y Flotador, pero ocasionan una disparidad binocular vertical proporcional con efectos aquí descritos cuando se utilizan con efectos de Movimiento Unísono. Tan pronto como el límite inferior de la profundidad de foco se mueve fuera del plano de iconos, la claridad de la imagen se degrada con rapidez. A partir de esta figura se puede apreciar que la curvatura de campo de un lente sustancialmente esférico limita el campo de visión de la imagen: la imagen es distinta únicamente dentro de la zona en-foco 434, saliendo rápidamente de foco para ángulos de visualización más oblicuos. Los lentes sustancialmente esféricos no son lentes de campo plano, y la curvatura de campo de estos lentes se amplifica para lentes de bajo $F\#$.

La figura 19b ilustra un lente asférico como aplicado al presente sistema. Como un lente asférico, su curvatura no es aproximada por una esfera. El lente asférico 438 está separado de la capa de iconos 442 por el separador óptico 440. El lente asférico 438 proyecta la imagen 444 del plano de iconos 442 normal al plano del material. La imagen se origina en el punto focal 446. La

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longitud focal del lente esférico 438 yace dentro del plano de iconos 442 para un amplio rango de ángulos de visualización, desde normal 444 a oblicuo 448, debido a que tiene un campo plano 452. La longitud focal del lente varía 5 de acuerdo con el ángulo de visión a través del mismo. La longitud focal es más corta para visualización normal 444 y aumenta conforme el ángulo de visualización se vuelve más oblicuo. En el ángulo de visualización oblicuo 448, el punto focal 450 sigue estando dentro del grosor del plano 10 de iconos y, por lo tanto, la imagen oblicua sigue estando en foco para este ángulo de visualización oblicuo 448. La zona en foco 454 es mucho más grande para el lente esférico 438 que la zona en foco 434 del lente sustancialmente esférico 418. Por lo tanto, el lente esférico 438 provee un 15 campo de visión agrandado sobre la anchura del icono de imagen asociado de forma que los bordes periféricos del icono de imagen asociado no se salen de visión en comparación con aquellos del lente esférico 418. Para el presente sistema se prefieren los lentes esféricos debido 20 al campo de visión más grande que proveen y el incremento resultante en la visibilidad de las imágenes asociadas.

Las figuras 20 a-c son secciones transversales que ilustran dos beneficios de utilidad que resultan del uso de una capa de iconos gruesa. Estos beneficios aplican 25 independientemente si el lente 456 empleado para verlos es

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sustancialmente esférico 418 o asférico 438, pero los beneficios son mayores en combinación con lentes esféricos 438. La figura 20a ilustra un material del sistema de capa de iconos delgada 460 que incluye lentes 456 separados de la capa de iconos 460 por el separador óptico 458. Los elementos de icono 462 son delgados 461 en comparación con la curvatura de campo del lente 463, limitando la zona enfoco a un ángulo pequeño, el ángulo entre la imagen proyectada en la dirección normal 464 y la imagen en ángulo oblicuo mayor 468 que tiene un punto focal 470 dentro de la capa de iconos 460. El mayor campo de visión se obtiene diseñando el foco de imagen normal 466 para que quede en la parte inferior del plano de iconos, elevando así al máximo el campo oblicuo del ángulo de visión, limitado por el punto al que el punto focal 470 yace en la parte superior del plano de iconos. El campo de visión del sistema en la figura 20a se limita a 30 grados.

La figura 20b ilustra los beneficios que se obtienen de la incorporación de un plano de iconos 471 que es delgado 472 en comparación a la curvatura de campo del lente 456. Los lentes 456 están separados de los elementos de icono gruesos 474 por el separador óptico 458. Los elementos de icono gruesos 474 permanecen en foco 475 sobre un campo de visión más grande, 55 grados, que los elementos de icono delgados 462 de la figura 20a. La imagen normal

476 proyectada a través de los lentes 456 desde el punto focal 478 está en foco nítido, y el foco permanece nítido mientras el ángulo de visión aumenta hasta alcanzar los 55 grados, en donde el punto focal 482 de la imagen oblicua 480 yace en la parte superior del plano de iconos grueso 471. El campo de visión incrementado es mayor para un lente de campo plano, tal como el lente esférico 438 de la figura 19b.

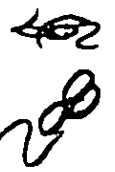
La figura 20c ilustra otra ventaja todavía de un plano de iconos grueso 492; reduciendo la sensibilidad del material del presente sistema a variaciones en el grosor S que pueden ser el resultado de variaciones en la fabricación. El lente 484 está separado una distancia S de la superficie inferior de la capa de iconos de grosor i . El lente 484 proyecta la imagen 496 desde el punto focal 498 colocado en la parte inferior de la capa de iconos 492. Esta figura está dibujada para demostrar que las variaciones en el espacio óptico S entre los lentes y la capa de iconos pueden variar sobre un rango igual al grosor de la capa de iconos i sin pérdida de foco de imagen 496, 500, 504. En el lente 486, el grosor del separador óptico es aproximadamente $(S + i/2)$ y el punto focal 502 de la imagen 500 sigue estando dentro del grosor i de la capa de iconos 492. En el lente 488, el grosor del separador óptico ha aumentado a $(S + i)$ 490 y el punto focal 506 de la

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imagen 504 yace en la parte superior del elemento de icono grueso 494. El grosor del separador óptico puede entonces variar sobre un rango correspondiente al grosor de la capa de iconos i: por lo tanto, una capa de iconos delgada 5 provee una pequeña tolerancia para variaciones en el grosor del separador óptico y una capa de iconos gruesa provee una mayor tolerancia para variaciones en el grosor del separador óptico.

Una capa de iconos 492 provee un beneficio 10 adicional. Lentes imperfectos, tal como lentes sustancialmente esféricos, pueden tener una longitud focal más corta 493 hacia sus bordes que en su centro 496. Este es un aspecto del defecto de aberración esférica común de lentes sustancialmente esféricos. Una capa de iconos gruesa 15 provee un elemento de icono que puede ser claramente enfocado sobre un rango de longitudes focales 498 a 495, mejorando así la claridad y contraste global de una imagen producida por un lente 484 que tiene variaciones de longitud focal.

20 La figura 21 es una vista plana que muestra la aplicación del presente sistema a moneda corriente y otros documentos de garantía tal como un hilo de seguridad "con ventanas". La figura 21 muestra una estructura de hilo con ventanas que incluye el material del sistema 508 que ha 25 sido cortado en un listón, denominado como un "hilo", que



típicamente se ubica en el rango de 0.5 mm a 10 mm de ancho. El hilo 508 se incorpora en el substrato de fibroso del documento 510 y provee zonas con ventanas 514. El hilo 508 opcionalmente puede incorporar una capa de sellado pigmentada, teñida, rellena o recubierta 516 para aumentar el contraste de imagen y/o para proveer características adicionales de seguridad y autenticación, tal como conductividad eléctrica, propiedades magnéticas, detección y autenticación de resonancia magnética nuclear, o para ocultar a la vista el material en iluminación reflejada cuando es visto desde el lado posterior del substrato (el lado opuesto al lado que presenta las imágenes sintéticas Unísonas y una capa de adhesivo 517 para fortalecer la unión entre el hilo 508 y el substrato fibroso 510. El hilo 508 se mantiene en una orientación para mantener los lentes lo más arriba posible para que los efectos de la imagen sean visibles en las zonas con ventanas 514. Tanto el substrato fibroso 510 como el hilo pueden ser sobreimpresos por elementos de impresión 518 y el substrato fibroso puede ser impreso 520 en su lado opuesto.

Las figuras 21 a,b ilustran ese hilo 508 y sus efectos de imagen 522 solo son visibles desde la superficie superior 521 del substrato 510 en las zonas con ventanas 514. El hilo 508 está cubierto por material de substrato

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fibroso en las zonas interiores 512 y los efectos de imagen 522 no son sustancialmente visibles en estas zonas. Los efectos OPM son particularmente dramáticos cuando se incorporan en el hilo 508. (Ver figura 22). Conforme el

5 substrato fibroso 510 es inclinado en varias direcciones, la imagen OPM se puede elaborar para explorar a través de la anchura 524 del hilo, produciendo un efecto visual asombroso y dramático. Esta característica de exploración de una imagen OPM hace posible presentar la imagen 522, la

10 cual es más grande que el ancho del hilo 508. El usuario que examina el documento que contiene un hilo con ventana 508 puede entonces inclinar el documento para explorar toda la imagen a través del hilo, corriéndolo como un signo de marquesina. Los efectos de las modalidades de Profundidad,

15 Flotador y Levitado también se pueden utilizar para favorecer un formato de hilo con ventana.

El hilo 508 se puede incorporar por lo menos parcialmente en documentos de garantía durante su fabricación a través de técnicas comúnmente empleadas en la

20 industria de la elaboración de papel. Por ejemplo, el hilo 508 puede ser presionado dentro de documentos mojados mientras las fibras todavía son maleables y no están consolidadas, como se contempla en la Patente EUA 4,534,398 la cual se incorpora en la presente invención por

25 referencia.

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El hilo con ventana del presente sistema es particularmente conveniente para aplicación a moneda corriente. Un grosor total típico para el material de hilo se ubica en el rango de 22 μ a 34 μ , mientras que el grosor total del papel moneda se puede ubicar en rangos tan elevados como 88 μ . Es posible incorporar un hilo de seguridad con ventana del presente sistema en papel moneda sin alterar sustancialmente el grosor total del papel reduciendo localmente el grosor del papel por una cantidad equivalente al grosor del hilo.

En una modalidad ejemplar, el hilo 508 comprende:

- a) uno o más separadores ópticos
- b) una o más disposiciones planas opcionalmente periódicas de micro-imágenes o iconos colocados dentro, en o junto a un separador óptico; y
- c) una o más disposiciones planas opcionalmente periódicas de micro-lentes no cilíndricos colocados en o junto a un separador óptico o una disposición de icono plano, en donde cada micro-lente tiene un diámetro base de menos de 50 micras.

En otra modalidad, las micro-imágenes o iconos constituyen cavidades o huecos rellenos que se forman en una superficie del separador o separadores ópticos, mientras que los micro-lentes no cilíndricos son micro-lentes esféricos, en donde cada micro-lente esférico tiene

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un diámetro base que oscila de alrededor de 15 a aproximadamente 35 micras. Por lo menos una capa de oscurecimiento o sellado pigmentada 516 se puede colocar en la disposición o disposiciones planas de micro-imágenes o iconos para aumentar el contraste y así la agudeza visual de los iconos y también para enmascarar la presencia del hilo 508 cuando el hilo está por lo menos parcialmente incorporado en un documento de garantía.

En otra modalidad todavía de la presente invención, el hilo 508 comprende:

- a) un separador óptico que tiene superficies planas opuestas superior e inferior;
- b) una disposición periódica de micro-imágenes o iconos que comprende cavidades rellenas formadas en la superficie plana inferior del separador óptico;
- c) una disposición periódica de micro-lentes multi-zonas de base poligonal o esférica de campo plano no cilíndricos colocados en la superficie plana superior del separador óptico, en donde cada micro-lente tiene un diámetro base que se ubica desde alrededor de 10 a aproximadamente 30 micras; y
- d) una capa de oscurecimiento o sellado pigmentada 516 colocada en la disposición de iconos.

El separador o separadores ópticos se pueden formar utilizando uno o más de los polímeros esencialmente

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sin color que incluyen, pero no se limitan a, poliéster, polipropileno, polietileno, tereftalato de polietileno, cloruro de polivinilideno, y similares. En una modalidad ejemplar, el separador o separadores ópticos se forman
5 utilizando poliéster o tereftalato de polietileno y tiene un grosor que se ubica en el rango de alrededor de 8 a aproximadamente 25 micras.

Las disposiciones de micro-lentes e iconos se pueden formar utilizando material curable por radiación
10 claro o sustancialmente transparente que incluye, pero no se limita a acrílicos, poliésteres, epoxias, uretanos y similares. De preferencia, las disposiciones se forman utilizando uretano acrilado el cual está disponible de Lord Chemicals bajo la designación de producto U107.

15 Las cavidades de los iconos formadas en la superficie plana inferior del separador óptico miden, cada una, de alrededor de 0.5 a aproximadamente 8 micras de profundidad y típicamente 30 micras de ancho en micro-
imágenes o iconos. Las cavidades se pueden rellenar con
20 cualquier material conveniente tal como resinas pigmentadas, tintas, tintes, metales, o materiales magnéticos. En una modalidad ejemplar, las cavidades se rellenan con una resina pigmentada que comprende un pigmento de sub-micra el cual está disponible de Sun
25 Chemical Corporation bajo la designación de producto

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Spectra Pac.

La capa de oscurecimiento o sellado pigmentada 516 se puede formar utilizando uno o más de una variedad de tintas o recubrimientos de opacidad que incluyen, pero no se limitan a recubrimientos pigmentados que comprenden un pigmento, tal como dióxido de titanio, dispersado dentro de un aglutinador o portador de material polimérico curable. De preferencia, la capa de oscurecimiento o sellado 516 se forma utilizando polímeros curables por radiación y tiene un grosor que se ubica en el rango de alrededor de 0.5 a aproximadamente 3 micras.

El hilo 508, el cual se describió anteriormente, se puede preparar de acuerdo con el siguiente método:

a) aplicar una resina curable por radiación clara o sustancialmente transparente a las superficies superior e inferior del separador óptico;

b) formar una disposición de micro-lentes en la superficie superior y una disposición de iconos en la forma de cavidades en la superficie inferior del separador óptico;

c) curar la resina clara o sustancialmente transparente utilizando una fuente de radiación;

d) rellenar las cavidades de la disposición de iconos con una tinta o resina pigmentada;

e) retirar el exceso de resina o tinta de la

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superficie inferior del separador óptico; y

f) aplicar una capa o recubrimiento de oscurecimiento o sellado pigmentado a la superficie inferior del separador óptico.

5 En muchos casos, es deseable que los hilos de seguridad empleados en moneda corriente y en otros documentos de identificación y financieros de gran valor sean detectados y autenticados por sensores de no-contacto de alta velocidad, tal como sensores de capacitancia,
10 sensores de campo magnético, sensores de opacidad y transmisión óptica, fluorescencia, y/o resonancia magnética nuclear.

La incorporación de materiales fluorescentes en el lente, sustrato, matriz de iconos o elementos de
15 relleno de iconos de una película Unisona puede permitir la autenticación forense o encubierta del material Unisono mediante la observación de la presencia y características espectrales de la fluorescencia. Se puede diseñar una película Unisona fluorescente para que tenga sus
20 propiedades fluorescentes visibles desde ambos lados del material o desde un solo lado del material. Sin una capa de aislamiento óptico en el material que está debajo de la capa de iconos, la fluorescencia de cualquier parte de un material Unisono será visible desde cualquiera de sus
25 lados. La incorporación de una capa de aislamiento óptico

hace posible separar la visibilidad de la fluorescencia desde sus dos lados. Por lo tanto, un material Unísono que incorpora una capa de aislamiento óptico debajo del plano de iconos se puede diseñar para que exhiba fluorescencia en un número de diferentes formas: color fluorescente A visible desde el lado del lente, falta de fluorescencia visible desde el lado de la capa de aislamiento óptico, color fluorescente A o B visible desde el lado de la capa de aislamiento óptico pero no desde el lado del lente, y color fluorescente A visible desde el lado del lente y color fluorescente A o B visible desde el lado de la capa de aislamiento óptico. La singularidad provista por la variedad de posibles rúbricas fluorescentes se puede emplear para mejorar adicionalmente la seguridad del material Unísono. La capa de aislamiento óptico puede ser una capa de material teñido o pigmentado, una capa de metal, o una combinación de capas pigmentadas y capas de metal, que absorbe o refleja la emisión fluorescente desde un lado del material y evita que sea vista desde el otro lado.

Los iconos formados a partir de huecos configurados y su inverso, iconos formados a partir de postes configurados, particularmente permiten la adición de funciones de autenticación legibles por máquina para un hilo de seguridad de material Unísono para moneda corriente

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y otros documentos de gran valor. La matriz de iconos, el
relleno de iconos, y cualquier número de recubrimientos de
refuerzo (recubrimientos de sellado) pueden, por separado
y/o en todas combinaciones, incorporar pigmentos no
5 fluorescentes, tintes no fluorescentes, pigmentos
fluorescentes, tintes fluorescentes, partículas de metal,
partículas magnéticas, materiales de rúbrica de resonancia
magnética nuclear, partículas de acción láser, materiales
LED orgánicos, materiales ópticamente variables, metal
10 evaporado, materiales de interfaz de película delgada,
polímeros de cristal líquido, materiales ópticos de sobre-
conversión y sub-conversión, materiales dicroicos,
materiales ópticamente activos (que poseen potencia
giratoria óptica), materiales ópticamente polarizados, y
15 otros materiales aliados.

En algunas circunstancias, tal como en el caso
donde un recubrimiento oscuro o a color (tal como un
material magnético o capa conductora) se ha agregado a un
material Unísono o cuando el color del plano de iconos es
20 objetable cuando se observa a través del lado posterior de
un substrato, puede ser deseable enmascarar u ocultar la
apariciencia de un hilo de seguridad de material Unísono
integrado, parcialmente integrado, o con ventanas contra un
lado de un substrato de papel tal como se observa en la luz
25 reflejada, mientras que el hilo es visible desde el lado

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opuesto del substrato. Otros tipos de hilos de seguridad de moneda corriente comúnmente incorporan una capa de metal, típicamente aluminio, para reflejar la luz que se filtra a través del substrato de superficie, proveyendo así
5 brillantez similar al substrato circundante. De manera similar, se puede utilizar aluminio u otro metal de reflexión neutra de color para enmascarar la apariencia de un hilo Unisono contra el lado posterior de un substrato de papel mediante la aplicación de la capa de metal en la
10 superficie posterior del material Unisono y después opcionalmente sellándola en su lugar. Se puede utilizar una capa pigmentada para el mismo propósito, el de ocultar u oscurecer la visibilidad del hilo de seguridad contra el lado "posterior" del documento, en lugar de una capa
15 metalizada, o junto con la misma. La capa pigmentada puede ser de cualquier color, incluyendo blanco, pero el color más efectivo es uno que coincida con el color y la intensidad de la luz internamente espaciada dentro y fuera del substrato fibroso.

20 La adición de una capa metalizada a un material Unisono se puede lograr en un número de formas, incluyendo la metalización directa de la capa de iconos o de sellado del material Unisono mediante evaporación, pulverización catódica, deposición química, u otro medio conveniente, o
25 laminación de la capa de iconos o de sellado del material

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Unísono a la superficie metalizada de una segunda película de polímero. Una práctica común es crear hilos de seguridad de moneda corriente metalizando una película, desmetalizando por patrón esta película para dejar
5 "listones" angostos de área metalizada, laminando la superficie metalizada a una segunda película de polímero, después cortando el material laminado para que los listones de metal queden aislados de los bordes de los hilos cortados por medio del adhesivo de laminación, protegiendo
10 así el metal contra el ataque químico en los bordes del hilo. Este método también se puede aplicar en el caso de la presente invención: el material Unísono simplemente puede reemplazar la segunda película de laminación. Por lo tanto, un material Unísono puede ser aumentado por la adición de
15 capas metalizadas configuradas o no configuradas.

Se pueden diseñar imágenes sintéticas como patrones binarios, que tienen un color (o ausencia de color) que define los iconos y un color diferente (o ausencia de color) que define el fondo; en este caso, cada
20 zona de iconos incluye una imagen completa en un solo tono que utiliza "píxeles" de imagen que están completos o incompletos. Se pueden producir imágenes sintéticas más sofisticadas mediante el aprovisionamiento de variaciones de tonos del color de icono seleccionado. La variación de
25 tonos de la imagen sintética se puede crear controlando la

densidad del color en cada imagen de icono o "fotografando a media tinta" de manera efectiva la imagen sintética a través de la inclusión o exclusión de elementos de diseño en grupos seleccionados de iconos.

5 El primer método, controlar la densidad del color en cada imagen de icono, se puede lograr controlando la densidad óptica del material mediante la creación de la imagen de icono micro-impresa. Un método conveniente para hacer esto utiliza la modalidad de iconos con huecos
10 rellenados, ya descrita anteriormente.

 El segundo método, "fotografando a media tinta" de la imagen sintética a través de la inclusión o exclusión de elementos de diseño en grupos seleccionados de iconos, que se ilustran en la figura 23, se logra incluyendo
15 elementos de diseño de imagen en una proporción de zonas de iconos que es igual a la densidad de color deseada. La figura 23 ilustra esto con un ejemplo que utiliza un patrón de repetición hexagonal para la zona de iconos 570 que sería coordinada con un patrón de lentes de repetición
20 hexagonal similar. Cada una de las zonas de iconos 570 no contiene información idéntica. Todos los elementos de imagen de icono 572, 574, 576 y 578 están presentes sustancialmente a la misma densidad de color. Los elementos de imagen de icono 572 y 574 están presentes en algunas de
25 las zonas de iconos y diferentes elementos de imagen de

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icono están presentes en otras zonas de iconos. Algunas zonas de iconos contienen el único elemento de imagen de icono 570. Específicamente, el elemento de imagen de icono 572 está presente en la mitad de las zonas de iconos, el elemento de imagen de icono 574 está presente en tres cuartas partes de las zonas de iconos, el elemento de imagen de icono 578 está presente en la mitad de las zonas de iconos, y el elemento de imagen de icono 576 está presente en una tercera parte de la zona de iconos. La información presente en cada zona de iconos determina si su lente asociado mostrará el color del patrón de imagen de icono o el color del fondo de imagen de icono desde una orientación de visualización particular. Cualquiera de los elementos de imagen 572 ó 578 será visible en todos los lentes asociados con este patrón de iconos, pero el espacio de la imagen sintética 580 del elemento de imagen de icono 572 traslapa el espacio de la imagen sintética del elemento de imagen de icono 578. Esto significa que la zona de traslape 582 de la imagen sintética de iconos 572 y 578 aparecerá a una densidad de color del 100%, debido a que cada lente proyectará el color de imagen de icono en esta zona. La parte que no se traslapa de estas dos imágenes sintéticas, 588, solo es visible en el 50% de los lentes, por lo que aparece a una densidad de color del 50%. La imagen sintética 586 del elemento de icono 576 es visible

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únicamente en un tercio de los lentes, por lo que aparece a una densidad del 33.3...%. La imagen sintética 584 del elemento de icono 576 aparece de manera correspondiente a una densidad del 75%. Queda claro, dentro del alcance de esta enseñanza que se puede obtener un rango tremendo de variaciones en tonos en la imagen sintética a través de la omisión selectiva de elementos de imagen de icono en los porcentajes seleccionados de zonas de iconos. Para una mayor efectividad, las distribuciones de los elementos de imagen de icono a través de las zonas de imagen de icono deberían ser relativamente uniformes.

Un método de diseño de imágenes de iconos relacionado, que se ilustra en la figura 24a, se puede utilizar para crear elementos de imágenes sintéticas combinados que son más pequeños en dimensión que la característica más pequeña de los elementos de imágenes sintéticas individuales. Esto es posible en la circunstancia común en donde el tamaño de característica más pequeño de una imagen de iconos es más grande que la precisión de colocación de la característica. Por lo tanto, una imagen de iconos puede tener características mínimas en el orden de dos micras en dimensión, pero esas características se pueden colocar con precisión en cualquier punto en una rejilla de 0.25 micras de separación. En este caso, la característica más pequeña de

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la imagen de iconos es ocho veces más grande que la
precisión de colocación de esa característica. Al igual que
con el diagrama previo, este método se ilustra utilizando
un patrón de iconos hexagonal 594, pero aplica de igual
5 forma a cualquier otra simetría de patrón utilizable. En
forma similar al método de la figura 23, este método se
basa en el uso de diferente información por lo menos en una
zona de iconos. En el ejemplo de la figura 24a, dos
patrones de icono diferentes 596 y 598, están presentes,
10 cada uno, en la mitad de las zonas de icono (para claridad
únicamente se muestra uno de cada patrón en esta figura).
Estas imágenes de icono producen una imagen sintética
compuesta 600 que incorpora la imagen sintética 602 creada
por los elementos de imagen de iconos 596, y la imagen
15 sintética 604, creada por elementos de imagen de iconos
598. Las dos imágenes sintéticas, 602 y 604, están
diseñadas para tener áreas traslapadas, 606 y 608, que
parecen tener una densidad de color del 100% mientras que
las áreas no traslapadas 605 tienen una densidad de color
20 del 50%. La dimensión mínima de las áreas traslapadas en la
imagen sintética compuesta puede ser tan pequeña como la
precisión de posicionamiento de magnificación escalada
sintética de los elementos de imagen de iconos, y por lo
tanto puede ser más pequeña que el tamaño de la
25 característica mínima de las dos imágenes sintéticas

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componentes que están diseñadas para traslape en una región pequeña. En el ejemplo de la figura 23, las regiones de traslape se utilizan para crear los caracteres para el número "10" con líneas más angostas que, de otra forma, sería posible.

Este método también se puede utilizar para crear patrones angostos de espacios entre elementos de imagen de iconos, como se muestra en la figura 24b. Las zonas de iconos hexagonales 609 podrían ser cuadradas o podrían tener cualquier otra forma conveniente para hacer una disposición de relleno de espacio, pero se prefiere la forma hexagonal. En este ejemplo, la mitad del icono configura la imagen de icono 610, y la mitad de éstos son la imagen de icono 611. Idealmente, estos dos patrones estarían distribuidos de manera relativamente uniforme entre las zonas de iconos. Todos los elementos de estos patrones se muestran como sustancialmente iguales y uniformes en cuanto a densidad de color. En aislamiento, estos dos patrones no sugieren claramente la forma de la imagen final, y esto se puede utilizar como un elemento de seguridad, la imagen no es evidente hasta que es formada por la disposición de lentes inferior. Se muestra un caso de imagen sintética 612 formada por la combinación de la imagen sintética de elementos de icono 610 con la imagen sintética de elementos de icono 611, en donde los espacios

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que permanecen entre las imágenes sintéticas separadas forman el número "10". En este caso se combinan dos imágenes sintéticas para formar la imagen sintética final, de forma que las partes coloreadas de esta imagen 613 muestran una densidad de color al 50%. Este método no queda limitado por los detalles de este ejemplo: se habrían podido utilizar tres iconos en lugar de dos, los espacios que definen el elemento deseado en las imágenes sintéticas compuestas pueden tener anchuras variables y una variedad de formas ilimitada, y este método se puede combinar ya sea con los métodos de las figuras 23, 24a,b ó 25, u otro método de diseño de imágenes de iconos que hemos mostrado.

La información oculta, encubierta se puede incorporar en las imágenes de iconos que no pueden ser vistas en las imágenes sintéticas resultantes. El hecho de tener dicha información encubierta oculta en las imágenes de iconos se puede utilizar, por ejemplo, para autenticación encubierta de un objeto. En la figura 25 se ilustran dos métodos para lograr esto. El primer método queda ilustrado por el uso de imágenes de iconos coincidentes 616 y 618. La imagen de iconos 616 muestra un patrón de límite sólido y el número "42" contenido dentro del límite. La imagen de iconos 618 muestra una forma sólida con el número "42" como un agujero gráfico en esa forma. En este ejemplo, las formas perimetrales de las

imágenes de iconos 616 y 618 son sustancialmente idénticas y sus posición relativa dentro de sus respectivas zonas de iconos, 634 y 636, también son sustancialmente idénticas. Cuando se crea una imagen sintética compuesta 620 a partir de estas imágenes de icono, el límite de la imagen sintética compuesta 622 mostrará una densidad de color del 100% debido a que todas las imágenes de iconos tienen un patrón en esa área correspondiente, por lo que existe un traslape completo en las imágenes sintéticas creadas a partir de las imágenes de iconos 616 y 618. La densidad de color del interior 624 de la imagen sintética compuesta 620 será del 50%, debido a que la imagen del espacio que rodea el "42" proviene de las imágenes de iconos 618 que solo rellenan la mitad de las zonas de iconos, y la imagen del "42" coloreado proviene de las imágenes de iconos 616 que también rellenan la mitad de las zonas de iconos. En consecuencia, no existe una diferenciación de tonos entre el "42" y su fondo, por lo que la imagen sintética compuesta observada 626 mostrará una imagen que tiene un límite de densidad de color del 100% 628 y un interior de densidad de color del 50% 630. El "42" encubiertamente presente en todas las imágenes de iconos 616 y 618 queda, por lo tanto, "neutralizado" y no será visto en la imagen sintética compuesta observada 626.

Un segundo método para incorporar información

encubierta en imágenes de iconos se ilustra por medio de triángulos 632 en la figura 25. Los triángulos 632 se pueden colocar aleatoriamente dentro de las zonas de iconos (que no se muestran en esta figura) o se pueden colocar en una disposición u otro patrón que no coincide sustancialmente con el periodo de la zona de iconos 634, 632. Las imágenes sintéticas son creadas a partir de una multiplicidad de imágenes de iconos regularmente dispuestas que son reflejadas por una disposición regular correspondiente de micro-lentes. Los patrones en el plano de iconos que no corresponden sustancialmente al periodo de la disposición de micro-lentes, no formarán imágenes sintéticas completas. Por lo tanto, el patrón de triángulos 632 no creará una imagen sintética coherente y no será visible en la imagen sintética observada 626. Este método no se limita a diseños geométricos simples, tal como triángulos 632; con este método, en el plano de iconos se puede incorporar otra información encubierta, tal como información alfa-numérica, códigos de barras, bits de datos, y patrones de gran escala.

La figura 26 ilustra un enfoque general para crear imágenes integrales completamente tridimensionales en un material Unisono (3-D Unisono). Una sola zona de iconos 640 contiene una imagen de iconos 642 que representa una vista en escala distorsionada de un objeto que se va a

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desplegar en 3-D, tal como se puede apreciar desde la posición estratégica de esa zona de iconos 640. En este caso, la imagen de iconos 642 está diseñada para formar una imagen sintética 670 de un cubo hueco 674. La imagen de iconos 642 tiene un marco en primer plano 644 que representa el lado más cercano 674 del cubo hueco 672, patrones de espacio ahusados 646 que representan las esquinas 676 del cubo hueco 672, y un marco de fondo 648 que representa el lado más alejado 678 del cubo hueco 672. Se puede apreciar que las proporciones relativas del marco en primer plano 644 y el marco de fondo 648 en la imagen de iconos 642 no corresponde a las proporciones del lado más cercano 674 y el lado más alejado 678 del cubo hueco de imágenes sintéticas 672. La razón para la diferencia en escala es que las imágenes que van a aparecer adicionalmente desde el plano del material Unísono experimentan una mayor magnificación, por lo que su tamaño en la imagen de iconos se debe reducir para proveer la escala correcta al momento de la magnificación para formar la imagen sintética 672.

En una ubicación diferente en el material 3-D Unísono se puede encontrar una zona de iconos 650 que incluye una imagen de iconos diferente 652. Al igual que con la imagen de iconos 642, la imagen de iconos 652 representa una vista en escala distorsionada de la imagen

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sintética 672, tal como se puede apreciar a partir de la posición estratégica diferente de esta zona de iconos 650. Las escalaciones relativas del marco en primer plano 654 y el marco de fondo 658 son similares a los elementos correspondientes de la imagen de iconos 642 (aunque esto no será cierto, en general), pero la posición del marco de fondo 658 ha cambiado, junto con el tamaño y la orientación de los patrones de esquina 656. La zona de iconos 660 se localiza una distancia más allá del material 3-D Unísono y presenta todavía otra imagen de iconos de escala distorsionada 662, incluyendo la imagen de iconos 662 con el marco en primer plano 664, los patrones de espacio ahusados 667, y el marco de fondo 668.

En general, la imagen de iconos en cada zona de iconos en un material 3-D Unísono será ligeramente diferente de sus vecinos cercanos y puede ser significativamente diferente de sus vecinos distantes. Se puede apreciar que la imagen de iconos 652 representa una etapa transitoria entre las imágenes de icono 642 y 662. En general, cada imagen de iconos en un material 3-D Unísono puede ser única, pero cada una representará una etapa transitoria entre las imágenes de iconos en cualquier lado de ésta.

La imagen sintética 670 se forma a partir de una multiplicidad de imágenes de icono tal como imágenes de

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icono 640, 650 y 660 tal como son sintéticamente reflejadas a través de una disposición de lentes asociados. La imagen sintética del cubo hueco 674 muestra los efectos de los diferentes factores de magnificación sintética que resultan de los periodos de repetición efectiva de los diferentes elementos de cada una de las imágenes de icono. Asumir que la imagen de cubo hueco 674 está destinada para ser vista como una imagen de Súper Profundidad. En este caso, si la zona de iconos 640 se colocó a cierta distancia del lado izquierdo inferior de la zona de iconos 650, y la zona de iconos 660 se colocó a cierta distancia del derecho superior de la zona de iconos 650, se puede apreciar que el periodo efectivo de los marcos en primer plano 644, 654 y 664 será menor que aquel de los marcos de fondo 648, 658 y 668, ocasionando así que la superficie más cercana 676 del cubo (que corresponde a los marcos en primer plano 644, 654 y 664) quede más cerca del plano del material Unísono y la superficie más alejada 678 del cubo quede a una mayor profundidad y más allá del plano del material Unísono, y que sea magnificada por un factor más grande. Los elementos de esquina 646, 656, y 667 se coordinan tanto con los elementos en primer plano como de fondo para crear el efecto de cambiar suavemente la profundidad entre ellos.

El método para diseñar las imágenes de iconos para 3-D Unísono se describe con mayor detalle en la figura

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27. Esta figura aísla el método para un proyector de una sola imagen 680. Como se describió previamente, un proyector de una sola imagen incluye un lente, un separador óptico, y una imagen de iconos; la imagen de iconos tiene sustancialmente las mismas dimensiones que el periodo de repetición del lente (permitiendo que las pequeñas diferencias en escala creen los efectos visuales Unísonos). El campo de visión para el lente y su icono asociado se muestra como el cono 682: esto también corresponde a una inversión del cono focal del lente, de forma que las proporciones del cono de campo de visión 682 quedan determinadas por el $F\#$ del lente. Aunque la figura muestra este cono con una base circular, la forma de la base en realidad será la misma que la forma de una zona de iconos, tal como un hexágono.

En este ejemplo se desea crear una imagen sintética 3-D Unísona que incorpora tres copias de la palabra "UNISONO", 686, 690 Y 694, al mismo tamaño visual en tres planos de imagen de Súper Profundidad diferentes 684, 690 y 692. El diámetro de los planos de imagen 684, 688 y 692 se expande con el cono de campo de visión: en otras palabras, conforme aumenta la profundidad de la imagen, aumenta el área cubierta por el cono de campo de visión. Por lo tanto, el campo de visión en el plano de profundidad más superficial 684 solo abarca las porciones

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de "NIS" de la palabra UNISONO, mientras que el plano profundo medio 688 abarca todos los "NIS" y porciones de "U" y "O" y el plano de mayor profundidad 692 abarca casi todo el término "UNISONO", faltando únicamente la parte de

5 "NO" final.

La información presentada (UNISONO 686, 690 y 694) por cada uno de estos planos de imagen sintética 684, 688 y 692, finalmente se debe incorporar en una sola imagen de icono en el proyector de imágenes 680. Esto se logra

10 capturando la información en el cono de campo de visión 686 en cada plano profundo 684, 688 y 692, escalando después los patrones de imágenes de iconos resultantes a las mismas dimensiones. La imagen de iconos 696 representa el campo de visión de la imagen UNISONA 686 tal como se aprecia en el

15 plano profundo 684, la imagen de iconos 704 representa el campo de visión de la imagen UNISONA 690 tal como se aprecia en el plano profundo 688, y la imagen de iconos 716 representa el campo de visión de la imagen UNISONA 694 tal como se aprecia en el plano profundo 692.

20 Dentro de la imagen de iconos 696, los elementos de imagen de icono 698 se originan a partir de una porción de la primera "N" de la imagen UNISONA 686, el elemento de imagen de icono 700 se origina a partir de una porción de la "I" de la imagen UNISONA 686, y los elementos de imagen

25 de icono 702 se originan a partir de las porciones de la

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"S" de la imagen UNISONA 686. Dentro de la imagen de iconos 704, el elemento de imagen de icono 706 se origina a partir de una porción de la "U" de la imagen UNISONA 690, el elemento de imagen de icono 708 se origina a partir de la primera "N" de la imagen UNISONA 690, el elemento de imagen de icono 710 se origina a partir de la "S" de la imagen UNISONA 690, y el elemento de imagen de icono 714 se origina a partir de una porción de la "O" de la imagen UNISONA 690. Se puede apreciar que aunque las imágenes sintéticas 686, 690, y 694 se presentan a una escala similar, la imagen de iconos 704 para el plano profundo medio 688 presenta sus letras de UNISONO a una escala más pequeña que aquellas de la imagen de iconos 696. Esto sirve para la magnificación sintética superior que la imagen de iconos 704 experimentará (cuando se combina sintéticamente con una multiplicidad de imágenes de icono circundantes para el mismo plano profundo). De manera similar, la imagen de iconos 716 incorpora elementos de imagen de iconos 718 que se originan a partir de la imagen UNISONA 694 y las letras de UNISONO que se incorporan en esta imagen de icono están a una escala más reducida.

La imagen de iconos final para este proyector de imágenes se crea combinando estas tres imágenes de iconos 696, 704 y 716 en una sola imagen de icono 730, que se muestra en la figura 28. Los elementos de icono combinados

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732 incorporan toda la información gráfica y de profundidad
necesaria para el proyector de imágenes 680 para hacer su
contribución a la imagen sintética formada a partir de una
multiplicidad de proyectores de imágenes, cada uno
5 incorpora la información específica de imágenes de iconos
que es el resultado de la intersección de su propio cono de
campo de visión, centrado en el proyector de imágenes, con
los niveles y elementos de la imagen sintética que se va a
producir. Debido a que cada proyector de imagen es
10 desplazado por lo menos un periodo de repetición de lente a
partir de cada segundo proyector de imagen, cada proyector
de imagen portará diferente información que resulte de la
intersección de su cono de campo de visión con el espacio
de imagen sintética.

15 Cada una de las imágenes de icono que se requiere
para presentar una imagen 3-D elegida, puede ser calculada
a partir del conocimiento del modelo digital tridimensional
de la imagen sintética, la posición de profundidad deseada
y la envergadura de la profundidad que se va a presentar en
20 la imagen sintética, el periodo de repetición de lente, el
campo de visión del lente, y la resolución gráfica final de
las imágenes de icono. Este último factor pone un límite
superior sobre el nivel de detalle que se puede presentar
en cada plano de profundidad. Debido a que los planos de
25 profundidad que yacen más allá del plano del material

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Unísono portan una mayor cantidad de información (debido al campo de visión incrementado), el límite de resolución gráfica de los iconos tiene el mayor impacto en la resolución de estos planos de profundidad de imágenes
5 sintéticas.

La figura 29 ilustra la forma en que el método de la figura 27 se puede aplicar a una imagen sintética tridimensional compleja, tal como una imagen del invaluable artefacto de marfil de mamut tallado de la época del hielo,
10 la Dama de Brassempouy 742. El proyector de imágenes individuales 738, que incorpora por lo menos un lente, un elemento de separación óptica, y una imagen de icono (que no se muestra en esta figura), yace en el plano 740 de un material Unísono que separa el espacio de la imagen
15 sintética flotante del espacio de la imagen sintética profunda. En este ejemplo, el espacio de la imagen sintética abarca el material Unísono de forma que una porción de la imagen yace en el espacio de la imagen sintética flotante y una porción yace en el espacio de la
20 imagen sintética profunda. El proyector de imágenes 738 tiene un campo de visión sustancialmente cónico que se extiende tanto hacia el espacio de la imagen sintética profunda 744 como al espacio de la imagen sintética flotante 746. Se selecciona un número elegido de planos de
25 imágenes profundas, 748 y 752-762, a cualquier separación

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que se requiera para obtener la resolución deseada del espacio de la imagen sintética profunda. De manera similar, se selecciona un número elegido de planos de imágenes flotantes, 750 y 764-774, a cualquier separación que se requiera para obtener la resolución deseada del espacio de la imagen sintética profunda. Algunos de estos planos, tal como los planos profundos 748 y los planos flotantes 750 se extenderán más allá de la imagen sintética y no contribuirán a la información final en la imagen de iconos. Para claridad, el número de planos de imagen que se muestra en la figura 29 se limita a un número pequeño pero el número real de planos de imagen seleccionado puede ser elevado, tal como 50 ó 100 planos, o más, para obtener la resolución deseada de profundidad de imagen sintética.

El método de las figuras 27 y 28 se aplica después para obtener la imagen de iconos en cada plano de profundidad determinando la forma de la intersección de la superficie del objeto 742 con el plano de profundidad seleccionado 756-774. Las imágenes de icono separadas resultantes son escaladas al tamaño final de la imagen de iconos combinada. Todas las imágenes de icono flotantes primero son giradas 180 grados (debido a que experimentan esa rotación nuevamente cuando son proyectadas, regresando así a su orientación correcta en la imagen sintética) después se combinan con las imágenes de icono profundas

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para formar la imagen de iconos final para este proyector de imágenes 738. Este procedimiento se repite para cada una de las posiciones de los proyectores de imágenes para obtener el patrón completo de imágenes de icono que se requieren para formar la imagen sintética completa 742.

La resolución de la imagen sintética depende de la resolución de los proyectores ópticos y de la resolución gráfica de las imágenes de icono. Se han obtenido resoluciones gráficas de imágenes de icono, menos de 0.1 micras, que exceden el límite de resolución óptica teórica de óptica de magnificación (0.2 micras). Se crea una imagen de icono típica con una resolución de 0.25 micras.

Los materiales Unísonos se pueden fabricar mediante procesamiento de red u hoja utilizando herramientas que incorporan por separado las microestructuras de icono y lente. Tanto las herramientas de lente como las herramientas de icono se originan a través del uso de fotomáscaras y métodos de fotorresistencia.

Las herramientas de lente inicialmente están diseñadas como máscaras de tipo de semiconductor, típicamente cromo negro sobre vidrio. Las máscaras que tienen suficiente resolución se pueden crear mediante fotorreducción, escritura por haz de electrones, o escritura láser. Una máscara típica para una herramienta de lente incorporará un patrón de repetición de hexágonos

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opacos en un periodo elegido, tal como 30 micras, con líneas nítidas que separen los hexágonos que tienen menos de 3 micras de ancho. Esta máscara después se utiliza para exponer la fotorresistencia sobre una placa de vidrio utilizando un sistema de exposición UV semiconductor convencional. El grosor de la resistencia es seleccionado para obtener la combadura deseada del lente. Por ejemplo, un grosor de 5 micras de fotorresistencia positiva AZ 4620 está recubierta sobre una placa de vidrio a través de medios convenientes, tal como recubrimiento centrífugo, recubrimiento por inmersión, recubrimiento por menisco, o rociado, para formar lentes que tengan una repetición nominal de 30 micras y una longitud focal nominal de 35 micras. La fotorresistencia es expuesta con el patrón de máscara, y desarrollada en vidrio en una forma convencional, después es secada y desgasificada a 100°C durante 30 minutos. Los lentes son formados por reflujo térmico de acuerdo con métodos estándar conocidos en la técnica. Los micro-lentes de fotorresistencia resultantes son recubiertos con un metal conductor, tal como oro o plata, y se forma una herramienta de níquel negativo a través de electroformación.

Las herramientas de icono son creadas de manera similar. Un patrón de iconos típicamente es diseñado con la ayuda de software CAD y este diseño es transmitido a un

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fabricante de máscaras de semiconductor. Esta máscara se utiliza de manera similar a la máscara de lente, excepto que el grosor de la resistencia que se va a exponer típicamente se ubica en el rango de 0.5 micras a 8 micras, dependiendo de la densidad óptica de la imagen sintética deseada. La fotorresistencia es expuesta con el patrón de máscara, desarrollada en vidrio en una forma convencional, recubierta con un metal conductor, y se forma una herramienta de níquel negativo a través de electroformación. De acuerdo con la elección del diseño de máscara original y en la opción de tipo de resistencia empleada (positiva o negativa), los iconos se pueden crear en la forma de huecos en el patrón de resistencia o se pueden crear en la forma de "mesas" o postes en el patrón de resistencia, o ambos.

Los materiales Unísonos se pueden fabricar a partir de una variedad de materiales y una multiplicidad de métodos que son conocidos en la técnica de la reproducción micro-óptica y de micro-estructuras, incluyendo estampado por extrusión, estampado curado por radiación, estampado suave, y moldeo por inyección, moldeo por inyección a reacción, y vaciado por reacción. Un método ejemplar de fabricación es formar los iconos como huecos en un polímero líquido curado por radiación que es vaciado contra una película base, tal como una película PET promovida por

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adhesión calibre 75, después formar los lentes a partir de polímero curado por radiación en la superficie opuesta de la película base en la alineación correcta o sesgada con respecto a los iconos, después rellenar los huecos de los
5 iconos con un material de coloración pigmentado de partícula de tamaño submicra por medio de una cuchilla raspadora tipo huecograbado contra la superficie de la película, solidificar el relleno a través de medios convenientes (por ejemplo, remoción de solvente, curado por
10 radiación o reacción química), y finalmente aplicar una capa de sellado opcional que puede ser clara, teñida, pigmentada o materiales de seguridad encubierta incorporada.

La fabricación del material de Movimiento Unísono
15 requiere que la herramienta de icono y la herramienta de lente incorporen un grado seleccionado de desalineación de los ejes de simetría de las dos disposiciones. Esta desalineación de los ejes de simetría de los patrones de icono y lente controla el tamaño de la imagen sintética y
20 la rotación de la imagen sintética en el material producido. Con frecuencia es deseable proveer las imágenes sintéticas sustancialmente alineadas ya sea con la dirección de red o con la dirección de red transversal, y en estos casos, la desalineación angular total de los
25 iconos y los lentes se divide por igual entre el patrón de

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lente y el patrón de icono. El grado de desalineación angular requerido generalmente es bastante pequeño. Por ejemplo, una desalineación angular total en el orden de 0.3 grados es conveniente para magnificar imágenes de icono de 30 micras a un tamaño de 5.7 mm en un material de Movimiento Unísono. En este ejemplo, la desalineación angular total se divide por igual entre las dos herramientas, de forma que cada herramienta es sesgada a través de un ángulo de 0.15 grados en la misma dirección para ambas herramientas. El sesgo es en la misma dirección debido a que las herramientas forman microestructuras en superficies opuestas de una película base, de forma que los sesgos de las herramientas se agregan entre sí, en lugar de cancelarse entre sí.

El sesgo se puede incorporar en las herramientas al momento del diseño original de las máscaras girando todo el patrón a través del ángulo deseado antes de escribir sobre éste. El sesgo también se puede incorporar mecánicamente en una herramienta de níquel plana cortándola al ángulo apropiado con un molino numéricamente controlado. La herramienta sesgada después es configurada en una herramienta cilíndrica utilizando el borde de sesgo cortado para alinear la herramienta al eje de rotación de un cilindro de impresión.

El sistema micro-óptico de magnificación

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sintética, en la presente invención, se puede combinar con características adicionales que incluyen, pero no se limitan a, estas modalidades como elementos sencillos o en varias combinaciones, tal como materiales de relleno de iconos, recubrimientos de refuerzo, recubrimientos superiores, tanto configurados como no configurados, relleno o inclusiones en el lente, separador óptico o materiales de icono, como un laminado o recubrimiento, tintas y/o adhesivos incluyendo la forma acuosa, curable por radiación o solvente, ópticamente transparente, traslúcido u opaco, pigmentado o teñido. Indicios en la forma de material positivo o negativo, recubrimientos o impresión incluyendo, pero no limitado a tintas, metales, materiales fluorescentes o magnéticos, materiales de absorción o emisión de rayos-X, infrarrojos, o ultravioleta, metales tanto magnéticos como no magnéticos incluyendo aluminio, níquel, cromo, plata, y oro; los recubrimientos y partículas magnéticas para detección o almacenamiento de información; tinte fluorescente y pigmentos como recubrimientos y partículas; recubrimientos fluorescentes IR, relleno, tintes o partículas; recubrimientos fluorescentes UV, relleno, tintes o partículas; tinte fosforescente y pigmentos como recubrimientos y partículas, tablas de madera, ADN, ARN u otros distintivos macro-moleculares, fibras dicróicas,

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radioisótopos, recubrimientos receptivos de impresión, barniz de aparejo, o pintura de imprimación, materiales químicamente reactivos, ingredientes micro-encapsulados, materiales afectados por campo, partículas conductoras y
5 recubrimientos tanto metálicos como no metálicos, agujeros micro-perforados, hilos o fibras coloreadas, parches de Unísono integrados en la superficie de un documento, etiqueta o superficie de materiales, pegadas a papel o polímero como un portador para adhesión al papel durante la
10 fabricación, hilos o partículas dicróicas fluorescentes, partículas o recubrimientos de dispersión Raman, recubrimientos o partículas de cambio de color, Unísono laminado a papel, planchas de papel, cartón, plástico, cerámica, tela o sustrato de metal, Unísono como un hilo,
15 parche, etiqueta, envoltura, papel aluminio de estampado en caliente, una cinta de desgarre, elementos holográficos, difractivos, Kinegram difractivos, isogramas, fotográficos u ópticos refractivos, materiales de cristal líquido, materiales de conversión ascendente y conversión
20 descendente.

El sistema micro-óptico de magnificación sintética en la presente invención tiene muchos campos de uso y aplicaciones. Entre los ejemplos se incluyen:

Aplicaciones gubernamentales y de defensa: ya sea
25 federal, estatal o extranjera (tal como pasaportes,

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credenciales de identificación, licencias para conducir, visas, certificados de nacimiento, registros vitales, tarjetas de registro de votantes, boletas de votación, tarjetas de seguro social, bonos, vales, timbres postales y
5 timbres fiscales);

Moneda corriente: ya sea federal, estatal o extranjera (tal como hilos de seguridad en papel moneda, características en moneda de polímero y características en papel moneda);

10 Documentos (tal como títulos, escrituras, licencias, diplomas y certificados);

Documentos financieros y negociables (tal como cheques bancarios certificados, cheques corporativos, cheques personales, comprobantes bancarios, certificados de
15 acciones, cheques de viajero, giros postales, tarjetas de crédito, tarjetas de débito, tarjetas para ATM, tarjetas de afinidad, tarjetas telefónicas de prepago, y tarjetas de regalo);

Información confidencial (tal como guiones de
20 películas, documentos legales, propiedad intelectual, registros médicos/registros hospitalarios, recetas/bloc de recetas, y "Recetas Secretas");

Protección de productos y marcas, incluyendo aquellos de tela y para el cuidado del hogar (tal como
25 detergentes para lavar, suavizantes de tela, detergentes

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para trastes, limpiadores del hogar, recubrimientos de superficies, refrescantes de telas, blanqueador y cuidado para telas especiales);

5 Cuidado de la belleza (tal como productos para el cuidado del cabello, tintes para el cabello, productos del cuidado y limpieza de la piel, cosméticos, fragancias, antitranspirantes y desodorantes, toallas femeninas, tampones y medias);

10 Cuidado de los bebés y la familia (tal como pañales, toallitas húmedas para bebés, baberos para bebés, colchonetas para cama y para cambiar al bebé, toallas de papel, papel de baño, y toallas faciales);

15 Cuidado de la salud (tal como el cuidado oral, salud y nutrición de mascotas, productos farmacéuticos de prescripción, productos farmacéuticos en mostrador, administración de medicamentos y cuidado de la salud personal, vitaminas de prescripción y suplementos nutricionales y deportivos; productos para los ojos con prescripción y sin prescripción; equipo y dispositivos
20 médicos vendidos a hospitales, médicos, y distribuidores médicos al por mayor (es decir, vendajes, equipo, dispositivos de implante, suministros quirúrgicos);

Empaque de alimentos y bebidas;

Empaque de productos secos;

25 Equipo, partes y componentes electrónicos;

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Ropa y calzado, incluyendo ropa deportiva, calzado de categoría autorizado y no autorizado, artículos deportivos y ropa de lujo; tela;

- 5 Productos farmacéuticos biotécnicos;
- Componentes y partes aeroespaciales;
- Componentes y partes automotrices;
- Productos deportivos;
- Productos tabacaleros;
- Software;
- 10 Discos compactos y DVD;
- Explosivos;
- Artículos de novedad (tal como envolturas y listones)
- Libros y revistas;
- 15 Productos escolares y suministros de oficina;
- Tarjetas comerciales;
- Documentación de envío y empaque;
- Portadas de cuadernos;
- Portadas de libros;
- 20 Marcas de libros;
- Boletos de transporte y eventos;
- Aplicaciones de apuestas y juegos (tal como boletos de lotería, tarjetas de juego, fichas y artículos de casino para uso en casinos, sorteos y apuestas);
- 25 Mobiliario para el hogar (tal como toallas, ropa

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blanca y muebles);

Revestimiento para pisos y tapicería de pared;

Joyería y relojes;

Bolsas de mano;

5 Arte, artículos de colección y objetos de interés antiguos;

Juguetes;

Escaparates (tal como escaparates de mercancía y punto de venta);

10 Marcación y etiquetado de productos (tal como etiquetas, etiquetas colgantes, hilos, tiras de desgarre, envolturas, imagen de seguridad o a prueba de alteración aplicada a un producto de marca o documento para autenticación o mejora, como camuflaje, y como rastreo de
15 activos).

Los materiales convenientes para las modalidades anteriormente descritas incluyen un amplio rango de polímeros. Acrílicos, poliésteres acrilados, uretanos acrilados, polipropilenos, epoxias, uretanos y poliésteres
20 que tienen propiedades ópticas y mecánicas convenientes tanto para microlentes como para elementos de iconos microestructurados. Materiales convenientes para la película de substrato opcional incluyen la mayoría de las películas de polímero comercialmente disponibles, incluyendo acrílico,
25 celofán, Saran®, nylon, policarbonato, poliéster,

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polipropileno, polietileno, y polivinilo. Materiales de relleno de icono micro-estructurado pueden incluir cualquiera de los materiales mencionados anteriormente como convenientes para elaborar elementos de icono micro-estructurados, así como tintas basadas en solvente y otros vehículos de tinte o pigmento comúnmente disponibles. Los tintes o pigmentos incorporados en estos materiales deberían ser compatibles con la composición química del vehículo. Los pigmentos deben tener un tamaño de partícula que sea sustancialmente más pequeño que las dimensiones más pequeñas de cualquier componente de un elemento de icono. Materiales de capa de sellado opcionales pueden incluir cualquiera de los materiales mencionados anteriormente como convenientes para elaborar elementos de icono micro-estructurados, además de muchas pinturas, tintas, recubrimientos, barnices, lacas y recubrimientos transparentes comercialmente disponibles diferentes empleados en las industrias de conversión de películas, papel e impresión. No existe una combinación preferida de materiales, la elección de materiales depende de los detalles de la geometría del material, de las propiedades ópticas del sistema, y del efecto óptico que se desee.

Aunque se han mostrado y descrito modalidades ejemplares, quedará claro para aquellos expertos en la técnica que se pueden realizar numerosos cambios,

modificaciones o alteraciones a la invención. Todos esos cambios, modificaciones y alteraciones deberán estar dentro del alcance de la presente invención.

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219**NOVEDAD DE LA INVENCIÓN**

Habiendo descrito el presente invento, se considera como una novedad y, por lo tanto, se reclama como
5 prioridad lo contenido en las siguientes:

REIVINDICACIONES

1.- Un sistema micro-óptico de magnificación
10 sintética que comprende:

a) uno o más separadores ópticos;

b) una micro-imagen compuesta de una disposición plana periódica de una pluralidad de iconos de imagen que tienen un eje de simetría por lo menos alrededor de uno de
15 sus ejes planos, y colocada en o junto al separador óptico;
y

c) una disposición plana periódica de elementos de enfoque de iconos de imagen que tienen un eje de simetría por lo menos alrededor de sus ejes planos, el eje
20 de simetría es el mismo eje plano que el de la disposición plana de micro-imagen, cada elemento de enfoque tiene un diámetro efectivo de menos de 50 micras y se asocia con un icono de imagen y provee un campo de visión agrandado sobre el ancho del icono de imagen asociado de forma que los
25 bordes periféricos del icono de imagen asociado no se salen

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de visión.

2.- El sistema micro-óptico de magnificación
sintética de conformidad con la reivindicación 1,
caracterizado porque los elementos de enfoque son
5 seleccionados del grupo que consiste de lentes no
cilíndricos y reflectores de enfoque no cilíndricos.

3.- El sistema micro-óptico de magnificación
sintética de conformidad con la reivindicación 2,
caracterizado porque los elementos de enfoque son elementos
10 de enfoque esféricos.

4.- El sistema micro-óptico de magnificación
sintética de conformidad con la reivindicación 3,
caracterizado porque los elementos de enfoque tienen
geometrías base en el plano de su disposición plana
15 seleccionadas del grupo que consiste de una base circular,
una base hexagonal, una base hexagonal redondeada, una base
cuadrada, una base triangular, una base triangular
redondeada, y mezclas de las mismas.

5.- El sistema micro-óptico de magnificación
20 sintética de conformidad con la reivindicación 2,
caracterizado porque los elementos de enfoque tienen un F
número equivalente a 4 o menos.

6.- El sistema micro-óptico de magnificación
sintética de conformidad con la reivindicación 3,
25 caracterizado porque los elementos de enfoque tienen un F

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número equivalente a 4 o menos.

7.- El sistema micro-óptico de magnificación sintética de conformidad con la reivindicación 1, caracterizado porque la relación de escala del periodo de repetición de los iconos de imagen al periodo de repetición de los elementos de enfoque es sustancialmente igual a 1 y los ejes de simetría de la disposición plana periódica de la micro-imagen y la disposición plana periódica de los elementos de enfoque de icono de imagen están desalineados.

10 8.- El sistema micro-óptico de magnificación sintética de conformidad con la reivindicación 7, caracterizado porque se proveen efectos de movimiento ortoparaláctico.

15 9.- El sistema micro-óptico de magnificación sintética de conformidad con la reivindicación 1, caracterizado porque la relación de escala del periodo de repetición de los iconos de imagen al periodo de repetición de los elementos de enfoque es mayor que 1 y los ejes de simetría de la disposición plana periódica de la micro-
20 imagen y la disposición plana periódica de los elementos de enfoque de icono de imagen están alineados.

10.- El sistema micro-óptico de magnificación sintética de conformidad con la reivindicación 1, caracterizado porque la relación de escala del periodo de repetición de los iconos de imagen al periodo de repetición

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de los elementos de enfoque es menor que 1 y los ejes de simetría de la disposición plana periódica de la micro-imagen y la disposición plana periódica de los elementos de enfoque de icono de imagen están alineados.

5 11.- El sistema micro-óptico de magnificación sintética de conformidad con la reivindicación 1, caracterizado porque la relación de escala del periodo de repetición de los iconos de imagen al periodo de repetición de los elementos de enfoque es axialmente asimétrica en los
10 planos de los iconos de imagen y los elementos de enfoque, la relación de escala es menor que 1 en un eje de simetría y es mayor que 1 en el otro eje de simetría, y los ejes de simetría de la disposición plana periódica de la micro-imagen y la disposición plana periódica de los elementos de
15 enfoque de icono de imagen están alineados.

 12.- El sistema micro-óptico de magnificación sintética de conformidad con la reivindicación 1, caracterizado porque cada elemento de enfoque tiene un diámetro efectivo de alrededor de 15 a aproximadamente 30
20 micras.

 13.- El sistema micro-óptico de magnificación sintética de conformidad con la reivindicación 1, caracterizado porque cada elemento de enfoque tiene un diámetro efectivo menor de 30 micras.

25 14.- El sistema micro-óptico de magnificación

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sintética de conformidad con la reivindicación 1, caracterizado porque tiene un grosor total menor de alrededor de 45 micras.

15.- El sistema micro-óptico de magnificación
5 sintética de conformidad con la reivindicación 1, caracterizado porque tiene un grosor total de alrededor de 10 a aproximadamente 40 micras.

16.- El sistema micro-óptico de magnificación
sintética de conformidad con la reivindicación 1,
10 caracterizado porque cada elemento de enfoque tiene una longitud focal menor de alrededor de 40 micras.

17.- El sistema micro-óptico de magnificación
sintética de conformidad con la reivindicación 1,
caracterizado porque cada elemento de enfoque tiene una
15 longitud focal de alrededor de 10 a menos de aproximadamente 30 micras.

18.- El sistema micro-óptico de magnificación
sintética de conformidad con la reivindicación 1,
caracterizado porque el efecto de morfismo es provisto para
20 ocasionar que una imagen sintéticamente magnificada se convierta en otra imagen sintéticamente magnificada.

19.- El sistema micro-óptico de magnificación
sintética de conformidad con la reivindicación 1,
caracterizado porque cada icono de imagen es formado a
25 partir de un método de impresión seleccionado del grupo que

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consiste de métodos de impresión por chorro de tinta, láser, impresión tipográfica, flexo, fotograbado e intaglio.

20.- El sistema micro-óptico de magnificación
5 sintética de conformidad con la reivindicación 1, caracterizado porque los iconos de imagen se forman como cavidades en un sustrato, los huecos en las cavidades se rellenan con un material de metal evaporado, un material teñido, un material pigmentado y combinaciones de los
10 mismos.

21.- El sistema micro-óptico de magnificación
sintética de conformidad con la reivindicación 1, caracterizado porque tiene dos capas de iconos de imagen a diferentes profundidades en el sistema y una combinación de
15 elementos de enfoque, algunos de los cuales tienen una longitud focal para enfocar una de las dos capas de iconos de imagen y algunos de los cuales tienen una longitud focal para enfocar la otra de las dos capas de iconos de imagen.

22.- El sistema micro-óptico de magnificación
20 sintética de conformidad con la reivindicación 1, caracterizado porque los elementos de enfoque son lentes no cilíndricos y una capa reflectora está colocada en el lado de la micro-imagen en oposición a los elementos de enfoque.

23.- El sistema micro-óptico de magnificación
25 sintética de conformidad con la reivindicación 1, que

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además comprende un material de indicación de alteración transparente el cual está colocado sobre los elementos de enfoque.

24.- El sistema micro-óptico de magnificación
5 sintética de conformidad con la reivindicación 1, que además comprende una segunda disposición plana periódica de elementos de enfoque colocados en el lado de la micro-imagen en oposición a los elementos de enfoque.

25.- El sistema micro-óptico de magnificación
10 sintética de conformidad con la reivindicación 24, que además comprende una segunda disposición plana de iconos de imagen en medio de las dos disposiciones planas de los elementos de enfoque.

26.- Un dispositivo de seguridad de documentos
15 que comprende:

a) uno o más separadores ópticos;
b) una micro-imagen compuesta de una disposición
plana periódica de una pluralidad de iconos de imagen que
tienen un eje de simetría por lo menos alrededor de uno de
20 sus ejes planos, y colocada en o junto al separador óptico;
y

c) una disposición plana periódica de elementos
de enfoque de iconos de imagen que tienen un eje de
simetría por lo menos alrededor de sus ejes planos, el eje
25 de simetría es el mismo eje plano que el de la disposición

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plana de micro-imagen, cada elemento de enfoque tiene un diámetro efectivo de menos de 50 micras y se asocia con un icono de imagen y provee un campo de visión agrandado sobre el ancho del icono de imagen asociado de forma que los
5 bordes periféricos del icono de imagen asociado no se salen de visión.

27.- El dispositivo de seguridad de documentos de conformidad con la reivindicación 26, caracterizado porque el dispositivo opera como una película de laminación sobre
10 un documento.

28.- El dispositivo de seguridad de documentos de conformidad con la reivindicación 26, caracterizado porque el documento es seleccionado del grupo que consiste de tarjetas de identificación, tarjetas de crédito, licencias
15 para conducir, documentos financieros, pagarés, cheques bancarios y moneda corriente.

29.- El dispositivo de seguridad de documentos de conformidad con la reivindicación 26, caracterizado porque el dispositivo es en la forma de un hilo de seguridad para
20 su incorporación en el papel moneda.

30.- El sistema micro-óptico de magnificación sintética de conformidad con la reivindicación 1, caracterizado porque los elementos de enfoque son seleccionados del grupo que consiste de lentes no
25 cilíndricos y reflectores de enfoque no cilíndricos.

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31.- El sistema micro-óptico de magnificación sintética de conformidad con la reivindicación 30, caracterizado porque los elementos de enfoque son elementos de enfoque esféricos.

5 32.- El sistema micro-óptico de magnificación sintética de conformidad con la reivindicación 31, caracterizado porque los elementos de enfoque tienen geometrías base en el plano de su disposición plana seleccionadas del grupo que consiste de una base circular,
10 una base hexagonal, una base hexagonal redondeada, una base cuadrada, una base triangular, una base triangular redondeada, y mezclas de las mismas.

33.- El sistema micro-óptico de magnificación sintética de conformidad con la reivindicación 30,
15 caracterizado porque los elementos de enfoque tienen un F número equivalente a 4 o menos.

34.- El sistema micro-óptico de magnificación sintética de conformidad con la reivindicación 31, caracterizado porque los elementos de enfoque tienen un F
20 número equivalente a 4 o menos.

35.- El sistema micro-óptico de magnificación sintética de conformidad con la reivindicación 26, caracterizado porque la relación de escala del periodo de repetición de los iconos de imagen al periodo de repetición
25 de los elementos de enfoque es sustancialmente igual a 1 y

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los ejes de simetría de la disposición plana periódica de la micro-imagen y la disposición plana periódica de los elementos de enfoque de icono de imagen están desalineados.

36.- El sistema micro-óptico de magnificación
5 sintética de conformidad con la reivindicación 35, caracterizado porque se proveen efectos de movimiento ortoparaláctico.

37.- El sistema micro-óptico de magnificación
sintética de conformidad con la reivindicación 26,
10 caracterizado porque la relación de escala del periodo de repetición de los iconos de imagen al periodo de repetición de los elementos de enfoque es mayor que 1 y los ejes de simetría de la disposición plana periódica de la micro-imagen y la disposición plana periódica de los elementos de
15 enfoque de icono de imagen están alineados.

38.- El sistema micro-óptico de magnificación
sintética de conformidad con la reivindicación 26,
caracterizado porque la relación de escala del periodo de repetición de los iconos de imagen al periodo de repetición
20 de los elementos de enfoque es menor que 1 y los ejes de simetría de la disposición plana periódica de la micro-imagen y la disposición plana periódica de los elementos de enfoque de icono de imagen están alineados.

39.- El sistema micro-óptico de magnificación
25 sintética de conformidad con la reivindicación 26,

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caracterizado porque la relación de escala del periodo de repetición de los iconos de imagen al periodo de repetición de los elementos de enfoque es axialmente asimétrica en los planos de los iconos de imagen y los elementos de enfoque, la relación de escala es menor que 1 en un eje de simetría y es mayor que 1 en el otro eje de simetría, y los ejes de simetría de la disposición plana periódica de la micro-imagen y la disposición plana periódica de los elementos de enfoque de icono de imagen están alineados.

10 40.- El sistema micro-óptico de magnificación sintética de conformidad con la reivindicación 26, caracterizado porque cada elemento de enfoque tiene un diámetro efectivo de alrededor de 15 a aproximadamente 30 micras.

15 41.- El sistema micro-óptico de magnificación sintética de conformidad con la reivindicación 26, caracterizado porque cada elemento de enfoque tiene un diámetro efectivo menor de 30 micras.

20 42.- El sistema micro-óptico de magnificación sintética de conformidad con la reivindicación 26, caracterizado porque tiene un grosor total menor de alrededor de 45 micras.

25 43.- El sistema micro-óptico de magnificación sintética de conformidad con la reivindicación 26, caracterizado porque tiene un grosor total de alrededor de

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10 a aproximadamente 40 micras.

44.- El sistema micro-óptico de magnificación sintética de conformidad con la reivindicación 26, caracterizado porque cada elemento de enfoque tiene una
5 longitud focal menor de alrededor de 40 micras.

45.- El sistema micro-óptico de magnificación sintética de conformidad con la reivindicación 26, caracterizado porque cada elemento de enfoque tiene una longitud focal de alrededor de 10 a menos de
10 aproximadamente 30 micras.

46.- El sistema micro-óptico de magnificación sintética de conformidad con la reivindicación 26, caracterizado porque el efecto de morfismo es provisto para ocasionar que una imagen sintéticamente magnificada se
15 convierta en otra imagen sintéticamente magnificada.

47.- El sistema micro-óptico de magnificación sintética de conformidad con la reivindicación 26, caracterizado porque cada icono de imagen es formado a partir de un método de impresión seleccionado del grupo que
20 consiste de métodos de impresión por chorro de tinta, láser, impresión tipográfica, flexo, fotograbado e intaglio.

48.- El sistema micro-óptico de magnificación sintética de conformidad con la reivindicación 26,
25 caracterizado porque los iconos de imagen se forman como

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cavidades en un substrato, los huecos en las cavidades se rellenan con un material de metal evaporado, un material teñido, un material pigmentado y combinaciones de los mismos.

5 49.- Un sistema micro-óptico de magnificación sintética que comprende:

a) uno o más separadores ópticos;

b) una micro-imagen compuesta de una disposición plana periódica de una pluralidad de iconos de imagen que
10 tienen un eje de simetría por lo menos alrededor de uno de sus ejes planos, y colocada en o junto al separador óptico;
y

c) una disposición plana periódica de elementos de enfoque de iconos de imagen que tienen un eje de
15 simetría por lo menos alrededor de sus ejes planos, el eje de simetría es el mismo eje plano que el de la disposición plana de micro-imagen, cada elemento de enfoque es un elemento de enfoque esférico que tiene un diámetro efectivo de menos de 50 micras y se asocia con un icono de imagen.

20 50.- El sistema micro-óptico de magnificación sintética de conformidad con la reivindicación 49, caracterizado porque los elementos de enfoque tienen geometrías base en el plano de su disposición plana seleccionadas del grupo que consiste de una base circular,
25 una base hexagonal, una base hexagonal redondeada, una base

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cuadrada, una base triangular, una base triangular redondeada, y mezclas de las mismas.

51.- El sistema micro-óptico de magnificación sintética de conformidad con la reivindicación 49, 5 caracterizado porque los elementos de enfoque tienen un F número equivalente a 4 o menos.

52.- El sistema micro-óptico de magnificación sintética de conformidad con la reivindicación 50, 10 caracterizado porque los elementos de enfoque tienen un F número equivalente a 4 o menos.

53.- El sistema micro-óptico de magnificación sintética de conformidad con la reivindicación 49, 15 caracterizado porque la relación de escala del periodo de repetición de los iconos de imagen al periodo de repetición de los elementos de enfoque es sustancialmente igual a 1 y los ejes de simetría de la disposición plana periódica de la micro-imagen y la disposición plana periódica de los elementos de enfoque de icono de imagen están desalineados.

54.- El sistema micro-óptico de magnificación 20 sintética de conformidad con la reivindicación 53, caracterizado porque se proveen efectos de movimiento ortoparaláctico.

55.- El sistema micro-óptico de magnificación sintética de conformidad con la reivindicación 49, 25 caracterizado porque la relación de escala del periodo de

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repetición de los iconos de imagen al periodo de repetición de los elementos de enfoque es mayor que 1 y los ejes de simetría de la disposición plana periódica de la micro-imagen y la disposición plana periódica de los elementos de enfoque de icono de imagen están alineados.

56.- El sistema micro-óptico de magnificación sintética de conformidad con la reivindicación 49, caracterizado porque la relación de escala del periodo de repetición de los iconos de imagen al periodo de repetición de los elementos de enfoque es menor que 1 y los ejes de simetría de la disposición plana periódica de la micro-imagen y la disposición plana periódica de los elementos de enfoque de icono de imagen están alineados.

57.- El sistema micro-óptico de magnificación sintética de conformidad con la reivindicación 49, caracterizado porque la relación de escala del periodo de repetición de los iconos de imagen al periodo de repetición de los elementos de enfoque es axialmente asimétrica en los planos de los iconos de imagen y los elementos de enfoque, la relación de escala es menor que 1 en un eje de simetría y es mayor que 1 en el otro eje de simetría, y los ejes de simetría de la disposición plana periódica de la micro-imagen y la disposición plana periódica de los elementos de enfoque de icono de imagen están alineados.

58.- El sistema micro-óptico de magnificación

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sintética de conformidad con la reivindicación 49, caracterizado porque cada elemento de enfoque tiene un diámetro efectivo de alrededor de 15 a aproximadamente 30 micras.

5 59.- El sistema micro-óptico de magnificación sintética de conformidad con la reivindicación 49, caracterizado porque cada elemento de enfoque tiene un diámetro efectivo menor de 30 micras.

10 60.- El sistema micro-óptico de magnificación sintética de conformidad con la reivindicación 49, caracterizado porque tiene un grosor total menor de alrededor de 45 micras.

15 61.- El sistema micro-óptico de magnificación sintética de conformidad con la reivindicación 49, caracterizado porque tiene un grosor total de alrededor de 10 a aproximadamente 40 micras.

20 62.- El sistema micro-óptico de magnificación sintética de conformidad con la reivindicación 49, caracterizado porque cada elemento de enfoque tiene una longitud focal menor de alrededor de 40 micras.

25 63.- El sistema micro-óptico de magnificación sintética de conformidad con la reivindicación 49, caracterizado porque cada elemento de enfoque tiene una longitud focal de alrededor de 10 a menos de aproximadamente 30 micras.

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64.- El sistema micro-óptico de magnificación sintética de conformidad con la reivindicación 49, caracterizado porque el efecto de morfismo es provisto para ocasionar que una imagen sintéticamente magnificada se
5 convierta en otra imagen sintéticamente magnificada.

65.- El sistema micro-óptico de magnificación sintética de conformidad con la reivindicación 49, caracterizado porque cada icono de imagen es formado a partir de un método de impresión seleccionado del grupo que
10 consiste de métodos de impresión por chorro de tinta, láser, impresión tipográfica, flexo, fotograbado e intaglio.

66.- El sistema micro-óptico de magnificación sintética de conformidad con la reivindicación 49,
15 caracterizado porque los iconos de imagen se forman como cavidades en un substrato, los huecos en las cavidades se rellenan con un material de metal evaporado, un material teñido, un material pigmentado y combinaciones de los mismos.

20 67.- Un dispositivo de seguridad de documentos que comprende:

- a) uno o más separadores ópticos;
- b) una micro-imagen compuesta de una disposición plana periódica de una pluralidad de iconos de imagen que
25 tienen un eje de simetría por lo menos alrededor de uno de

sus ejes planos, y colocada en o junto al separador óptico;
y

c) una disposición plana periódica de elementos de enfoque de iconos de imagen que tienen un eje de simetría por lo menos alrededor de sus ejes planos, el eje de simetría es el mismo eje plano que el de la disposición plana de micro-imagen, cada elemento de enfoque es un elemento de enfoque esférico que tiene un diámetro efectivo de menos de 50 micras y se asocia con un icono de imagen.

68.- Un método para producir un sistema micro-óptico de magnificación sintética que comprende los pasos para:

a) proveer uno o más separadores ópticos;

b) proveer una micro-imagen compuesta de una disposición plana periódica de una pluralidad de iconos de imagen que tienen un eje de simetría por lo menos alrededor de uno de sus ejes planos, y colocada en o junto al separador óptico; y

c) proveer una disposición plana periódica de elementos de enfoque de iconos de imagen que tienen un eje de simetría por lo menos alrededor de sus ejes planos, el eje de simetría es el mismo eje plano que el de la disposición plana de micro-imagen, cada elemento de enfoque tiene un diámetro efectivo de menos de 50 micras y se asocia con un icono de imagen y provee un campo de visión

agrandado sobre el ancho del icono de imagen asociado de forma que los bordes periféricos del icono de imagen asociado no se salen de visión.

69.- Un método para producir un sistema micro-
5 óptico de magnificación sintética que comprende los pasos para:

a) proveer uno o más separadores ópticos;
b) proveer una micro-imagen compuesta de una
disposición plana periódica de una pluralidad de iconos de
10 imagen que tienen un eje de simetría por lo menos alrededor
de uno de sus ejes planos, y colocada en o junto al
separador óptico; y

c) proveer una disposición plana periódica de
elementos de enfoque de iconos de imagen que tienen un eje
15 de simetría por lo menos alrededor de sus ejes planos, el
eje de simetría es el mismo eje plano que el de la
disposición plana de micro-imagen, cada elemento de enfoque
es un elemento de enfoque esférico que tiene un diámetro
efectivo de menos de 50 micras y se asocia con un icono de
20 imagen.

70.- Un método para producir un dispositivo de
seguridad de documentos que comprende los pasos para:

a) proveer uno o más separadores ópticos;
b) proveer una micro-imagen compuesta de una
25 disposición plana periódica de una pluralidad de iconos de

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imagen que tienen un eje de simetría por lo menos alrededor de uno de sus ejes planos, y colocada en o junto al separador óptico; y

c) proveer una disposición plana periódica de
5 elementos de enfoque de iconos de imagen que tienen un eje de simetría por lo menos alrededor de sus ejes planos, el eje de simetría es el mismo eje plano que el de la disposición plana de micro-imagen, cada elemento de enfoque tiene un diámetro efectivo de menos de 50 micras y se
10 asocia con un icono de imagen y provee un campo de visión agrandado sobre el ancho del icono de imagen asociado de forma que los bordes periféricos del icono de imagen asociado no se salen de visión.

71.- Un método para producir un dispositivo de
15 seguridad de documentos que comprende los pasos para:

a) proveer uno o más separadores ópticos;

b) proveer una micro-imagen compuesta de una
disposición plana periódica de una pluralidad de iconos de
imagen que tienen un eje de simetría por lo menos alrededor
20 de uno de sus ejes planos, y colocada en o junto al separador óptico; y

c) proveer una disposición plana periódica de
elementos de enfoque de iconos de imagen que tienen un eje
de simetría por lo menos alrededor de sus ejes planos, el
25 eje de simetría es el mismo eje plano que el de la

disposición plana de micro-imagen, cada elemento de enfoque es un elemento de enfoque esférico que tiene un diámetro efectivo de menos de 50 micras y se asocia con un icono de imagen.

5 72.- Un método para controlar los efectos de movimiento en un sistema micro-óptico de magnificación sintética, que comprende los pasos para:

a) proveer uno o más separadores ópticos;

10 b) proveer una micro-imagen compuesta de una disposición plana periódica de una pluralidad de iconos de imagen que tienen un eje de simetría por lo menos alrededor de uno de sus ejes planos, y colocada en o junto al separador óptico;

15 c) proveer una disposición plana periódica de elementos de enfoque de iconos de imagen que tienen un eje de simetría por lo menos alrededor de sus ejes planos, el eje de simetría es el mismo eje plano que el de la disposición plana de micro-imagen, cada elemento de enfoque tiene un diámetro efectivo de menos de 50 micras y se
20 asocia con un icono de imagen y provee un campo de visión agrandado sobre el ancho del icono de imagen asociado de forma que los bordes periféricos del icono de imagen asociado no se salen de visión; y

 d) seleccionar la relación de escala del periodo
25 de repetición de los iconos de imagen al periodo de

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repetición de los elementos de enfoque del grupo que
consiste de menos de 1, sustancialmente igual a 1, y mayor
que 1, y seleccionar si los ejes de simetría de la
disposición plana periódica de la micro-imagen y la
5 disposición plana periódica de los elementos de enfoque de
iconos de imagen están alineados o desalineados.

73.- Un método para controlar los efectos de
movimiento en un sistema micro-óptico de magnificación
sintética, que comprende los pasos para:

- 10 a) proveer uno o más separadores ópticos;
- b) proveer una micro-imagen compuesta de una
disposición plana periódica de una pluralidad de iconos de
imagen que tienen un eje de simetría por lo menos alrededor
de uno de sus ejes planos, y colocada en o junto al
15 separador óptico;
- c) proveer una disposición plana periódica de
elementos de enfoque de iconos de imagen que tienen un eje
de simetría por lo menos alrededor de sus ejes planos, el
eje de simetría es el mismo eje plano que el de la
20 disposición plana de micro-imagen, cada elemento de enfoque
es un elemento de enfoque esférico que tiene un diámetro
efectivo de menos de 50 micras y se asocia con un icono de
imagen; y
- d) seleccionar la relación de escala del periodo
25 de repetición de los iconos de imagen al periodo de

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repetición de los elementos de enfoque del grupo que consiste de menos de 1, sustancialmente igual a 1, y mayor que 1, y seleccionar si los ejes de simetría de la disposición plana periódica de la micro-imagen y la
5 disposición plana periódica de los elementos de enfoque de iconos de imagen están alineados o desalineados.

74.- Un método para controlar los efectos de movimiento en un dispositivo de seguridad de documentos, que comprende los pasos para:

- 10 a) proveer uno o más separadores ópticos;
- b) proveer una micro-imagen compuesta de una disposición plana periódica de una pluralidad de iconos de imagen que tienen un eje de simetría por lo menos alrededor de uno de sus ejes planos, y colocada en o junto al
15 separador óptico;
- c) proveer una disposición plana periódica de elementos de enfoque de iconos de imagen que tienen un eje de simetría por lo menos alrededor de sus ejes planos, el eje de simetría es el mismo eje plano que el de la
20 disposición plana de micro-imagen, cada elemento de enfoque tiene un diámetro efectivo de menos de 50 micras y se asocia con un icono de imagen y provee un campo de visión agrandado sobre el ancho del icono de imagen asociado de forma que los bordes periféricos del icono de imagen
25 asociado no se salen de visión; y

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d) seleccionar la relación de escala del periodo de repetición de los iconos de imagen al periodo de repetición de los elementos de enfoque del grupo que consiste de menos de 1, sustancialmente igual a 1, y mayor que 1, y seleccionar si los ejes de simetría de la disposición plana periódica de la micro-imagen y la disposición plana periódica de los elementos de enfoque de iconos de imagen están alineados o desalineados.

75.- Un método para controlar los efectos de movimiento en un dispositivo de seguridad de documentos, que comprende los pasos para:

a) proveer uno o más separadores ópticos;

b) proveer una micro-imagen compuesta de una disposición plana periódica de una pluralidad de iconos de imagen que tienen un eje de simetría por lo menos alrededor de uno de sus ejes planos, y colocada en o junto al separador óptico;

c) proveer una disposición plana periódica de elementos de enfoque de iconos de imagen que tienen un eje de simetría por lo menos alrededor de sus ejes planos, el eje de simetría es el mismo eje plano que el de la disposición plana de micro-imagen, cada elemento de enfoque es un elemento de enfoque esférico que tiene un diámetro efectivo de menos de 50 micras y se asocia con un icono de imagen; y

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d) seleccionar la relación de escala del periodo de repetición de los iconos de imagen al periodo de repetición de los elementos de enfoque del grupo que consiste de menos de 1, sustancialmente igual a 1, y mayor que 1, y seleccionar si los ejes de simetría de la disposición plana periódica de la micro-imagen y la disposición plana periódica de los elementos de enfoque de iconos de imagen están alineados o desalineados.

76.- Un icono de imagen para uso en un sistema micro-óptico de magnificación sintética, el sistema micro-óptico de magnificación sintética incluye:

a) uno o más separadores ópticos;

b) una micro-imagen compuesta de una disposición plana periódica de una pluralidad de iconos de imagen que tienen un eje de simetría por lo menos alrededor de uno de sus ejes planos, y colocada en o junto al separador óptico;

y

c) una disposición plana periódica de elementos de enfoque de iconos de imagen que tienen un eje de simetría por lo menos alrededor de sus ejes planos, el eje de simetría es el mismo eje plano que el de la disposición plana de micro-imagen, cada elemento de enfoque está asociado con un icono de imagen; y

los iconos de imagen están formados como cavidades en un substrato, los huecos en las cavidades

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están rellenas con un material de metal evaporado, un material teñido, un material pigmentado y combinaciones de los mismos.

77.- Un icono de imagen para uso en un dispositivo de seguridad de documentos, el sistema micro-
5 óptico de magnificación sintética incluye:

a) uno o más separadores ópticos;

b) una micro-imagen compuesta de una disposición plana periódica de una pluralidad de iconos de imagen que
10 tienen un eje de simetría por lo menos alrededor de uno de sus ejes planos, y colocada en o junto al separador óptico;
y

c) una disposición plana periódica de elementos de enfoque de iconos de imagen que tienen un eje de
15 simetría por lo menos alrededor de sus ejes planos, el eje de simetría es el mismo eje plano que el de la disposición plana de micro-imagen, cada elemento de enfoque está asociado con un icono de imagen; y

los iconos de imagen están formados como
20 cavidades en un sustrato, los huecos en las cavidades están rellenas con un material de metal evaporado, un material teñido, un material pigmentado y combinaciones de los mismos.

78.- Un sistema micro-óptico de magnificación
25 sintética que comprende:

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a) uno o más separadores ópticos;

b) una micro-imagen compuesta de una disposición plana periódica de una pluralidad de iconos de imagen que tienen un eje de simetría por lo menos alrededor de uno de sus ejes planos, y colocada en o junto al separador óptico;
5 y

c) una disposición plana periódica de elementos de enfoque de iconos de imagen que tienen un eje de simetría por lo menos alrededor de sus ejes planos, el eje de simetría es el mismo eje plano que el de la disposición plana de micro-imagen, cada elemento de enfoque es un lente multi-zonas de base poligonal.
10

79.- Un dispositivo de seguridad de documentos que comprende:

15 a) uno o más separadores ópticos;

b) una micro-imagen compuesta de una disposición plana periódica de una pluralidad de iconos de imagen que tienen un eje de simetría por lo menos alrededor de uno de sus ejes planos, y colocada en o junto al separador óptico;
20 y

c) una disposición plana periódica de elementos de enfoque de iconos de imagen que tienen un eje de simetría por lo menos alrededor de sus ejes planos, el eje de simetría es el mismo eje plano que el de la disposición plana de micro-imagen, cada elemento de enfoque es un lente
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multi-zonas de base poligonal.

80.- Un método para elaborar un sistema micro-
óptico de magnificación sintética, que comprende los pasos
para:

5 a) proveer uno o más separadores ópticos;

b) proveer una micro-imagen compuesta de una
disposición plana periódica de una pluralidad de iconos de
imagen que tienen un eje de simetría por lo menos alrededor
de uno de sus ejes planos, y colocada en o junto al
10 separador óptico; y

c) proveer una disposición plana periódica de
elementos de enfoque de iconos de imagen que tienen un eje
de simetría por lo menos alrededor de sus ejes planos, el
eje de simetría es el mismo eje plano que el de la
15 disposición plana de micro-imagen, cada elemento de enfoque
es un lente multi-zonas de base poligonal.

81.- Un método para elaborar un dispositivo de
seguridad de documentos, que comprende los pasos para:

a) proveer uno o más separadores ópticos;

20 b) proveer una micro-imagen compuesta de una
disposición plana periódica de una pluralidad de iconos de
imagen que tienen un eje de simetría por lo menos alrededor
de uno de sus ejes planos, y colocada en o junto al
separador óptico; y

25 c) proveer una disposición plana periódica de

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elementos de enfoque de iconos de imagen que tienen un eje de simetría por lo menos alrededor de sus ejes planos, el eje de simetría es el mismo eje plano que el de la disposición plana de micro-imagen, cada elemento de enfoque
5 es un lente multi-zonas de base poligonal.

82.- Un hilo de seguridad que comprende:

- a) uno o más separadores ópticos;
- b) una o más disposiciones planas opcionalmente periódicas de micro-imágenes o iconos colocadas dentro, en,
10 o junto a un separador óptico; y
- c) una o más disposiciones planas opcionalmente periódicas de micro-lentes no cilíndricos colocados en o junto a cualquiera de un separador óptico o una disposición de iconos plana, en donde cada micro-lente tiene un
15 diámetro base de menos de 50 micras.

83.- Un hilo de seguridad que comprende:

- a) un separador óptico que tiene superficies planas superior e inferior opuestas;
- b) una disposición periódica de micro-imágenes o
20 iconos que comprende cavidades rellenas formadas en la superficie plana inferior del separador óptico;
- c) una disposición periódica de micro-lentes multi-zonas de base poligonal o esféricos, de campo plano, no cilíndricos colocados en la superficie plana superior
25 del separador óptico, en donde cada micro-lente tiene un

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diámetro base que se ubica en el rango de alrededor de 20 a aproximadamente 30 micras; y

d) una capa de oscurecimiento o sellado pigmentada 516 colocada en la disposición de iconos.

5 84.- Un método para elaborar un hilo de seguridad, que comprende los pasos para:

a) aplicar una resina curable por radiación clara o sustancialmente transparente a las superficies superior e inferior del separador óptico;

10 b) formar una disposición de micro-lentes en la superficie superior y una disposición de iconos en la forma de cavidades en la superficie inferior del separador óptico;

15 c) curar la resina clara o sustancialmente transparente utilizando una fuente de radiación;

d) rellenar las cavidades de la disposición de iconos con una resina pigmentada o tinta;

e) retirar el exceso de resina o tinta de la superficie inferior del separador óptico; y

20 f) aplicar una capa o recubrimiento de oscurecimiento o sellado pigmentado a la superficie inferior del separador óptico.

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RESUMEN DE LA INVENCION

Un material de película que utiliza una disposición bidimensional regular de lentes no cilíndricos para agrandar micro-imágenes, denominadas iconos, para formar una imagen sintéticamente magnificada a través del rendimiento unido de una multiplicidad de sistemas de imagen de iconos/lentes individuales; el sistema micro-óptico de magnificación sintética incluye uno o más separadores ópticos (5), una micro-imagen formada de una disposición plana periódica de una pluralidad de iconos de imagen (4) que tienen un eje de simetría alrededor por lo menos de uno de sus ejes planos y que están colocados en o junto al separador óptico (5), y una disposición plana periódica de elementos de enfoque de iconos de imagen (1) que tienen un eje de simetría por lo menos alrededor de uno de sus ejes planos, el eje de simetría es el mismo eje plano que el eje de la disposición plana de micro-imagen (4); el presente sistema puede proveer un número de efectos visuales distintivos, tal como efectos de movimiento y tridimensionales.

PATENT COOPERATION TREATY

From the INTERNATIONAL SEARCHING AUTHORITY

To:
TODD DEVEAU
THOMAS, KAYDEN, HORSTEMEYER & RISLEY LLP
100 GALLERIA PARKWAY
SUITE 1750
ATLANTA, GA 30339

PCT

NOTIFICATION OF TRANSMITTAL OF
THE INTERNATIONAL SEARCH REPORT AND
THE WRITTEN OPINION OF THE INTERNATIONAL
SEARCHING AUTHORITY, OR THE DECLARATION

(PCT Rule 44.1)

Applicant's or agent's file reference 821402-2090 + Pull - 1110	Date of mailing (day/month/year) 15 MAR 2006
International application No. PCT/US04/39315	FOR FURTHER ACTION See paragraphs 1 and 4 below
Applicant NANOVENTIONS	International filing date (day/month/year) 22 November 2004 (22.11.2004)

- ☒ The applicant is hereby notified that the international search report and the written opinion of the International Searching Authority have been established and are transmitted herewith.
Filing of amendments and statement under Article 19:
The applicant is entitled, if he so wishes, to amend the claims of the international application (see Rule 46):
When? The time limit for filing such amendments is normally two months from the date of transmittal of the international search report.
Where? Directly to the International Bureau of WIPO, 34 chemin des Colombettes
1211 Geneva 20, Switzerland, Facsimile No.: (41-22) 338.82.70.
For more detailed instructions, see the notes on the accompanying sheet.
- ☐ The applicant is hereby notified that no international search report will be established and that the declaration under Article 17(2)(a) to that effect and the written opinion of the International Searching Authority are transmitted herewith.
- ☐ With regard to the protest against payment of (an) additional fee(s) under Rule 40.2, the applicant is notified that:
☐ the protest together with the decision thereon has been transmitted to the International Bureau together with the applicant's request to forward the texts of both the protest and the decision thereon to the designated Offices.
☐ no decision has been made yet on the protest; the applicant will be notified as soon as a decision is made.
- Reminders**
Shortly after the expiration of 18 months from the priority date, the international application will be published by the International Bureau. If the applicant wishes to avoid or postpone publication, a notice of withdrawal of the international application, or of the priority claim, must reach the International Bureau as provided in Rules 90b(1) and 90b(3), respectively, before the completion of the technical preparations for international publication.
The applicant may submit comments on an informal basis on the written opinion of the International Searching Authority to the International Bureau. The International Bureau will send a copy of such comments to all designated Offices unless an international preliminary examination report has been or is to be established. These comments would also be made available to the public but not before the expiration of 30 months from the priority date.
Within 19 months from the priority date, but only in respect of some designated Offices, a demand for international preliminary examination must be filed if the applicant wishes to postpone the entry into the national phase until 30 months from the priority date (in some Offices even later); otherwise, the applicant must, within 28 months from the priority date, perform the prescribed acts for entry into the national phase before those designated Offices.
In respect of other designated Offices, the time limit of 30 months (or later) will apply even if no demand is filed within 19 months.
See the Annex to Form PCT/IB/301 and, for details about the applicable time limits, Office by Office, see the *PCT Applicant's Guide*, Volume II, National Chapters and the WIPO Internet site.

Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US Commissioner for Patents P.O. Box 1450 Alexandria, Virginia 22313-1450 Facsimile No. (571) 273-3201	Authorized officer Ricky Mack Telephone No. 571 272 1562
---	--

Form PCT/ISA/220 (January 2004)

(See notes on accompanying sheet)

DOCKETED

ISR

5/15/06

Comment on Abstract due 4/15/06

Demand due from transmittal date due 6/15/06

IDS for 821402-1110 due 6/15/06

From the INTERNATIONAL SEARCHING AUTHORITY

To:
TODD DEVBAU
THOMAS, KAYDEN, HORSTEMEYER & RISLEY LLP
100 GALLERIA PARKWAY
SUITE 1750
ATLANTA, GA 30339

PCT

NOTIFICATION OF TRANSMITTAL OF
THE INTERNATIONAL SEARCH REPORT AND
THE WRITTEN OPINION OF THE INTERNATIONAL
SEARCHING AUTHORITY, OR THE DECLARATION

(PCT Rule 44.1)

Date of mailing (day/month/year)	
Applicant's or agent's file reference 821402-2090	FOR FURTHER ACTION See paragraphs 1 and 4 below
International application No. PCT/US04/39315	International filing date (day/month/year) 22 November 2004 (22.11.2004)
Applicant NANOVENTIONS	

1. ☒ The applicant is hereby notified that the international search report and the written opinion of the International Searching Authority have been established and are transmitted herewith.
- Filing of amendments and statements under Article 19:**
The applicant is entitled, if he so wishes, to amend the claims of the international application (see Rule 46):
- When?** The time limit for filing such amendments is normally two months from the date of transmittal of the international search report.
- Where?** Directly to the International Bureau of WIPO, 34 chemin des Colombettes
1211 Geneva 20, Switzerland, Facsimile No.: (41-22) 338.82.70.
- For more detailed instructions, see the notes on the accompanying sheet.
2. ☐ The applicant is hereby notified that no international search report will be established and that the declaration under Article 17(2)(a) to that effect and the written opinion of the International Searching Authority are transmitted herewith.
3. ☐ With regard to the protest against payment of (an) additional fee(s) under Rule 40.2, the applicant is notified that:
- ☐ the protest together with the decision thereon has been transmitted to the International Bureau together with the applicant's request to forward the texts of both the protest and the decision thereon to the designated Offices.
- ☐ no decision has been made yet on the protest; the applicant will be notified as soon as a decision is made.
4. **Reminders**
- Shortly after the expiration of 18 months from the priority date, the international application will be published by the International Bureau. If the applicant wishes to avoid or postpone publication, a notice of withdrawal of the international application, or of the priority claim, must reach the International Bureau as provided in Rules 90bis.1 and 90bis.3, respectively, before the completion of the technical preparations for international publication.
- The applicant may submit comments on an informal basis on the written opinion of the International Searching Authority to the International Bureau. The International Bureau will send a copy of such comments to all designated Offices unless an international preliminary examination report has been or is to be established. These comments would also be made available to the public but not before the expiration of 30 months from the priority date.
- Within 19 months from the priority date, but only in respect of some designated Offices, a demand for international preliminary examination must be filed if the applicant wishes to postpone the entry into the national phase until 30 months from the priority date (in some Offices even later); otherwise, the applicant must, within 20 months from the priority date, perform the prescribed acts for entry into the national phase before those designated Offices.
- In respect of other designated Offices, the time limit of 30 months (or later) will apply even if no demand is filed within 19 months.
- See the Annex to Form PCT/IB/301 and, for details about the applicable time limits, Office by Office, see the *PCT Applicant's Guide*, Volume II, National Chapters and the WIPO Internet site.

SCANNED

Name and mailing address of the ISA/ US Mail Stop PCT, Attn: ISA/US Commissioner for Patents P.O. Box 1450 Alexandria, Virginia 22313-1450 Facsimile No. (571) 273-3201	Authorized officer Ricki Mack <i>Lynne Lee For</i> Telephone No. 571 272 1562
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Form PCT/ISA/220 (January 2004)

(See notes on accompanying sheet)

THOMAS, KAYDEN
HORSTEMEYER & RISLEY, LLP

MAR 20 2006

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference 821402-2090	FOR FURTHER ACTION see Form PCT/ISA/220 as well as, where applicable, item 5 below.	
International application No. PCT/US04/39315	International filing date (day/month/year) 22 November 2004 (22.11.2004)	(Earliest) Priority Date (day/month/year) 11 November 2003 (11.11.2003)
Applicant NANOVENTIONS		

This international search report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This international search report consists of a total of 3 sheets.



It is also accompanied by a copy of each prior art document cited in this report.

1. Basis of the Report

a. With regard to the language, the international search was carried out on the basis of:



the international application in the language in which it was filed.



a translation of the international application into _____, which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1(b))

b. ☐ With regard to any nucleotide and/or amino acid sequence disclosed in the international application, see Box No. I.

2. ☐ Certain claims were found unsearchable (See Box No. II)

3. ☐ Unity of invention is lacking (See Box No. III)

4. With regard to the title,



the text is approved as submitted by the applicant.



the text has been established by this Authority to read as follows:

5. With regard to the abstract,



the text is approved as submitted by the applicant.



the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box No. IV. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. With regard to the drawings,

a. the figure of the drawings to be published with the abstract is Figure No. _____



as suggested by the applicant.



as selected by this Authority, because the applicant failed to suggest a figure.



as selected by this Authority, because this figure better characterizes the invention.

b. ☒

none of the figures is to be published with the abstract.

Box IV TEXT OF THE ABSTRACT (Continuation of Item 5 of the first sheet)

NEW ABSTRACT

A film material utilizing a regular two-dimensional array of non-cylindrical lenses to enlarge micro images, called icons, to form a synthetically magnified image through united performance of a multiplicity of individual lens/icon image systems. The synthetic magnification optic system includes one or more optical spacers (5), a micro-image formed of a periodic planar array of plurality of image icons (4) having an axis of symmetry about at least one of its planar axes and positioned on or next to the optical spacer (5), and a periodic planar array of a plurality of image icon focusing elements (1).

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US04/39315

A. CLASSIFICATION OF SUBJECT MATTER

IPC: G03H 01/00; G02B 13/18 (2006.01); G2/02, G3/10, 27/08 (2006.01); G01B 15/02 (2006.01); G01N 23/06 (2006.01)

USPC: 359/2, 619, 620, 626, 627, 628, 708, 718, 721; 380/54

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 359/2, 619, 620, 626, 627, 628, 708, 718, 721; 380/54

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
noneElectronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EAST

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X — T	US 6,900,944B2 (TOMCZYK) 31 MAY 2005 (31.05.05), col. 9-col. 10	1-84
X — T	US 6,870,681 B1 (MAGBEE) 22 MARCH 2005 (22.03.2005), col. 5 and 6	1-84

☐ Further documents are listed in the continuation of Box C.	☐ See patent family annex.
* Special categories of cited documents:	
"A" document defining the general state of the art which is not considered to be of particular relevance	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"E" earlier application or patent published on or after the international filing date	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another claim or other special reason (as specified)	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"O" document referring to an oral disclosure, use, exhibition or other means	"A" document member of the same patent family
"P" document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search

14 February 2006 (14.02.2006)

Date of mailing of the international search report

15 MAR 2006

Name and mailing address of the ISA/US

Mail Stop PCT, Attn: ISA/US

Commissioner for Patents

P.O. Box 1450

Alexandria, Virginia 22313-1450

Facsimile No. (571) 273-3201

Authorized officer

Ricky Mack

Telephone No. 571 272 1562

From the
INTERNATIONAL SEARCHING AUTHORITY

To:
TODD DEVBAU
THOMAS, KAYDEN, HORSTEMEYER & RISLEY LLP
100 GALLERIA PARKWAY
SUITE 1750
ATLANTA, GA 30339

PCT

WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY

(PCT Rule 43bis.1)

Date of mailing
(day/month/year) 15 MAR 2006

Applicant's or agent's file reference

821402-2090

FOR FURTHER ACTION

See paragraph 2 below

International application No.

PCT/US04/39315

International filing date (day/month/year)

22 November 2004 (22.11.2004)

Priority date (day/month/year)

11 November 2003 (11.11.2003)

International Patent Classification (IPC) or both national classification and IPC

IPC: Please See Continuation Sheet

USPC: 359/2, 619, 620, 626, 627, 628, 708, 718, 721, 380/54

Applicant

NANOVENTIONS

1. This opinion contains indications relating to the following items:

- ☒ Box No. I Basis of the opinion
- ☐ Box No. II Priority
- ☐ Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- ☐ Box No. IV Lack of unity of invention
- ☒ Box No. V Reasoned statement under Rule 43bis.1(a)(i) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
- ☐ Box No. VI Certain documents cited
- ☐ Box No. VII Certain defects in the international application
- ☐ Box No. VIII Certain observations on the international application

2. FURTHER ACTION

If a demand for international preliminary examination is made, this opinion will be considered to be a written opinion of the International Preliminary Examining Authority ("IPEA") except that this does not apply where the applicant chooses an Authority other than this one to be the IPEA and the chosen IPEA has notified the International Bureau under Rule 66.1bis(b) that written opinions of this International Searching Authority will not be so considered.

If this opinion is, as provided above, considered to be a written opinion of the IPEA, the applicant is invited to submit to the IPEA a written reply together, where appropriate, with amendments, before the expiration of 3 months from the date of mailing of Form PCT/ISA/220 or before the expiration of 22 months from the priority date, whichever expires later.

For further options, see Form PCT/ISA/220.

3. For further details, see notes to Form PCT/ISA/220.

Name and mailing address of the ISA/ US

Mail Stop PCT, Attn: ISA/US
Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450

Facsimile No. (571) 273-3201

Date of completion of this opinion

14 February 2006 (14.02.2006)

Authorized officer

Ricky Mack

Telephone No. 571 272 1562

Form PCT/ISA/237 (cover sheet) (April 2005)

WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY

International application No.

PCT/US04/39315

Box No. I Basis of this opinion

1. With regard to the language, this opinion has been established on the basis of:

- ☒ the international application in the language in which it was filed
☐ a translation of the international application into _____, which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1(b)).

2. With regard to any nucleotide and/or amino acid sequence disclosed in the international application and necessary to the claimed invention, this opinion has been established on the basis of:

a. type of material

- ☐ a sequence listing
☐ table(s) related to the sequence listing

b. format of material

- ☐ on paper
☐ in electronic form

c. time of filing/furnishing

- ☐ contained in the international application as filed.
☐ filed together with the international application in electronic form.
☐ furnished subsequently to this Authority for the purposes of search.

3. ☐ In addition, in the case that more than one version or copy of a sequence listing and/or table(s) relating thereto has been filed or furnished, the required statements that the information in the subsequent or additional copies is identical to that in the application as filed or does not go beyond the application as filed, as appropriate, were furnished.

4. Additional comments:

WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US04/39315

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Box No. V Reasoned statement under Rule 43 bis.1(a)(i) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Claims 1-84	YES
	Claims NONE	NO
Inventive step (IS)	Claims 1-84	YES
	Claims NONE	NO
Industrial applicability (IA)	Claims 1-84	YES
	Claims NONE	NO

2. Citations and explanations:

Claims 1-84 the criteria set out in PCT Article 33(2)-(3), because the prior art does not teach or fairly suggest a planar array of image icon focusing elements having an axis of symmetry about at least one of its planar axis, the axis of symmetry being the same planar axis as that of the micro image planar array wherein each focusing element is polygonal base multi-zonal element or lens having base diameter of less than 50 microns as claimed

Claims 1-84 the criteria set out in PCT Article 33(4), and thus have industrial applicability because the subject matter claimed can be made or used in industry.

WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US04/39315

Supplemental Box

In case the space in any of the preceding boxes is not sufficient.

Continuation of IPC:

G03H 01/00; G03B 13/18(2006.01), 02/02, 03/10, 27/08(2006.01); G01B 15/02(2006.01); G01N 23/06(2006.01)

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NOTES TO FORM PCT/ISA/220

These Notes are intended to give the basic instructions concerning the filing of amendments under Article 19. The Notes are based on the requirements of the Patent Cooperation Treaty, the Regulations and the Administrative Instructions under that Treaty. In case of discrepancy between these Notes and those requirements, the latter are applicable. For more detailed information, see also the *PCT Applicant's Guide*, a publication of WIPO.

In these Notes, "Article," "Rule" and "Section" refer to the provisions of the PCT, the PCT Regulations and the PCT Administrative Instructions, respectively.

INSTRUCTIONS CONCERNING AMENDMENTS UNDER ARTICLE 19

The applicant has, after having received the international search report and the written opinion of the International Searching Authority, one opportunity to amend the claims of the international application. It should however be emphasized that, since all parts of the international application (claims, description and drawings) may be amended during the international preliminary examination procedure, there is usually no need to file amendments of the claims under Article 19 except where, e.g. the applicant wants the latter to be published for the purposes of provisional protection or has another reason for amending the claims before international publication. Furthermore, it should be emphasized that provisional protection is available in some States only (see *PCT Applicant's Guide*, Volume I/A, Annexes B1 and B2).

The attention of the applicant is drawn to the fact that amendments to the claims under Article 19 are not allowed where the International Searching Authority has declared, under Article 17(2), that no international search report would be established (see *PCT Applicant's Guide*, Volume I/A, paragraph 296).

What parts of the international application may be amended?

Under Article 19, only the claims may be amended.

During the international phase, the claims may also be amended (or further amended) under Article 34 before the International Preliminary Examining Authority. The description and drawings may only be amended under Article 34 before the International Preliminary Examining Authority.

Upon entry into the national phase, all parts of the international application may be amended under Article 28 or, where applicable, Article 41.

When? Within 2 months from the date of transmittal of the international search report or 16 months from the priority date, whichever time limit expires later. It should be noted, however, that the amendments will be considered as having been received on time if they are received by the International Bureau after the expiration of the applicable time limit but before the completion of the technical preparations for international publication (Rule 46.1).

Where not to file the amendments?

The amendments may only be filed with the International Bureau and not with the receiving Office or the International Searching Authority (Rule 46.2).

Where a demand for international preliminary examination has been/is filed, see below.

How? Either by cancelling one or more entire claims, by adding one or more new claims or by amending the text of one or more of the claims as filed.

A replacement sheet must be submitted for each sheet of the claims which, on account of an amendment or amendments, differs from the sheet originally filed.

All the claims appearing on a replacement sheet must be numbered in Arabic numerals. Where a claim is cancelled, no renumbering of the other claims is required. In all cases where claims are renumbered, they must be renumbered consecutively (Section 205(b)).

The amendments must be made in the language in which the international application is to be published.

What documents must/may accompany the amendments?

Letter (Section 205(b)):

The amendments must be submitted with a letter.

The letter will not be published with the international application and the amended claims. It should not be confused with the "Statement under Article 19(1)" (see below, under "Statement under Article 19(1)").

The letter must be in English or French, at the choice of the applicant. However, if the language of the international application is English, the letter must be in English; if the language of the international application is French, the letter must be in French.

(12) **United States Patent**
Tomczyk

(10) Patent No.: **US 6,900,944 B2**
(45) Date of Patent: **May 31, 2005**

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290

(54) **LENTICULAR CARD AND PROCESSES FOR MAKING**

(75) Inventor: **John Tomczyk, Shoreview, MN (US)**

(73) Assignee: **Taylor Corporation, North Mankato, MN (US)**

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **10/406,614**

(22) Filed: **Apr. 3, 2003**

(65) **Prior Publication Data**

US 2003/0219574 A1 Nov. 27, 2003

Related U.S. Application Data

(63) Continuation of application No. PCT/US01/46682, filed on Nov. 2, 2001.

(60) Provisional application No. 60/245,404, filed on Nov. 2, 2000.

(30) **Foreign Application Priority Data**

Nov. 2, 2001 (WO) PCT/US01/46682

(51) Int. Cl.⁷ G02B 27/10; G06K 19/00

(52) U.S. Cl. 359/619; 235/487

(58) Field of Search 359/619; 235/487, 235/380, 375; 428/142, 156, 195, 1.4

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,264,164 A 8/1966 Jerolte et al. 428/29

4,414,316 A 11/1983 Conley 430/496
4,897,533 A • 1/1990 Lyszczyk 235/487
5,466,723 A 11/1995 Dotson 522/96
5,473,406 A 12/1995 Hassall et al. 355/22
5,532,786 A 7/1996 Hassall et al. 355/22
6,073,854 A • 6/2000 Bravenec et al. 235/487
6,185,042 B1 • 2/2001 Lomb et al. 359/619

OTHER PUBLICATIONS

ISO/IEC 7810:1995(E), "Identification Cards—Physical Characteristics," Aug. 15, 1995, pp. i-iii and pp. 1-5.

ISO/IEC 7816 -1, "Identification Cards—Integrated Circuit(s) Cards With Contacts," Jul. 1, 1987, pp. 1-4.

* cited by examiner

Primary Examiner—Georgia Epps

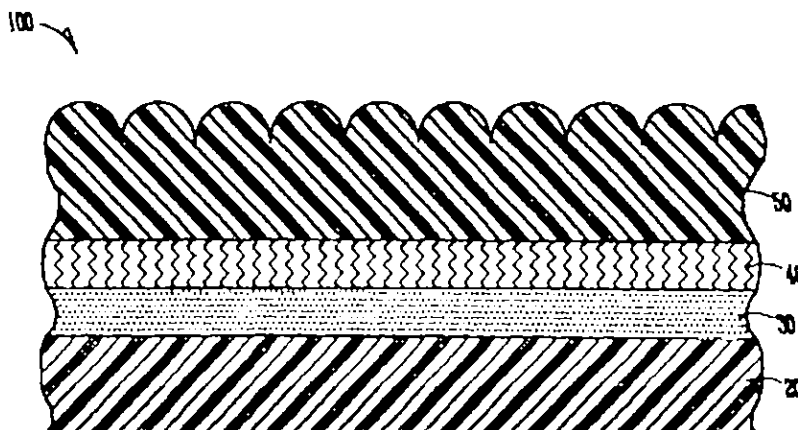
Assistant Examiner—M. Hasan

(74) Attorney, Agent, or Firm—Merchant & Gould, PC

(57) **ABSTRACT**

A process for making a lenticular card including: providing an imaged transparent sheet having a first smooth side and a second side with a lenticulated region, the transparent sheet optionally having at least one printed image area on the first smooth side and a moisture cure adhesive layer over the printed image areas and non-image areas of the first smooth side, and the moisture cure adhesive layer being applied with a screen press through a screen; and combining the imaged transparent sheet on the adhesive layer side of the transparent sheet with a backing sheet by nipping the paired sheets with a nip roller. The invention also provides processes useful for preparing a lenticular card including an optional core sheet, or optional primer layers.

43 Claims, 2 Drawing Sheets



2/2
2a1

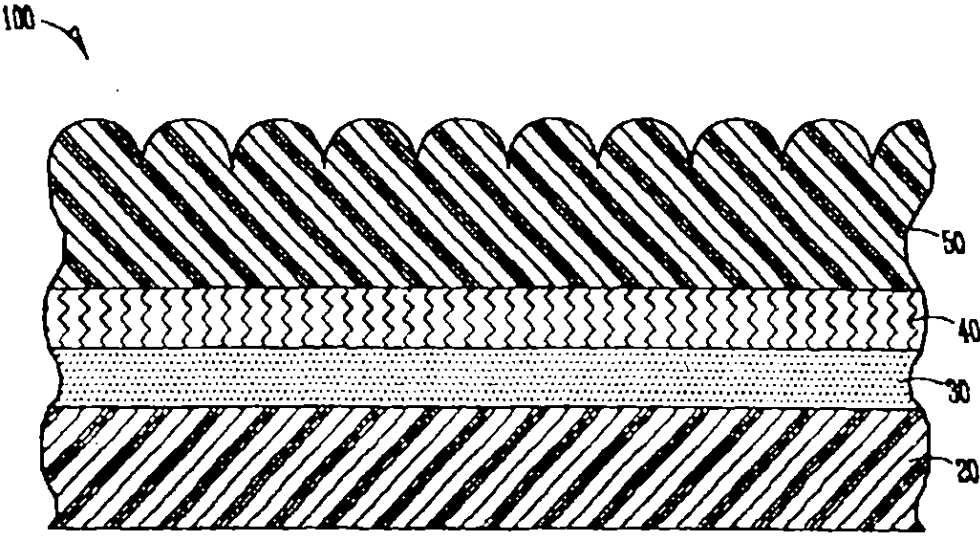


Fig. 1

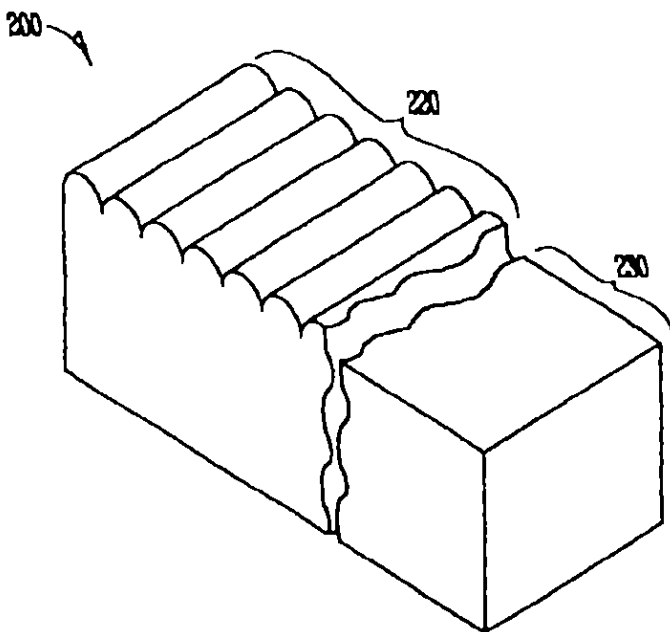


Fig. 2

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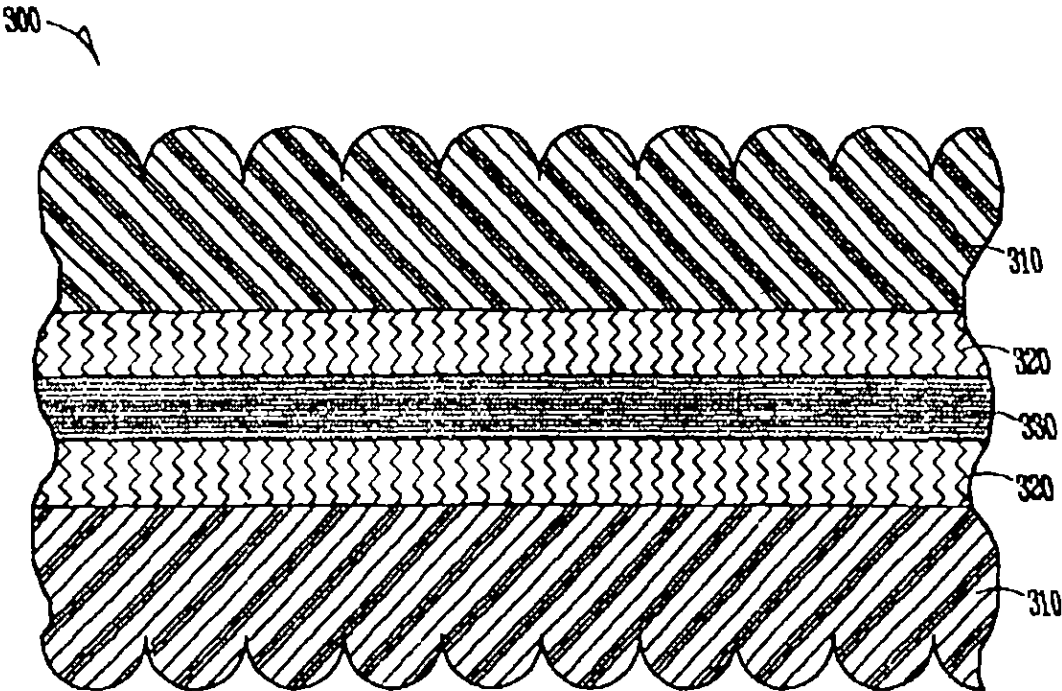


Fig. 3

LENTICULAR CARD AND PROCESSES FOR MAKING

RELATED APPLICATIONS

This application is a continuation under 35 U.S.C. 111(a) of International Application Serial No. PCT/US01/46682 filed 02 Nov. 2001 and published in English as WO 02/40291 A2 on May 23, 2002, which claims priority from U.S. Provisional Application Ser. No. 60/245,404 filed 02 Nov. 2000, which applications and publication are incorporated herein by reference.

FIELD OF THE INVENTION

The present invention provides for a lenticular card, and processes for printing and making the card. More specifically the present invention provides processes for the preparation of printed lenticular cards having desired printed image properties, physical dimensions, and physical characteristics as described herein.

BACKGROUND OF THE INVENTION

The ability to litho-print a lenticular lens using a conventional off-set printing press configured with a UV Lamp is known in the art, see for example U.S. Pat. No. 6,073,854 below. The ability to adhere the printed lens to other plastic substrates and obtain a destructive bond between the lens and the substrate can be intricate and difficult, see for example, U.S. Pat. Nos. 5,473,406, and 5,532,786.

Processes for the preparation of articles with a lenticular surface are known, reference for example the following documents.

In U.S. Pat. No. 4,414,316, issued Nov. 8, 1983, to Conley, there is disclosed a flexible composite sheet material having a thermoset patterned relief surface of high quality and definition which is particularly useful for producing high quality optical sheet components such as a lenticular screen sheet for producing three-dimensional pictures and photographs. The composite sheet comprises a flexible base film having front and rear surfaces and a layer of a cured thermosetting polymer overlying the front surface of the base film. The cured thermosetting polymer layer has a nonplanar outer surface defining a predetermined desired relief pattern of high quality and durability and of fine definition in the thermosetting polymer layer. See for example Example 1 therein.

In U.S. Pat. No. 5,466,723, issued Nov. 14, 1995, to Dotson, there is disclosed a radiation curable adhesive composition which comprises from 15 to 85 percent by weight of beta-carboxyethyl acrylate and from 85 to 15 percent by weight of 2-phenoxyethyl acrylate based on the total weight of the composition. The adhesive provides improved adhesion for laminating a lineiform image sheet to a lenticular array sheet.

In U.S. Pat. No. 5,473,406 (apparatus), issued Dec. 5, 1995, and U.S. Pat. No. 5,532,786 (method), issued Jul. 2, 1996, both to Hassall, et al., there is disclosed an image sheet (12) coated with a radiation curable adhesive (48) at a coating station and then laminated to a lenticular array sheet (20) at a laminating station (50). A lamination of the image and array sheets is then positioned on an aligning station (56) where the lenticules of the array sheet are aligned with the image lines (16) of the image sheet. The adhesive is set at a curing station (60).

In U.S. Pat. No. 6,073,854, issued Jun. 13, 2000, to Bravenec et al., there is disclosed a card (10) for use as a

telephone authorization card or the like is comprised of a layer of a backing material (20) such as a stiff plastic material which has some pliability. A thin sheet lenticular lens material (12) has a flat surface (14) on which is printed selected interlaced images. On the other side of the lens material is formed a plurality of lenticules (16) through which the images are viewed. The flat side of the lenticular material is secured to one face (22) of the backing in a convenient manner. A cutting tool is used to form an opening (32) in the outer face of the lenticules and a programmed microchip (30) is inserted in the opening and secured in place. On the outer face of the backing material a magnetic strip (40) containing magnetically encoded indicia is secured. The card is usable in a reader (R) which can scan the magnetic strip and read information from the microchip to allow the user to place a telephone call or conduct other transactions.

In U.S. Pat. No. 3,264,164, issued Aug. 2, 1966, to Jerome et al., there is disclosed a color dynamic, three-dimensional flexible film and method of making the film. The film includes a transparent sheet having a lenticulated outer surface and line printed or image opposite surface.

The above patents are incorporated by reference herein in their entirety.

In view of limitations of available processes for preparing lenticulated articles, such as efficiency and cost, a need exists for improved processes for the preparation of high quality lenticulated articles.

SUMMARY OF THE INVENTION

In accordance with the present invention, processes are provided for the preparation of lenticular articles including:

A process for making a lenticular card comprising:

providing an imaged transparent sheet having a first smooth side and a second side with a lenticulated region, the transparent sheet having at least one printed image area on the first smooth side and a moisture cure adhesive layer over the printed image areas and non-image areas of the first smooth side, and the moisture cure adhesive layer being applied with a screen press through a screen; and

combining the imaged transparent sheet on the adhesive layer side of the transparent sheet with a backing sheet by nipping the paired sheets with a nip roller;

A process for making a lenticular card comprising:

providing an imaged backing sheet having a first side and a second side, the backing sheet having a printed image on one side and a moisture cure adhesive layer over the printed image areas and non-image areas of the imaged side, and the moisture cure adhesive layer being applied with a screen press through a screen; and

combining the backing sheet on the adhesive layer side with the first side of a transparent sheet having a first smooth side and a second side having a lenticulated region by nipping the paired sheets with a nip roller;

A process for making a lenticular card comprising:

providing an imaged transparent sheet having a first smooth side and a second side having a lenticulated region, the transparent sheet having a printed image on the first smooth side and a radiation curable adhesive layer over the printed image areas and non-image areas of the first smooth side, and the radiation curable adhesive layer being applied with a screen press through a screen;

activating the radiation curable adhesive by irradiating the adhesive layer; and

combining a backing sheet with the transparent sheet on the resulting activated adhesive layer side of the transparent sheet by nipping the paired sheets with a nip roller; and

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A process for making a lenticular card comprising:

providing an imaged transparent sheet having a first smooth side and a second side with a lenticulated region, the imaged transparent sheet having a printed image on the first smooth side;

providing a backing sheet with a radiation curable adhesive layer on one side of the backing sheet, and the radiation curable adhesive layer being applied with a screen press through a screen;

combining the backing sheet with the imaged transparent sheet to form a composite sheet by nipping the paired sheets with a nip roller, the adhesive layer on the smooth side of the transparent sheet being interposed between the backing and transparent sheets; and

irradiating the adhesive layer within the resulting composite sheet by directing radiation through the transparent sheet side of the composite sheet.

Thus, the present invention provides, in embodiments, economical processes for making lenticular cards articles with improved properties, such as improved indestructibility, as illustrated herein.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and other objectives, features and advantages of the invention will be apparent from the following more particular description of the preferred embodiments of the invention, as illustrated in the accompanying drawings.

FIG. 1 illustrates a lenticular card embodiment of the present invention.

FIG. 2 illustrates an embodiment of the present invention showing a perspective view of a card having a top or outer surface with both a partial lenticular area and a partial smooth area.

FIG. 3 illustrates a lenticular card embodiment of the present invention showing a section view of a card having both a top outer lenticular surface and a bottom outer lenticular surface.

DETAILED DESCRIPTION OF THE INVENTION

Applicants have discovered a improved and efficient process for making printed pieces, such as a credit/debit cards, gift cards, security card, phone cards, business cards, novelty cards, playing cards, trading cards, promotional cards, or like cards and which pieces include a lenticulated area on one or both sides of the finished card.

Definitions

The following definitions are used, unless otherwise described.

A "destructive bond" is generally a type of adhesive bond which once formed between two joined sheets or surfaces cannot be mechanically separated or undone without accompanying destruction or damage to two joined sheets or surfaces which destruction or damage is readily evident to an observer or detectable by a suitable equipped detector device.

"Transparent" as used in "transparent sheet" includes clear, semi-transparent, translucent, and the like adjectives that describe the ability of the sheet to either or both: transmit at least some light energy from a light or radiation source to the adhesive layer to effectuate the photocuring of the adhesive, or alternatively, to transmit at least some light energy from a light or radiation source to the image layer to

permit visualization or detection of the imager by an observer or a machine.

The terms "include", "for example", "such as", and the like are used illustratively and are not intended to limit the present invention.

The indefinite articles "a" and "an" mean "at least one" or "one or more" when used in this application, including the claims, unless specifically indicated otherwise.

"Optional" or "optionally" mean that the subsequently described event or circumstance may but need not occur, and that the description includes instances where the event or circumstance occurs and instances in which it does not. For example, "optionally include a magnetic stripe" means that the magnetic stripe may be present but need not be present, and the description includes situations where the magnetic stripe is included and situations where the magnetic stripe is not included.

"Mils" or "mils" or "mil" is a unit of length equal to one thousandth (10^{-3}) of an inch (0.0254 millimeter), used to specify, for example, the thickness of sheet materials.

The present invention provides durable phone, gift, membership, loyalty, and like cards, such as with an approximate overall thickness of about 30 mils, and which cards can optionally include a magnetic stripe and optionally can be imaged or printed by, for example, thermal or ink jet imaging methods, and which printed images optionally can be further encoded. Such cards have traditionally been made by, for example, compression lamination to meet ISO specifications. In a desire to differentiate themselves card-marketers and end-users desire card formats and appearance features with interesting visual effects. Examples include holographic film, clear cards, gift cards, and the like. The ability to efficiently produce cards having either or both an apparent 3-dimensional (3D) and an animating effect through a lenticular lens layer is desirable. Fulfilling the requirements that the card: has about 30 mil total thickness; has an encodable magnetic stripe; is thermally or ink jet imageable; and can be produced economically is a formidable challenge. See for example, ISO/IEC 7810:1995(E) "Identification Cards—Physical Characteristics" and ISO/IEC 7816-1:1987(E) "Identification Cards—Integrated circuit(s) cards with contacts."

Currently available methods can provide a lens sheet or lenticulated sheet array, which can vary in thickness, for example, from about 5 mils to about 35 mils, and from about 10 mils to about 30 mils. The thickness of the extruded lenticular lens layer is suggested by the formula:

$$r=Cx/f$$

or

$$r=(r'-n)r'/x'$$

where r is the radius of curvature of a lenticular lens, C is a constant, f is the focal length of optimal focus thickness for the plastic, n' is the index of refraction of the lens construction material, such as an extruded plastic, and n is index of refraction of air. From the formula it is evident that the thicker the plastic the lower the pitch or lenticules per inch (LPI). The lower the pitch, the more coarse the lens. A coarse lens can give undesirable lens effects, for example, distortion of an underlying image. The desired pitch for a card of approximately $3\frac{1}{2} \times 2\frac{1}{4}$ " is for example between about 70 LPI and about 100 LPI. A coarser lens would require image graphics and text be significantly large, to avoid lens effects, and which lens effects are generally not

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desired by graphic designers. Thus to run a higher pitch lens a lenticular sheet plastic would need to be, for example, between 15 to about 20 mils thick and would need a white opaque sheet constructed of, for example, plastic mounted to the back of the lens to bring the card to a total thickness of about 30 mils. The opacity of the plastic backing sheet mounted to the back of the lens sheet, in embodiments, should be sufficiently opaque so as not to exhibit "show-through", that is, an image printed on the back of the plastic backing sheet should not be visible to an observer viewing the front surface of the lenticular card through the lenticular or smooth areas. The plastic backing sheet should also preferably be thermally imageable and constructed of a material that can be hot stamped, such as with an encodable magnetic stripe. Generally, for the card to be thermally imageable, the surface to be imaged should be very smooth and the plastic must be able to withstand the elevated temperatures of the thermal imaging process. Thermal imaging processes work well on, for example, laminated vinyl, polyester or co-polyester, such as polyethylene terephthalate glycol (PETG) and amorphous polyethylene terephthalate (APET, also known as poly(oxyethyleneoxyterephthaloyl)). Suitable polyesters, such as PETG 6763 and APET 9921, are commercially available in lenticulated form, for example, Vinyl Plastics, Inc., Sheboygan Falls, Wis. See also EASTAPAK polyester 9921 and related materials from Eastman Chemical, affiliated or alternative suppliers. Clear PVC lenticular sheet material and PVC backing sheet material, commercially available from Goex, Janesville, Wisc., were found to be a preferred materials because of their superior destructive bonding and imaging properties. UV curable Dymax adhesive material, commercially available from Dymax Corporation, was found to be a superior bonding adhesive, especially with PVC materials. Moisture cure adhesives were found to provide satisfactory bonding properties with polystyrene or polyester materials and was additionally advantaged by lower cost compared to the Dymax adhesive.

SUNCURE inks is a line of inks, commercially available from Sun Chemical, Carlstadt, N.J., and are examples of UV curable printing inks suitable for use in the present invention. Other inks suitable for use in the present invention are commercially available from, for example, Flint Inks, St. Paul, Minn.

Bonding the printed lens sheet and the opaque vinyl or polyester backer sheet proved cumbersome or resulted in product pieces with inferior quality, for example lacking the above mentioned indestructibility property, using prior art bonding methods. In the present invention, the desired bond can be, for example, an adhesive that dries to a solid and is destructive to the lens sheet, the optional core sheet if present, and the backer sheet if subsequent separation is attempted. Thus the processes of the present invention can further provide secure card articles which are either or both tamper resistant and tamper evident. In the present invention, the resulting card articles preferably satisfy one or more of the specification standards in the above mentioned ISO/IEC 7810. The present invention provides improved and alternative approaches to making lenticular cards having high quality printed images and which images can be, for example, printed externally, such as, on an opaque backing sheet, such as a bar code or a magnetic stripe, and printed internally and viewable through the either the lenticular or the smooth regions of the transparent or translucent front surface sheet.

DESCRIPTION OF PREFERRED EMBODIMENTS

The following examples in conjunction with the accompanying figures provide illustrative and representative pro-

cedures for preparing card articles of the present invention. In embodiments the present invention provides a process for making a lenticular card comprising:

providing an imaged transparent sheet having a first smooth side and a second side with a lenticulated region, the transparent sheet having at least one printed image area on the first smooth side and a moisture cure adhesive layer over the printed image areas and non-image areas of the first smooth side, and the moisture cure adhesive layer being applied with a screen press through a screen; and

combining the imaged transparent sheet on the adhesive layer side of the transparent sheet with a backing sheet by nipping the paired sheets with a nip roller.

In embodiments the present invention also provides a process for making a lenticular card comprising:

providing an imaged backing sheet having a first side and a second side, the backing sheet having a printed image on one side and a moisture cure adhesive layer over the printed image areas and non-image areas of the imaged side, and the moisture cure adhesive layer being applied with a screen press through a screen; and

combining the backing sheet on the adhesive layer side with the first side of a transparent sheet having a first smooth side and a second side having a lenticulated region by nipping the paired sheets with a nip roller.

In the above processes the adhesive layer can be, for example, activated prior to combining the sheets. The activation of the adhesive can, for example, displace solvent from the adhesive layer and shorten the adhesive cure time and provide in some instances improved destructive bonding. The above processes can further comprise post-curing the adhesive layer with heating.

In embodiments the present invention provides a process for making a lenticular card comprising:

providing an imaged transparent sheet having a first smooth side and a second side having a lenticulated region, the transparent sheet having a printed image on the first smooth side and a radiation curable adhesive layer over the printed image areas and non-image areas of the first smooth side, and the radiation curable adhesive layer being applied with a screen press through a screen;

activating the radiation curable adhesive by irradiating the adhesive layer; and

combining a backing sheet with the transparent sheet on the resulting activated adhesive layer side of the transparent sheet by nipping the paired sheets with a nip roller.

In embodiments the present invention provides a process for making a lenticular card comprising:

providing an imaged transparent sheet having a first smooth side and a second side with a lenticulated region, the imaged transparent sheet having a printed image on the first smooth side;

providing a backing sheet with a radiation curable adhesive layer on one side of the backing sheet, and the radiation curable adhesive layer being applied with a screen press through a screen;

combining the backing sheet with the imaged transparent sheet to form a composite sheet by nipping the paired sheets with a nip roller, the adhesive layer on the smooth side of the transparent sheet being interposed between the backing and transparent sheets; and

irradiating the adhesive layer within the resulting composite sheet by directing radiation through the transparent sheet side of the composite sheet.

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In the above process involving irradiation, the irradiating can be accomplished, for example, by focused or unfocused ultraviolet light. The irradiating can cure the adhesive, for example, in from about 1 to about 20 seconds. Irradiation conditions can depend upon a number of process variables and the configuration of mechanical and processing components employed, such as web width and speed, lamp power ratings, lamp proximity, and the like considerations. Exemplary irradiation apparatus and conditions can be, for example: two metal halide ultraviolet (UV) lamps which deliver about 400 Watts per inch to a 42 inch wide web or belt of a lithographic press operating at from about 40 to about 100 feet per minute; or two medium pressure mercury vapor ultraviolet (UV) lamps which deliver about 300 Watts per inch to a 30 inch wide web or belt of a lithographic press operating at from about 50 to about 120 feet per minute. Other optimal web or belt speeds can be readily determined by trial and error in view of variability observed in cure rates based on, for example, differences in ink colors selected and their UV light adsorption properties, ink area coverage, and lamp intensity, and the like considerations, with the aid of, for example, a unicure radiometer by measuring power per unit area, such as in the range of about 0.25 Joules per square centimeter to about 2.0 Joules per square centimeter. In embodiments the radiation or photo-cure adhesive can be, for example, a UV pressure sensitive adhesive (PSA), which can, for example, post cure to a tough, durable but flexible solid. In embodiments the photo-cure adhesive can be, for example, electron beam curable.

In the foregoing processes the backing sheet alternatively can be a second transparent sheet, for example, identical or similar to the first transparent sheet to provide a two-sided or double-sided transparent article with an optional transparent, semi-transparent or opaque core. The alternative transparent backing sheet can be a second sheet having a first smooth side and a second side having a lenticulated region and wherein the first smooth side of the transparent backing sheet optionally contacts the adhesive layer before combining with the imaged transparent sheet. Thus the present invention in embodiments provides a process for making an lenticular card article comprising:

providing a first transparent sheet having a first smooth side and a second side with a lenticulated region, the transparent sheet having a printed image on the first smooth side and an adhesive layer over the printed image areas and non-image areas of the first smooth side; and

combining by nipping a second transparent sheet having a first smooth side and a second side with a lenticulated region together with the first transparent sheet on the adhesive layer side of the first transparent sheet, wherein the first smooth side second transparent sheet contacts the adhesive layer.

In the above-mentioned processes the backing sheet can be, for example, paper, resin, plastic, glass, rubber, metal, alloy, or combinations thereof. In the above-mentioned processes the backing sheet can be, for example, polystyrene, polyvinyl chloride (PVC), PVC laminated polystyrene, compression laminated polystyrene, compression laminated PVC, polyester, polyolefins such as polyethylene, polypropylene, and the like, ABS, acrylics, epoxies, polyurethanes, polycarbonates, or combinations or laminates thereof. In the above mentioned processes the backing sheet can be, for example, opaque, transparent or semi-transparent. In the above-mentioned processes the transparent sheet can be configured in the processing machinery as a continuous web. Similarly, the backing sheet can be configured in the processing machinery as a continuous web.

The above mentioned processes can optionally further comprise applying a primer layer to the smooth side of the transparent sheet prior to applying an image layer or the adhesive layer. The above mentioned processes can optionally further comprise applying a primer layer to the backing sheet prior to applying an image layer or the adhesive layer. The above mentioned processes can optionally further comprise applying a primer layer to the backing sheet after applying an image layer or the adhesive layer. Various primer or adhesion promoter compositions are commercially available, and one skilled in the art can readily select a particular adhesion promoter composition for use in the present invention depending upon, for example, the composition of the base film layers contacted and the particular formulation of the adhesive selected, such as a thermosetting resin. An example of a primer layer is 16330 UV curable primer containing a benzophenone initiator, which primer is commercially available from Northwest Coatings Corp., Oak Creek, Wis. The primer layer when applied to the lenticular sheet or backing sheet can provide superior adhesion of the ink and adhesive layer to either sheet and provide a superior destructive bond between adjacent layers. In the above mentioned processes the transparent sheet can be, for example, from about 10 mils to about 26 mils thick and the backing sheet can be from about 4 mils to about 20 mils thick. The printed image areas are preferably printed in "reverse-read" or "wrong-read" format, that is, reversed, backwards, or mirror image, such that the resulting image when viewed through the outer surface of the transparent lenticular sheet by an observer or machine sensor is "right-read" such that the highest possible original image fidelity is retained in the observed printed image. The printed image areas preferably include a colored ink, for example, one or more conventional litho-ink formulations or UV curable inks. The printed image areas can include one or many colored inks, such as from 2 to about 10 different colored inks, for example, with a single primary color (R, G, B), four color process color (C, M, Y, K), white (W), a custom or spot color, such as those known colors available from PANTONE®, and the like suppliers, and combinations thereof.

In the above mentioned processes the adhesive can be applied to either or both the transparent sheet or the backing sheet with any suitable means, for example, a roll coater, spray coater, a curtain coater, and like devices, and preferably a screen press through a screen.

In the above mentioned processes the nipping the paired sheets with a nip roller can be accomplished, for example, with a nip roller pair which applies, for example, from about 10 to about 1,000 p.s.i. The applied pressure can be from about 0 to about 10 bar, for example, a typical and suitable operating pressure is from about 7 to about 8.5 bar. The above processes can further include an optional core sheet interposed between the transparent sheet and the backing sheet and as illustrated herein. The core sheet can be transparent, semi-transparent, or opaque. The above processes can further include where the resulting combined sheets are cut or punched into individual finished pieces, for example, with an on-line slitter or punch press.

In embodiments the present invention provides a lenticular card prepared by the process according to any one of the above mentioned processes comprising:

an imaged transparent sheet having a first front surface with a smooth region and a lenticulated region, and a second rear surface bearing an image;

a core sheet bonded to the transparent sheet with an adhesive; and

a backing sheet bonded to the core sheet with an adhesive.

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The lenticular card article prepared by the above process can further comprise where the resulting card can be a secure card article which can be tamper resistant, tamper evident, or both, and which features are known to those skilled in the art and which feature or features can be readily incorporated in the manufacture of the above mentioned lenticular card article, for example, in materials of construction, processing, finishing, or application. The lenticular card article prepared by the above process can further comprise including an image on the non-bonded surface of the backing sheet, for example, an image provided on the outer surface of the card article, such as a thermal image, an ink jet image, an encodable magnetic stripe, and the like marking technologies.

The lenticular card article prepared by the above processes can have, for example, a thickness of from about 10 to about 40 mils, such as preferably a thickness of about 30 mils plus or minus about 1.5 mils, and a finished trim size, for example, of about 3 1/4 inches wide by about 2 1/4 inches high. The front surface of the transparent sheet can be, for example, extruded and can include a front surface with both one or more lenticulated regions and one or more smooth regions. In embodiments the surface area of the front surface of the transparent sheet can be, for example, about one half lenticulated region and about one half smooth region. In other embodiments the front surface can be, for example, from about 10 to about 75 percent lenticulated region and from about 90 to about 25 percent smooth region.

Referring to the Figures, FIG. 1 illustrates a lenticular card embodiment of the present invention. Backing sheet 20, for example, an opaque or clear plastic such as a vinyl laminate layer, is coated with an adhesive layer 30, for example but not limited to, a glue or resin formulation. An optional core sheet 35 (not shown), for example, an opaque or clear plastic sheet, can be situated between adhesive layer 30 and image layer 40. It is understood that when an optional core sheet 35 is present a second adhesive layer 37 (not shown) is preferred between core sheet 35 and the image layer 40. Image layer 40 can be, for example, a curable ink. The lenticular top sheet 50 can be, for example, a clear plastic sheet. An optional primer layer (not shown) can be interposed between layers 20-30, 30-40, or 40-50.

In FIG. 2 there is shown a perspective view of an exemplary card 200 having a top or outer surface with both a partial lenticular area and a partial smooth area. The partial lenticulated surface area can be formed by limiting or restricting the lenticulation formation process, for example, to one side, to restricted areas of the top surface of the card, and like approaches. Card 200 is shown with a portion of the top surface with partial lenticulated surface area 220, and a portion of the top surface with a partial smooth surface area 230.

FIG. 3 shows a sectional view of a card 300 having a dual or two-sided lenticular outer surface 310, that is where both the top outer surface and a bottom outer surface are partially or completely lenticular or lenticulated. The lenticular top outer surface 310 and the lenticular bottom outer surfaces 310 can be transparent or translucent and constructed of, for example, a clear plastic. Printed image layer 320 can be, for example, a conventional based printing ink or a UV curable ink or inks. Adhesive layer 330 can be, for example, a resin, a glue, a curable polymer, or like materials. An optional primer layer (not shown) can be, for example, interposed between layers 310 and 320. It will be readily understood that a card having the two-sided lenticular surface or len-

ticular surfaces as illustrated here, both sides as in FIG. 3 can have complete or partial lenticulation areas on either or both outer surface as suggested for the one-sided lenticular surface in FIG. 2. The card 300 can have an optional core sheet (not shown) situated between adhesive layers 330 on both sides.

EXAMPLE I

Lenticulated Card No. 1.

Materials and Layer Specifications

Transparent Sheet: 18 mils 75 LPI APET Clear Lens

Image Inks: 4-Color Process UV litho-inks; 1 Hit Opaque White UV litho-ink

Core Sheet: 10 mils white opaque polystyrene

Adhesive: solvent based moisture urethane adhesive

Backsheet: 2 mils clear PVC laminating film

The core sheet and the backsheet were fused together in a compression laminator, for example, with a platen with thermal heating on the 2 mils clear PVC laminating film. The adhesive failed when PVC was used as the backsheet, that is, the moisture cure urethane used in this experiment did not satisfactorily bond to the PVC.

Process 1

A transparent sheet of 18 mils clear 75 LPI APET (polyester) lenticular lens was printed with an interlaced animated image matching the frequency of the 75 LPI pitch lenticular lens. The lens used could be made thicker or thinner and made from polymer materials other than APET polyester, including but not limited to, for example, vinyl, PETG, polycarbonate, and like materials. Inks were printed on the transparent sheet using a litho press configured with UV lamps, such as metal halide or mercury lamps, and irradiation from the UV lamps was used to cure the printed inks.

One or more process colors or PANTONE® Matching System (PMS, i.e. a color standard for non-process colors) colors can be printed in conjunction with, or in place of, the 4-color process image. The total thickness of the imaged transparent sheet, that is, the lenticular sheet plus printed image(s) is about 18 mils. The styrene core has two bonding surfaces. One of its surfaces contacts the adhesive that adheres the core sheet to the printed lenticular sheet. The other surface can optionally have one or more image colors and is laminated with a clear vinyl laminate sheet which seals the printed image colors. The laminated vinyl surface, as either the backsheet or optional core, provides a flat surface for additional optional thermal imaging and can withstand heat from either or both application of a hot stamped magnetic image and heat from thermal imaging processes. The styrene core sheet used was 10 mils white opaque litho-grade polystyrene. A thinner or thicker polystyrene layer can be used as long as the combined thickness of the total construction of the vinyl laminate, polystyrene, and the printed lenticular sheet, including all adhesive layers is approximately 30 mils to satisfy, for example, ISO/IEC card standards. The polystyrene core sheet used was matte/matte finish, however matte/gloss or gloss/gloss combination finishes could alternatively be used. The polystyrene core sheet was printed with one or more colors on its backside with litho UV inks using, for example, a UV configured printing press. The resulting printed or imaged polystyrene core sheet was thereafter compression laminated on its back side with a 2 mils thick vinyl compression laminating film. The film was matte/matte finish and had a heat activated adhesive applied to one side. After compression lamination, the resulting printed and laminated polystyrene sheets were registered and square cut to match the layback and guide of the printed lenticular sheet. Ideally, the

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size of the cut polystyrene and lenticular sheet should be approximately the same size. A solvent-based (ethyl acetate) moisture cure urethane AV6370/with CA600 catalyst, available from Pierce and Stevens, was screen printed at about 50% solids on the printed lenticular sheet, using a 137 Mesh screen. However, it is noted that other moisture cure urethane or solvent-less urethane adhesives could alternatively be used. Although the application method for the adhesive used was a screen press, it is noted that, for example, a roll coater, rotary letter press, rotary screen press, curtain coater, and the like coater devices and coating methods could also be used. The combined vinyl laminate and the polystyrene core sheets were transported, adhesive side up, with a conveyor to a heat tunnel and heated to activate the adhesive upon reaching a temperature of about 160 degrees ° F. and to flash solvents from the adhesive layer. It is readily appreciated that some moisture cure urethanes do not need to be activated with elevated temperatures and that room temperature may be satisfactory to accomplish activation. After solvent was removed, the adhesive was a tacky pressure sensitive adhesive. The adhesive activated sheets were then transported to an air conditioner unit to remove excess heat that can cause distortion in the plastic. Adhesive activated sheets mounted without this cooling step tended to warp if mounted warm. Adhesive activated sheets were then combined, that is mounted, with the lenticulated sheet and passed through a nip roller. The sheets were jogged to a common guide and gripper so the lenticulated sheet image matched the combined backing sheet copy within a reasonable tolerance, for example, of about plus or minus 0.015 inches. The sheets were stacked and left at ambient temperatures of about 25° C. to complete polymerization and full cure. The specified full cure for the adhesive was between about 48 and about 96 hours. Final cure was tested by the pull strength of the bond. Piece parts corresponding to cards were then punched from the cure composite sheet using a Print Machinery Company (PMC) die, that is a hollow steel die process. The resulting cards were then magnetically striped by applying a one-half inch wide magnetic film using a Franklin Hot stamped magnetic film applicator machine. An alternative process includes laminating the styrene core using a flush magnetic laminate film wherein the magnetic material is incorporated into the laminate to eliminate a separate step of applying a magnetic strip. Cards were then thermally imaged and encoded using a Data Card Machine. The adhesive bond strength of the resulting cards of this Example was less satisfactory, for example, in curing, or with vinyl or polyester backing materials compared with other backing materials such as styrene.

EXAMPLE II

Lenticulated Card No. 2.

Materials and Layer Specifications

Transparent Sheet: 18 mils 75 LPI APET Clear Lens

Image Inks: 4-Color Process UV litho-inks; 1 Hit Opaque White UV litho-ink; Black Ink-UV Cured

Adhesive: UV Curable Radcure 10PSA-B (a 2-part pressure sensitive adhesive that cures to a solid over time)

Core Sheet: 10 mils white opaque polystyrene core

Adhesive: UV Curable Radcure 10PSA-B

Backing Sheet: 2 mils clear PVC laminating film

Note: this adhesive system failed to provide a destructive bond when PVC was used as the backing sheet.

Process 2

The process of Example I was repeated with the exception that a UV curable pressure sensitive adhesive (PSA), Radcure 10 PSA-B, a two-part adhesive, was mixed according

to manufacturer recommendations and was screen printed on the printed lenticular sheet, using a 137 Mesh screen. UV light irradiation was used on a 30 inch wide web running at 60 feet per minute and using two 300 Watts per inch medium pressure mercury vapor UV lamps to activate the adhesive layer, and the adhesive became pressure sensitive. The plastic polystyrene core was then mounted to the lenticular sheet bearing the adhesive and then combined with the vinyl backing sheet using the same adhesive used between the core and backer sheet, and the combined backer, core, and lenticular sheets were nipped together with a nip roller. Over time, of about 24-48 hours, the adhesive post cured to a flexible solid. The sheets were transported; adhesive side up, via a conveyor to expose the adhesive to the manufacturer's recommended amount of UV light. The core sheet, 10 mils laminated on one side with 2 mils laminating film bearing the activated adhesive, was mounted to the imaged lenticular sheet and run through a nip roller. The sheets were jogged to a common guide and gripper so the lens image matched the back copy within a reasonable tolerance. The sheets were stacked and left to polymerize to full cure. For this adhesive a period of 48 hours was specified. Final cure strength was tested by pull strength of the bond. Piece Parts were made as punched cards; the cards were magnetically striped and thermally imaged and encoded as in Example 1. Analysis of the resulting cards indicated that the UV adhesive used in this process did not work as well for curing to a vinyl or polyester backing sheets compared to a superior result for a polystyrene backing. About 500,000 cards were produced with this process.

EXAMPLE III

Lenticulated Card No. 3.

Materials and Layer Specifications

Transparent Sheet: 18 mils 75 LPI APET Clear Lens (Alternatively, a PVC lens was used and did not have curl as was the situation with an APET and PVC backing combinations)

Image Inks: 4-Color Process UV litho-inks; 1 Hit Opaque White UV litho-ink; Black Ink-UV Cured

Adhesive: UV activated acrylate urethane adhesive (for example Dymax 3-3094, a polyurethane oligomer mixture commercially available from Dymax Corp., Torrington, Conn.)

Core Sheet: 8 mils White PVC Core

Adhesive: UV activated acrylate urethane (Dymax 3-3094)

Backing Sheet: 2 mils clear PVC laminating film (applied to both sides of an 8 mils white PVC core)

This adhesive worked well and provided a desired destructive bond when PVC was used as the backing sheet which sheet could be either laminated or non-laminated.

Process 3

The process of Example II was repeated with the exception that an alternative UV curable acrylate-urethane adhesive was screen printed on the preprinted lenticular sheet, using a 230 Mesh screen. Dymax 3-3094, a one-part adhesive was screen printed on the laminated PVC backing. The adhesive was activated after mounting the lenticular and the core sheets together. The adhesive could be cured instantly, for example, by one or more UV lamp(s) flood outputting with 365 nm wavelength of UV light, even if the radiation cure was through a partially translucent, that is semi-opaque with a relative opacity of about 30 percent, such as a printed lenticular sheet imaged with 1-color opaque white. After the nip roller, the sheets were conveyed with the printed lens on top, and exposed to the manufacturer's recommended dose of UV light. UV dose levels were determined experimentally with both 300 Watt lamps at maximum illumination. The

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dose levels can depend on a number of factors, such as belt speed and the color adsorption properties and the amount of inks used. An adhesive bond formed instantly. The sheets were stacked. Piece parts were made by punching cards. The punched cards were magnetically striped and thermally imaged and encoded as in Example 1. To meet the ISO/IEC specification a test was to bend the corners of the card, repeatedly back and forth, until the backing or the lens cracked but before layers separated. The cards prepared and tested in this example showed no layer separation prior to cracking.

EXAMPLE IV

2-Sided Lenticulated Card No. 4.

Materials and Layer Specifications

Transparent Top Sheet: 18 mils 75 LPI APET Clear Lens

Image Inks: 4-Color Process UV litho-inks; 1 Hit Opaque

White UV litho-ink;

Black Ink-UV Cured

Adhesive: UV activated acrylate urethane adhesive (Alternatively, Dymax adhesive could be used here in combination with any of the core materials, or a moisture cure adhesives such as the urethanes could be used with, for example, polystyrene or polyester cores)

Optional Core Sheet: 8 mils White PVC Core or an 8 mils White polystyrene core (un-laminated)

Optional Adhesive: UV activated acrylate urethane adhesive if Optional Core Sheet is used

Image Inks: 4-Color Process UV litho-inks; 1 Hit Opaque White UV litho-ink; Black Ink-UV Cured

Backing Sheet or Transparent Bottom Sheet: 18 mils 75 LPI APET Clear Lens (same as the Transparent Top Sheet)

Process 4

The process of Example II was repeated with the exception that the backer sheet was a lenticular sheet. All of the above mentioned adhesives are satisfactory here.

All cited publications, patents, and patent documents are incorporated by reference herein in their entirety. The invention has been described with reference to various specific and preferred embodiments and techniques. However, it should be understood that many variations and modifications may be made while remaining within the spirit and scope of the invention.

What is claimed is:

1. A process for making a lenticular card comprising:

providing an imaged transparent sheet having a first smooth side and a second side with a lenticulated region, the transparent sheet having at least one printed image area on the first smooth side and a moisture cure adhesive layer over the printed image areas and non-image areas of the first smooth side, and the moisture cure adhesive layer being applied with a screen press through a screen;

combining the imaged transparent sheet on the adhesive layer side of the transparent sheet with a backing sheet by nipping the paired sheets with a nip roller; and post-curing the adhesive layer with heating.

2. The process according to claim 1 wherein the backing sheet is a second transparent sheet having a first smooth side and a second side having a lenticulated region and wherein the first smooth side of the transparent backing sheet contacts the adhesive layer before combining with the imaged transparent sheet.

3. The process according to claim 1 wherein the backing sheet is paper, resin, plastic, glass, rubber, metal, alloy, or combinations thereof.

4. The process according to claim 1 wherein the backing sheet is polystyrene, polyvinylchloride (PVC), PVC lami-

nated polystyrene, compression laminated polystyrene, compression laminated PVC, polyester, polyolefins, or combinations or laminates thereof.

5. The process according to claim 1 further comprising including a core sheet interposed between the transparent sheet and the backing sheet wherein the core sheet bears or contacts an adhesive layer on both sides of the core sheet.

6. The process according to claim 1 further comprising wherein the resulting combined sheets are cut or punched into individual finished pieces.

7. A lenticular card prepared by the process according to claim 1 comprising:

an imaged transparent sheet having a first front surface with a smooth region and a lenticulated region, and a second rear surface bearing an image;

a core sheet bonded to the transparent sheet with an adhesive; and

a backing sheet bonded to the core sheet with an adhesive.

8. The card according to claim 7 wherein the resulting card is a secure card article which is tamper resistant, tamper evident, or both.

9. The card according to claim 7 further comprising an image on the non-bonded surface of the backing sheet.

10. The card according to claim 7 wherein the image is a thermal image.

11. The card according to claim 7 wherein the image is an ink jet image.

12. The card according to claim 7 wherein the image is an encodable magnetic stripe.

13. The card according to claim 7 wherein the card has a thickness of from about 10 to about 40 mils.

14. The card according to claim 7 wherein the card has a thickness of about 30 mils plus or minus about 1.5 mils.

15. The card according to claim 7 wherein the card has a finished trim size of about 3 1/4 inches wide by about 2 1/4 inches high.

16. The card according to claim 7 wherein the front surface of the transparent sheet is extruded and includes a front surface with a lenticulated region and a smooth region.

17. The card according to claim 7 wherein the surface area of the front surface of the transparent sheet is about one half lenticulated region and about one half smooth region.

18. The card according to claim 7 wherein the front surface is from about 10 to about 75 percent lenticulated region and from about 90 to about 25 percent smooth region.

19. The lenticular card according to claim 7 further comprising a magnetic stripe on the non-bonded side of the backing sheet.

20. A process for making a lenticular card comprising:

providing an imaged transparent sheet having a first smooth side and a second side having a lenticulated region, the transparent sheet having a printed image on the first smooth side and a radiation curable adhesive layer over the printed image areas and non-image areas of the first smooth side, and the radiation curable adhesive layer being applied with a screen press through a screen;

activating the radiation curable adhesive by irradiating the adhesive layer; and

combining a backing sheet with the transparent sheet on the resulting activated adhesive layer side of the transparent sheet by nipping the paired sheets with a nip roller.

21. The process according to claim 20 wherein the irradiating is accomplished by focused or unfocused ultraviolet light.

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22. The process according to claim 20 wherein the irradiating cures the adhesive in from about 1 to about 20 seconds.

23. The process according to claim 20 wherein the adhesive is a UV pressure sensitive adhesive (PSA).

24. The process according to claim 20 wherein the adhesive is electron beam curable.

25. A process for making a lenticular card comprising: providing an imaged backing sheet having a first side and a second side, the backing sheet having a printed image on one side and a moisture cure urethane adhesive layer over the printed image areas and non-image areas of the imaged side;

combining the backing sheet on the adhesive layer side with the first side of a transparent sheet having a first smooth side and a second side having a lenticulated region by nipping the paired sheets with a nip roller; and

past-curing the adhesive layer with heating.

26. A process for making a lenticular card comprising: providing an imaged transparent sheet having a first smooth side and a second side with a lenticulated region, the imaged transparent sheet having a printed image on the first smooth side;

providing a backing sheet with a radiation curable urethane adhesive layer on one side of the backing sheet;

combining the backing sheet with the imaged transparent sheet to form a composite sheet by nipping the paired sheets with a nip roller, the adhesive layer on the smooth side of the transparent sheet being interposed between the backing and transparent sheets; and

irradiating the adhesive layer within the resulting composite sheet by directing radiation through the transparent sheet side of the composite sheet wherein the irradiating is accomplished by focused or unfocused ultraviolet light.

27. The process according to claim 26 wherein the irradiating cures the adhesive in from about 1 to about 20 seconds.

28. The process according to claim 26 wherein the adhesive is a UV pressure sensitive adhesive (PSA) or a UV acrylate urethane adhesive.

29. The process according to claim 26 wherein the adhesive is electron beam curable.

30. A lenticular card prepared by a process comprising: providing an imaged transparent sheet having a first smooth side and a second side with a lenticulated region, the transparent sheet having at least one printed image area on the first smooth side and a moisture cure adhesive layer over the printed image areas and non-image areas of the first smooth side, and the moisture cure adhesive layer being applied with a screen press through a screen; and

combining the imaged transparent sheet on the adhesive layer side of the transparent sheet with a backing sheet by nipping the paired sheets with a nip roller.

the lenticular card comprising:

an imaged transparent sheet having a first front surface with a smooth region and a lenticulated region, and a second rear surface bearing an image; and

a backing sheet bonded to the imaged transparent sheet with an adhesive, wherein the card has a thickness of from about 10 to about 40 mils.

31. A lenticular card prepared by a process comprising: providing an imaged transparent sheet having a first smooth side and a second side with a lenticulated

region, the transparent sheet having at least one printed image area on the first smooth side and a moisture cure adhesive layer over the printed image areas and non-image areas of the first smooth side, and the moisture cure adhesive layer being applied with a screen press through a screen; and

combining the imaged transparent sheet on the adhesive layer side of the transparent sheet with a backing sheet by nipping the paired sheets with a nip roller,

the lenticular card comprising:

an imaged transparent sheet having a first front surface with a smooth region and a lenticulated region, and a second rear surface bearing an image; and

a backing sheet bonded to the imaged transparent sheet with an adhesive, wherein the card has a thickness of about 30 mils plus or minus about 1.5 mils.

32. A lenticular card prepared by a process comprising:

providing an imaged transparent sheet having a first smooth side and a second side with a lenticulated region, the transparent sheet having at least one printed image area on the first smooth side and a moisture cure adhesive layer over the printed image areas and non-image areas of the first smooth side, and the moisture cure adhesive layer being applied with a screen press through a screen; and

combining the imaged transparent sheet on the adhesive layer side of the transparent sheet with a backing sheet by nipping the paired sheets with a nip roller,

the lenticular card comprising:

an imaged transparent sheet having a first front surface with a smooth region and a lenticulated region, and a second rear surface bearing an image; and

backing sheet bonded to the imaged transparent sheet with an adhesive, wherein the card has a finished trim size of about 3 1/4 inches wide by about 2 1/4 inches high.

33. A lenticular card prepared by a process comprising:

providing an imaged transparent sheet having a first smooth side and a second side with a lenticulated region, the transparent sheet having at least one printed image area on the first smooth side and a moisture cure adhesive layer over the printed image areas and non-image areas of the first smooth side, and the moisture cure adhesive layer being applied with a screen press through a screen; and

combining the imaged transparent sheet on the adhesive layer side of the transparent sheet with a backing sheet by nipping the paired sheets with a nip roller,

the lenticular card comprising:

an imaged transparent sheet having a first front surface with a smooth region and a lenticulated region, and a second rear surface bearing an image; and

a backing sheet bonded to the imaged transparent sheet with an adhesive, wherein the front surface of the transparent sheet is extruded and includes a front surface with a lenticulated region and a smooth region.

34. A lenticular card prepared by a process comprising:

providing an imaged transparent sheet having a first smooth side and a second side with a lenticulated region, the transparent sheet having at least one printed image area on the first smooth side and a moisture cure adhesive layer over the printed image areas and non-image areas of the first smooth side, and the moisture cure adhesive layer being applied with a screen press through a screen; and

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combining the imaged transparent sheet on the adhesive layer side of the transparent sheet with a backing sheet by nipping the paired sheets with a nip roller,

the lenticular card comprising:

an imaged transparent sheet having a first front surface with a smooth region and a lenticulated region, and a second rear surface bearing an image; and

a backing sheet bonded to the imaged transparent sheet with an adhesive, wherein the surface area of the front surface of the transparent sheet is about one half lenticulated region and about one half smooth region.

35. A lenticular card prepared by a process comprising:

providing an imaged transparent sheet having a first smooth side and a second side with a lenticulated region, the transparent sheet having at least one printed image area on the first smooth side and a moisture cure adhesive layer over the printed image areas and non-image areas of the first smooth side, and the moisture cure adhesive layer being applied with a screen press through a screen; and

combining the imaged transparent sheet on the adhesive layer side of the transparent sheet with a backing sheet by nipping the paired sheets with a nip roller,

the lenticular card comprising:

an imaged transparent sheet having a first front surface with a smooth region and a lenticulated region, and a second rear surface bearing an image; and

a backing sheet bonded to the imaged transparent sheet with an adhesive, wherein the front surface is from about 10 to about 75 percent lenticulated region and from about 90 to about 25 percent smooth region.

36. A process for making a lenticular card comprising:

providing an imaged transparent sheet having a first side and a second side with a lenticulated region, the transparent sheet having at least one printed image area on the first side and a moisture cure urethane adhesive layer over the printed image areas and non-image areas of the first side; and

combining the imaged transparent sheet on the adhesive layer side of the transparent sheet with a backing sheet by nipping the paired sheets with a nip roller wherein the resulting lenticular card is tamper resistant, tamper evident, or both.

37. A process for making a lenticular card comprising: providing an imaged backing sheet having a first side and a second side, the backing sheet having a printed image on one side and a moisture cure urethane adhesive layer over the printed image areas and non-image areas of the imaged side; and

combining the backing sheet on the adhesive layer side with the first side of a transparent sheet having a first side and a second side having a lenticulated region by nipping the paired sheets with a nip roller wherein the resulting lenticular card is tamper resistant, tamper evident, or both.

38. A process for making a lenticular card comprising:

providing an imaged transparent sheet having a first side and a second side with a lenticulated region, the transparent sheet having at least one printed image area on the first side and a moisture cure urethane layer over the printed image areas and the non-image areas of the first side; and

combining the imaged transparent sheet on the moisture cure urethane layer side of the transparent sheet with a backing sheet by nipping the paired sheets with a nip roller.

39. The process according to claim 38 wherein the moisture cure urethane layer is applied by a roll coater, spray coater, a curtain coater, or a screen press.

40. The process according to claim 38 wherein the backing sheet includes a magnetic stripe.

41. A process for making a lenticular card comprising:

providing an imaged backing sheet having a first side and a second side, the backing sheet having a printed image on one side and a moisture cure urethane layer over the printed image areas and non-image areas of the imaged side; and

combining the backing sheet on the moisture cure urethane layer side with the first side of a transparent sheet having a non-lenticulated first side and a second side having a lenticulated region by nipping the paired sheets with a nip roller.

42. The process according to claim 41 wherein the moisture cure urethane layer is applied by a roll coater, spray coater, a curtain coater, or a screen press.

43. The process according to claim 41 wherein the backing sheet includes a magnetic stripe.

* * * * *

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Magee

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(45) Date of Patent: ***Mar. 22, 2005**

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(54) **DIRECTIONAL IMAGE TRANSMISSION SHEET AND METHOD OF MAKING SAME**

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(73) Assignee: **University of Arkansas, N.A., Little Rock, AR (US)**

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 1115 days.

This patent is subject to a terminal disclaimer.

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(22) Filed: **Jun. 25, 1997**

Related U.S. Application Data

(63) Continuation-in-part of application No. 08/227,055, filed on Apr. 13, 1994, now Pat. No. 5,644,431, which is a continuation-in-part of application No. 09/948,109, filed on Sep. 21, 1992, now Pat. No. 5,303,525.

(51) Int. Cl.⁷ **G02B 27/10**

(52) U.S. Cl. **359/626; 359/619**

(58) Field of Search **359/619, 626, 359/621, 622, 623, 454, 455, 458; 40/454**

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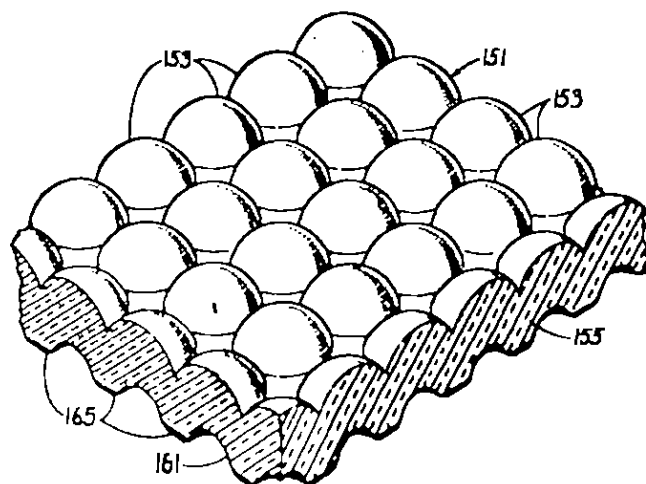
Primary Examiner—Rick Mack

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(57) **ABSTRACT**

There is disclosed a partially transparent, directional viewing sheet formed of plastic material with convex and concave lenses of elliptical cross-section, preferably lenticular lenses, formed respectively on the front and back surfaces of the sheet, there being intervening spaces with convex surfaces between the concave lenses which spaces are not transparent to images and may be imprinted with an image that is viewable through the sheet from some directions. Preferably the concave lens focal length is typically about one-half of the focal length of the convex lens. Elliptical cross-section of the lenses minimizes spherical aberration and sharpens the focus. The thickness of the sheet causes focal points of the lenses to substantially coincide producing the effect of a tiny Galilean telescope. The view through such a sheet in a direction substantially aligned with the optical axis of the tiny telescope is a minimally distorted view of objects distant from or near to the opposite side of the sheet while off-axis viewing will present the image imprinted on the intervening convex surfaces between the concave lenses on the back surface of the sheet. Such convex surfaces are preferred over flat surfaces for high speed printing in offset printing presses.

14 Claims, 5 Drawing Sheets



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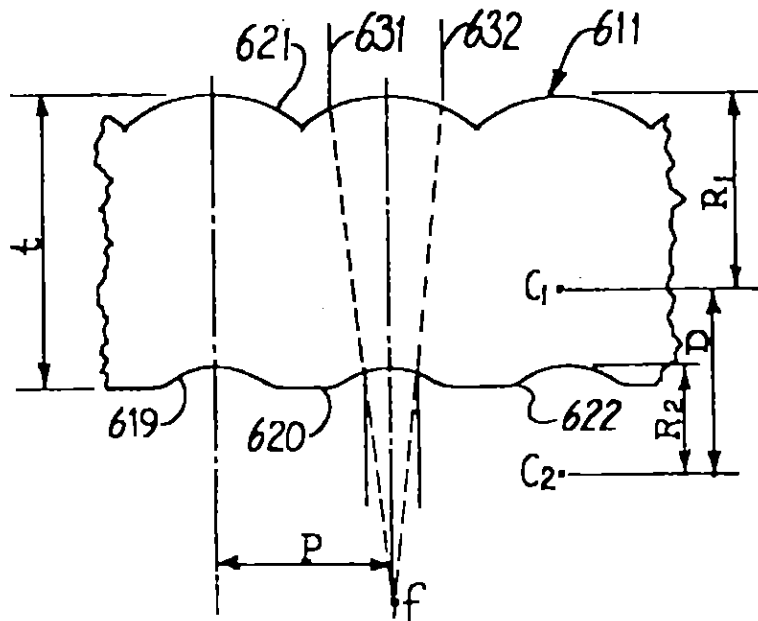


FIG. 1B

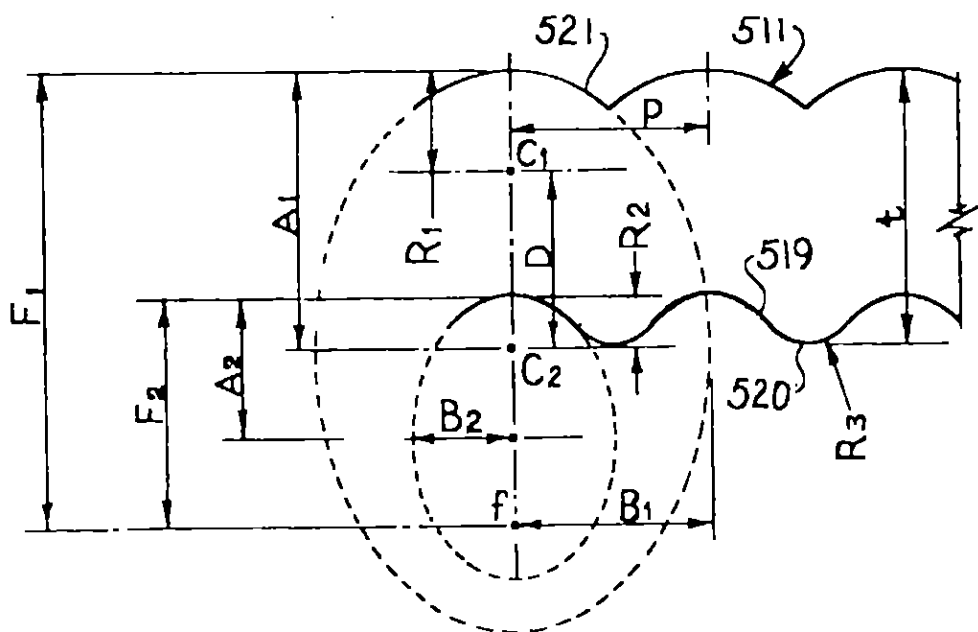


FIG 1A

48
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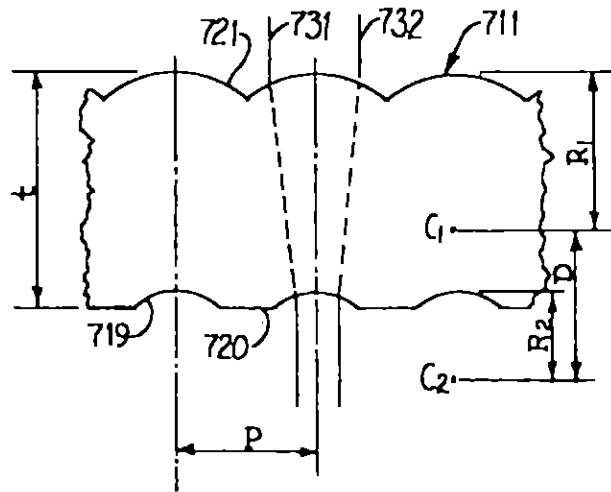


FIG. 1C



FIG. 2

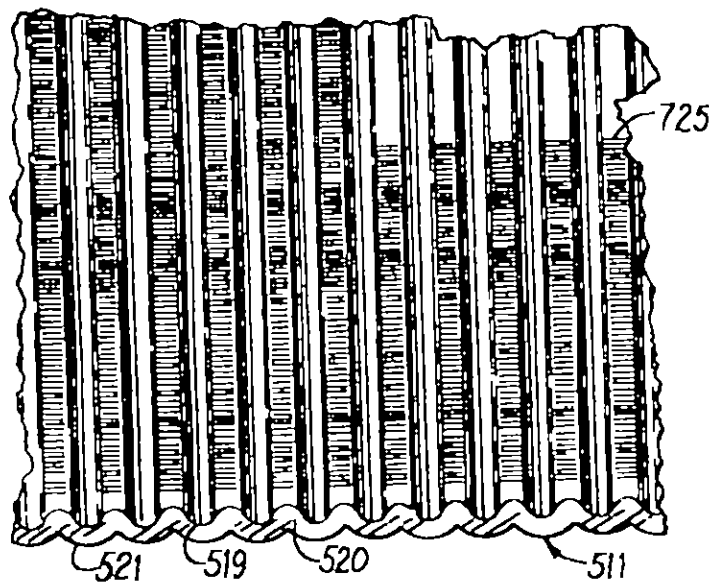


FIG. 3

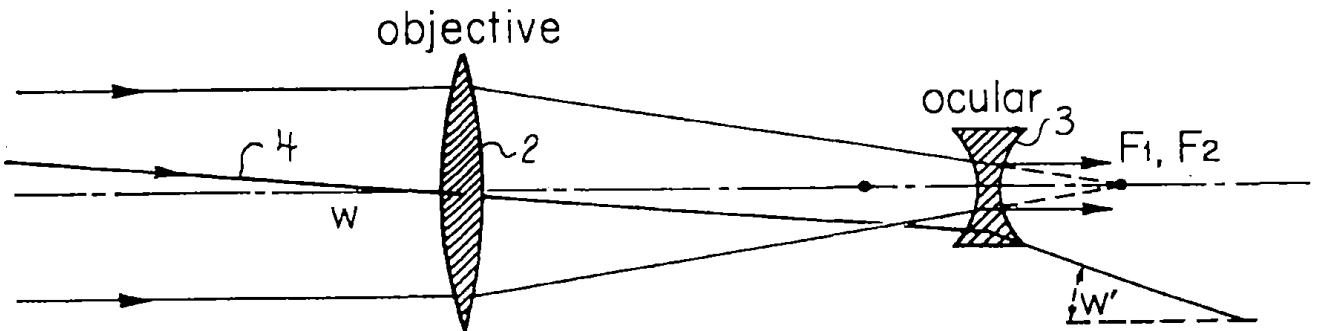


FIG. 4

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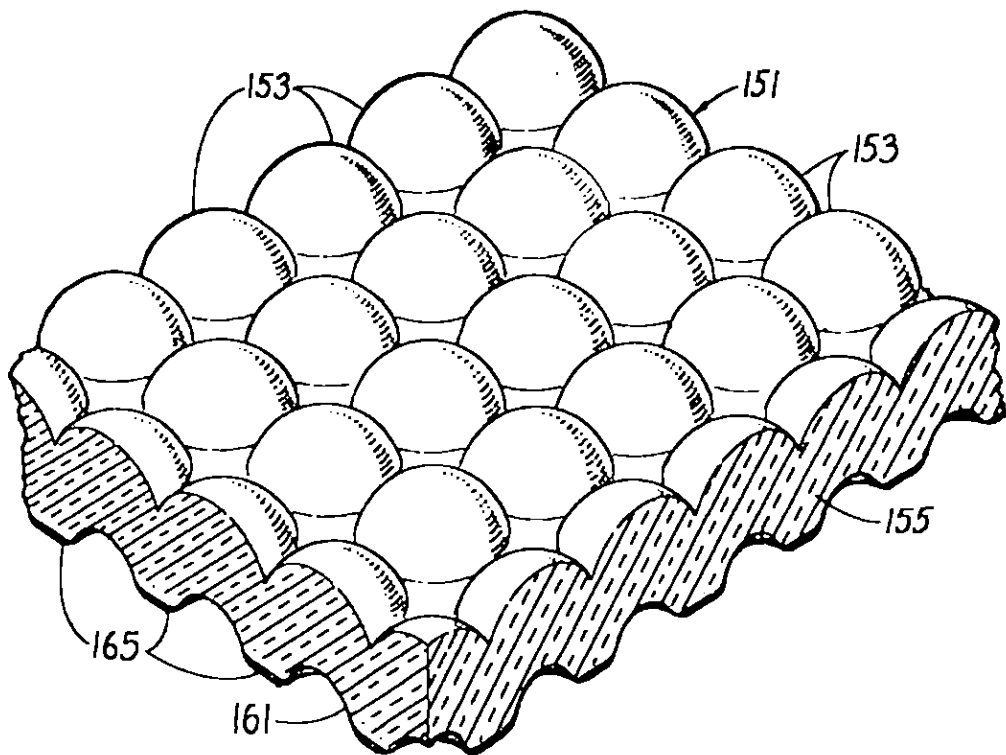


FIG. 5

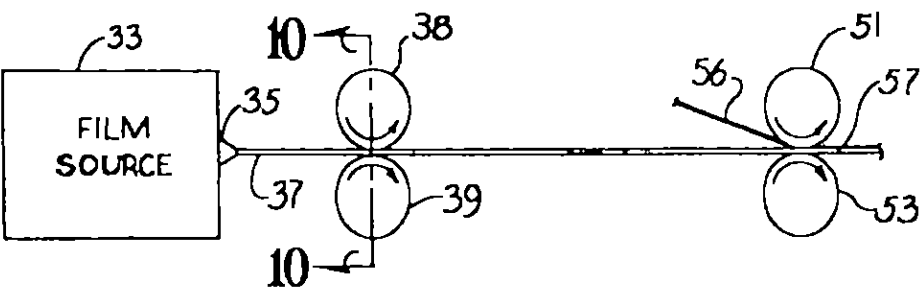


FIG. 6

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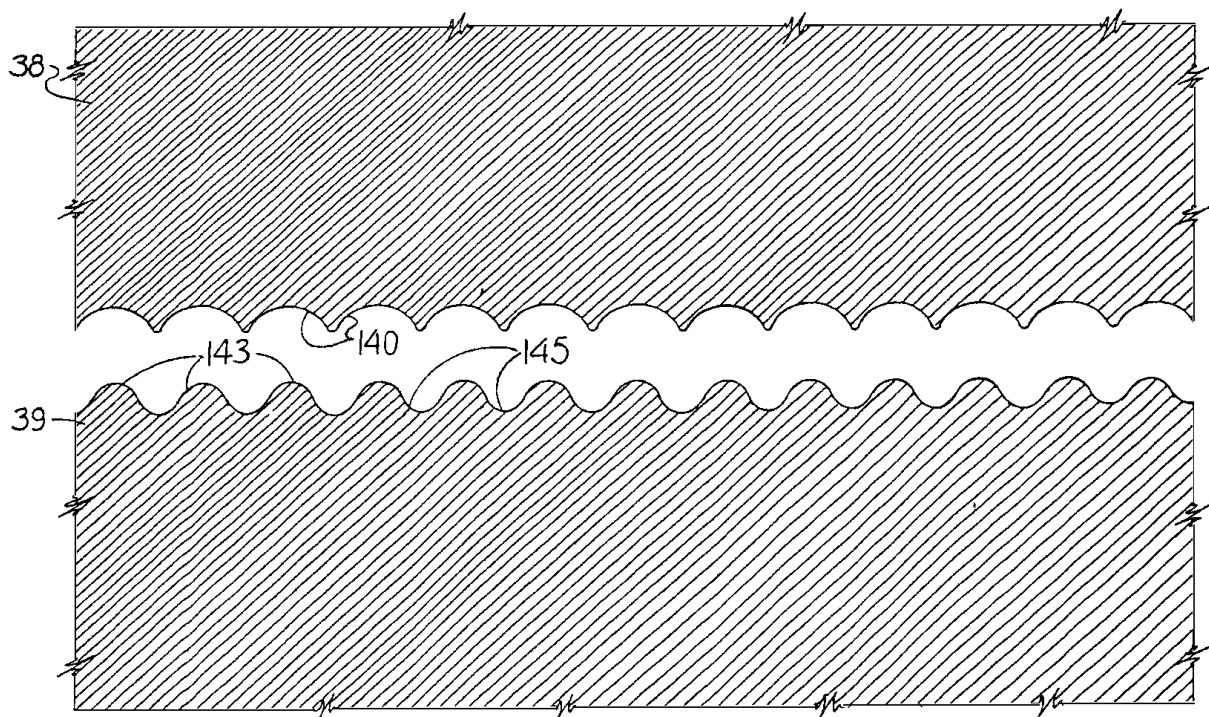


FIG. 7

DIRECTIONAL IMAGE TRANSMISSION SHEET AND METHOD OF MAKING SAME

CROSS-REFERENCE TO RELATED APPLICATION

This application is a continuation-in-part of application titled: DIRECTIONAL IMAGE TRANSMISSION SHEET AND METHOD OF MAKING SAME, Ser. No. 08/227,055, filed Apr. 13, 1994 U.S. Pat. No. 5,644,431 which is a continuation-in-part of Ser. No. 948,109, filed Sep. 21, 1992, now U.S. Pat. No. 5,303,525.

SUMMARY OF THE INVENTION

The present invention relates to transparent or semi-transparent sheets which are configured to transmit certain light energy images having certain directions of propagation while reflecting, absorbing, or modifying images or energy from other directions. Such sheet material is useful for producing panels for controlled solar heating, in controlling light transmission in building windows, in greenhouses, as described in my prior patents but has further uses, for example, for computer display screens, and in imprinted packaging film. The relevant portions of the description of my previous applications or patents identified herein is incorporated by reference.

It has long been known to incorporate lenticular lenses in a surface of thin plastic sheet material and to place a printed image on the opposite surface of the sheet material arranged so that the apparent image as viewed from different directions depends upon the direction of viewing with three or more different images being presented to the viewer as the direction of viewing changes. Such sheet materials have been used to produce moving image novelties and to produce stereoscopic effects and three-dimensional illusions. It has also been known to produce partially transparent film material having opaque striations formed within the sheet to produce the effect of louvers within the transparent sheet material. Such louver simulating material has a high transmission coefficient for light energy in certain directions while having a very low or near-zero light transmission coefficient for other directions. The louver simulating sheet material could have louvers of light absorbing or light reflecting composition. Examples of such prior devices for directional transmission of light energy and images are shown in U.S. Pat. No. 3,653,138 (U.S. Cl. 40/130R) and U.S. Pat. No. 4,021,945 (U.S. Cl. 40/28C). Other disclosures of lenticular lens arrays include my patent for SIDING OR ROOFING EXTERIOR PANELS FOR CONTROLLED SOLAR HEATING, Ser. No. 07/948,109, filed Sep. 21, 1992, now U.S. Pat. No. 5,303,525, and those cited as references in U.S. Pat. No. 5,303,525.

According to the present invention, a transparent or partially transparent sheet material is provided which has convex lenses formed on the front surface and concave lenses formed on the back surface of the sheet. In the preferred embodiments the convex lenses on the front surface will have a larger radius of curvature (and a longer focal length) than the concave lenses on the back surface and will have an elliptical arc (rather than circular) cross-section. Also in the preferred embodiments the convex lenses with the larger radius of curvature will substantially cover the surface on which they are formed with substantially no intervening non-convex surfaces while the concave lenses with the smaller radius of curvature will also have a smaller aperture, and, as they are equal in number to the larger lenses, there will be a space between the small radius lenses

which will normally be a non-concave and at least partially convex surface. This intervening non-concave surface may occupy approximately half the area of the sheet on the back side and may be imprinted by generally conventional printing techniques with a desired monochrome or multi-color image, for example, one suitable for packaging film or incorporation in a product package. As will later be explained, the preferred embodiment of the directional image transmission sheet is capable of presenting an effectively transparent characteristic with a high transmission coefficient and low distortion for viewing from the front in one direction, such as perpendicular to the sheet. When viewed from another direction, such as at a side angle of 45°, the sheet does not appear to be transparent, but rather the printed matter on the back surface of the sheet is visible substantially without distortion.

In addition to providing the features and advantages discussed above, it is an object of the present invention to provide a thin transparent plastic sheet material having convex elliptical cross-section lenses embossed or otherwise formed in a front surface thereof which match one-to-one with concave lenses embossed or otherwise formed in the back surface of the sheet with the effective radii of curvature of the lenses being determined to cause the focal point of each lens on the front surface to substantially coincide with the focal point of the corresponding lens on the back surface whereby a Galilean telescope effect is produced allowing images to be viewed through the sheet material substantially without distortion from a direction perpendicular or nearly perpendicular to the sheet material.

It is another object of the present invention to provide such a sheet material wherein the concave lenses on the back surface of the sheet have a radius of curvature of no greater than about three-quarters the radius of curvature of the convex lenses on the front surface of the sheet.

It is still another object of the present invention to provide such a sheet material wherein the lenses are elongated lenticular lenses arranged in a parallel fashion and wherein the width of the lenses is less than about one millimeter (about 0.04 inches).

It is yet another object of the present invention to provide such a sheet material wherein the lenses on the back surface are concave and of substantially less width than those on the front surface so that there are intervening spaces between the concave lenses, and such surfaces are non-concave and adapted to be imprinted with a solid color or an information imparting pattern which may be viewed only from oblique angles from the front surface of the sheet material.

BRIEF DESCRIPTION OF THE DRAWINGS

Other objects and advantages of the present invention will be apparent from consideration of the following description in conjunction with the appended drawings in which:

FIG. 1-A is a greatly enlarged sectional view of an image transmission sheet material according to the invention;

FIG. 1-B is an alternative embodiment of a greatly enlarged sectional view of an image transmission sheet material according to the invention;

FIG. 1-C is a further alternative embodiment of a greatly enlarged sectional view of an image transmission sheet material according to the invention;

FIG. 2 is a top plan view of sheet material as shown in FIG. 1-A, having advertising graphic material imprinted thereon;

FIG. 3 is a greatly enlarged perspective view from the bottom of the material of FIG. 2, showing the area indicated by 3 in FIG. 2;

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FIG. 4 is an illustration of a prior art Galilean telescope useful in explaining the invention;

FIG. 5 is a greatly enlarged isometric view of another alternative form of sheet material employing spherical rather than lenticular lenses; and

FIG. 6 is a partially schematic illustration of apparatus for producing sheet material according to the invention by a roll embossing process;

FIG. 7 is a greatly enlarged fragmentary sectional view of the embossing roll portion of the apparatus of FIG. 6.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to the drawings and particularly FIGS. 1-A, 2, and 3, a sheet material 511 is shown which is formed of transparent plastic material which may be very flexible, somewhat rigid, or very rigid. Plastic materials that may be employed include polyvinyls, acrylics, or other forms of polymerized organic compounds. While organic plastic composition is preferred for the sheet material 511, it would be possible to implement the invention with sheet material formed of glass, or other inorganic or non-plastic materials. A preferred plastic material is PET-G, index of refraction of 1.567. The primary uses of the invention involve visible light, but its use with infrared or ultraviolet light is not precluded.

The top or first surface of the sheet material 511 has converging lenses 521 formed therein as smooth convex cylindrical protuberances in sheet material 511. The bottom or back surface of the sheet material 511 has lenses 519 formed therein by smooth, concave, cylindrical surfaces acting as diverging lenticular lenses. Lenses 519 and 521 each have an elliptical arc cross-section rather than a circular arc cross-section, as specified in Table 1 below.

The lenses 519 are registered with lenses 521, and in the example of FIG. 1-A, lenses 519 are optically coaxial with lenses 521. Lenses 519 are of lesser width than lenses 521 and the spaces between lenses 519 resulting from this lesser width are generally convex curved surface portions 520.

In FIG. 1-A certain dimensions and locations are assigned reference letters for convenience in explaining the inventions. The overall thickness of the sheet material 511 is designated by t . The center to center spacing of the lenses 521 which is also the center to center spacing of the lenses 519 is designated P . The lenses 521 and 519 in FIG. 1-A are illustrated as being cylinders having precisely elliptical configurations, but it will be understood that similar but more complex non-circular shapes could be employed in accordance with known optical techniques.

In FIG. 1-A the center of curvature of the circular surface of one of the lenses 521 is indicated at C_1 . The center of curvature of the corresponding concave lens 519 circular surface is indicated at C_2 . The corresponding radii of curvature are indicated by reference letters R_1 , and R_2 . The focal point for the lenses 521 and 519 substantially coincide and are indicated at f in FIG. 1-A. In accordance with known optical principles the focal length and focal point may be determined from the effective radius of curvature R_1 , or R_2 and the index of refraction of the material of which sheet 511 is formed.

Although not illustrated in FIG. 1-A (see FIG. 1-B or FIG. 4), parallel rays of light which are caused to converge by lenses 521 will be caused to diverge by lenses 519 by just the amount necessary to restore them to parallelism. This is a consequence of the fact that focal points of the lenses 519 and 521 are approximately coincident.

The optical characteristics and functions of the transparent sheet material illustrated in FIG. 1-A can more readily be understood by considering the schematic diagram of a Galilean telescope shown in FIG. 4. A Galilean telescope normally comprises a single converging objective convex-convex lens 2 and a single diverging ocular convex-concave lens 3. When used as a telescopic viewing device the arrangement in FIG. 4 would view an object far to the left with the viewer's eye placed relatively close at the right of ocular lens 3. For focusing on an object at infinity (a relatively great distance) the distance between the objective lens and ocular lens is adjusted so that the focal point of the objective lens (F_1) substantially coincides with a point F_2 at a distance from the ocular lens equal to the focal length of the ocular lens.

The Galilean telescope provides a limited amount of image magnification equal to the ratio of the longer focal length of the objective lens to the shorter focal length of the ocular lens. This is indicated in FIG. 4 where a ray designated 4 from a distant point is shown to have an angle of incidence W at the objective which after passing through objective 2 and ocular 3 has a substantially greater angle W . The Galilean telescope has a disadvantage of low magnification, but has the advantage of producing an erect image rather than an inverted image. Neither the degree of magnification of the Galilean optical system nor the fact that it presents an erect image is of particular importance in regard to the present invention.

The Galilean telescope has another characteristic which is important, however. The position of the object being viewed and the eye of the viewer can be reversed from that previously described so that the viewer's eye is to the left of the objective and the object to be viewed is to the right of the ocular. In this situation particularly, the distance of the eye of the viewer from the objective 2 is of little consequence. When objects are viewed in this reverse fashion through the Galilean telescope, the image is diminished rather than magnified, but as will be seen, this is not significant as respects the present invention. It should be pointed out that Galilean telescopes have spherical or aspherical lenses whereas the lenses that are described relative to FIGS. 1, 2, and 3, are cylindrical lenticular lenses. Thus, the optical effects described above are observed in only one dimension, and in the dimension at right angles to that one dimension there is essentially no convergence or divergence, or other dominant optical effect for incident rays.

Referring now particularly to FIGS. 2 and 3, FIG. 2 shows the appearance of a large area of sheet 511 on which there has been imprinted an image 723. The image 723 may be any type of decorative or informative graphic or textual information; in FIG. 2 it is represented as product identification as might be used in sheet material used for packaging film. FIG. 2 represents the appearance of sheet material 511 when viewed from a direction that will cause the image 523 imprinted on the back of sheet material 511 to be visible.

FIG. 3 is a perspective view of a greatly enlarged fragmentary portion of the sheet material indicated by the dashed circle and identifying numeral 3 in FIG. 2. In addition to showing the convex lens surfaces 521, the concave lens surfaces 519, and the intervening surfaces 520, imprinting 725 is shown which produces the image 723 seen in FIG. 2 as will be explained hereinafter. It will be noted that the imprint 725 on sheet material 511 is only laid down on portions of the intervening surfaces 520. It will usually be desired to print that portion of the intervening surfaces 520 not within imprint 725 with a white pigment or other background shade or color. Conventional plastic film print-

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ing equipment and techniques may be used for imprinting of sheet material 511 if it is flexible film suitable for packaging.

It has been found to be advantageous to make the intervening spaces 520 with a convex arcuate surface, which may conveniently be a circular arc of from 90° to 150° . The intervening space arc may or may not be tangent to the convex lens arc at the point where they join.

While printing on flat intervening spaces 720 as shown in FIG. 1-C can be accomplished by several various printing methods, presses and methods commonly used for high speed printing of plastic film for packaging or other purposes operate much more effectively on the film sheet 511 illustrated in FIGS. 1-A, 2 and 3 with the intervening spaces 520 of convex arcuate form. Flat intervening spaces create edges or corners at their junction with the convex lens and offset printing processes of high speed presses tend to cause ink to overrun into the lens area. On the other hand, arcuate intervening spaces, such as 520, allow the area to be imprinted to be closely controlled by adjusting pressure of the printing rolls thus avoiding migration of printing ink into the convex lens cavity.

Although it is believed that the function and operation of the directional image transmission sheet 511 is apparent from the previous description, the function may be more fully explained as follows. The convex lenticular lenses 521 and the concave lenticular lenses 519 are proportioned with respect to radius of curvature and are spaced apart by a distance that relates to the index of refraction of the transparent material of sheet 511 in a way such that each pair of lenses 521 and 519 functions in a manner similar to a Galilean telescope (usually, but not always, one focused at infinity).

In FIG. 1-A the center of curvature for the near-circular arc of one of the lenses 521 is indicated at C_1 and the center of curvature of the arc of one of lenses 519 is indicated at C_2 . In the embodiment illustrated in FIG. 1-A the focal points of lenses 521 coincide with the focal points of lenses 519 and one such coincident focal point is indicated at f . It is notable that while one might think it desirable to have the centers of curvature for lenses 721 and 719 be coincident, this is found to be undesirable and substantially inoperative for indices of refraction of common material. Certain useful dimensions are labeled in FIG. 1-A with the thickness of sheet material 511 at its thickest points being designated t , typically $0.0160''$, the effective radius of curvature of lenses 519 being designated R_2 , typically $0.00481''$, and the radius of curvature of lenses 521 being designated R_1 , typically $0.00962''$. The center-to-center distance or pitch of the lenses 521 (and also of the lenses 519) is designated P , typically $0.0125''$. The distance between centers of curvature C_1 and C_2 is designated D . The major semi-axis of the ellipse for a convex lens is A_1 and for a concave lens is A_2 ; the minor semi-axis of the ellipse for a convex lens is B_1 and for a concave lens is B_2 . The relation between R (effective radius of curvature on the major axis) and the semi-axes is known to be given by $R=B \times B/A$.

Table 1 herein below gives exemplary dimensions for the sheet material embodiment of FIG. 1-A and alternative embodiments. The optical function of the sheet material of FIGS. 1-A, 1-B, and 1-C is similar to that of a Galilean telescope focused at infinity in that rays indicated (in FIG. 1-B) at 631 and 632 which enter a lens 621 with parallel directions of propagation are partially converged within sheet material 611 but are then diverged by a lens 619 whereby they are again rendered approximately parallel.

For some uses of sheet material such as 511, one may prefer that the telescope effect of the lenses 521 and 519 be

altered to simulate a Galilean telescope focused at a closer distance rather than at infinity, and in such case, the lenses 519 and 521 would be spaced farther apart and their focal points would not exactly coincide. To some extent, the lenses 519 and 521 are operative for the invention functions when closer together than for coincident focus points, but this is not usually preferred. Generally lens spacing is preferably from 0.8 to 1.2 times the coincident focus distance.

In FIG. 1-A lenses 521 are formed of elliptical arc cross-section subtending an angle of approximately 80° (plus and minus 40° within the circle of effective radius). In some applications, such as solar energy control film, one may wish to have arc of cross-section subtend greater angles up to 90° or 120° to achieve a greater range of acceptance angle for the optical arrangement. In other cases one may wish to have the arc of lenses 521 subtend an angle of 60° or less.

It is well known that spherical or cylindrical lenses of circular arc cross-section suffer from a deficiency known as spherical aberration. The adverse effect of spherical aberration arises when the circular arc curve does not provide the appropriate angle of incidence for a ray parallel to and distant from the optical axis with the result that the refraction angle for such rays causes them to have a focal point closer to the lens than for near axial rays, hence causing imperfect focusing. In the optical arts aspheric lenses have been developed to greatly reduce the effects of spherical aberration and such techniques can be employed in the design of the optics of sheet material according to the present invention. Complex mathematical calculations are employed to generate lens curvatures with aspheric properties and such curves may not conform to simple geometric functions. An elliptical curve cross-section is a simple geometric form which is employed according to the invention to alleviate the problem of spherical aberration, at least in part. Herein the term "elliptical curve or elliptical lens" should be understood to apply generally to oval curves altered from pure circular shape to alleviate spherical aberration effects, even when they do not conform strictly to the classic formula of an ellipse.

Ellipsoidal or elliptical-cylinder (aspherical) lens surfaces that may be employed are, for an index of refraction of 1.586, a major to minor axis ratio of 1.29; and for an index of refraction of 1.567 a ratio of 1.30; and for an index of refraction of 1.5 a ratio of 1.34. See Table 1. Suitable elliptical-cylinder lens surfaces for any index of refraction can be calculated by Snell's law and conventional ray tracing techniques.

The discussion above with respect to the convex lenses 521 is generally applicable also to the concave lenses 519. In FIG. 1-A the radius of curvature of lenses 519 is one-half that of lenses 521, but the angle subtended by the arc of lenses 519 is approximately the same 80° . Accordingly, lenses 519 occupy only half of the back surface of sheet material 511 and the other area is occupied by the convex intervening spaces 520. Although conventional refracting lenses are disclosed herein, lens-like functions can be obtained with holographic lens based on diffraction phenomena, and substitution of holographic lenses for those specifically disclosed may be feasible and desirable in some circumstances.

From the above discussion and reference to FIGS. 1-A, 2, 3, and 4, it will be seen that the sheet material of FIG. 1-A provides a screen-type optical arrangement which provides a clear image of objects viewed through the sheet material

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from the top in FIG. 1-A when the viewing angle does not exceed 15° to 20° ; when the viewing angle exceeds about 20° , the viewer sees instead a magnified representation of the multiplicity of intervening spaces 520 imprinted with graphic or textual images using printing pigment 725. Both in cases of effectively transparent image viewing, and of imprinted mask viewing, the viewed images are condensed in the sense that they are only strip samples of the full image, but the strips are so small and so closely spaced that they give the appearance of a complete image in a manner similar to the lines of a television screen display.

The elliptical configuration of lens surfaces according to the present invention is an important feature. Without the elliptical configuration the angular width of the transparent image window without significant distortion would be very narrow. Clearly it is necessary to have an appropriate ellipse major-to-minor axis ratio for the lens surfaces, and this is found to be dependent essentially on the index of refraction of the sheet material. The major-minor axis ratio (A/B) ranges from as high as about 1.35 to as low as about 1.25. The elliptical arc is at the end of a major axis. A particular A/B ratio can be determined by successive approximation ray tracing using Snell's Law and the index of refraction to determine proper arc slope at 30° (or 45°) off axis for causing the off axis ray focal point to substantially correspond to the near axis ray focal point. The A/B ratio which determines this arc slope is the desired A/B ratio. The inherent properties of the ellipse assure that a focal point (focal distance) match at 30° off axis will result in insignificant mismatch at points between 0° and 30° off axis. More sophisticated optical design techniques could no doubt be used to obtain the same results.

Sheet material 511 of FIGS. 1-A, 2, and 3, may also be modified to shift lenses 519 with respect to lenses 521. Whereas the lenses 519 and 521 in FIG. 1-A are represented as being substantially coaxial, they may be shifted in relative position so that the Galilean telescope formed thereby is, in effect, tilted left or right by an angle of a few degrees up to approximately 30° . In other words, the optical axes for the lens pairs may be non-perpendicular to the surfaces of the sheet material. It is only necessary that the lenses from one surface be in register with the lenses on the other surface, that is that they have the same relative orientation as to each pair of lenses.

Referring to FIG. 1-B, a sheet material 611 is shown which is formed of transparent plastic material similar to that of sheet material 511. The top or first surface of the sheet material 611 has converging lenses 621 formed therein as smooth, convex, elliptically cylindrical protuberances in the sheet material 611. The bottom or back surface of the sheet material 611 has indentations 619 formed therein which are smooth, concave, elliptically cylindrical surfaces acting as diverging lenticular lenses.

The lenses 619 are registered with lenses 621, and thus lenses 619 are optically coaxial with lenses 621. Lenses 619 are of lesser width than lenses 621 (typically one-half of the width) and the spaces between lenses 619 resulting from this lesser width are partially flat or planar surface portions 620. Where the flat or planar area of surface portion 620 joins a lens 619, there is provided a rounded portion 622 with a radius much smaller than the effective radius of lens 619. This allows the partially flat portions 620 to be slightly convex so that high-speed printing using an off-set press or the like is facilitated by avoiding overrun of ink into lenses 621.

In FIG. 1-B, dimensions and locations are assigned reference letters for convenience in relating such to Table I and

in explaining the inventions. The overall thickness of the sheet material 611 is designated by t, typically 0.627 mm or 0.0247". The center-to-center spacing of the lenses 621 which is also the center-to-center spacing of the lenses 619 is designated P, typically 0.4 mm or 0.0157". Alternative parameters for the configuration of FIG. 1-B are shown in Table 1.

Referring to FIG. 1-C, a sheet material 711 is shown which is formed of transparent plastic material similar to that of sheet material 511. The top or first surface of the sheet material 711 has converging lenses 721 formed therein as smooth convex elliptically cylindrical protuberances in the sheet material 711. The bottom or back surface of the sheet material 711 has lenses 719 formed therein by smooth, concave, elliptically cylindrical surfaces acting as diverging lenticular lenses. The index of refraction of sheet material 711 is assumed to be approximately 1.5 and a different index would change the dimensions below the embodiment of FIG. 1-C is taken from FIG. 1 of prior copending application Ser. No. 227,055, now U.S. Pat. No. 5,644,431, and all subject matter thereof which is relevant to FIG. 1-C is incorporated herein by reference.

The lenses 719 are registered with lenses 721 and in the example of FIG. 1-C, lenses 719 are optically coaxial with lenses 721. Lenses 719 are of lesser width than lenses 721 and the spaces between lenses 719 resulting from this lesser width are generally flat or planar surface portions 720.

In FIG. 1-C dimensions and locations are assigned reference letters for convenience in relating such to Table I and in explaining the inventions. The overall thickness of the sheet material 711 is designated by t, typically 0.627 mm or 0.0247". The center to center spacing of the lenses 721 which is also the center to center spacing of the lenses 519 and 719, in FIG. 1-C are cylinders having elliptical are configurations, but it will be understood that similar but more complex non-circular shapes could be employed in accordance with known optical techniques.

In FIG. 1-C the center of curvature of the circular surface of one of the lenses 721 is indicated at C_1 . The center of curvature of the corresponding concave lens 719 circular surface is indicated at C_2 . The corresponding radii of curvature are indicated by reference letters R_1 , typically 0.4 mm or 0.0157" and R_2 , (and typically 0.2 mm or 0.00787"). The focal point for the lenses 721 and 719 substantially coincide as described herein above. In accordance with known optical principles the focal length and focal point may be determined from the effective radii of curvature R_1 and R_2 and the index of refraction of the material of which sheet 711 is formed. Other dimensions of this and other lenses configurations are shown in Table I. Also illustrated in FIG. 1-C is the fact that parallel rays of light indicated at 731 and 732 which are caused to converge by lenses 721 will be caused to diverge by lenses 719 by just the amount necessary to restore them to parallelism. This is a consequence of the fact that focal points of the lenses 719 and 721 are approximately coincident.

FIG. 5 shows a modification of sheet material according to the present invention which employs ellipsoidal, aspherical lenses rather than the lenticular lenses of FIG. 1-A, 1-B, or 1-C. Sheet material 151 is provided with a plurality of lenses 153 in the form of ellipsoidal segment projections. These lenses 153 may be arranged in a rectangular array of rows and columns as indicated in FIG. 5 or may be arranged in a hexagonal array. Lenses 153 may have small intervening spaces between them as shown in FIG. 5, or they may overlap and run together with no intervening spaces.

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The back side of the sheet material 151 is provided with a rectangular array of concave lenses 161 which are in register with the lenses 153 on the front side. The effective radius of curvature and the aperture diameters of lenses 161 are approximately half that of lenses 153, leaving intervening spaces 165 between lenses 161 which may optionally be imprinted with a solid color pigment or imprinted with a graphic or textual pattern.

A sheet material of FIG. 5 virtually corresponds to sheet material 611 of FIG. 1-B except that the array of lenses is two-dimensional, rather than one-dimensional. The lenses 153 may have a diameter less than one millimeter; the actual appearance of a sheet material, particularly at a distance, will be much different than that perceived in the greatly enlarged view of FIG. 5. The primary functional difference of sheet material 151 relative to sheet material 511, 611 or 711 is the fact that its directional characteristics are two-dimensional rather than one-dimensional. Whereas sheet materials 511, 611 or 711 of FIG. 1-A through FIG. 3 restricts image transmission within a limited angle only from right to left, there is substantially no such limitation in other directions. Sheet material 151 of FIG. 5 has two-dimensional limited image transmission capability, both within angles to the right and left and angles up and down. The sheet material of FIG. 5 is useful in packaging applications similar to those previously described, solar energy control applications, and in other applications. The exemplary dimensions of Table I are also applicable to the system of FIG. 5.

TABLE 1 below gives exemplary dimensions for sheet materials of FIGS. 1-6.

The configuration of the sheet material 511, 611 or 711 as shown in FIGS. 1-A, 1-B, or 1-C is particularly well suited to economical manufacture because registration between convex lenses forming projections, and concave lenses forming indentations can be assured in a single two-side embossing operation by which the sheet material 511, 611 or 711 may be formed.

FIG. 6 shows a schematic illustration of a configuration of generally conventional manufacturing apparatus which is suitable for forming sheet material 511 as shown in FIG. 1-A, for example. A sheet extruder 33 of conventional form extrudes a thin sheet 37 of plastic sheet material through a nozzle 35. The sheet 37 may be from about one foot to several feet in width, and, for example, may be about 0.04 inches (1 millimeter) thick. The sheet 37 passes immediately to embossing rolls 38 and 39 which are chilled rolls typically having a configuration as shown in FIG. 7 thereby shaping the sheet 37 in a manner similar to that shown for sheet 511 in FIG. 1-A. Alternatively, the extrusion or other forming process could be carried out separately and sheet 37 (if a thermoplastic material) could be reheated before passing through rolls 38 and 39 for the embossing process.

As shown in FIG. 7 it is preferred that embossing is done to produce the elongated lenses 521 generally parallel to the direction of travel of sheet 37. Thus, it is a simple matter to control registration of concave lens indentations 719 relative to lenses 721 by adjusting and fixing the relative position of arcuate grooves 140 relative to projections 143 as shown in FIG. 7. Embossing rolls such as 38 and 39 are sometimes machined with a helical cut for production of grooves 140 and projections 143, in which case the direction of the cuts, their pitch and the diameters of rolls 39 and 41 must be matched so that the registration will be maintained as rolls 39 and 41 turn at the same speed in opposite directions. Of course, if the grooves 140 and the projections 143 are cut as

a series of circular elements rather than helically, the relative rotational position or diameters of rolls 38 and 39 is of no consequence.

It may be desired to provide additional cooling (not shown in FIG. 6) for sheet 37 after passing through rolls 38 and 39. In some cases it may be desired to provide sheet 37 with a film backing to create a generally flat surface on one side of the finished sheet material. It may be convenient to apply a backing sheet 56 in a continuous operation. A backing sheet 56 is laid down on sheet 37 from a supply roll (not shown), after which the sheets are pressed together by nip rolls 51 and 53.

A preferred material for sheet 37 is polyethylene terephthalate, grade G (PET-G) available from Eastman Chemical. It has an index of refraction of about 1.567. Another material for sheet 37 is polycarbonate plastic. Other suitable materials in particular circumstances may include polyvinyl chloride, pvc with UV inhibitors, acrylic plastic, and other thermoplastic or thermosetting transparent materials.

Suitable material compositions for opaque mask 47 may include polyether plastics, cellulosic plastics, or one of the above mentioned plastics with a dye or coloring agent dispersed therein such as calcium carbonate, magnesium oxide, or other conventional white pigment or dye.

Plastic sheet 56 is preferably formed of the same material as plastic sheet 37, or may alternatively be formed of polyvinyl chloride, acetates, polyethylene, polypropylene, or acrylic plastics.

The sheet 511 in FIG. 1-A may have a total thickness indicated at *t* from 0.004 inches (0.1 millimeters) to 0.2 inches (5 millimeters). Typically the effective radius of curvature of the lenses 521 formed in sheet 511 will be about $\frac{1}{4}$ to $\frac{3}{4}$ of such total thickness. The thickness of the flat transparent sheet 56 may be about one-third of the thickness of sheet 37, but this dimension is variable within wide limits, and in many applications the sheet 56 would be omitted entirely.

Thus, it will be seen from FIGS. 6 and 7 that an important advantage of the configuration of sheet material shown in FIGS. 1 and 5 is the ease with which such film can be manufactured by generally conventional processes, and the fact that film having very small lenticular lens radii below 1.0 millimeter (0.04 inches) can be employed with ease because the lenses and the mask forming elements are produced and located in a single operation of two-side embossing or the like. Alternatively, other processes than roll embossing may be used to form sheet material such as sheet material 511, 611 or 711, as convenient. It should be noted that the sheet 56 which optionally is laminated to sheet material 511, sheet material 611, or sheet material 711 may be applied on either side of sheet material 511 (or one of the other sheets) to form a composite sheet 57 as illustrated in FIG. 6. For clarity and simplicity the addition of a transparent sheet of uniform thickness such as sheet 56 is not illustrated in FIGS. 1-A, 1-B, or 1-C. It is apparent, however, that the lamination of such a sheet over either one of the convex lens surfaces or one of the concave lens surfaces, or both, will provide a substantially flat exterior surface for the sheet material which may be desirable in some cases. In addition, particularly when the sheet is applied over the surface having convex lenses formed therein, a significant dead-air space will be provided that will increase the thermal insulating properties of the composite sheet 57 formed of embossed sheet 37 and uniform thickness sheet 56. If desired, a further sheet of uniform thickness similar to sheet

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56 could be applied to the opposite surface of sheet 37 thereby forming a sheet material of three layers with substantially smooth flat surfaces on both sides.

From the foregoing description and explanation, it will be seen that the invention provides a directional image transmission sheet and a particular process for making such sheet which has advantageous features for a wide variety of uses including such diverse uses as wrapping film and solar energy control sheet material for incorporation in windows for buildings or other structures. In addition to the modifications and variations to the invention shown, described or suggested above, it will be apparent to those skilled in the art that numerous other modifications may be made to better suit the uses or circumstances for which the sheet material is to be employed. Accordingly, the scope of the invention is not to be considered limited to those embodiments shown, described or suggested herein, but is to be determined with reference to the appended claims.

Although the theory of operation and design factors presented above is believed correct, the operability, utility, and advantages of sheet materials according to the invention should be based on actual results and performance thereof rather than upon theoretical principles or mathematical analysis.

TABLE 1

REFRACTION INDEX (N)	PITCH (P)	EFFECTIVE RADIUS (R ₁ , R ₂)	C ₁ to C ₂ DISTANCE (D)	TOTAL THICKNESS (t)	ANGULAR WIDTHS (A ₁ , A ₂)	ELLIPSE (A/B)
1.5	0.0157"	0.0157", -0.00787"	0.0157"	0.0247"	60°, 60°	.0282/ .0210
1.5	0.0236"	0.0236", -0.0118"	0.0236"	0.0378"	60°, 60°	.0424/ .0316
1.567	0.0125"	0.00967", -0.00481"	0.00848"	0.0160"	80°, 80°	.01624/ .0125
1.586	0.1083"	0.0625", -0.3125"	0.050"	0.0969"	120°, 120°	.104/ .0806
1.567	0.0125"	0.0096", -0.0048"	0.0085"	0.0148"	80°, 80°	.01624/ .0125
1.567	0.0125"	0.0096", -0.00772"	0.00425"	0.0074"	80°, 60°	.01624/ .0125

What is claimed is:

1. A partially transparent sheet for directional light transmission and image viewing comprising:

- a body of at least partially transparent solid material with a predetermined thickness substantially less than its other dimensions, and having a front surface and a back surface;
- a multiplicity of convex lenses with a predetermined index of refraction covering a substantial area on said body front surface with each of said lenses having a least transverse dimension of less than two millimeters;
- a multiplicity of concave lenses with a predetermined index of refraction of said body back surface, each being generally in register with a respective one of said convex lenses, the transverse dimension of said concave lenses being less than three-fourths of the center-to-center pitch thereof, surfaces between said concave lenses being at least in part in the form of a convex arcuate surface, the effective radii of curvature of said concave lenses being selected with regard to the effective radii of curvature of said convex lenses, said index of refraction, and said body thickness to cause parallel rays converged by said convex lenses to be returned approximately to parallelism upon passing through said concave lenses;

whereby said sheet, when viewed in a direction nearly parallel with the paths from lenses on the front surface to corresponding lenses on the back surface, appears transparent and transmits a substantially undistorted image, while said sheet appears non-transparent to images when viewed in a substantially different direction.

2. A sheet as recited in claim 1 wherein said at least partially transparent solid material is a sheet of plastic with a thickness of from 0.02 to 4.0 millimeters.

3. A sheet as recited in claim 2 wherein said convex lenses are formed integrally in said at least partially transparent solid material.

4. A sheet as recited in claim 1 wherein said convex lenses are formed integrally in said at least partially solid material.

5. A sheet as recited in claim 1 wherein said convex lenses and said concave lenses are lenticular lenses with substantially mutually parallel orientation.

6. A sheet as recited in claim 1 wherein the distance separating each said concave lens from its corresponding convex lens is between 0.8 times and 1.2 times the difference of the absolute values of the focal lengths thereof.

7. A sheet as recited in claim 1 wherein an opaque image-forming pattern is imposed on said at least partially convex arcuate surfaces between said concave lenses.

8. A sheet as recited in claim 5 wherein an opaque image-forming pattern is imposed on said at least partially convex arcuate surfaces between said concave lenses.

9. An optical lens system comprising a transparent sheet having a first surface and an opposite surface constituted by a plurality of parallel circular section or elliptical section lenticulated lenses, a plurality of spaced apart parallel non-concave opaque portions on said first surface, each of said opaque portions comprising one segment of an image, said lenticulated lenses being in a fixed spatial relationship with respect to said opaque portions,

a plurality of concave lens portions interspaced between said opaque portions which permit the passage of light from said lenticular lenses at a first range of angles, said image being viewed through said lenticular lenses at a second range of angles different from said first range of angles,

whereby an object positioned beneath said first surface, which is not in the same plane as said opaque portion, is viewable through said sheet at said first range of angles, and is not viewable through said sheet at said second range of angles, with said object being physically unattached to said transparent sheet.

10. An optical lens system comprising:

- a transparent sheet having a first surface and an opposite second surface constituted by a plurality of parallel lenticulated convex lenses,

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said first surface being constituted by a plurality of spaced-apart, raised parallel portions having a composite image positioned thereupon with indented transparent concave lens portions therebetween which permit the passage of light, said convex lenses and said concave lenses being positioned with nearly coincident focal points and combining to form a combined lens, whereby an object image positioned beneath said sheet at a preselected distance is viewed through the transparent concave lens portions.

11. The optical lens system as described in claim 10 wherein said raised parallel portions act as an inking system to automatically register ink to said raised parallel planar portions and to prevent the transfer of ink to the indented transparent concave portions therebetween.

12. Packaging having an area of transparent sheet having a first surface and an opposite surface constituted by a plurality of lenticular lenses, a plurality of spaced apart parallel raised opaque portions on said first surface, each of said opaque portions comprising one segment of an image, said lenticular lenses being in fixed spatial relationship with respect to said opaque portions,

a plurality of void portions interspersed between said opaque portions which permit the passage of light from said lenticular lenses at a first range of angles, said void portions each having a lens surface therein,

said image being viewed through said lenticular lenses at a second range of angles different from said first range of angles,

whereby objects packed in said packaging positioned beneath said first surface, which are not in the same plane as said opaque portions, are viewable through said sheet at said first range of angles, and are not viewable through said sheet at said second range of angles, with said objects being physically unattached to said transparent sheet.

13. Packaging having an area of transparent sheet having a first surface and an opposite surface constituted by a plurality of lenticular lenses, a plurality of spaced apart parallel raised opaque portions on said first surface, each of

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said opaque portions comprising one segment of an image, said lenticular lenses being in fixed spatial relationship with respect to said opaque portions,

a plurality of void portions interspersed between said opaque portions which permit the passage of light from said lenticular lenses at a first range of angles,

said image being viewed through said lenticular lenses at a second range of angles different from said first range of angles,

whereby objects packed in said packaging positioned beneath said first surface, which are not in the same plane as said opaque portions, are viewable through said sheet at said first range of angles, and are not viewable through said sheet at said second range of angles, with said objects being physically unattached to said transparent sheet.

14. An optical lens system comprising a transparent sheet having a first surface and an opposite surface constituted by a plurality of convex lenticulated lenses, a plurality of spaced apart parallel non-concave opaque portions on said first surface, each of said opaque portions having an image portion positioned thereupon, said lenticulated lenses being in a fixed spatial relationship with respect to said opaque portions,

a plurality of indented transparent concave lens portions interspersed between said opaque portions which permit the passage of light from said lenticular lenses at a first range of angles, said image being viewed through said lenticular lenses and said concave lens portions at a second range of angles different from said first range of angles,

whereby an object positioned a substantial distance beneath said first surface, which is not in the same plane as said opaque portions, is viewable through said sheet at said second range of angles, with said object being physically unattached to said transparent sheet.

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REQUEST

The undersigned requests that the present international application be processed according to the Patent Cooperation Treaty.

International Application No.

International Filing Date

Name of receiving Office and "PCT International Application"

Applicant's or agent's file reference
(if desired) (12 characters maximum) 821402-209045
316

Box No. I TITLE OF INVENTION MICRO-OPTIC SECURITY AND IMAGE PRESENTATION SYSTEM	
Box No. II APPLICANT ☐ This person is also inventor	
Name and address: (Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this box is the applicant's State (that is, country) of residence (if no State of residence is indicated below.)	
NANOVENTIONS, INC. 1050 Northfield Court Suite 300 Roswell, Georgia 30076 US	
Telephone No. 678-366-5929	
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Teleprinter No.	
Applicant's registration No. with the Office	
State (that is, country) of nationality: US	State (that is, country) of residence: US
This person is applicant for the purposes of: ☐ all designated States ☒ all designated States except the United States of America ☐ the United States of America only ☐ the States indicated in the Supplemental Box	
Box No. III FURTHER APPLICANT(S) AND/OR (FURTHER) INVENTOR(S)	
Name and address: (Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this box is the applicant's State (that is, country) of residence (if no State of residence is indicated below.)	
STEENBLIK, Richard A. 240 Seale Lane Alpharetta, Georgia 30022 US	
This person is: ☐ applicant only ☒ applicant and inventor ☐ inventor only (If this check-box is marked, do not fill in below.)	
Applicant's registration No. with the Office	
State (that is, country) of nationality: US	State (that is, country) of residence: US
This person is applicant for the purposes of: ☐ all designated States ☐ all designated States except the United States of America ☒ the United States of America only ☐ the States indicated in the Supplemental Box	
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Box No. IV AGENT OR COMMON REPRESENTATIVE; OR ADDRESS FOR CORRESPONDENCE	
The person identified below is hereby/has been appointed to act on behalf of the applicant(s) before the competent International Authorities as: ☒ agent ☐ common representative	
Name and address: (Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)	
DEVEAU, Todd Thomas, Kayden, Horstemeyer & Risley LLP 100 Galleria Parkway Suite 1750 Atlanta, Georgia 30339 US	
Telephone No. 770-933-9500	
Facsimile No. 770-951-0933	
Teleprinter No.	
Agent's registration No. with the Office 29,528	
☐ Address for correspondence: Mark this check-box where no agent or common representative is/has been appointed and the space above is used instead to indicate a special address to which correspondence should be sent.	

Box No. V DESIGNATIONS

The filing of this request constitutes under Rule 4.9(a), the designation of all Contracting States bound by the PCT on the international filing date, for the grant of every kind of protection available and, where applicable, for the grant of both regional and national patents.

However,

- ☐ DE Germany is not designated for any kind of national protection
- ☐ KR Republic of Korea is not designated for any kind of national protection
- ☐ RU Russian Federation is not designated for any kind of national protection

(The check-boxes above may be used to exclude (irrevocably) the designations concerned in order to avoid the ceasing of the effect, under the national law, of an earlier national application from which priority is claimed. See the Notes to Box No. V as to the consequences of such national law provisions in these and certain other States.)

Box No. VI PRIORITY CLAIM

The priority of the following earlier application(s) is hereby claimed:

Filing date of earlier application (day/month/year)	Number of earlier application	Where earlier application is:		
		national application: country or Member of WTO	regional application: regional Office	international application: receiving Office
item (1) 21 November 2003 (21.11.2003)	60/524,281	US		
item (2) 22 January 2004 (22.01.2004)	60/538,392	US		
item (3) 12 November 2004 (12.11.2004)	60/827,234	US		

- ☐ Further priority claims are indicated in the Supplemental Box.

The receiving Office is requested to prepare and transmit to the International Bureau a certified copy of the earlier application(s) (only if the earlier application was filed with the Office which for the purposes of this international application is the receiving Office) identified above as:

- ☒ all items ☐ item (1) ☐ item (2) ☐ item (3) ☐ other, see Supplemental Box

* Where the earlier application is an ARIPO application, indicate at least one country party to the Paris Convention for the Protection of Industrial Property or one Member of the World Trade Organization for which that earlier application was filed (Rule 4.10(b)(ii)):

Box No. VII INTERNATIONAL SEARCHING AUTHORITY

Choice of International Searching Authority (ISA) (if two or more International Searching Authorities are competent to carry out the international search, indicate the Authority chosen; the two-letter code may be used):

ISA / US

Request to use results of earlier search; reference to that search (if an earlier search has been carried out by or requested from the International Searching Authority):

Date (day/month/year) Number Country (or regional Office)

Box No. VIII DECLARATIONS

The following declarations are contained in Boxes Nos. VIII (i) to (v) (mark the applicable check-boxes below and indicate in the right column the number of each type of declaration):

Number of declarations

- ☐ Box No. VIII (i) Declaration as to the identity of the inventor :
- ☐ Box No. VIII (ii) Declaration as to the applicant's entitlement, as at the international filing date, to apply for and be granted a patent :
- ☐ Box No. VIII (iii) Declaration as to the applicant's entitlement, as at the international filing date, to claim the priority of the earlier application :
- ☐ Box No. VIII (iv) Declaration of inventorship (only for the purposes of the designation of the United States of America) :
- ☐ Box No. VIII (v) Declaration as to non-prejudicial disclosures or exceptions to lack of novelty :

If none of the following sub-boxes used, this sheet should not be included in the request.

Name and address: (Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)

HURT, Mark J.
3816 Tumberry Court
Duluth, Georgia 30096
US

This person is:

- ☐ applicant only
☒ applicant and inventor
☐ inventor only (If this check-box is marked, do not fill in below.)

Applicant's registration No. with the Office

State (that is, country) of nationality:
US

State (that is, country) of residence:
US

This person is applicant for the purposes of:

- ☐ all designated States ☐ all designated States except the United States of America ☒ the United States of America only ☐ the States indicated in the Supplemental Box

Name and address: (Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)

JORDAN, Gregory R.
1293 Dalesford Drive
Alpharetta, Georgia 30004
US

This person is:

- ☐ applicant only
☒ applicant and inventor
☐ inventor only (If this check-box is marked, do not fill in below.)

Applicant's registration No. with the Office

State (that is, country) of nationality:
US

State (that is, country) of residence:
US

This person is applicant for the purposes of:

- ☐ all designated States ☐ all designated States except the United States of America ☒ the United States of America only ☐ the States indicated in the Supplemental Box

Name and address: (Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)

This person is:

- ☐ applicant only
☐ applicant and inventor
☐ inventor only (If this check-box is marked, do not fill in below.)

Applicant's registration No. with the Office

State (that is, country) of nationality:

State (that is, country) of residence:

This person is applicant for the purposes of:

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Name and address: (Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)

This person is:

- ☐ applicant only
☐ applicant and inventor
☐ inventor only (If this check-box is marked, do not fill in below.)

Applicant's registration No. with the Office

State (that is, country) of nationality:

State (that is, country) of residence:

This person is applicant for the purposes of:

- ☐ all designated States ☐ all designated States except the United States of America ☐ the United States of America only ☐ the States indicated in the Supplemental Box

☐ Further applicants and/or (further) inventors are indicated on another continuation sheet.

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This international application contains:		This international application is accompanied by the following items(s) (mark the applicable check-box(es) and indicate in right column the number of each item):		Number of items
(a) In paper form, the following number of sheets:		1. ☒ fee calculation sheet		1
request (including declaration sheets)	4	2. ☐ original separate power of attorney		
description (excluding sequence listing and/or tables related thereto)	74	3. ☐ original general power of attorney		
claims	19	4. ☐ copy of general power of attorney; reference number, if any:		
abstract	0	5. ☐ statement explaining lack of signature		
drawings	31	6. ☐ priority document(s) identified in Box No. VI as item(s):		
Sub-total number of sheets	128	7. ☐ translation of international application into (language):		
sequence listing		8. ☐ separate indications concerning deposited microorganism or other biological material		
tables related thereto		9. ☐ sequence listing in computer readable form (indicate type and number of carriers)		
(for both, actual number of sheets if filed in paper form, whether or not also filed in computer readable form; see (c) below)		(i) ☐ copy submitted for the purposes of international search under Rule 13ter only (and not as part of the international application):		
Total number of sheets	128	(ii) ☐ (only where check-box (b)(i) or (c)(i) is marked in left column) additional copies including, where applicable, the copy for the purposes of international search under Rule 13ter		
(b) ☐ only in computer readable form (Section 801(a)(i))		(iii) ☐ together with relevant statement as to the identity of the copy or copies with the sequence listing mentioned in left column		
(i) ☐ sequence listing		10. ☐ tables in computer readable form related to sequence listing (indicate type and number of carriers)		
(ii) ☐ tables related thereto		(i) ☐ copy submitted for the purposes of international search under Section 802(b-quater) only (and not as part of the international application)		
(c) ☐ also in computer readable form (Section 801(a)(ii))		(ii) ☐ (only where check-box (b)(ii) or (c)(ii) is marked in left column) additional copies including, where applicable, the copy for the purposes of international search under Section 802(b-quater)		
(i) ☐ sequence listing		(iii) ☐ together with relevant statement as to the identity of the copy or copies with the tables mentioned in left column		
(ii) ☐ tables related thereto		11. ☒ other (specify): Return Receipt Postcard		
Type and number of carriers (diskette, CD-ROM, CD-R or other) on which are contained the				
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☐ tables related thereto:				
(additional copies to be indicated under items 9(ii) and/or 10(ii), in right column)				

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Figure of the drawings which should accompany the abstract:

Language of filing of the international application:

English

Box No. X SIGNATURE OF APPLICANT, AGENT OR COMMON REPRESENTATIVE

Next to each signature, indicate the name of the person signing and the capacity in which the person signs (if such capacity is not obvious from reading the request).


Todd Deveau, Reg. No. 29,528

For receiving Office use only	
1. Date of actual receipt of the purported international application:	2. Drawings: ☐ received: ☐ not received:
3. Corrected date of actual receipt due to later but timely received papers or drawings completing the purported international application:	
4. Date of timely receipt of the required corrections under PCT Article 11(2):	
5. International Searching Authority (if two or more are competent): ISA /	6. ☐ Transmittal of search copy delayed until search fee is paid

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NOTIFICATION CONCERNING
SUBMISSION OR TRANSMITTAL
OF PRIORITY DOCUMENT

(PCT Administrative Instructions, Section 411)

To:

DEVEAU, Todd
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ETATS-UNIS D'AMERIQUE

Date of mailing (day/month/year) 28 April 2005 (28.04.2005)	IMPORTANT NOTIFICATION
Applicant's or agent's file reference 821402-2090	
International application No. PCT/US04/038315	International filing date (day/month/year) 22 November 2004 (22.11.2004)
International publication date (day/month/year)	Priority date (day/month/year) 21 November 2003 (21.11.2003)
Applicant NANOVENTIONS, INC. et al	

DOCKETED

- By means of this Form, which replaces any previously issued notification concerning submission or transmittal of priority documents, the applicant is hereby notified of the date of receipt by the International Bureau of the priority document(s) relating to all earlier application(s) whose priority is claimed. Unless otherwise indicated by the letters "NR", in the right-hand column or by an asterisk appearing next to a date of receipt, the priority document concerned was submitted or transmitted to the International Bureau in compliance with Rule 17.1(a) or (b).
- (If applicable)* The letters "NR" appearing in the right-hand column denote a priority document which, on the date of mailing of this Form, had not yet been received by the International Bureau under Rule 17.1(a) or (b). Where, under Rule 17.1(a), the priority document must be submitted by the applicant to the receiving Office or the International Bureau, but the applicant fails to submit the priority document within the applicable time limit under that Rule, the attention of the applicant is directed to Rule 17.1(e) which provides that no designated Office may disregard the priority claim concerned before giving the applicant an opportunity, upon entry into the national phase, to furnish the priority document within a time limit which is reasonable under the circumstances.
- (If applicable)* An asterisk (*) appearing next to a date of receipt, in the right-hand column, denotes a priority document submitted or transmitted to the International Bureau but not in compliance with Rule 17.1(a) or (b) (the priority document was received after the time limit prescribed in Rule 17.1(a) or the request to prepare and transmit the priority document was submitted to the receiving Office after the applicable time limit under Rule 17.1(b)). Even though the priority document was not furnished in compliance with Rule 17.1(a) or (b), the International Bureau will nevertheless transmit a copy of the document to the designated Office, for their consideration. In case such a copy is not accepted by the designated Office as the priority document, Rule 17.1(e) provides that no designated Office may disregard the priority claim concerned before giving the applicant an opportunity, upon entry into the national phase, to furnish the priority document within a time limit which is reasonable under the circumstances.

Priority date	Priority application No.	Country or regional Office or PCT receiving Office	SCANNED of priority document
21 November 2003 (21.11.2003)	60/524,281	US	02 February 2005 (02.02.2005)
22 January 2004 (22.01.2004)	60/538,392	US	02 February 2005 (02.02.2005)
12 November 2004 (12.11.2004)	60/827,234	US	11 March 2005 (11.03.2005)

THOMAS, KAYDEN
HORSTEMEIER & RISLEY, LLP

MAY 03 2005

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02E**MICRO-OPTIC SECURITY AND IMAGE PRESENTATION SYSTEM****CROSS-REFERENCE TO RELATED APPLICATIONS**

- This application claims benefit of and priority to US Provisional Patent Application No. 60/524,281 filed on November 21, 2003, US Provisional Patent
- 5 Application No. 60/538,392, filed on January 22, 2004, and US Provisional Patent Application No. 60/_____ filed on November 12, 2004, and where permissible, each of which is incorporated by reference in their entirety.

Field of the Invention

- The present invention relates to a synthetic magnification micro-optic system
- 10 that in an exemplary embodiment is formed as a polymer film. The unusual optical effects provided by the various embodiments of the disclosure can be used as a security device for overt and covert authentication of currency, documents, and products as well as visual enhancement of products, packaging, printed material, and consumer goods.

15 **Background**

- Various optical materials have been employed to provide authentication of currency and documents, to identify and distinguish authentic products from counterfeit products, and to provide visual enhancement of manufactured articles and packaging. Examples include holographic displays, and other image systems
- 20 involving lenticular structures and arrays of spherical micro-lenses. Holographic displays have become prevalent for use with credit cards, drivers' licenses, and clothing tags.

An example of a lenticular structure for document security is disclosed in U.S. Patent 4,892,336 to Kaule, et al. directed to a security thread for embedding within a

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document to provide anti-falsification measures. The security thread is transparent having a printed pattern on one side, on the opposite side, a lenticular lens structure coordinated with the printed pattern. The lenticular lens structure is described as comprised of a plurality of parallel cylinder lenses, or alternatively spherical or

5 honeycomb lenses.

U.S. Patent 5,712,731 to Drinkwater, et al. discloses a security device that includes an array of micro-images coupled with an array of substantially spherical micro-lenses. The lenses may also be astigmatic lenses. The lenses are each typically 50-250 μm and with a focal length of typically 200 μm .

10 These approaches all suffer from similar drawbacks. They result in a relatively thick structure that is not particularly suitable for use with document authentication. Their use of cylindrical or spherical lenses provides a narrow field of view resulting in fuzzy images and requiring exact and difficult alignment of the focal point of the lenses with the associated images. Additionally, they have not proven

15 particularly effective as security or anti-counterfeiting measures.

In view of these and other deficiencies, a need exists in the industry for secure and visually unique optical materials that can facilitate overt authentication of currency, documents, manufactured articles, and products and for optical materials that provide visual enhancement of manufactured articles, products, and packaging.

20 Summary

The present disclosure relates to a film material that utilizes a regular two-dimensional array of non-cylindrical lenses to enlarge micro-images, called icons herein, and to form a synthetically magnified image through the united performance of a multiplicity of individual lens/icon image systems. The synthetically magnified

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images and the background surrounding them can be either colorless or colored, and either or both the images and the background surrounding them can be transparent, translucent, pigmented, fluorescent, phosphorescent, display optically variable color, metallized, or substantially retroreflective. The material displaying colored images on

5 a transparent or tinted background is particularly well suited for use in combination with underlying printed information. When a piece of such material is applied over printed information both the printed information and the images are seen at the same time in spatial or dynamic motion relationship to each other. Material of this kind can also be overprinted, i.e. have print applied to the uppermost (lens) surface of the

10 material. Alternatively, the material displaying colored images (of any color, including white and black) on a translucent or substantially opaque background of different color is particularly well suited for stand-alone use or with overprinted information, not in combination with underlying printed information.

The magnitude of the synthetic magnification achieved can be controlled by

15 the selection of a number of factors, including the degree of 'skew' between the axes of symmetry of the lens array and the axes of symmetry of the icon array. Regular periodic arrays possess axes of symmetry that define lines that the pattern could be reflected around without changing the basic geometry of the pattern, that in the ideal of arrays are infinite in extent. A square array, for example, can be reflected around

20 any diagonal of any square without changing the relative orientation of the array: if the sides of the squares are aligned with the x and y axes of the plane, then the sides of the squares will still be aligned with those axes after reflection, with the assumption that all sides are identical and indistinguishable.

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Instead of mirroring the square array the array can be rotated through an angle equal to the angle between the axes of symmetry of the same type. In the case of a square array the array can be rotated through an angle of 90 degrees, the angle between diagonals, to arrive at an array orientation which is indistinguishable from the original array. Similarly, an array of regular hexagons can be mirrored or rotated about a number of axes of symmetry, including the "diagonals" of the hexagon (the lines connecting opposite vertices) or "midpoint divisors" (lines that connect between the center points of faces on opposite sides of the hexagon). The angle between the axes of symmetry of either type is sixty degrees (60°) results in an array orientation that is indistinguishable from the original orientation.

If a lens array and an icon array are initially arranged with their planar dimensions defining their respective x-y plane, one of the axes of symmetry being chosen to represent the x axis of the first array, the corresponding type of axis of symmetry (for example, diagonal axis of symmetry) being chosen to represent the x axis of the second array, with the two arrays separated by a substantially uniform distance in the z axis direction, then the arrays are said to have zero skew if the x axes of the arrays appear to be parallel to each other when the arrays are viewed along the z axis direction. In the case of hexagonal arrays, rotation of one array through an angle of 60 degrees, or multiples thereof, puts the arrays in alignment again, so there is no skew, just as there is no skew for a rotation of 90 degrees, or multiples thereof, in the case of square arrays. Any angular misalignment between the x axes that is different from these "zero skew rotations" is called the skew. A small skew, such as 0.06 degree, can create a large magnification, in excess of 1,000x, and a large skew, such as 20 degrees produces a small magnification, potentially as small as 1x. Other

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factors, such as the relative scales of the two arrays and the F# of the lens, can affect both the magnification of the synthetic image as well as its rotation, orthoparallactic movement, and apparent visual depth.

There are a number of distinct visual effects that can be provided by the present material (subsequently referred to as "Unison" for the material in general, or by the names "Unison Motion", "Unison Deep", "Unison SuperDeep", "Unison Float", "Unison SuperFloat", "Unison Levitate", "Unison Morph", and "Unison 3-D" for Unison material presenting those respective effects), and their various embodiments producing each of these effects, generally described as follows:

10 *Unison Motion presents images that show orthoparallactic movement (OPM) – when the material is tilted the images move in a direction of tilt that appears to be perpendicular to the direction anticipated by normal parallax. Unison Deep and SuperDeep present images that appear to rest on a spatial plane that is visually deeper than the thickness of the material. Unison Float and SuperFloat present images that*
15 *appear to rest on a spatial plane that is a distance above the surface of the material; and Unison Levitate presents images that oscillate from Unison Deep (or SuperDeep) to Unison Float (or SuperFloat) as the material is rotated through a given angle (e.g. 90 degrees), then returning to Unison Deep (or SuperDeep) again as the material is further rotated by the same amount. Unison Morph presents synthetic images that*
20 *change form, shape, or size as the material is rotated or viewed from different viewpoints. Unison 3-D presents images that show large scale three-dimensional structure, such as an image of a face.*

Multiple Unison effects can be combined in one film, such as a film that incorporates multiple Unison Motion image planes that can be different in form,

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color, movement direction, and magnification. Another film can combine a Unison Deep image plane and a Unison Float image plane, while yet another film can be designed to combine Unison Deep, Unison Motion, and Unison Float layers, in the same color or in different colors, those images having the same or different graphical elements. The color, graphical design, optical effect, magnification, and other visual elements of multiple image planes are largely independent; with few exceptions, planes of these visual elements can be combined in arbitrary ways.

For many currency, document and product security applications it is desirable that the total thickness of the film be less than 50 microns, (also referred to herein as " μ ", or " μm "), for example less than about 45 microns, and as a further example in the range of about 10 microns to about 40 microns. This can be accomplished, for example, through the use of focusing elements having an effective base diameter of less than 50 microns, as a further example less than 30 microns, and as yet a further example, from about 10 microns to about 30 microns. As another example, a focusing element having a focal length of less than about 40 microns, and as a further example having a focal length of about 10 to less than about 30 microns, can be used. In a particular example focusing elements having a base diameter of 35 microns and a focal length of 30 microns can be used. An alternate, hybrid refractive/diffractive embodiment, can be made as thin as 8 microns.

The films herein are highly counterfeit resistant because of their complex multi-layer structure and their high aspect-ratio elements that are not amenable to reproduction by commonly available manufacturing systems.

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Thus, the present system provides a micro-optic system preferably in the form of a polymer film having a thickness that when viewed by unaided eye(s) in reflective or transmitted light projects one or more images that:

- i. show orthoparallactic movement (Unison Motion);
- 5 ii. appear to lie on a spatial plane deeper than the thickness of the polymer film (Unison Deep and Unison SuperDeep);
- iii. appear to lie on a spatial plane above a surface of the polymer film (Unison Float and Unison SuperFloat);
- iv. oscillate between a spatial plane deeper than the thickness of
10 the polymer film and a spatial plane above a surface of the film as the film is azimuthally rotated (Unison Levitate);
- v. transform from one form, shape, size, color (or some combination of these properties) into a different form, shape, size, or color (or some combination of these properties) (Unison Morph); and/or
- 15 vi. appear to have realistic three-dimensionality (Unison 3-D).

The present disclosure more particularly provides a synthetic magnification micro-optic system and method of making the same comprising:

- (a) one or more optical spacers;
- (b) a micro image comprised of a periodic planar array of a plurality of image
20 icons having an axis of symmetry about at least one of its planar axes, and positioned on or next to the optical spacer; and
- (c) a periodic planar array of image icon focusing elements having an axis of symmetry about at least one of its planar axes, the axis of symmetry being the same planar axis as that of the micro image planar array, each focusing element being either

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a polygonal base multi-zonal focusing element, a lens providing an enlarged field of view over the width of the associated image icon so that the peripheral edges of the associated image icon do not drop out of view, or an aspheric focusing element having an effective diameter of less than 50 microns.

5 The system can include one or more of the aforementioned effects. A method is provided by which said effects can be selectively included within the system.

 The present disclosure further provides a security device suitable for at least partial incorporation in or on, and for use on or in association with, a security document, label, tear tape, tamper indicating device, sealing device, or other
10 authentication or security device, which comprises at least one micro-optic system, as defined above. More particularly the present disclosure provides a document security device and method of making the same comprising:

 (a) one or more optical spacers;

 (b) a micro image comprised of a periodic planar array of a plurality of image
15 icons having an axis of symmetry about at least one of its planar axes, and positioned on or next to the optical spacer, and

 (c) a periodic planar array of image icon focusing elements having an axis of symmetry about at least one of its planar axes, the axis of symmetry being the same planar axis as that of the micro image planar array, each focusing element being either
20 a polygonal base multi-zonal focusing element, a lens providing an enlarged field of view over the width of the associated image icon so that the peripheral edges of the associated image icon do not drop out of view, or an aspheric focusing element having an effective diameter of less than 50 microns.

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Additionally, the present disclosure provides a visual enhancement device which comprises at least one micro-optic system, as defined above and having the above described effects, for visual enhancement of clothing, skin products, documents, printed matter, manufactured goods, packaging, point of purchase displays, publications, advertising devices, sporting goods, financial documents and transaction cards, and all other goods.

Also provided is a security document or label having at least one security device, as defined above, at least partially embedded therein and/or mounted thereon.

Other features and advantages of the present disclosure will be apparent to one of ordinary skill from the following detailed description and accompanying drawings.

Other systems, devices, methods, features, and advantage will be or become apparent to one with skill in the art upon examination of the following drawings and detailed description. It is intended that all such additional systems, methods, features, and advantages be included within this description, be within the scope of the present disclosure, and be protected by the accompanying claims.

Unless otherwise defined, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this invention belongs. All publications, patent applications, patents and other references mentioned herein are incorporated by reference in their entirety. In case of conflict, the present specification, including definitions, will control. In addition, the materials, methods, and examples are illustrative only and not intended to be limiting.

Brief Description of the Figures:

Many aspects of the disclosure can be better understood with reference to the drawings. The components in the drawings are not necessarily to scale, emphasis

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instead being placed upon clearly illustrating the principles of the present disclosure. Moreover, in the drawings, like reference numerals designate corresponding parts throughout the several views.

Fig. 1a is a cross-section of a micro-optic system exemplifying one embodiment of the present disclosure providing orthoparallactic movement of the images of the system.

Fig. 1b is an isometric cutaway view of the embodiment of Fig. 1a.

Fig. 2a illustrates an orthoparallactic synthetic image motion effect of the embodiment of Figs. 1a-b.

Figs. 2 b-c illustrate the visual effects of the Deep and Float embodiments of the present system.

Figs. 2 d-f illustrate the visual effects obtained by rotation of a Levitate embodiment of the present system.

Figs. 3 a-i are plan views showing various embodiments and fill-factors of different patterns of symmetric two dimensional arrays of lenses of the present system.

Fig. 4 is a graph illustrating different combinations of Deep, Unison, Float, and Levitate embodiment effects produced by variation of the icon element period/lens period ratio.

Figs. 5 a-c are plan views illustrating how the synthetic magnification of the icon images can be controlled by the relative angle between the lens array and icon array axes of the present system.

Figs. 6 a-c are plan views illustrating an embodiment accomplishing a morphing effect of synthetically magnified images of the present system.

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Figs. 7 a-c are cross-sections showing various embodiments of the icon layer of the present system.

Figs. 8 a-b are plan views illustrating both 'positive' and 'negative' icon element embodiments.

5 Fig. 9 is a cross-section view illustrating an embodiment of a multi-level material for creating regions of a synthetically magnified image having different properties.

10 Fig. 10 is a cross-section view illustrating another embodiment of a multi-level material for creating regions of a synthetically magnified image having different properties.

Figs. 11 a-b are cross-section views showing reflective optics and pinhole optics embodiments of the present system.

15 Figs. 12 a-b are cross-section views comparing the structures of an all-refractive material embodiment with a hybrid refractive/reflective material embodiment.

Fig. 13 is a cross-section view showing a 'peel-to-reveal' tamper-indicating material embodiment.

Fig. 14 is a cross-section view illustrating a 'peel-to-change' tamper-indicating material embodiment.

20 Figs. 15 a-d are cross-section views showing various embodiments of two-sided systems.

Figs. 16 a-f are cross-section views and corresponding plan views illustrating three different methods for creating grayscale or tonal icon element patterns and subsequent synthetically magnified images by the present system.

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Figs. 17 a-d are cross-section views showing the use of the present system in conjunction with printed information.

Figs. 18 a-f are cross-section views illustrating the application of the present system to, or incorporation into, various substrates and in combination with printed
5 information.

Figs. 19 a-b are cross-section views comparing the in-focus field of view of a spherical lens with that of a flat field aspheric lens when each are incorporated into the present system.

Figs. 20 a-c are cross-section views illustrating two benefits of utility which
10 result from the use of a thick icon layer in the present system.

Fig. 21 is a plan view that shows the application of the present system to currency as a "windowed" security thread.

Fig. 22 illustrates the orthoparallactic motion embodiment of the present system of images in connection with a "windowed" security thread.

15 Fig. 23 illustrates half-toning a synthetic image of the present system.

Fig. 24a illustrates use of the present system to create combined synthetic images that are smaller in dimension than the smallest feature of the individual synthetic images.

Fig. 24b illustrates use of the present system to create narrow patterns of gaps
20 between icon image elements.

Fig. 25 illustrates incorporation of covert, hidden information into icon images of the present system.

Fig. 26 illustrates creating fully three-dimensional images with the present system.

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Fig. 27 illustrates the method for designing icon images for the three-dimensional embodiment of Fig. 26.

Fig. 28 illustrates the icon image resulting from the method of Fig. 27.

Fig. 29 illustrates how the method of Fig. 27 can be applied to a complex
5 three-dimensional synthetic image.

Fig. 30 illustrates the central zone focal properties of an exemplary hexagonal base multi-zonal lens having an effective diameter of 28 microns.

Fig. 31 illustrates the central zone focal properties of a spherical lens having a diameter of 28 microns.

Fig. 32 illustrates the performance of the side zones of the hexagonal lens of
10 Fig. 30.

Fig. 33 illustrates the performance of the outer zones of the spherical lens of Fig. 31.

Detailed Description of the Embodiments

15 Reference is now made in detail to the description of the embodiments as illustrated in the figures. While several embodiments are described in connection with these figures, there is no intent to limit the invention to the embodiment or embodiments disclosed herein. On the contrary, the intent is to cover all alternatives, modifications, and equivalents.

20 Fig. 1a illustrates one embodiment of the present micro-optic system 12 providing orthoparallactic movement of the images of the system.

The system 12 micro-lenses 1 that have at least two substantially equal axes of symmetry and that are arranged in a two-dimensional periodic array. Lens diameter 2 is preferably less than 50 μ and the interstitial space between lenses 3 is preferably 5 μ

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or less. (We use the terms " μ " and " μm " interchangeably to mean the same measurement). Micro-lens 1 focuses an image of icon element 4 and projects this image 10 toward a viewer. The system is commonly used in situations having normal levels of ambient lighting, so the illumination of the icon images arises from reflected or transmitted ambient light. Icon element 4 is one element of a periodic array of icon elements having periods and dimensions substantially similar to those of the lens array including lens 1. Between the lens 1 and the icon element 4 is an optical spacer 5, which may be contiguous with the lens 1 material or may optionally be a separate substrate 8 – in this embodiment the lenses 9 are separate from the substrate. The icon elements 4 may be optionally protected by a scaling layer 6, preferably of a polymer material. Scaling layer 6 may be transparent, translucent, tinted, pigmented, opaque, metallic, magnetic, optically variable, or any combination of these that provide desirable optical effects and/or additional functionality for security and authentication purposes, including support of automated currency authentication, verification, tracking, counting and detection systems, that rely on optical effects, electrical conductivity or electrical capacitance, magnetic field detection.

The total thickness 7 of the system is typically less than 50μ ; the actual thickness depends on the F# of the lenses 1 and the diameter of the lenses 2, and the thickness of additional security feature or visual effect layers. The repeat period 11 of the icon elements 4 is substantially identical to the repeat period of the lenses 1; the "scale ratio", the ratio of the repeat period of the icons to the repeat period of the lenses, is used to create many different visual effects. Axially symmetric values of the scale ratio substantially equal to 1.0000 result in Unison Motion orthoparallactic effects when the symmetry axes of the lenses and the icons are misaligned, axially

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symmetric values of the scale ratio less than 1.0000 result in Unison Deep and Unison SuperDeep effects when the symmetry axes of the lenses and the icons are substantially aligned, and axially symmetric values of the scale ratio greater than 1.0000 result in Unison Float and Unison SuperFloat effects when the symmetry axes of the lenses and the icons are substantially aligned. Axially asymmetric values of the scale ratio, such as 0.995 in the X direction and 1.005 in the Y direction, result in Unison Levitate effects.

Unison Morph effects can be obtained by scale distortions of either or both the lens repeat period and the icon repeat period, or by incorporating spatially varying information into the icon pattern. Unison 3-D effects are also created by incorporating spatially varying information into the icon pattern, but in this embodiment the information represents different viewpoints of a three dimensional object as seen from specific locations substantially corresponding to the locations of the icons.

Fig. 1b presents an isometric view of the present system, as depicted in cross-section in Fig. 1a, having square array patterns of lenses 1 and icons 4 of repeat period 11 and optical spacer thickness 5 (Fig. 1a is not specific to a square array pattern, but is a representative cross-section of all regular periodic array patterns). The icon elements 4 are shown as "\$" images, clearly seen in the cut-away section at the front. While there is substantially a one-to-one correspondence between lenses 1 and icon elements 4, the axes of symmetry of the lens array will not, in general, be exactly aligned with the axes of symmetry of the icon array.

In the case of the Unison (orthoparallactic motion) material embodiment of Figs. 1a-b with a scale ratio of 1.0000, when the lens 1 axes and icon elements 4 axes

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are substantially aligned, the resulting synthetic images of the icon elements (in this example, a giant "\$") "blow-up" and are magnified by a factor that theoretically approaches infinity. Slight angular misalignment of the lens 1 axes and icon elements 4 axes reduces the magnification factor of the synthetic images of the icon elements and causes the magnified synthetic images to rotate.

The synthetic magnification factor of Unison Deep, Unison Float, and Unison Levitate embodiments depends on the angular alignment of the lens 1 axes and the icon elements 4 axes as well as the scale ratio of the system. When the scale ratio is not equal to 1.0000 the maximum magnification obtained from substantial alignment of these axes is equal to the absolute value of $1/(1.0000 - (\text{scale ratio}))$. Thus a Unison Deep material having a scale ratio of 0.995 would exhibit a maximum magnification of $|1/(1.000 - 0.995)| = 200x$. Similarly, a Unison Float material having a scale ratio of 1.005 would also exhibit a maximum magnification of $|1/(1.000 - 1.005)| = 200x$. In a manner similar to the Unison Motion material embodiment, slight angular misalignment of the lens 1 axes and icon elements 4 axes of the Unison Deep, Unison Float, and Unison Levitate embodiments reduces the magnification factor of the synthetic images of the icon elements and causes the magnified synthetic images to rotate.

The synthetic image produced by a Unison Deep or SuperDeep icon pattern is upright with respect to the orientation of the Unison Deep or SuperDeep icon pattern, while the synthetic image produced by a Unison Float or SuperFloat icon pattern is upside down, rotated one hundred and eighty degrees (180°) with respect to the orientation of the Unison Float or Super Float icon pattern.

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Fig. 2a schematically depicts the counter-intuitive orthoparallactic image motion effects seen in the Unison Motion embodiment. The left side of Fig. 2a depicts a piece of Unison Motion material 12 in plan view being oscillated 18 about horizontal axis 16. If the synthetically magnified image 14 moved according to parallax, it would appear to be displaced up and down (as shown in Fig. 2a) as the material 12 was oscillated around the horizontal axis 16. Such apparent parallax motion would be typical of real objects, conventional print, and holographic images. Instead of exhibiting parallax motion, synthetically magnified image 14 shows orthoparallactic motion 20 – motion which is perpendicular to the normally expected parallax motion direction. The right side of Fig. 2a depicts a perspective view of a piece of material 12 exhibiting the orthoparallactic motion of a single synthetically magnified image 14 as it is oscillated 18 about horizontal rotational axis 16. The dotted outline 22 shows the position of the synthetically magnified image 14 after it has moved to the right by orthoparallax and the dotted outline 24 shows the position of the synthetically magnified image 14 after it has moved to the left by orthoparallax.

The visual effects of the Unison Deep and Unison Float embodiments are isometrically depicted in Figs. 2 b,c. In Fig. 2b, a piece of Unison Deep material 26 presents synthetically magnified images 28 that stereoscopically appear to lie beneath the plane of the Unison Deep material 26 when viewed by the eyes of the observer 30. In Fig. 2c, a piece of Unison Float material 32 presents synthetically magnified images 34 that stereoscopically appear to lie above the plane of the Unison Float material 34 when viewed by the eyes of the observer 30. The Unison Deep and Unison Float effects are visible from all azimuthal viewing positions and over a wide

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range of elevation positions, from vertical elevation (such that the line of sight from the eyes of the observer 30 to the Unison Deep material 26 or Unison Float material 32 is perpendicular to the surface of the materials) down to a shallow elevation angle which is typically less than 45 degrees. The visibility of the Unison Deep and Unison
5 Float effects over a wide range of viewing angles and orientations provides a simple and convenient method of differentiating Unison Deep and Unison Float materials from simulations utilizing cylindrical lenticular optics or holography.

The Unison Levitate embodiment effect is illustrated in Figs. 2 d-f by isometric views showing the stereoscopically perceived depth position of a
10 synthetically magnified image 38 in three different azimuthal rotations of the Unison Levitate material 36 and the corresponding plan view of the Unison Levitate material 36 and synthetically magnified image 38 as seen by the eyes of the observer 30. Fig. 2d depicts the synthetically magnified image 38 (hereafter referred to as 'the image') as stereoscopically appearing to lie in a plane beneath the Unison Levitate material 36
15 when said material is oriented as shown in the plan view. The heavy dark line in the plan view serves as an azimuthal orientation reference 37 for the sake of explanation. Note that in Fig. 2d the orientation reference 37 is aligned in a vertical direction and the image 38 is aligned in a horizontal direction. The image 38 appears in the Unison Deep position because the scale ratio is less than 1.000 along a first axis of the Unison
20 Levitate material 36 that is aligned substantially parallel to a line connecting the pupils of the observer's two eyes (this will be hereafter called the 'stereoscopic scale ratio'). The stereoscopic scale ratio of the Unison Levitate material 36 is greater than 1.000 along a second axis perpendicular to this first axis, thereby producing a Unison Float effect of the image 38 when the second axis is aligned substantially parallel to a

line connecting the pupils of the observer's eyes, as shown in Fig. 2f. Note that the orientation reference 37 is in a horizontal position in this figure. Fig. 2e depicts an intermediate azimuthal orientation of the Unison Levitate material 36 that produces a Unison Motion orthoparallactic image effect because the stereoscopic scale ratio in
5 this azimuthal orientation is substantially 1.000.

The visual effect of a Unison Levitate image 38 moving from beneath the Unison Levitate material 36 (Fig. 2d) up to the level of the Unison Levitate material 36 (Fig. 2e) and further up above the level of the Unison Levitate material 36 (Fig. 2f) as the material is azimuthally rotated can be enhanced by combining the Unison
10 Levitate material 36 with conventionally printed information. The unchanging stereoscopic depth of the conventional print serves as a reference plane to better perceive the stereoscopic depth movement of the images 38.

When a Unison material is illuminated by a strongly directional light source such as a 'point' light source (ex: a spotlight or an LED flashlight) or a collimated
15 source (ex: sunlight), "shadow images" of the icons may be seen. These shadow images are unusual in many ways. While the synthetic image presented by Unison does not move as the direction of illumination is moved, the shadow images produced do move. Furthermore, while the Unison synthetic images may lie in different visual planes than the plane of the material, the shadow images always lie in the plane of the
20 material. The color of the shadow image is the color of the icon. So black icons create black shadow images, green icons create green shadow images, and white icons create white shadow images.

The movement of the shadow image as the angle of illumination moves is tied to the specific depth or motion Unison effect in a way that parallels the visual effect

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present in the synthetic image. Thus the movement of a shadow image as the angle of the light is altered parallels the movement that the synthetic image shows when the angle of view is altered. In particular:

Motion shadow images move orthoparallactically as the light source is moved.

5 Deep shadow images move in the same direction as the light source.

Float shadow images move opposite to the direction of the light source.

Levitate shadow images move in directions that are a combination of the above:

10 Levitate Deep shadow images move in the same direction as the light in the left-right direction, but opposite from the direction of the light in the up-down direction; Levitate Float shadow images move opposite to the light in the left right direction but in the same direction as the light in the up-down direction; Levitate Motion shadow images show orthoparallactic motion with respect to the light movement.

15 Unison Morph shadow images show morphing effects as the light source is moved.

Additional unusual shadow image effects are seen when a diverging point light source, such as an LED light, is moved toward and away from a Unison film. When the light source is further away its diverging rays more closely approximate
20 collimated light, and the shadow images produced by Deep, SuperDeep, Float, or SuperFloat Unison synthetic images appear approximately the same size as the synthetic images. When the light is brought closer to the surface the shadow images of Deep and SuperDeep materials shrink because the illumination is strongly divergent, while the shadow images of Float and SuperFloat materials expand.

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Illuminating these materials with converging illumination causes Deep and SuperDeep shadow images to enlarge to a size greater than the synthetic images, while Float and SuperFloat shadow images shrink.

The shadow images of Unison motion material do not change scale significantly as the convergence or divergence of illumination is changed, rather, the shadow images rotate about the center of illumination. Unison Levitate shadow images shrink in one direction and enlarge in the perpendicular direction when the convergence or divergence of the illumination is changed. Unison Morph shadow images change in ways specific to the particular Morph pattern as the convergence or divergence of the illumination is changed.

All of these shadow image effects can be used as additional authentication methods for Unison materials utilized for security, anti-counterfeiting, brand protection applications, and other similar applications.

Figs. 3 a-i are plan views showing various embodiments and fill-factors of different patterns of symmetric two-dimensional arrays of micro-lenses. Figs. 3a, d and g depict micro-lenses 46, 52, and 60, respectively, that are arranged in regular hexagonal array pattern 40. (The dashed array pattern lines 40, 42, and 44 indicate the symmetry of the pattern of lenses but do not necessarily represent any physical element of the lens array.) The lenses of Fig. 3a have substantially circular base geometry 46, the lenses of Fig. 3g have substantially hexagonal base geometries 60, and the lenses of Fig. 3d have intermediate base geometries which are rounded-off hexagons 52. A similar progression of lens geometries applies to the square array 42 of lenses 48, 54, and 62, wherein these lenses have base geometries which range from substantially circular 48, to rounded-off square 54, to substantially square 62, as seen

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in Figs. 3b, e, and h. Correspondingly, the equilateral triangular array 44 holds lenses having base geometries that range from substantially circular 50, to rounded-off triangle 58, to substantially triangular 64, as seen in Figs. 3c, f and i.

The lens patterns of Figs. 3 a-i are representative of lenses that can be used for the present system. The interstitial space between the lenses does not directly contribute to the synthetic magnification of the images. A material created using one of these lens patterns will also include an array of icon elements that is arranged in the same geometry and at approximately the same scale, allowing for differences in scale utilized to produce Unison Motion, Unison Deep, Unison Float, and Unison Levitate effects. If the interstitial space is large, such as is shown in Fig. 3c, the lenses are said to have a low fill-factor and the contrast between the image and the background will be reduced by light scattered from icon elements. If the interstitial spaces are small the lenses are said to have a high fill-factor and the contrast between the image and the background will be high, providing the lenses themselves have good focal properties and icon elements are in the lenses' focal planes. It is generally easier to form high optical quality micro-lenses with a circular or nearly circular base than with a square or triangular base. A good balance of lens performance and minimizing of interstitial space is shown in Fig. 3d; a hexagonal array of lenses having base geometries that are rounded hexagons.

Lenses having a low F# are particularly suitable for use in the present system. By low F# we mean less than 4, and in particular for Unison Motion approximately 2 or lower. Low F# lenses have high curvature and a correspondingly large sag, or center thickness, as a proportion of their diameter. A typical Unison lens, with an F# of 0.8, has a hexagonal base 28 microns wide and a center thickness of 10.9 microns.

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A typical Drinkwater lens, with a diameter of 50 microns and a focal length of 200 microns, has an F# of 4 and a center thickness of 3.1 microns. If scaled to the same base size, the Unison lens has a sag almost six times larger than the Drinkwater lens.

We have discovered that polygonal base multi-zonal lenses, for example
5 hexagonal base multi-zonal lenses, have important and unexpected advantages over circular base spherical lenses. As explained above, hexagonal base multi-zonal lenses significantly improve manufacturability by virtue of their stress-relieving geometry, but there are additional unexpected optical benefits obtained through the use of hexagonal base multi-zonal lenses.

10 We refer to these lenses as multi-zonal because they possess three optical zones that each provide a different and unique benefit to the subject invention. The three zones are the central zone (constituting approximately half of the area of the lens), the side zones, and the corner zones. These polygonal lenses have an effective diameter that is the diameter of a circle drawn inside the corner zones around the
15 central zone and including the side zones.

The central zone of the hexagonal base multi-zonal lens of the subject invention has an aspheric form (for example, having the form defined by [$y = (5.1316E)X^4 - (0.01679)X^3 + (0.124931)X + 11.24824$] for a 28 micron diameter lens with a nominal 28 micron focal length) that brings light to a focus at
20 least as well as a spherical surface having the same diameter and focal length. Figure 30 illustrates the central zone 780 focal properties 782 of a nominal 28 micron diameter hexagonal base multi-zonal lens 784 with a nominal 28 micron focal length in a polymer substrate 786 (lens and substrate $n=1.51$) and Figure 31 illustrates the central zone 788 focal properties 790 of a 28 micron diameter spherical lens 792 with

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a nominal 30 micron focal length in a polymer substrate 794 (lens and substrate $n=1.51$). Comparison of these two figures clearly demonstrates that the hexagonal base multi-zonal lens 784 of the subject disclosure performs at least as well as the spherical lens 792. The central zone 789 of the hexagonal base multi-zonal lens 784 provides high image resolution and shallow depth of field from a wide variety of viewing angles.

Each of the six side zones 796 of the hexagonal base multi-zonal lens 784 of the subject invention have focal lengths that depend on the location with the zone in a complex way, but the effect is to cause the focus of the side zones 796 to be spread over a range of values 798 spanning approximately ± 10 percent of the central zone focus, as illustrated in Figure 32. This vertical blurring 798 of the focal point effectively increases the depth of field of the lens in these zones 796, and provides a benefit that is equivalent to having a flat-field lens. The performance of the outer zones 800 of spherical lens 792 can be seen in Figure 33. The vertical blurring of the focal point 802 is significantly less for the spherical lens 792 than it is for the hexagonal base multi-zonal lens 784.

This is particularly important for off-normal viewing: the increased depth of field, and effectively flatter field, mitigates the abrupt image defocus that can occur with a spherical lens when its curved focal surface separates from the icon plane. Consequently, a Unison material using hexagonal base multi-zonal lenses displays synthetic images that fade from focus more softly at higher viewing angles than the equivalent Unison material using spherical lenses. This is desirable because it increases the effective viewing angle of the material and therefore increases its usefulness as a security device or an image presentation device.

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The corner zones 806 of the hexagonal base multi-zonal lens 784 of Figure 32 possess diverging focal properties that provide the unexpected benefit of scattering 808 ambient illumination onto the icon plane and thereby reducing the sensitivity of the Unison material to illumination conditions. The spherical lens 792 of Figure 33
5 does not scatter the ambient illumination over as wide an area (as seen by the absence of rays scattered into the icon plane regions 804), so Unison materials made using spherical lenses have greater synthetic image brightness variations when viewed from a variety of angles than Unison materials made using hexagonal base multi-zonal lenses.

10 The benefit obtained from the exemplary hexagonal base multi-zonal lenses is further magnified because hexagonal base multi-zonal lenses have a higher fill factor (ability to cover the plane) than spherical lenses. The interstitial space between spherical lenses provides virtually no scattering of ambient light, while this non-scattering area is much smaller in the case of hexagonal base multi-zonal lenses.

15 Thus it is seen that even though the focal properties of a hexagonal base multi-zonal lens are inferior to those of a spherical lens as evaluated by conventional optical standards, in the context of the subject invention hexagonal base multi-zonal lenses provide unexpected benefits and advantages over spherical lenses.

Either type of lens can benefit from the addition of scattering microstructures
20 or scattering materials introduced into, or incorporated into, the lens interstitial spaces to enhance the scattering of ambient illumination onto the icon plane. Furthermore, the lens interstitial spaces can be filled with a material that will form a small radius meniscus, with either converging or diverging focal properties, to direct ambient illumination onto the icon plane. These methods may be combined, for example, by

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incorporating light scattering particles into a lens interstitial meniscus fill material.

Alternatively, the lens interstitial zones can be originally manufactured with suitably scattering lens interstitial zones.

A spherical lens having these proportions is very difficult to manufacture
5 because the high contact angle between the surface of the film and the edge of the lens acts as a stress concentrator for the forces applied to separate the lens from the tool during manufacture. These high stresses tend to cause the adhesion of the lens to the film to fail and to failure of removal of the lens from the tool. Furthermore, the optical performance of a low F# spherical lens is progressively compromised for
10 radial zones away from the center of the lens: low F# spherical lenses do not focus well except near their central zone.

Hexagonal base lenses have an unexpected and significant benefit over lenses that have a more substantially circular base: hexagonal lenses release from their tools with lower peeling force than the optically equivalent lenses with substantially
15 circular bases. Hexagonal lenses have a shape that blends from substantially axially symmetric near their center to hexagonally symmetric, with corners that act as stress concentrators, at their bases. The stress concentrations caused by the sharp base corners reduce the overall peeling force required to separate the lenses from their molds during manufacturing. The magnitude of this effect is substantial – the peeling
20 forces can be reduced during manufacturing by a factor of two or more for hexagonal base lenses as compared to substantially circular base lenses.

The image contrast of the material can be enhanced by filling the lens interstitial spaces with a light absorbing (dark colored) opaque pigmented material, effectively forming a mask for the lenses. This eliminates the contrast reduction that

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arises from light scattered from the icon layer through the lens interstitial spaces. An additional effect of this interstitial fill is that the overall image becomes darker because incoming ambient illumination is blocked from passing through the interstitial spaces to the icon plane. The image clarity produced by lenses having aberrant focusing at their periphery can also be improved by an opaque pigmented interstitial fill, providing that this fill occludes the aberrant peripheral lens zone.

A different effect can be obtained by filling the lens interstitial spaces with a white or light colored material, or a material color matched to a substrate to be used with the Unison material. If the light colored lens interstitial fill is dense enough and the icon plane incorporates a strong contrast between the icon elements and the background, the Unison synthetic image will be substantially invisible when viewed with reflected light, yet will be distinctly visible when viewed in transmitted light from the lens side, but not visible when viewed from the icon side. This provides the novel security effect of having a one-way transmission image that is visible only in transmitted light and visible only from one side.

Fluorescing materials can be utilized in a lens interstitial coating instead of, or in addition to, visible light pigments to provide additional means of authentication.

Fig. 4 graphs the effects of changing the stereoscopic scale ratio, SSR (the icon element repeat period/ the lens array repeat period), along an axis of the present material. Zones of the system having an SSR greater than 1.0000 will produce Unison Float and SuperFloat effects, zones having an SSR of substantially 1.0000 will produce Unison Motion orthoparallactic motion (OPM) effects, and zones having an SSR less than 1.0000 will produce Unison Deep and Unison SuperDeep effects. All of these effects can be produced and transitioned from one to another in a variety of

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ways along an axis of system film. This figure illustrates one of an infinite variety of such combinations. The dashed line 66 indicates the SSR value corresponding substantially to 1.0000, the dividing line between Unison Deep and Unison SuperDeep and Unison Float and Unison SuperFloat, and the SSR value which demonstrates OPM. In zone 68 the SSR of the Unison material is 0.995, creating a Unison Deep effect.

Adjacent to this is zone 70 in which the SSR is ramped from 0.995 up to 1.005, producing a spatial transition from a Unison Deep to a Unison Float effect. The SSR in the next zone 72 is 1.005 creating a Unison Float effect. The next zone 74 creates a smooth transition down from a Unison Float effect to a Unison Deep effect. Zone 76 proceeds stepwise up from a Unison Deep effect, to OPM, to a Unison Float effect, and zone 78 steps it back down to OPM. The variations in repeat period needed to accomplish these effects are generally most easily implemented in the icon element layer. In addition to varying the SSR in each zone, it may be desirable to vary the rotational angle of each zone of the arrays, preferably within the icon element array, to keep the synthetically magnified images substantially similar in size.

The easiest way to interpret this graph is to see it as a cross-section of the stereoscopic depth that will be perceived across this axis of a piece of system material. It is therefore possible to create a stereoscopically sculpted field of images, a contoured visual surface, by local control of the SSR and optionally by corresponding local control of the array rotational angle. This stereoscopically sculpted surface can be used to represent an unlimited range of shapes, including human faces. A pattern of icon elements that create the effect of a stereoscopically

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sculpted grid, or periodic dots, can be a particularly effective way to visually display a complex surface.

Figs. 5 a-c are plan views depicting the effect of rotating one array pattern with respect to the other in the production of material of the present system. Fig. 5a shows a lens array 80 having a regular periodic array spacing 82, without substantial change in the angle of the array axes. Fig. 5b shows an icon element array 84 with a progressively changing array axis orientation angle 86. If the lens array 80 is combined with the icon element array 84 by translating the lens array over the icon array, as drawn, then the approximate visual effect that results is shown in Fig. 5c. In Fig. 5c the material 88 created by combining lens array 80 and icon array 84 creates a pattern of synthetically magnified images 89, 90, 91 that vary in scale and rotation across the material. Towards the lower left edge of the material 88 image 89 is large and shows no rotation. Image 90, toward the upper middle section of material 88 is smaller and is rotated through a significant angle with respect to image 89. The different scales and rotations between images 89 and 90 are the result of the differences in the angular misalignment of the lens pattern 82 and the icon element pattern 86.

Figs. 6 a-c illustrate a method for causing one synthetically magnified OPM image 98 to morph into another synthetically magnified image 102 as the first image moves across a boundary 104 in the icon element patterns 92 and 94. Icon element pattern 92 bears circle-shaped icon elements 98, shown in the magnified inset 96. Icon element pattern 94 bears star-shaped icon elements 102, shown in the magnified inset 100. Icon element patterns 92 and 94 are not separate objects, but are joined at their boundary 104. When the material is assembled using this combined pattern of

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icon elements the resulting OPM images will show the morphing effects depicted in Figs. 6b and c. Fig. 6b shows OPM circle images 98 moving to the right 107 across the boundary 104 and emerging from the boundary as star images 102 also moving to the right. Image 106 is in transition, part circle and part star, as it crosses the

5 boundary. Fig. 6c of the figure shows the images after they have moved further to the right: image 98 is now closer to the boundary 104 and image 106 has almost completely crossed the boundary to complete its morphing from circle to star. The morphing effect can be accomplished in a less abrupt manner by creating a transition zone from one icon element pattern to the other, instead of having a hard boundary

10 104. In the transition zone the icons would gradually change from circle to star through a series of stages. The smoothness of the visual morphing of the resulting OPM images will depend on the number of stages used for the transition. The range of graphical possibilities is endless. For example: the transition zone could be designed to make the circle appear to shrink while sharp star points protruded up

15 through it, or alternatively the sides of the circle could appear to dent inward to create a stubby star that progressively became sharper until it reached its final design.

Figs. 7 a-c are cross-sections of materials of the present system that illustrate alternative embodiments of the icon elements. Fig. 7a depicts a material having lenses 1 separated from icon elements 108 by optical spacer 5. Icon elements 108 are

20 formed by patterns of colorless, colored, tinted, or dyed material applied to the lower surface of optical spacer 5. Any of the multitude of common printing methods, such as ink jet, laserjet, letterpress, flexo, gravure, and intaglio, can be used to deposit icon elements 108 of this kind so long as the print resolution is fine enough.

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Fig. 7b depicts a similar material system with a different embodiment of icon elements 112. In this embodiment the icon elements are formed from pigments, dyes, or particles embedded in a supporting material 110. Examples of this embodiment of icon elements 112 in supporting material 110 include: silver particles in gelatin, as a
5 photographic emulsion, pigmented or dyed ink absorbed into an ink receptor coating, dye sublimation transfer into a dye receptor coating, and photochromic or thermochromic images in an imaging film.

Fig. 7c depicts a microstructure approach to forming icon elements 114. This method has the benefit of almost unlimited spatial resolution. The icon elements 114
10 can be formed from the voids in the microstructure 113 or the solid regions 115, singly or in combination. The voids 113 can optionally be filled or coated with another material such as evaporated metal material having a different refractive index, or dyed or pigmented material.

Figs. 8 a,b depict positive and negative embodiments of icon elements. Fig.
15 8a shows positive icon elements 116 that are colored, dyed, or pigmented 120 against a transparent background 118. Fig. 8b shows negative icon elements 122 that are transparent 118 against a colored, dyed, or pigmented background 120. A material of the present system may optionally incorporate both positive and negative icon elements. This method of creating positive and negative icon elements is particularly
20 well adapted to the microstructure icon elements 114 of Fig. 7c.

Fig. 9 shows a cross-section of one embodiment of a pixel-zone material of the present system. This embodiment includes zones with lenses 124 having a short focus and other zones with lenses having a long focus 136. The short focus lenses 124 project images 123 of icon elements 129 in icon plane 128 disposed at the focal plane

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of lenses 124. The long focus lenses 136 project images 134 of icon elements 137 in icon plane 132 disposed at the focal plane of lenses 136. Optical separator 126 separates short focus lenses 124 from their associated icon plane 128. Long focus lenses 136 are separated from their associated icon plane 132 by the sum of the

5 thicknesses of optical separator 126, icon plane 128, and second optical separator 130. Icon elements 137 in the second icon plane 132 are outside the depth of focus of short focus lenses 124 and therefore do not form distinct synthetically magnified images in the short focus lens zones. In a similar manner, icon elements 129 are too close to long focus lenses 136 to form distinct synthetically magnified images. Accordingly,

10 zones of material bearing short focus lenses 124 will display images 123 of the icon elements 129, while zones of material bearing long focus lenses 136 will display images 134 of icon elements 137. The images 123 and 134 that are projected can differ in design, color, OPM direction, synthetic magnification factor, and effect, including the Deep, Unison, Float, and Levitate effects described above.

15 Fig. 10 is a cross-section of an alternate embodiment of a pixel-zone material of the present system. This embodiment includes zones with lenses 140 elevated by a lens support mesa 144 above the bases of the non-elevated lenses 148. The focal length of the elevated lenses 140 is the distance 158, placing the focus of these lenses in the first icon plane 152. The focal length of the non-elevated lenses 148 is the

20 distance 160, placing the focus of these lenses in the second icon plane 156. These two focal lengths, 158 and 160, may be chosen to be similar or dissimilar. The elevated lenses 140 project images 138 of icon elements 162 in icon plane 152 disposed at the focal plane of lenses 140. The non-elevated lenses 148 project images 146 of icon elements 164 in icon plane 156 disposed at the focal plane of lenses 148.

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The elevated lenses 140 are separated from their associated icon elements 162 by the sum of the thickness of the lens support mesa 144 and the optical separation 150. The non-elevated lenses 148 are separated from their associated icon elements 164 by the sum of the thickness of the optical separation 150, the icon layer 152, and the icon separator 154. Icon elements 164 in the second icon plane 156 are outside the depth of focus of the elevated lenses 140 and therefore do not form distinct synthetically magnified images in the elevated lens zones. In a similar manner, icon elements 152 are too close to non-elevated lenses 148 to form distinct synthetically magnified images. Accordingly, zones of material bearing elevated lenses 140 will display images 138 of the icon elements 162, while zones of material bearing non-elevated lenses 136 will display images 146 of icon elements 156. The images 138 and 146 that are projected can differ in design, color, OPM direction, synthetic magnification factor, and effect, including Deep, Unison, Float, and Levitate effects.

Figs. 11 a,b are cross-sections illustrating non-refractive embodiments of the present system. Fig. 11a illustrates an embodiment that utilizes a focusing reflector 166 instead of a refractive lens to project images 174 of icon elements 172. The icon layer 170 lies between the viewer's eyes and the focusing optics. Focusing reflectors 166 can be metallized 167 to obtain high focusing efficiency. The icon layer 170 is maintained at a distance equal to the focal length of the reflectors by optical separator 168. Fig. 11b discloses a pinhole optics embodiment of this material. Opaque upper layer 176, preferably black in color for contrast enhancement, is pierced by apertures 178. Optical separator element 180 controls the field of view of the system. Icon elements 184 in icon layer 182 are imaged through apertures 178 in a manner similar to the pinhole optics of a pinhole camera. Because of the small amount of light

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passed through the apertures, this embodiment is most effective when it is back-illuminated, with light passing through the icon plane 182 first, then through the apertures 178. Effects of each of the above-described embodiments, OPM, Deep, Float, and Levitate, can be created using either the reflective system design or the

5 pinhole optics system design.

Figs. 12 a,b are cross-sections comparing the structures of an all-refractive material 188 with a hybrid refractive/reflective material 199. Fig. 12a depicts an exemplary structure, with micro-lenses 192 separated from the icon plane 194 by optical separator 198. Optional scaling layer 195 contributes to the total refractive

10 system thickness 196. Lenses 192 project icon images 190 toward the viewer (not shown). Hybrid refractive/reflective material 199 includes micro-lenses 210 with icon plane 208 directly beneath them. Optical spacer 200 separates the lenses 210 and the icon plane 208 from reflective layer 202. Reflective layer 202 can be metallized, such as by evaporated or sputtered aluminum, gold, rhodium, chromium, osmium,

15 depleted uranium or silver, by chemically deposited silver, or by multi-layer interference films. Light scattered from icon layer 208 reflects from reflective layer 202, passes through icon layer 208 and into lenses 210 which project images 206 toward the viewer (not shown). Both of these figures are drawn to approximately the same scale: by visual comparison it can be seen that the total system thickness 212 of

20 the hybrid refractive/reflective system 199 is about half the total system thickness 196 of the all-refractive system 188. Exemplary dimensions for equivalent systems are 29μ total refractive system 188 thickness 196 and 17μ for total hybrid refractive/reflective system 199 thickness 212. The thickness of a refractive/reflective system can be further reduced by scaling. Thus, a hybrid system having lenses 15μ in

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diameter can be made with a total thickness of about 8μ . Effects of each of the above described embodiments, OPM, Deep, Float, Levitate, Morph, and 3-D can be created using the hybrid refractive/diffractive design.

Fig. 13 is a cross-section showing a 'peel-to-reveal' tamper-indicating material embodiment of the present system. This embodiment does not display an image until it is tampered with. The untampered structure is shown in region 224, where a refractive system 214 is optically buried under a top layer 216 consisting of an optional substrate 218 and a peelable layer 220 which is conformal to the lenses 215. Peelable layer 220 effectively forms negative lens structures 220 that fit over positive lenses 215 and negate their optical power. Lenses 215 cannot form images of the icon layer in the untampered region, and the light scattered 222 from the icon plane is unfocused. Top layer 216 may include an optional film substrate 218. Tampering, shown in region 226, causes the release of top layer 216 from the refractive system 214, exposing the lenses 215 so that they can form images 228. Effects of each of the above described embodiments, OPM, Deep, Float, and Levitate, can be included in a tamper indicating 'peel-to-reveal' system of the type of Fig. 13.

Fig. 14 is a cross-section illustrating a 'peel-to-change' tamper-indicating material embodiment of the present system. This embodiment displays a first image 248 of a first icon plane 242 prior to tampering 252, then displays a second image 258 at region 254 after it has been tampered with. The untampered structure is shown in region 252, where two refractive systems, 232 and 230, are stacked. The first icon plane 242 is located beneath the lenses 240 of the second system. Prior to tampering in region 252 the first, or upper, system 232 presents images of the first icon plane 242. The second icon plane 246 is too far outside the depth of focus of lenses 234 to

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form distinct images. The first lenses 234 are separated from the second lenses 240 by an optional substrate 236 and a peelable layer 238 which is conformal to the second lenses 240. Peelable layer 232 effectively forms negative lens structures 238 that fit over positive lenses 240 and negate their optical power. Top layer 232 may
5 include optional film substrate 236. Tampering results in the peeling 256 of the top layer 232, shown in region 254, from the second refractive system 230, exposing the second lenses 240 so that they can form images 258 of the second icon layer 246. Second lenses 240 do not form images of the first icon layer 242 because the icon layer is too close to the lenses 240.

10 This embodiment of a tamper indicating material is well suited to application as a tape or label applied to an article. Tampering releases the top layer 232, leaving the second system 230 attached to the article. Prior to tampering, this embodiment presents a first image 248. After tampering 254 the second system 230, still attached to the article, presents a second image 258 while the peeled layer 256 presents no
15 image at all. Effects of each of the above described embodiments, OPM, Deep, Float, and Levitate, can be included in either the first system 232 or the second system 230.

Note that an alternative embodiment accomplishing a similar effect to that of Fig. 14 is to have two separate systems laminated to each other. In this embodiment when the upper layer is peeled it takes the first icon plane and its image(s) with it,
20 revealing the second system and its image(s).

Figs. 15 a-d are cross-sections showing various two-sided embodiments of the present system. Fig. 15a depicts a two-sided material 260 that includes a single icon plane 264 that is imaged 268 by lenses 262 on one side and imaged 270 by a second set of lenses 266 on the opposite side. The image 268 seen from the left side (as

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drawn) is the mirror image of the image 270 seen from the right side. Icon plane 264 may contain icon elements that are symbols or images which appear similar in mirror image, or icon elements which appear different in mirror image, or combinations of icon elements wherein a portion of the icon elements are correct-reading when viewed from one side and the other icon elements are correct-reading when viewed from the other side. Effects of each of the above described embodiments, OPM, Deep, Float, and Levitate, can be displayed from either side of a two-sided material according to this embodiment.

Fig. 15b illustrates another two-sided embodiment 272 having two icon planes 276 and 278 that are imaged, 282 and 286 respectively, by two sets of lenses, 274 and 280 respectively. This embodiment is essentially two separate systems, 287 and 289, such as illustrated in Fig. 1a, that have been joined together with an icon layer spacer 277 in between them. The thickness of this icon layer spacer 277 will determine the degree that the 'wrong' icon layer is imaged 284 and 288 by a set of lenses. For example, if the thickness of icon layer spacer 277 is zero, such that icon layers 276 and 278 are in contact, then both icon layers will be imaged by both sets of lenses 274 and 280. In another example, if the thickness of icon layer spacer 277 is substantially larger than the depth of focus of lenses 274 and 280, then the 'wrong' icon layers will not be imaged by the lenses 274 and 280. In yet another example, if the depth of focus of one set of lenses 274 is large, but the depth of focus of the other set of lenses is small (because the lenses 274 and 280 have different F#'s), then both icon planes 276 and 278 will be imaged 282 through lenses 274 but only one icon plane 278 will be imaged through lenses 280, so a material of this type would show two images from one side but only one of those images, mirrored, from the opposite side. Effects of

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each of the above described embodiments, OPM, Deep, Float, and Levitate, can be displayed from either side of a two-sided material according to this embodiment, and the projected images 282 and 286 can be of the same or different colors.

Fig. 15c shows yet another two-sided material 290 having a pigmented icon layer spacer 298 that blocks the lenses on one side of the material from seeing the 'wrong' set of icons. Lenses 292 image 294 icon layer 296 but cannot image icon layer 300 because of the presence of pigmented icon layer 298. Similarly, lenses 302 image 304 icon layer 300, but cannot image icon layer 296 because of the presence of pigmented icon layer 298. Effects of each of the above described embodiments, OPM, Deep, Float, and Levitate, can be displayed from either side of a two-sided material according to this embodiment, and the projected images 294 and 304 can be of the same or different colors.

Fig. 15d discloses a further two-sided material 306 embodiment having lenses 308 that image 318 icon layer 314 and lenses 316 on the opposite side that image 322 icon layer 310. Icon layer 310 is close to, or substantially in contact with, the bases of lenses 308 and icon layer 314 is close to, or substantially in contact with, the bases of lenses 316. Icons 310 are too close to lenses 308 to form an image, so their light scatters 320 instead of focusing. Icons 314 are too close to lenses 316 to form an image, so their light scatters 324 instead of focusing. Effects of each of the above described embodiments, OPM, Deep, Float, and Levitate, can be displayed from either side of a two-sided material according to this embodiment, and the projected images 318 and 322 can be of the same or different colors.

Figs. 16 a-f are cross-sections and corresponding plan views illustrating three different methods for creating grayscale or tonal icon element patterns and subsequent

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synthetically magnified images with the present system. Figs. 16 a-c are cross-section details of the icon side of a material 307, including part of optical separator 309 and a transparent micro structured icon layer 311. The icon elements are formed as bas-relief surfaces 313, 315, 317 that are then filled with a pigmented or dyed material 323, 325, 327 respectively. The underside of the icon layer may be optionally sealed by a sealing layer 321 that can be transparent, tinted, colored, dyed, or pigmented, or opaque. The bas-relief micro structures of icon elements 313, 315, and 317 provide thickness variations in the dyed or pigmented fill material, 323, 325, and 327 respectively, that create variations in the optical density of the icon element as seen in plan view. The plan views corresponding to icon elements 323, 325, and 327 are plan views 337, 339, and 341. The use of this method to create grayscale or tonal synthetically magnified images is not limited to the specifics of the examples disclosed here, but may be generally applied to create an unlimited variety of grayscale images.

Fig. 16 a includes icon element 313, dyed or pigmented icon element fill 323, and corresponding plan view 337. The cross section view of the icon plane at the top of this figure can only show one cutting plane through the icon elements. The location of the cutting plane is indicated by the dashed line 319 through the plane views 337, 339, and 341. Accordingly, the cross-section of icon element 313 is one plane through a substantially hemispherical-shaped icon element. By suitably limiting the overall dye or pigment density of the fill 323, thickness variations of the dyed or pigmented fill 323 create a tonal, or grayscale, optical density variations represented in the plan view 337. An array of icon elements of this type can be

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synthetically magnified within the present material system to produce images that show equivalent grayscale variations.

Fig. 16 b includes icon element 315, dyed or pigmented icon element fill 325, and corresponding plan view 339. Plan view 339 shows that the icon element 315 is a
5 bas-relief representation of a face. The tonal variations in an image of a face are complex, as shown by the complex thickness variations 325 in the cross-section view. As disclosed with regard to icon element 313, an array of icon elements of this type, as shown by 315, 325, and 339, can be synthetically magnified within the present material system to produce images that show equivalent grayscale variations
10 representing, in this example, the image of a face.

Fig. 16 c includes icon element 317, dyed or pigmented fill 327, and corresponding plan view 341. In a manner similar to the discussion of Figs. 16 a,b, above, the bas-relief shape of this icon element structure produces a tonal variation in the appearance of the dyed and pigmented fill 327 and in the synthetically magnified
15 image produced by the present material system. Icon element 317 illustrates a method for creating a bright center in a rounded surface, as compared to the effect of icon element 313 which creates a dark center in a rounded surface.

Figs. 16 d,e disclose another embodiment 326 of transparent bas-relief micro structured icon layer 311 including icon elements 329 and 331 that are coated with a
20 high refractive index material 328. The icon layer 311 can be sealed with an optional sealing layer 321 that fills the icon elements 329 and 331, 330 and 332, respectively. The high refractive index layer 328 enhances the visibility of sloping surfaces by creating reflections from them by total internal reflection. Plan views 342 and 344 present representative images of the appearance of icon elements 329 and 331 and

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their synthetically magnified images. This high refractive index coating embodiment provides a kind of edge-enhancement effect without adding pigment or dye to make the icons and their images visible.

Fig. 16 f discloses yet another embodiment 333 of transparent bas-relief micro structured icon 335 utilizing an air, gas, or liquid volume 336 to provide visual definition for this phase interface 334 microstructure. Optional sealing layer 340 may be added with or without optional adhesive 338 to entrap the air, gas, or liquid volume 336. The visual effect of a phase interface icon element is similar to that of a high refractive index coated icon element 329 and 331.

Figs. 17 a-d are cross-sections showing the use of the present system as a laminating film in conjunction with printed information, such as may be utilized in the manufacture of I.D. cards and driver's licenses, wherein the material 348 (consisting of the coordinated micro-array of lenses and images described above) covers a substantial proportion of the surface. Fig. 17a depicts an embodiment of Unison used as a laminate over print 347. Material 348 having at least some optical transparency in the icon layer is laminated to fibrous substrate 354, such as paper or paper substitute, with lamination adhesive 350, covering or partly covering print element 352 that had previously been applied to the fibrous substrate 354. Because the material 348 is at least partially transparent, the print element 352 can be seen through it and the effect of this combination is to provide the dynamic image effect of the present system in combination with the static print.

Fig. 17b shows an embodiment of the system material used as a laminate over a print element 352 applied to a nonfibrous substrate 358, such as a polymer film. As in Fig 17a, material 348 having at least some optical transparency in the icon layer is

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laminated to nonfibrous substrate 358, such as polymer, metal, glass, or ceramic substitute, with lamination adhesive 350, covering or partly covering print element 352 that had previously been applied to the nonfibrous substrate 354. Because the material 348 is at least partially transparent, the print element 352 can be seen through it and the effect of this combination is to provide the dynamic image effect in combination with the static print.

Fig. 17c depicts the use of a print element directly on the lens side of material 360. In this embodiment material 348 has print element 352 directly applied to the upper lens surface. This embodiment does not require that the material be at least partly transparent: the print element 352 lies on top of the material and the dynamic image effects can be seen around the print element. In this embodiment the material 348 is used as the substrate for the final product, such as currency, ID cards, and other articles requiring authentication or providing authentication to another article.

Fig. 17d depicts the use of a print element directly on the icon side of an at-least partially transparent material 362. Print element 352 is applied directly to the icon layer or sealing layer of an at-least partially transparent system material 348. Because the system material 348 is at least partially transparent, the print element 352 can be seen through it and the effect of this combination is to provide the dynamic image effect in combination with the static print. In this embodiment the system material 348 is used as the substrate for the final product, such as currency, ID cards, and other articles requiring authentication or providing authentication to another article.

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Each of the embodiments of Figs. 17 a-d can be used singly or in combination. Thus, for example, a system material 348 can be both overprinted (Fig. 17c) and backside printed (Fig. 17d), then optionally laminated over print on a substrate (Figs. 17 a,b). Combinations such as these can further increase the counterfeiting, simulation, and tampering resistance of the material of the present system.

Figs. 18 a-f are cross-sections illustrating the application of the present system to, or incorporation into, various substrates and in combination with printed information. The embodiments of Figs. 18 a-f differ from those of Figs. 17 a-d in that the former figures disclose system material 348 that covers most or all of an article, whereas the present figures disclose embodiments wherein the system material or its optical effect do not substantially cover a whole surface, but rather cover only a portion of a surface. Fig. 18a depicts a piece of at-least partially transparent system material 364 adhered to a fibrous or non-fibrous substrate 368 with adhesive element 366. Optional print element 370 has been directly applied to the upper, lens, surface of material 364. Print element 370 may be part of a larger pattern that extends beyond the piece of material 364. The piece of material 364 is optionally laminated over print element 372 that was applied to the fibrous or non-fibrous substrate prior to the application of the material 364.

Fig. 18b illustrates an embodiment of single-sided system material 364 incorporated into an non-optical substrate 378 as a window, wherein at least some of the edges of the system material 364 are captured, covered, or enclosed by the non-optical substrate 378. Print elements 380 may be optionally applied on top of the system material lens surface and these print elements may be aligned with, or correspond to, print elements 382 applied to the non-optical substrate 378 in the area

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adjacent to print element 380. Similarly, print elements 384 can applied to the opposite side of the non-optical substrate aligned with, or corresponding to, print elements 386 applied to the icon or scaling layer 388 of the system material 364. The effect of a window of this kind will be to present distinct images when the material is viewed from the lens side and no images when viewed from the icon side, providing a one-way image effect.

Fig. 18c shows a similar embodiment to that of Fig. 18b, except that the system material 306 is double-sided material 306 (or other double-sided embodiment described above). Print elements 390, 392, 394, and 396 substantially correspond in function to print elements 380, 382, 384, 386, previously described. The effect of a material window of this kind will be to present different distinct images when the material is viewed from opposite sides. For example, a window incorporated into a currency paper could display the numerical denomination of the bill, such as "10" when viewed from the face side of the bill, but when viewed from the back side of the bill the Unison window could display different information, such as "USA", that may be in the same color as the first image or a different color.

Fig. 18d illustrates a transparent substrate 373 acting as the optical spacer for a material formed by a zone of lenses 374 of limited extent and an icon layer 376 extending substantially beyond the periphery of the zone of lenses 374. In this embodiment the present effects will only be visible in that zone that includes both lenses and icons (corresponding to lens zone 374 in this figure). Both the lenses 374 and the adjacent substrate may optionally be printed 375, and print elements may also be applied to the icon layer 376 or to an optional scaling layer covering the icons (not indicated in this figure – see Fig. 1). Multiple lens zones can be used on an article

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after the manner of this embodiment; wherever a lens zone is placed the Unison effects will be seen; the size, rotation, stereoscopic depth position, and OPM properties of the images can be different for each lens zone. This embodiment is well suited for application to ID cards, credit cards, drivers' licenses, and similar applications.

Fig. 18e shows an embodiment that is similar to that of Fig. 18d, except that the icon plane 402 does not extend substantially beyond the extent of the lens zone 400. Optical spacer 398 separates the lenses 400 from the icons 402. Print elements 404 and 406 correspond to print elements 375 and 377 in Fig. 18d. Multiple zones 400 can be used on an article after the manner of this embodiment; each zone can have separate effects. This embodiment is well suited for application to ID cards, credit cards, drivers' licenses, and similar applications.

Fig. 18f depicts an embodiment that is similar to Fig. 18d except that the present embodiment incorporates optical spacer 408 that separates lenses 413 from icon plane 410. Lenses 413 extend substantially beyond the periphery of the icon zone 412. Print elements 414 and 416 correspond to print elements 375 and 377 in Fig. 18d. Multiple lens zones can be used on an article after the manner of this embodiment; wherever a lens zone is placed the present effects will be seen; the size, rotation, stereoscopic depth position, and OPM properties of the images can be different for each lens zone. This embodiment is well suited for application to ID cards, credit cards, drivers' licenses, and similar applications.

Figs. 19 a,b illustrate cross-sectional views comparing the in-focus field of view of a spherical lens with that of a flat field aspheric lens when each are incorporated into a structure of the type described above. Fig. 19a illustrates a

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substantially spherical lens as applied in a system as described above. Substantially spherical lens 418 is separated from icon plane 422 by optical spacer 420. Image 424 projected out perpendicular to the surface of the material originates at focal point 426 within the icon layer 422. The image 424 is in sharp focus because the focal point 426 is within the icon layer 422. When the lens is viewed from an oblique angle, then image 428 is blurry and out of focus because the corresponding focal point 430 is no longer in the icon plane, but is above it a substantial distance. Arrow 432 shows the field curvature of this lens, equivalent to the sweep of the focal point from 426 to 430. The focal point is within the icon plane throughout the zone 434, then moves outside of the icon plane in zone 436. Lenses which are well suited to application in coordination with a plane of printed images or icons typically have a low F#, typically less than 1, resulting in a very shallow depth of focus – higher F# lenses can be used effectively with Deep and Float effects, but cause proportionate vertical binocular disparity with effects described herein when used with Unison Motion effects. As soon as the lower limit of the depth of focus moves outside of the icon plane the image clarity degrades rapidly. From this figure it can be seen that the field curvature of a substantially spherical lens limits the field of view of the image: the image is distinct only within the in-focus zone 434, rapidly going out of focus for more oblique viewing angles. Substantially spherical lenses are not flat-field lenses, and the field curvature of these lenses is amplified for low F# lenses.

Fig. 19b illustrates an aspheric lens as applied to the present system. As an aspheric lens, its curvature is not approximated by a sphere. Aspheric lens 438 is separated from icon layer 442 by optical spacer 440. Aspheric lens 438 projects image 444 of icon plane 442 normal to the plane of the material. The image

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originates at focal point 446. The focal length of aspheric lens 438 lies within the icon plane 442 for a wide range of viewing angles, from normal 444 to oblique 448, because it has a flat-field 452. The focal length of the lens varies according to the angle of view through it. The focal length is shortest for normal viewing 444 and
5 increases as the viewing angle becomes more oblique. At the oblique viewing angle 448 the focal point 450 is still within the thickness of the icon plane, and the oblique image is therefore still in focus for this oblique viewing angle 448. The in-focus zone 454 is much larger for the aspheric lens 438 than the in-focus zone 434 of the substantially spherical lens 418. The aspheric lens 438 thus provides an enlarged field
10 of view over the width of the associated image icon so that the peripheral edges of the associated image icon do not drop out of view compared to that of the spherical lens 418. Aspheric lenses are preferred for the present system because of the larger field of view they provide and the resulting increase in visibility of the associated images.

Figs. 20 a-c are cross-sections illustrating two benefits of utility which result
15 from the use of a thick icon layer. These benefits apply whether the lens 456 used to view them is substantially spherical 418 or aspheric 438, but the benefits are greatest in combination with aspheric lenses 438. Fig. 20a illustrates a thin icon layer 460 system material including lenses 456 separated from icon layer 460 by optical spacer 458. Icon elements 462 are thin 461 in comparison to the field curvature of the lens
20 463, limiting the in-focus zone to a small angle, the angle between the image projected in the normal direction 464 and the highest oblique angle image 468 that has a focal point 470 within the icon layer 460. The greatest field of view is obtained by designing the normal image focus 466 to lie at the bottom of the icon plane, thereby maximizing the oblique field of view angle, limited by the point at which the focal

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point 470 lies at the top of the icon plane. The field of view of the system in Fig. 20a is limited to 30 degrees.

Fig. 20b illustrates the benefits obtained from the incorporation of an icon plane 471 that is thick 472 in comparison to the field curvature of lens 456. Lenses 456 are separated from thick icon elements 474 by optical spacer 458. Thick icon elements 474 remain in focus 475 over a larger field of view, 55 degrees, than the thin icon elements 462 of Fig. 20a. The normal image 476 projected through lenses 456 from focal point 478 is in clear focus, and the focus remains clear while the angle of view increases all the way up to 55 degrees, where oblique image 480 focal point 482 lies at the top of the thick icon plane 471. The increased field of view is greatest for a flat-field lens, such as the aspheric lens 438 of Fig. 19b.

Fig. 20c illustrates yet another advantage of a thick icon plane 492; reducing the sensitivity of the present system material to variations in thickness S that may result from manufacturing variations. Lens 484 is spaced a distance S from the bottom surface of icon layer of thickness i . Lens 484 projects image 496 from focal point 498 disposed at the bottom of icon layer 492. This figure is drawn to demonstrate that variations in the optical space S between the lenses and the icon layer can vary over a range equal to the thickness of the icon layer i without loss of image 496, 500, 504 focus. At lens 486 the optical spacer thickness is about $(S + i / 2)$ and the focal point 502 of image 500 is still within the thickness i of icon layer 492. At lens 488 the thickness of the optical spacer has increased to $(S + i)$ 490 and the focal point 506 of image 504 lies at the top of thick icon element 494. The optical spacer thickness can therefore vary over a range corresponding to the thickness of the icon layer i : a thin icon layer therefore provides a small tolerance for optical spacer

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thickness variations and a thick icon layer provides a larger tolerance for optical spacer thickness variations.

An additional benefit is provided by a thick icon layer 492. Imperfect lenses, such as substantially spherical lenses, may have a shorter focal length 493 towards their edges than at their center 496. This is one aspect of the common spherical aberration defect of substantially spherical lenses. A thick icon layer provides an icon element that can be clearly focused over a range of focal lengths, 498 to 495, thereby improving the overall clarity and contrast of an image produced by a lens 484 having focal length variations.

Fig. 21 is a plan view that shows the application of the present system to currency and other security documents as a 'windowed' security thread. Fig. 21 shows a windowed thread structure including system material 508 that has been slit into a ribbon, referred to as a "thread", that is typically in the range of 0.5 mm to 10 mm in width. Thread 508 is incorporated into the fibrous document substrate 510 and provides windowed zones 514. The thread 508 may optionally incorporate a pigmented, dyed, filled, or coated sealing layer 516 to increase image contrast and/or to provide additional security and authentication features, such as electrical conductivity, magnetic properties, nuclear magnetic resonance detection and authentication, or to hide the material from view in reflected illumination when viewed from the back side of the substrate (the side opposite the side presenting the Unison synthetic images and an adhesive layer 517 to strengthen the bond between the thread 508 and the fibrous substrate 510. The thread 508 is maintained in an orientation to keep the lenses uppermost so that the image effects are visible in the windowed zones 514. Both the fibrous substrate 510 and the thread may be

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overprinted by print elements 518 and the fibrous substrate may be printed 520 on its opposite face.

Fig. 21 illustrates that thread 508 and its image effects 522 are only visible from the upper surface 521 of the substrate 510 in the windowed zones 514. Thread 508 is covered by fibrous substrate material at the inside zones 512 and the image effects 522 are not substantially visible in these zones. OPM effects are particularly dramatic when incorporated into thread 508. (See Fig. 22) As the fibrous substrate 510 is tilted in various directions the OPM image can be made to scan across the width 524 of the thread, producing a startling and dramatic visual effect. This scanning feature of an OPM image makes it possible to present image 522 which is larger than the width of the thread 508. The user examining the document containing a windowed thread 508 can then tilt the document to scan the whole image across the thread, scrolling it like a marquee sign. The effects of the Deep, Float, and Levitate embodiments can also be used to advantage in a windowed thread format.

The thread 508 may be at least partially incorporated in security papers during manufacture by techniques commonly employed in the paper-making industry. For example, thread 508 may be pressed within wet papers while the fibers are unconsolidated and pliable, as taught by U.S. Patent 4,534,398 which is incorporated herein by reference.

The windowed thread of the present system is particularly well suited for application to currency. A typical total thickness for the thread material is in the range of 22 μ to 34 μ , while the total thickness of currency paper may range as high as 88 μ . It is possible to incorporate a windowed security thread of the present system into currency paper without substantially altering the total thickness of the paper by

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locally reducing the thickness of the paper by an amount equivalent to the thickness of the thread.

In an exemplary embodiment, thread 508 comprises:

- (a) one or more optical spacers;
- 5 (b) one or more optionally periodic planar arrays of micro-images or icons positioned within, on, or next to an optical spacer; and
- (c) one or more optionally periodic planar arrays of non-cylindrical micro lenses positioned on or next to either an optical spacer or a planar icon array, with each micro-lens having a base diameter of less than 50 microns.

- 10 In another embodiment, the micro-images or icons constitute filled voids or recesses that are formed on a surface of the one or more optical spacers, while the non-cylindrical micro-lenses are aspheric micro-lenses, with each aspheric micro-lens having a base diameter ranging from about 15 to about 35 microns. At least one pigmented sealing or obscuring layer 516 may be positioned on the planar array(s) of
- 15 micro-images or icons for increasing contrast and thus visual acuity of the icons and also for masking the presence of thread 508 when the thread is at least partially embedded in a security document.

In yet another embodiment of the present invention, thread 508 comprises:

- (a) an optical spacer having opposing upper and lower planar
- 20 surfaces;
- (b) a periodic array of micro-images or icons comprising filled recesses formed on the lower planar surface of the optical spacer;
- (c) a periodic array of non-cylindrical, flat field, aspheric or polygonal base multi-zonal micro-lenses positioned on the upper planar surface of the

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optical spacer, wherein each micro-lens have a base diameter ranging from about 20 to about 30 microns; and

(d) a pigmented sealing or obscuring layer 516 positioned on the icon array.

5 The optical spacer(s) may be formed using one or more essentially colorless polymers including, but not limited to, polyester, polypropylene, polyethylene, polyethylene terephthalate, polyvinylidene chloride, and the like. In an exemplary embodiment, the optical spacer(s) is formed using polyester or polyethylene terephthalate and has a thickness ranging from about 8 to about 25 microns.

10 The icon and micro-lens arrays can be formed using substantially transparent or clear radiation curable material including, but not limited to acrylics, polyesters, epoxies, urethanes and the like. Preferably, the arrays are formed using acrylated urethane which is available from Lord Chemicals under the product designation UI07.

15 The icon recesses formed on the lower planar surface of the optical spacer each measures from about 0.5 to about 8 microns in depth and typically 30 microns in micro-image or icon width. The recesses can be filled with any suitable material such as pigmented resins, inks, dyes, metals, or magnetic materials. In an exemplary embodiment, the recesses are filled with a pigmented resin comprising a sub-micron
20 pigment which is available from Sun Chemical Corporation under the product designation Spectra Pac.

The pigmented sealing or obscuring layer 516 can be formed using one or more of a variety of opacifying coatings or inks including, but not limited to, pigmented coatings comprising a pigment, such as titanium dioxide, dispersed within

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a binder or carrier of curable polymeric material. Preferably, the sealing or obscuring layer 516 is formed using radiation curable polymers and has a thickness ranging from about 0.5 to about 3 microns.

Thread 508, which is described above, may be prepared in accordance with the following method:

- (a) applying a substantially transparent or clear radiation curable resin to the upper and lower surfaces of the optical spacer;
- (b) forming a micro-lens array on the upper surface and an icon array in the form of recesses on the lower surface of the optical spacer;
- 10 (c) curing the substantially transparent or clear resin using a source of radiation;
- (d) filling the icon array recesses with a pigmented resin or ink;
- (e) removing excess resin or ink from the lower surface of the optical spacer; and
- 15 (f) applying a pigmented sealing or obscuring coating or layer to the lower surface of the optical spacer.

In many cases, it is desirable that security threads used in currency and in other high value financial and identification documents be detected and authenticated
20 by high-speed non-contact sensors, such as capacitance sensors, magnetic field sensors, optical transmission and opacity sensors, fluorescence, and/or nuclear magnetic resonance.

Incorporation of fluorescent materials into the lens, substrate, icon matrix, or icon fill elements of a Unison film can enable covert or forensic authentication of the

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Unison material by observation of the presence and spectral characteristics of the fluorescence. A fluorescing Unison film can be designed to have its fluorescent properties visible from both sides of the material or from only one side of the material. Without an optical isolation layer in the material beneath the icon layer, the

5 fluorescence of any part of a Unison material will be visible from either of its sides. Incorporation of an optical isolation layer makes it possible to separate the visibility of the fluorescence from its two sides. Thus a Unison material incorporating an optical isolation layer beneath the icon plane may be designed to exhibit fluorescence in a number of different ways: fluorescent color A visible from the lens side, no

10 fluorescence visible from the optical isolation layer side, fluorescent color A or B visible from the optical isolation layer side but not from the lens side, and fluorescent color A visible from the lens side and fluorescent color A or B visible from the optical isolation layer side. The uniqueness provided by the variety of fluorescent signatures possible can be used to further enhance the security of the Unison material. The

15 optical isolation layer can be a layer of pigmented or dyed material, a layer of metal, or a combination of pigmented layers and metal layers, that absorbs or reflects the fluorescent emission from one side of the material and prevents it from being seen from the other side.

Icons formed from shaped voids and their inverse, icons formed from shaped

20 posts, are particularly enabling for adding machine-readable authentication features to a Unison material security thread for currency and other high value documents. The icon matrix, the icon fill, and any number of back coats (sealing coats) can all, separately and/or in all combinations, incorporate non-fluorescing pigments, non-fluorescing dyes, fluorescing pigments, fluorescing dyes, metal particles, magnetic

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particles, nuclear magnetic resonance signature materials, lasing particles, organic LED materials, optically variable materials, evaporated metal, thin film interference materials, liquid crystal polymers, optical upconversion and downconversion materials, dichroic materials, optically active materials (possessing optical rotary power), optically polarizing materials, and other allied materials.

In some circumstances, such as when a dark or colored coating (such as a magnetic material or conductive layer) has been added to a Unison material or when the color of the icon plane is objectionable when seen through the back side of a substrate, it may be desirable to mask or hide the appearance of an embedded, partially embedded, or windowed Unison material security thread from one side of a paper substrate as seen in reflected light, while the thread is visible from the opposite side of the substrate. Other types of currency security threads commonly incorporate a metal layer, typically aluminum, to reflect light that filters through the surface substrate, thereby providing similar brightness to the surrounding substrate.

Aluminum or other color neutral reflecting metal can be used in similar manner to mask the appearance of a Unison thread from the back side of a paper substrate by applying the metal layer on the back surface of the Unison material and then optionally sealing it in place. A pigmented layer can be utilized for the same purpose, that of hiding or obscuring the visibility of the security thread from the "back" side of the document, in place of a metallized layer, or in conjunction with it. The pigmented layer can be of any color, including white, but the most effective color is one that matches the color and intensity of the light internally scattered within, and outside of, the fibrous substrate.

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The addition of a metallized layer to a Unison material can be accomplished in a number of ways, including direct metallization of the icon or sealing layer of the Unison material by evaporation, sputtering, chemical deposition, or other suitable means, or lamination of the icon or sealing layer of the Unison material to the metallized surface of a second polymer film. It is common practice to create currency security threads by metallizing a film, pattern demetallizing this film to leave narrow 'ribbons' of metallized area, laminating the metallized surface to a second polymer film, then slitting the laminated material such that the metal ribbons are isolated from the edges of the slit threads by the laminating adhesive, thereby protecting the metal from chemical attack at the edges of the thread. This method can also be applied in the case of the subject invention: the Unison material can simply replace the second laminating film. Thus a Unison material can be augmented by the addition of patterned or unpatterned metallized layers.

Synthetic images can be designed as binary patterns, having one color (or absence of color) defining the icons and a different color (or absence of color) defining the background; in this case each icon zone includes a complete single-tone image that utilizes image 'pixels' that are either full on or full off. More sophisticated synthetic images can be produced by providing tonal variations of the selected icon color. The synthetic image tonal variation can be created by controlling the density of the color in each icon image or by effectively 'half-toning' the synthetic image by including or excluding design elements in selected groups of icons.

The first method, controlling the density of the color in each icon image, may be accomplished by controlling the optical density of the material creating the

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microprinted icon image. One convenient method to do this utilizes the filled void icon embodiment, already described previously.

The second method, 'half-toning' the synthetic image by including or excluding design elements in selected groups of icons, illustrated in Figure 23, accomplished by including image design elements in a proportion of icon zones that is equal to the color density desired. Figure 23 illustrates this with an example using a hexagonal repeat pattern for the icon zones 570 that would be coordinated with a similar hexagonal repeat pattern of lenses. Each of the icon zones 570 do not contain identical information. All of the icon image elements, 572, 574, 576, and 578 are present at substantially the same color density. Icon image elements 572 and 574 are present in some of the icon zones and different icon image elements are present in other icon zones. Some icon zones contain the single icon image element 570. Specifically, the icon image element 572 is present in half of the icon zones, icon image element 574 is present in three-fourths of the icon zones, icon image element 578 is present in half of the icon zones, and icon image element 576 is present in one-third of the icon zones. The information present in each icon zone determines whether its associated lens will show the color of the icon image pattern or the color of the icon image background from a particular viewing orientation. Either image elements 572 or 578 will be visible in all of the lenses associated with this icon pattern, but the synthetic image 580 space of icon image element 572 overlaps the synthetic image space of icon image element 578. This means that the overlap zone 582 of the synthetic images of icons 572 and 578 will appear at 100% color density, because every lens will project icon image color in this zone. The non-overlapping part of these two synthetic images, 588, is only visible in 50% of the lenses, so it

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appears at 50% color density. The synthetic image 586 of icon element 576 is visible in only one third of the lenses, so it appears at 33.3...% density. The synthetic image 584 of icon image element 576 correspondingly appears at 75% color density. It is clear within the scope of this teaching that a tremendous range of tonal variations can be obtained in the synthetic image through selective omission of icon image elements in selected percentages of icon zones. For greatest effectiveness the distributions of the icon image elements across the icon image zones should be relatively uniform.

A related icon image design method, illustrated in Figure 24a, can be used to create combined synthetic image elements that are smaller in dimension than the smallest feature of the individual synthetic image elements. This is possible in the common circumstance where the smallest feature size of an icon image is larger than the placement accuracy of the feature. Thus an icon image may have minimum features on the order of two microns in dimension, but those features may be placed accurately on any point on a grid of 0.25 micron spacing. In this case the smallest feature of the icon image is eight times larger than the placement accuracy of that feature. As with the previous diagram this method is illustrated using a hexagonal icon pattern 594, but it applies equally well to any other usable pattern symmetry. In similar fashion to the method of Figure 23, this method relies on the use of different information in at least one icon zone. In the example of Figure 24a two different icon patterns, 596 and 598, are each present in half of the icon zones (for clarity only one of each pattern is shown in this figure). These icon images produce a composite synthetic image 600 that incorporates synthetic image 602 created by icon image elements 596, and synthetic image 604, created by icon image elements 598. The two synthetic images, 602 and 604, are designed to have overlapped areas, 606 and 608,

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that appear to have 100% color density while the non-overlapped areas 605 have 50% color density. The minimum dimension of the overlapped areas in the composite synthetic image may be as small as the synthetic magnification-scaled positioning accuracy of the icon image elements, and therefore may be smaller than the minimum
5 feature size of the two constituent synthetic images that are designed to overlap in a small region. In the example of Figure 23, the overlap regions are used to create the characters for the number "10" with narrower lines than would otherwise be possible.

This method can also be used to create narrow patterns of gaps between icon image elements, as shown in Figure 24b. Hexagonal icon zones 609 could be square
10 or any other suitable shape to make a space-filling array, but hexagonal is preferred. In this example, half the icon patterns the icon image 610, and half of them are the icon image 611. Ideally these two patterns would be relatively uniformly distributed among the icon zones. All of the elements of these patterns are depicted as being of substantially equal and uniform color density. In isolation these two patterns do not
15 clearly suggest the form of the final image, and this can be used as a security element – the image is not obvious until it is formed by the overlying lens array. One instance of the synthetic image 612 formed by the combination of the synthetic image of icon elements 610 with the synthetic image of icon elements 611 is shown, whereby the gaps that remain between the separate synthetic images form the numeral "10". In
20 this case, two synthetic images are combined to form the final synthetic image, so the colored parts of this image 613 show 50% color density. This method is not limited by the details of this example: three icons could have been used instead of two, the gaps defining the desired element in the composite synthetic images can have variable widths and unlimited shape variety, and this method can be combined with either the

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methods of Figures 23, 24a,b or 25, or an other icon image design method we have taught.

Covert, hidden information can be incorporated into the icon images that cannot be seen in the resulting synthetic images. Having such covert information hidden in the icon images can be used, for example, for covert authentication of an object. Two methods for accomplishing this are illustrated by Figure 25. The first method is illustrated by the use of matched icon images 616 and 618. Icon image 616 shows a solid border pattern and the number "42" contained inside of the border. Icon image 618 shows a solid shape with the number "42" as a graphical hole in that shape.

10 In this example, the perimeter shapes of icon images 616 and 618 are substantially identical and their relative position within their respective icon zones, 634 and 636, are also substantially identical. When a composite synthetic image 620 is created from these icon images, the border of the composite synthetic image 622 will show 100% color density because all icon images have a pattern in that corresponding area,

15 so there is full overlap in the synthetic images created from icon images 616 and 618. The color density of the interior 624 of the composite synthetic image 620 will be 50%, since the image of the space surrounding the "42" comes from icon images 618 that only fill half the icon zones, and the image of the colored "42" comes from icon images 616 that also fill half the icon zones. Consequently, there is no tonal

20 differentiation between the "42" and its background, so the observed composite synthetic image 626 will show an image having a 100% color density border 628 and a 50% color density interior 630. The "42" covertly present in all of the icon images 616 and 618 is thereby "neutralized" and will not be seen in the observed composite synthetic image 626.

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A second method for incorporating covert information into icon images is illustrated by triangles 632 in Figure 25. Triangles 632 may be randomly placed within the icon zones (not shown in this figure) or they can be placed in an array or other pattern that does not substantially match the period of the icon zones 634, 632.

- 5 Synthetic images are created from a multiplicity of regularly arrayed icon images that are imaged by a corresponding regular array of micro-lenses. Patterns in the icon plane that do not substantially correspond to the period of the micro-lens array will not form complete synthetic images. The pattern of triangles 632 therefore will not create a coherent synthetic image and will not be visible in the observed synthetic
- 10 image 626. This method is not limited to simple geometric designs, such as triangles 632: other covert information, such as alpha-numeric information, bar codes, data bits, and large-scale patterns can be incorporated into the icon plane with this method.

- Figure 26 illustrates a general approach to creating fully three dimensional
- 15 integral images in a Unison material (Unison 3-D). A single icon zone 640 contains icon image 642 that represents a scale-distorted view of an object to be displayed in 3-D as seen from the vantage point of that icon zone 640. In this case the icon image 642 is designed to form a synthetic image 670 of a hollow cube 674. Icon image 642 has a foreground frame 644 that represents the nearest side 674 of hollow cube 672,
- 20 tapered gap patterns 646 that represent the corners 676 of the hollow cube 672, and a background frame 648 that represents the farthest side 678 of the hollow cube 672. It can be seen that the relative proportions of the foreground frame 644 and the background frame 648 in the icon image 642 do not correspond to the proportions of the nearest side 674 and the farthest side 678 of the synthetic image hollow cube 672.

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The reason for the difference in scale is that images that are to appear further from the plane of the Unison material experience greater magnification, so their size in the icon image must be reduced in order to provide the correct scale upon magnification to form the synthetic image 672.

5 At a different location on the Unison 3-D material we find icon zone 650 that includes a different icon image 652. As with icon image 642, icon image 652 represents a scale-distorted view of the synthetic image 672 as seen from the different vantage point of this icon zone 650. The relative scaling of foreground frame 654 and background frame 658 are similar to the corresponding elements of icon image 642
10 (although this will not be true, in general), but the position of the background frame 658 has shifted, along with the size and orientation of the corner patterns 656. Icon zone 660 is located a further distance away on the Unison 3-D material and it presents yet another scale-distorted icon image 662, including icon image 662 with foreground frame 664, tapered gap patterns 667, and background frame 668.

15 In general, the icon image in each icon zone in a Unison 3-D material will be slightly different from its nearby neighbors and may be significantly different from its distant neighbors. It can be seen that icon image 652 represents a transitional stage between icon images 642 and 662. In general, each icon image in a Unison 3-D material may be unique, but each will represent a transitional stage between the icon
20 images to either side of it.

Synthetic image 670 is formed from a multiplicity of icon images like icon images 640, 650, and 660 as synthetically imaged through an associated lens array. The synthetic image of the hollow cube 674 shows the effects of the different synthetic magnification factors that result from the effective repeat periods of the

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- different elements of each of the icon images. Let us assume that the hollow cube image 674 is intended to be viewed as a SuperDeep image. In this case if icon zone 640 was disposed some distance to the lower left of icon zone 650, and icon zone 660 was disposed some distance to the upper right of icon zone 650, it can be seen that the
- 5 effective period of the foreground frames 644, 654, and 664 will be less than that of the background frames 648, 658, and 668, thereby causing the closest face 676 of the cube (corresponding to the foreground frames 644, 654, and 664) to lie closer to the plane of the Unison material and the farthest face 678 of the cube to lie deeper and further from the plane of the Unison material, and to be magnified by a greater factor.
- 10 The corner elements 646, 656, and 667 coordinate with both the foreground and background elements to create the effect of smoothly changing depth between them.

- The method of designing icon images for Unison 3-D is more fully described in Figure 27. This figure isolates the method for a single image projector 680. As previously described, a single image projector includes a lens, an optical spacer, and
- 15 an icon image; the icon image having substantially the same dimensions as the repeat period of the lens (allowing for the small differences in scale that create the Unison visual effects). The field of view for the lens and its associated icon is shown as the cone 682: this also corresponds to an inversion of the focal cone of the lens, so the proportions of the field of view cone 682 are determined by the F# of the lens.
- 20 Although the figure shows this cone as having a circular base, the base shape will actually be the same as the shape of an icon zone, such as a hexagon.

In this example we wish to create a Unison 3-D synthetic image that incorporates three copies of the word "UNISON", 686, 690 and 694, at the same visual size at three different SuperDeep image planes 684, 690, and 692. The

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diameter of the image planes 684, 688, and 692 expands with the field of view cone: in other words, as the depth of image increases, area covered by the field of view cone increases. Thus the field of view at the shallowest depth plane 684 only encompasses portions of "NIS" of the word UNISON, while the middle depth plane 688 encompasses all of "NIS" and portions of "U" and "O" and the deepest depth plane 692 encompasses almost all of "UNISON", lacking only part of the final "N".

The information they presented (UNISONs 686, 690, and 694) by each of these synthetic image planes 684, 688, and 692, must ultimately be incorporated into a single icon image in image projector 680. This is accomplished by capturing the information in the field of view cone 686 at each depth plane 684, 688, and 692, then scaling the resulting icon image patterns to the same dimensions. Icon image 696 represents the field of view of UNISON image 686 as seen at depth plane 684, icon image 704 represents the field of view of UNISON image 690 as seen at depth plane 688, and icon image 716 represents the field of view of UNISON image 694 as seen at depth plane 692.

Within icon image 696 icon image elements 698 originate from a portion of the first "N" of UNISON image 686, icon image element 700 originates from a portion of the "T" of UNISON image 686, and icon image elements 702 originate from portions of the "S" of UNISON image 686. Within icon image 704 icon image element 706 originates from a portion of the "U" of UNISON image 690, icon image element 708 originates from the first "N" of UNISON image 690, icon image element 710 originates from the "S" of UNISON image 690, and icon image element 714 originates from a portion of the "O" of UNISON image 690. Note that although the synthetic images 686, 690, and 694 are presented at similar scale, icon image 704 for

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the middle depth plane 688 presents its UNISON letters at a smaller scale than those of icon image 696. This accounts for the higher synthetic magnification that icon image 704 will experience (when synthetically combined with a multiplicity of surrounding icon images for the same depth plane). In similar manner, icon image

5 716 incorporates icon image elements 718 that originate from the UNISON image 694 and the UNISON letters incorporated in its icon image are at a further reduced scale.

The final icon image for this image projector is created by combining these three icon images 696, 704, and 716 into a single icon image 730, shown in Figure 28. The combined icon elements 732 incorporate all of the graphical and depth

10 information necessary for the image projector 680 to make its contribution to the synthetic image formed from a multiplicity of image projectors, each incorporating the specific icon image information that results from the intersection of its own field of view cone, centered on the image projector, with the levels and elements of the synthetic image to be produced. Since each image projector is displaced by at least

15 one lens repeat period from every other image projector, each image projector will carry different information resulting from the intersection of its field of view cone with the synthetic image space.

Each of the icon images required to present a chosen 3-D image can be computed from knowledge of the three-dimensional digital model of the synthetic

20 image, desired depth position and depth span to be presented in the synthetic image, the lens repeat period, the lens field of view, and the ultimate graphical resolution of the icon images. This latter factor puts an upper limit on the level of detail that can be presented at each depth plane. Since depth planes that lie further from the plane of the Unison material carry a larger amount of information (because of the increased

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field of view) the graphical resolution limit of the icons has the greatest impact on the resolution of these synthetic image depth planes.

Figure 29 illustrates how the method of Figure 27 can be applied to a complex three-dimensional synthetic image, such as an image of the priceless ice-age carved mammoth ivory artifact, the Lady of Brassenpouy 742. Individual image projector 738, incorporating at least a lens, an optical spacing element, and an icon image (not shown in this figure), lies in the plane 740 of a Unison material that separate the float synthetic image space from the deep synthetic image space. In this example the synthetic image space spans the Unison material such that a portion of the image lies in the float synthetic image space and a portion lies in the deep synthetic image space. The image projector 738 has a substantially conical field of view that extends both into the deep synthetic image space 744 and into the float synthetic image space 746. A chosen number of deep image planes are selected, 748 and 752-762, at whatever spacing is required to obtain the deep synthetic image space resolution desired. Similarly, a chosen number of float image planes are selected, 750 and 764-774, at whatever spacing is required to obtain the float synthetic image space resolution desired. Some of these planes, such as deep planes 748 and float planes 750 will extend beyond the synthetic image and will not contribute to the final information in the icon image. For clarity, the number of image planes shown in Figure 29 is limited to a small number but the actual number of image planes selected may be high, such as 50 or 100 planes, or more, to obtain the desired synthetic image depth resolution.

The method of Figures 27 and 28 is then applied to obtain the icon image at each depth plane by determining the shape of the intersection of the surface of the object 742 with the selected depth plane 756-774. The resulting separate icon images

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are scaled to the final size of the combined icon image. All of the float icon images are first rotated 180 degrees (because they undergo that rotation again when they are projected, thereby returning them to their correct orientation in the synthetic image) then they are combined with the deep icon images to form the final icon image for this
5 image projector 738. This process is repeated for each of the positions of the image projectors to obtain the complete pattern of icon images required to form the full synthetic image 742.

The resolution of the synthetic image depends on the resolution of the optical projectors and the graphical resolution of the icon images. We have obtained icon
10 image graphical resolutions, less than 0.1 micron, that exceed the theoretical optical resolution limit of magnifying optics (0.2 micron). A typical icon image is created with a resolution of 0.25 micron.

Unison materials can be manufactured by sheet or web processing utilizing tools that separately incorporate the lens and icon microstructures. Both the lens tools
15 and the icon tools are originated using photomasks and photoresist methods.

Lens tools are initially designed as semiconductor-type masks, typically black chrome on glass. Masks having sufficient resolution can be created by photoreduction, electron beam writing, or laser writing. A typical mask for a lens tool will incorporate a repeating pattern of opaque hexagons at a chosen period such as 30
20 microns, with clear lines separating the hexagons that are less than 2 microns wide. This mask is then used to expose photoresist on a glass plate using a conventional semiconductor UV exposure system. The thickness of the resist is selected to obtain the desired sag of the lens. For example, a thickness of 5 microns of AZ 4620 positive photoresist is coated onto a glass plate by suitable means, such as by spin

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coating, dip coating, meniscus coating, or spraying, to form lenses having a nominal 30 micron repeat and a nominal 35 micron focal length. The photoresist is exposed with the mask pattern, and developed down to the glass in a conventional manner, then dried and degassed at 100 C for 30 minutes. The lenses are formed by thermal
5 reflow according to standard methods that are known in the art. The resulting photoresist micro-lenses are coated with a conductive metal, such as gold or silver, and a negative nickel tool is created by electroforming.

Icon tools are created in a similar manner. An icon pattern is typically designed with the aid of CAD software and this design is transmitted to a
10 semiconductor mask manufacturer. This mask is used in similar manner to the lens mask, except the thickness of the resist to be exposed is typically in the range of 0.5 micron to 8 microns, depending on the optical density of the desired synthetic image. The photoresist is exposed with the mask pattern, developed down to glass in a conventional manner, coated with a conductive metal, and a negative nickel tool is
15 created by electroforming. According the choice of original mask design and in the choice of resist type used (positive or negative), the icons can be created in the form of voids in the resist pattern or they can be created in the form of "mesas" or posts in the resist pattern, or both.

Unison materials can be manufactured from a variety of materials and a
20 multiplicity of methods that are known in the art of micro-optic and microstructure replication, including extrusion embossing, radiation cured casting, soft embossing, and injection molding, reaction injection molding, and reaction casting. An exemplary method of manufacture is to form the icons as voids in a radiation cured liquid polymer that is cast against a base film, such as 75 gage adhesion-promoted

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PET film, then to form the lenses from radiation cured polymer on the opposite face of the base film in correct alignment or skew with respect to the icons, then to fill the icon voids with a submicron particle pigmented coloring material by gravure-like doctor blading against the film surface, solidify the fill by suitable means (ex: solvent removal, radiation curing, or chemical reaction), and finally apply an optional sealing layer that may be either clear, dyed, pigmented, or incorporate covert security materials.

The manufacture of Unison Motion material requires that the icon tool and the lens tool incorporate a chosen degree of misalignment of the axes of symmetry of the two arrays. This misalignment of the icon and lens patterns axes of symmetry controls the synthetic image size and synthetic image rotation in the produced material. It is often desirable to provide the synthetic images substantially aligned with either the web direction or the cross-web direction, and in these cases the total angular misalignment of the icons and the lenses is divided equally between the lens pattern and the icon pattern. The degree of angular misalignment required is usually quite small. For example, a total angular misalignment on the order of 0.3 degree is suitable to magnify 30 micron icon images to a size of 5.7 mm in a Unison Motion material. In this example, the total angular misalignment is divided equally between the two tools, so each tool is skewed through an angle of 0.15 degree in the same direction for both tools. The skew is in the same direction because the tools form microstructures on opposite faces of a base film, so the skews of the tools add to each other, instead of canceling each other.

Skew can be incorporated into the tools at the time of the original design of the masks by rotating the whole pattern through the desired angle before writing it.

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Skew can also be mechanically incorporated into a flat nickel tool by cutting it at the appropriate angle with a numerically controlled mill. The skewed tool is then formed into a cylindrical tool using the skew-cut edge to align the tool to the rotational axis of an impression cylinder.

- 5 The synthetic magnification micro-optic system herein can be combined with additional features including but not limited to these embodiments as single elements or in various combinations, such as icon fill materials, back coatings, top coatings, both patterned and non-patterned, fill or inclusions in the lens, optical spacer or icon materials, as a laminate or coating, inks and or adhesives including aqueous, solvent
- 10 or radiation curable, optically transparent, translucent or opaque, pigmented or dyed Indicia in the form of positive or negative material, coatings, or print including but not limited to inks, metals, fluorescent, or magnetic materials, X-ray, infrared, or ultra-violet absorbent or emitting materials, metals both magnetic and non-magnetic including aluminum, nickel, chrome, silver, and gold; magnetic coatings and particles
- 15 for detection or information storage; fluorescent dye and pigments as coatings and particles; IR fluorescent coatings, fill, dyes or particles; UV fluorescent coatings, fill, dyes or particles; phosphorescent dye and pigments as coatings and particles, planchettes, DNA, RNA or other macro-molecule taggants, dichroic fibers, radioisotopes, print receptive coatings, sizing, or primers, chemically reactive
- 20 materials, micro-encapsulated ingredients, field affected materials, conductive particles and coatings both metallic and non-metallic, micro-perforated holes, colored threads or fibers, patches of Unison embedded in the surface of a document, label, or materials surface, bonded to paper or polymer as a carrier to adhere to paper during manufacture, fluorescent Dichroic threads or particles, raman scattering coatings or

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- particles, color shifting coatings or particles, Unison laminated to paper, paper board, card board, plastic, ceramic, fabric, or metal substrate, Unison as a thread, patch, label, over wrap, hot stamp foil, or tear tape, holographic, diffractive, diffractive kinegram, isograms, photographic or refractive optical elements, liquid crystal
- 5 materials, Up Conversion and Down Conversion materials.

The synthetic magnification micro-optic system herein has many fields of use and applications. Examples include:

- Government and defense applications – whether Federal, State or Foreign (such as Passports, ID Cards, Driver's Licenses, Visas, Birth Certificates, Vital
- 10 Records, Voter Registration Cards, Voting Ballots, Social Security Cards, Bonds, Food Stamps, Postage Stamps, and Tax Stamps);
- currency – whether Federal, State or Foreign (such as security threads in paper currency, features in polymer currency, and features on paper currency);
- documents (such as Titles, Deeds, Licenses, Diplomas, and Certificates);
- 15 financial and negotiable instruments (such as Certified Bank Checks, Corporate Checks, Personal Checks, Bank Vouchers, Stock Certificates, Travelers' Checks, Money Orders, Credit cards, Debit cards, ATM cards, Affinity cards, Prepaid Phone cards, and Gift Cards);
- confidential information (such as Movie Scripts, Legal Documents,
- 20 Intellectual Property, Medical Records/Hospital Records, Prescription Forms/Pads, and "Secret Recipes");
- product and brand protection, including Fabric & Home Care (such as Laundry Detergents, fabric conditioners, dish care, household cleaners, surface coatings, fabric refreshers, bleach, and care for special fabrics);

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beauty care (such as Hair care, hair color, skin care & cleansing, cosmetics, fragrances, antiperspirants & deodorants, feminine protection pads, tampons and pantliners);

- 5 baby and family care (such as Baby diapers, baby and toddler wipes, baby bibs, baby change & bed mats, paper towels, toilet tissue, and facial tissue);

- health care (such as Oral care, pet health and nutrition, prescription pharmaceuticals, over-the counter pharmaceuticals, drug delivery and personal health care, prescription vitamins and sports and nutritional supplements; prescription and non-prescription eyewear, Medical devices and equipment sold to Hospitals, Medical
10 Professionals, and Wholesale Medical Distributors (ie: bandages, equipment, implantable devices, surgical supplies);

food and beverage packaging;

dry goods packaging;

electronic equipment, parts & vomponents;

- 15 apparel and footwear, including sportswear clothing, footwear, licensed and non-licensed upscale, sports and luxury apparel items, fabric;

biotech pharmaceuticals;

aerospace components and parts;

automotive components and parts;

- 20 sporting goods;

tobacco Products;

software;

compact disks and DVD's;

explosives;

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- novelty items (such as gift wrap and ribbon)
- books and magazines;
- school products and office supplies;
- business cards;
- 5 shipping documentation and packaging;
- notebook covers;
- book covers;
- book marks;
- event and transportation tickets;
- 10 gambling and gaming applications (such as Lottery tickets, game cards, casino chips and items for use at or with casinos, raffle and sweepstakes);
- home furnishing (such as towels, linens, and furniture);
- flooring and wallcoverings;
- jewelry & watches;
- 15 handbags;
- art, collectibles and memorabilia;
- toys;
- displays (such as Point of Purchase and Merchandising displays);
- product marking and labeling (such as labels, hangtags, tags, threads, tear strips,
- 20 over-wraps, securing a tamperproof image applied to a branded product or document for authentication or enhancement, as camouflage, and as asset tracking.

Suitable materials for the embodiments described above include a wide range of polymers. Acrylics, acrylated polyesters, acrylated urethanes, polypropylenes, *epoxies*, urethanes, and polyesters have suitable optical and mechanical properties for both the

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microlenses and the microstructured icon elements. Suitable materials for the optional substrate film include most of the commercially available polymer films, including acrylic, cellophane, Saran, nylon, polycarbonate, polyester, polypropylene, polyethylene, and polyvinyl. Microstructured icon fill materials can include any of the materials listed above as suitable for making microstructured icon elements, as well as solvent based inks and other commonly available pigment or dye vehicles. Dyes or pigments incorporated into these materials should be compatible with the chemical makeup of the vehicle. Pigments must have a particle size that is substantially smaller than the smallest dimensions of any component of an icon element. Optional sealing layer materials can include any of the materials listed above as suitable for making microstructured icon elements, plus many different commercially available paints, inks, overcoats, varnishes, laquers, and clear coats used in the printing and paper and film converting industries. There is no preferred combination of materials -- the choice of materials depends on the details of the material geometry, on the optical properties of the system, and on the optical effect that is desired.

Although exemplary embodiments have been shown and described, it will be clear to those of ordinary skill in the art that a number of changes, modifications, or alterations to the invention as described can be made. All such changes, modifications, and alterations should therefore be seen as within the scope of the disclosure.

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We claim:

1. A synthetic magnification micro-optic system comprising:
 - (a) one or more optical spacers;
 - (b) a micro image comprised of a periodic planar array of a plurality of image
5 icons having an axis of symmetry about at least one of its planar axes, and positioned on or next to the optical spacer, and
 - (c) a periodic planar array of image icon focusing elements having an axis of symmetry about at least one of its planar axes, the axis of symmetry being the same planar axis as that of the micro image planar array, each focusing element having an
10 effective diameter of less than 50 microns and being associated with an image icon and providing an enlarged field of view over the width of the associated image icon so that the peripheral edges of the associated image icon do not drop out of view.
2. The synthetic magnification micro-optic system of claim 1, wherein the focusing elements are selected from the group consisting of non-cylindrical lenses
15 and non-cylindrical focusing reflectors.
3. The synthetic magnification micro-optic system of claim 2, wherein the focusing elements are aspheric focusing elements.
4. The synthetic magnification micro-optic system of claim 3, wherein the focusing elements have base geometries in the plane of their planar array selected
20 from the group consisting of a circular base, a hexagonal base, a rounded off hexagonal base, a square base, a triangular base, a rounded off triangular base, and mixtures thereof.
5. The synthetic magnification micro-optic system of claim 2, wherein the focusing elements have an F number equivalent to 4 or less.

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6. The synthetic magnification micro-optic system of claim 3, wherein the focusing elements have an F number equivalent to 4 or less.
7. The synthetic magnification micro-optic system of claim 1, wherein the scale ratio of the repeat period of the image icons to the repeat period of the focusing elements is substantially equal to 1 and the axes of symmetry of the periodic planar array of the micro image and the periodic planar array of image icon focusing elements are misaligned.
8. The synthetic magnification micro-optic system of claim 7, wherein orthoparallactic motion effects are provided.
9. The synthetic magnification micro-optic system of claim 1, wherein the scale ratio of the repeat period of the image icons to the repeat period of the focusing elements is greater than 1 and the axes of symmetry of the periodic planar array of the micro image and the periodic planar array of image icon focusing elements are aligned.
10. The synthetic magnification micro-optic system of claim 1, wherein the scale ratio of the repeat period of the image icons to the repeat period of the focusing elements is less than 1 and the axes of symmetry of the periodic planar array of the micro image and the periodic planar array of image icon focusing elements are aligned.
11. The synthetic magnification micro-optic system of claim 1, wherein the scale ratio of the repeat period of the image icons to the repeat period of the focusing elements is axially asymmetric in the planes of the image icons and the focusing elements, the scale ratio being less than 1 in one axis of symmetry and being greater than 1 in the other axis of symmetry, and the axes of symmetry of the periodic

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planar array of the micro image and the periodic planar array of image icon focusing elements are aligned.

12. The synthetic magnification micro-optic system of claim 1, each focusing element having an effective diameter of from about 15 to about 30 microns.
- 5 13. The synthetic magnification micro-optic system of claim 1, each focusing element having an effective diameter of less than 30 microns.
14. The synthetic magnification micro-optic system of claim 1, having a total thickness of less than about 45 microns.
15. The synthetic magnification micro-optic system of claim 1, having a
10 total thickness of about 10 to about 40 microns.
16. The synthetic magnification micro-optic system of claim 1, each focusing element having a focal length of less than about 40 microns.
17. The synthetic magnification micro-optic system of claim 1, each focusing element having a focal length of about 10 to less than about 30 microns.
- 15 18. The synthetic magnification micro-optic system of claim 1, wherein a morphing effect is provided for causing one synthetically magnified image to morph into another synthetically magnified image.
19. The synthetic magnification micro-optic system of claim 1, each image icon being formed from a printing method selected from the group consisting of ink
20 jet, laserjet, letterpress, flexo, gravure, and intaglio printing methods.
20. The synthetic magnification micro-optic system of claim 1, wherein the image icons are formed as recesses in a substrate, the voids in the recesses being filled with an evaporated metal material, a dyed material, a pigmented material and combinations thereof.

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21. The synthetic magnification micro-optic system of claim 1, having two layers of image icons at different depths in the system and a combination of focusing elements some having a focal length for focusing on one of the two layers of image icons and some having a focal length for focusing on the other of the two layers of
5 image icons.

22. The synthetic magnification micro-optic system of claim 1, wherein the focusing elements are non-cylindrical lenses and a reflective layer is positioned on the side of the micro image opposite the focusing elements.

23. The synthetic magnification micro-optic system of claim 1, including a
10 transparent tamper indicating material is placed over the focusing elements.

24. The synthetic magnification micro-optic system of claim 1, including a second periodic planar array of focusing elements placed on the side of the micro image opposite the focusing elements.

25. The synthetic magnification micro-optic system of claim 24, having a
15 second planar array of image icons in between the two planar arrays of focusing elements.

26. A document security device comprising:

(a) one or more optical spacers;

(b) a micro image comprised of a periodic planar array of a plurality of image
20 icons having an axis of symmetry about at least one of its planar axes, and positioned on or next to the optical spacer; and

(c) a periodic planar array of image icon focusing elements having an axis of symmetry about at least one of its planar axes, the axis of symmetry being the same planar axis as that of the micro image planar array, each focusing element having an

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effective diameter of less than 50 microns and being associated with an image icon and providing an enlarged field of view over the width of the associated image icon so that the peripheral edges of the associated image icon do not drop out of view.

27. The document security device of claim 26, the device operating as a
5 laminating film on a document.

28. The document security device of claim 26, the document being selected from the group consisting of I.D. cards, credit cards, drivers' licenses, financial documents, bank notes, bank checks and currency.

29. The document security device of claim 26, wherein the device is in the
10 form of a security thread for incorporation into currency paper.

30. The synthetic magnification micro-optic system of claim 1, wherein the focusing elements are selected from the group consisting of non-cylindrical lenses and non-cylindrical focusing reflectors.

31. The synthetic magnification micro-optic system of claim 30, wherein
15 the focusing elements are aspheric focusing elements.

32. The synthetic magnification micro-optic system of claim 31, wherein the focusing elements have base geometries in the plane of their planar array selected from the group consisting of a circular base, a hexagonal base, a rounded off hexagonal base, a square base, a triangular base, a rounded off triangular base, and
20 mixtures thereof.

33. The synthetic magnification micro-optic system of claim 30, wherein the focusing elements have an F number equivalent to 4 or less.

34. The synthetic magnification micro-optic system of claim 31, wherein the focusing elements have an F number equivalent to 4 or less.

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35. The synthetic magnification micro-optic system of claim 26, wherein the scale ratio of the repeat period of the image icons to the repeat period of the focusing elements is substantially equal to 1 and the axes of symmetry of the periodic planar array of the micro image and the periodic planar array of image icon focusing elements are misaligned.

36. The synthetic magnification micro-optic system of claim 35, wherein orthoparallactic motion effects are provided.

37. The synthetic magnification micro-optic system of claim 26, wherein the scale ratio of the repeat period of the image icons to the repeat period of the focusing elements is greater than 1 and the axes of symmetry of the periodic planar array of the micro image and the periodic planar array of image icon focusing elements are aligned.

38. The synthetic magnification micro-optic system of claim 26, wherein the scale ratio of the repeat period of the image icons to the repeat period of the focusing elements is less than 1 and the axes of symmetry of the periodic planar array of the micro image and the periodic planar array of image icon focusing elements are aligned.

39. The synthetic magnification micro-optic system of claim 26, wherein the scale ratio of the repeat period of the image icons to the repeat period of the focusing elements is axially asymmetric in the planes of the image icons and the focusing elements, the scale ratio being less than 1 in one axis of symmetry and being greater than 1 in the other axis of symmetry, and the axes of symmetry of the periodic planar array of the micro image and the periodic planar array of image icon focusing elements are aligned.

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40. The synthetic magnification micro-optic system of claim 26, each focusing element having an effective diameter of from about 15 to about 30 microns.
41. The synthetic magnification micro-optic system of claim 26, each focusing element having an effective diameter of less than 30 microns.
- 5 42. The synthetic magnification micro-optic system of claim 26, having a total thickness of less than about 45 microns.
43. The synthetic magnification micro-optic system of claim 26, having a total thickness of about 10 to about 40 microns.
44. The synthetic magnification micro-optic system of claim 26, each
10 focusing element having a focal length of less than about 40 microns.
45. The synthetic magnification micro-optic system of claim 26, each focusing element having a focal length of about 10 to less than about 30 microns.
46. The synthetic magnification micro-optic system of claim 26, wherein a
morphing effect is provided for causing one synthetically magnified image to morph
15 into another synthetically magnified image.
47. The synthetic magnification micro-optic system of claim 26, each image icon being formed from a printing method selected from the group consisting of ink jet, laserjet, letterpress, flexo, gravure, and intaglio printing methods.
48. The synthetic magnification micro-optic system of claim 26, wherein
20 the image icons are formed as recesses in a substrate, the voids in the recesses being filled with an evaporated metal material, a dyed material, a pigmented material and combinations thereof.
49. A synthetic magnification micro-optic system comprising:
- (a) one or more optical spacers;

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(b) a micro image comprised of a periodic planar array of a plurality of image icons having an axis of symmetry about at least one of its planar axes, and positioned on or next to the optical spacer, and

(c) a periodic planar array of image icon focusing elements having an axis of symmetry about at least one of its planar axes, the axis of symmetry being the same planar axis as that of the micro image planar array, each focusing element being an aspheric focusing element having an effective diameter of less than 50 microns and being associated with an image icon.

50. The synthetic magnification micro-optic system of claim 49, wherein the focusing elements have base geometries in the plane of their planar array selected from the group consisting of a circular base, a hexagonal base, a rounded off hexagonal base, a square base, a triangular base, a rounded off triangular base, and mixtures thereof.

51. The synthetic magnification micro-optic system of claim 49, wherein the focusing elements have an F number equivalent to 4 or less.

52. The synthetic magnification micro-optic system of claim 50, wherein the focusing elements have an F number equivalent to 4 or less.

53. The synthetic magnification micro-optic system of claim 49, wherein the scale ratio of the repeat period of the image icons to the repeat period of the focusing elements is substantially equal to 1 and the axes of symmetry of the periodic planar array of the micro image and the periodic planar array of image icon focusing elements are misaligned.

54. The synthetic magnification micro-optic system of claim 53, wherein orthoparallactic motion effects are provided.

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55. The synthetic magnification micro-optic system of claim 49, wherein the scale ratio of the repeat period of the image icons to the repeat period of the focusing elements is greater than 1 and the axes of symmetry of the periodic planar array of the micro image and the periodic planar array of image icon focusing elements are aligned.

56. The synthetic magnification micro-optic system of claim 49, wherein the scale ratio of the repeat period of the image icons to the repeat period of the focusing elements is less than 1 and the axes of symmetry of the periodic planar array of the micro image and the periodic planar array of image icon focusing elements are aligned.

57. The synthetic magnification micro-optic system of claim 49, wherein the scale ratio of the repeat period of the image icons to the repeat period of the focusing elements is axially asymmetric in the planes of the image icons and the focusing elements, the scale ratio being less than 1 in one axis of symmetry and being greater than 1 in the other axis of symmetry, and the axes of symmetry of the periodic planar array of the micro image and the periodic planar array of image icon focusing elements are aligned.

58. The synthetic magnification micro-optic system of claim 49, each focusing element having an effective diameter of from about 15 to about 30 microns.

59. The synthetic magnification micro-optic system of claim 49, each focusing element having an effective diameter of less than 30 microns.

60. The synthetic magnification micro-optic system of claim 49, having a total thickness of less than about 45 microns.

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61. The synthetic magnification micro-optic system of claim 49, having a total thickness of about 10 to about 40 microns.

62. The synthetic magnification micro-optic system of claim 49, each focusing element having a focal length of less than about 40 microns.

5 63. The synthetic magnification micro-optic system of claim 49, each focusing element having a focal length of about 10 to less than about 30 microns.

64. The synthetic magnification micro-optic system of claim 49, wherein a morphing effect is provided for causing one synthetically magnified image to morph into another synthetically magnified image.

10 65. The synthetic magnification micro-optic system of claim 49, each image icon being formed from a printing method selected from the group consisting of ink jet, laserjet, letterpress, flexo, gravure, and intaglio printing methods.

66. The synthetic magnification micro-optic system of claim 49, wherein the image icons are formed as recesses in a substrate, the voids in the recesses being
15 filled with an evaporated metal material, a dyed material, a pigmented material and combinations thereof.

67. A document security device comprising:

(a) one or more optical spacers;

(b) a micro image comprised of a periodic planar array of a plurality of image
20 icons having an axis of symmetry about at least one of its planar axes, and positioned on or next to the optical spacer; and

(c) a periodic planar array of image icon focusing elements having an axis of symmetry about at least one of its planar axes, the axis of symmetry being the same planar axis as that of the micro image planar array, each focusing element being an

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aspheric focusing element having an effective diameter of less than 50 microns and being associated with an image icon.

68. A method of producing a synthetic magnification micro-optic system, comprising the steps of:

- 5 (a) providing one or more optical spacers;
- (b) providing a micro image comprised of a periodic planar array of a plurality of image icons having an axis of symmetry about at least one of its planar axes, and positioned on or next to the optical spacer; and
- (c) providing a periodic planar array of image icon focusing elements having
- 10 an axis of symmetry about at least one of its planar axes, the axis of symmetry being the same planar axis as that of the micro image planar array, each focusing element having an effective diameter of less than 50 microns and being associated with an image icon and providing an enlarged field of view over the width of the associated image icon so that the peripheral edges of the associated image icon do not drop out
- 15 of view.

69. A method of producing a synthetic magnification micro-optic system, comprising the steps of:

- (a) providing one or more optical spacers;
- (b) providing a micro image comprised of a periodic planar array of a
- 20 plurality of image icons having an axis of symmetry about at least one of its planar axes, and positioned on or next to the optical spacer; and
- (c) providing a periodic planar array of image icon focusing elements having an axis of symmetry about at least one of its planar axes, the axis of symmetry being the same planar axis as that of the micro image planar array, each focusing element

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being an aspheric focusing element having an effective diameter of less than 50 microns and being associated with an image icon.

70. A method for producing a document security device, comprising the steps of:

- 5 (a) providing one or more optical spacers;
- (b) providing a micro image comprised of a periodic planar array of a plurality of image icons having an axis of symmetry about at least one of its planar axes, and positioned on or next to the optical spacer; and
- (c) providing a periodic planar array of image icon focusing elements having
- 10 an axis of symmetry about at least one of its planar axes, the axis of symmetry being the same planar axis as that of the micro image planar array, each focusing element having an effective diameter of less than 50 microns and being associated with an image icon and providing an enlarged field of view over the width of the associated image icon so that the peripheral edges of the associated image icon do not drop out
- 15 of view.

71. A method of producing a document security device, comprising the steps of:

- (a) providing one or more optical spacers;
- (b) providing a micro image comprised of a periodic planar array of a
- 20 plurality of image icons having an axis of symmetry about at least one of its planar axes, and positioned on or next to the optical spacer; and
- (c) providing a periodic planar array of image icon focusing elements having an axis of symmetry about at least one of its planar axes, the axis of symmetry being the same planar axis as that of the micro image planar array, each focusing element

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being an aspheric focusing element having an effective diameter of less than 50 microns and being associated with an image icon.

72. A method of controlling motion effects in a synthetic magnification micro-optic system, comprising the steps of:

- 5 (a) providing one or more optical spacers;
- (b) providing a micro image comprised of a periodic planar array of a plurality of image icons having an axis of symmetry about at least one of its planar axes, and positioned on or next to the optical spacer;
- (c) providing a periodic planar array of image icon focusing elements having
10 an axis of symmetry about at least one of its planar axes, the axis of symmetry being the same planar axis as that of the micro image planar array, each focusing element having an effective diameter of less than 50 microns and being associated with an image icon and providing an enlarged field of view over the width of the associated image icon so that the peripheral edges of the associated image icon do not drop out
15 of view; and
- (d) selecting the scale ratio of the repeat period of the image icons to the repeat period of the focusing elements from the group consisting of less than 1, substantially equal to 1, and greater than 1, and selecting whether the axes of symmetry of the periodic planar array of the micro image and the periodic planar
20 array of image icon focusing elements are aligned or misaligned.

73. A method of controlling motion effects in a synthetic magnification micro-optic system, comprising the steps of:

- (a) providing one or more optical spacers;

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(b) providing a micro image comprised of a periodic planar array of a plurality of image icons having an axis of symmetry about at least one of its planar axes, and positioned on or next to the optical spacer;

5 (c) providing a periodic planar array of image icon focusing elements having an axis of symmetry about at least one of its planar axes, the axis of symmetry being the same planar axis as that of the micro image planar array, each focusing element being an aspheric focusing element having an effective diameter of less than 50 microns and being associated with an image icon; and

(d) selecting the scale ratio of the repeat period of the image icons to the
10 repeat period of the focusing elements from the group consisting of less than 1, substantially equal to 1, and greater than 1, and selecting whether the axes of symmetry of the periodic planar array of the micro image and the periodic planar array of image icon focusing elements are aligned or misaligned.

74. A method of controlling motion effects in a document security device,
15 comprising the steps of:

(a) providing one or more optical spacers;

(b) providing a micro image comprised of a periodic planar array of a plurality of image icons having an axis of symmetry about at least one of its planar axes, and positioned on or next to the optical spacer;

20 (c) providing a periodic planar array of image icon focusing elements having an axis of symmetry about at least one of its planar axes, the axis of symmetry being the same planar axis as that of the micro image planar array, each focusing element having an effective diameter of less than 50 microns and being associated with an image icon and providing an enlarged field of view over the width of the associated

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image icon so that the peripheral edges of the associated image icon do not drop out of view; and

- (d) selecting the scale ratio of the repeat period of the image icons to the repeat period of the focusing elements from the group consisting of less than 1, substantially equal to 1, and greater than 1, and selecting whether the axes of symmetry of the periodic planar array of the micro image and the periodic planar array of image icon focusing elements are aligned or misaligned.

75. A method of controlling motion effects in a document security device, comprising the steps of:

- 10 (a) providing one or more optical spacers;
- (b) providing a micro image comprised of a periodic planar array of a plurality of image icons having an axis of symmetry about at least one of its planar axes, and positioned on or next to the optical spacer;
- (c) providing a periodic planar array of image icon focusing elements having 15 an axis of symmetry about at least one of its planar axes, the axis of symmetry being the same planar axis as that of the micro image planar array, each focusing element being an aspheric focusing element having an effective diameter of less than 50 microns and being associated with an image icon; and
- (d) selecting the scale ratio of the repeat period of the image icons to the 20 repeat period of the focusing elements from the group consisting of less than 1, substantially equal to 1, and greater than 1, and selecting whether the axes of symmetry of the periodic planar array of the micro image and the periodic planar array of image icon focusing elements are aligned or misaligned.

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76. An image icon for use in a synthetic magnification micro-optic system, the synthetic magnification micro-optic system including:

(a) one or more optical spacers;

5 (b) a micro image comprised of a periodic planar array of a plurality of image icons having an axis of symmetry about at least one of its planar axes, and positioned on or next to the optical spacer; and

(c) a periodic planar array of image icon focusing elements having an axis of symmetry about at least one of its planar axes, the axis of symmetry being the same planar axis as that of the micro image planar array, each focusing element being
10 associated with an image icon; and

the image icons being formed as recesses in a substrate, the voids in the recesses being filled with an evaporated metal material, a dyed material, a pigmented material and combinations thereof.

77. An image icon for use in a document security device, the synthetic
15 magnification micro-optic system including:

(a) one or more optical spacers;

(b) a micro image comprised of a periodic planar array of a plurality of image icons having an axis of symmetry about at least one of its planar axes, and positioned on or next to the optical spacer; and

20 (c) a periodic planar array of image icon focusing elements having an axis of symmetry about at least one of its planar axes, the axis of symmetry being the same planar axis as that of the micro image planar array, each focusing element being associated with an image icon; and

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the image icons being formed as recesses in a substrate, the voids in the recesses being filled with an evaporated metal material, a dyed material, a pigmented material and combinations thereof.

78. A synthetic magnification micro-optic system comprising:

- 5 (a) one or more optical spacers;
- (b) a micro image comprised of a periodic planar array of a plurality of image icons having an axis of symmetry about at least one of its planar axes, and positioned on or next to the optical spacer; and
- 10 (c) a periodic planar array of image icon focusing elements having an axis of symmetry about at least one of its planar axes, the axis of symmetry being the same planar axis as that of the micro image planar array, each focusing element being a polygonal base multi-zonal lens.

79. A document security device comprising:

- (a) one or more optical spacers;
- 15 (b) a micro image comprised of a periodic planar array of a plurality of image icons having an axis of symmetry about at least one of its planar axes, and positioned on or next to the optical spacer; and
- (c) a periodic planar array of image icon focusing elements having an axis of symmetry about at least one of its planar axes, the axis of symmetry being the same
- 20 planar axis as that of the micro image planar array, each focusing element being a polygonal base multi-zonal lens.

80. A method of making a synthetic magnification micro-optic system, comprising the steps of:

- (a) providing one or more optical spacers;

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(b) providing a micro image comprised of a periodic planar array of a plurality of image icons having an axis of symmetry about at least one of its planar axes, and positioned on or next to the optical spacer, and

(c) providing a periodic planar array of image icon focusing elements having
5 an axis of symmetry about at least one of its planar axes, the axis of symmetry being the same planar axis as that of the micro image planar array, each focusing element being a polygonal base multi-zonal lens.

81. A method of making document security device, comprising the steps of:

10 (a) providing one or more optical spacers;

(b) providing a micro image comprised of a periodic planar array of a plurality of image icons having an axis of symmetry about at least one of its planar axes, and positioned on or next to the optical spacer, and

(c) providing a periodic planar array of image icon focusing elements having
15 an axis of symmetry about at least one of its planar axes, the axis of symmetry being the same planar axis as that of the micro image planar array, each focusing element being a polygonal base multi-zonal lens.

82. A security thread comprising:

(a) one or more optical spacers;

20 (b) one or more optionally periodic planar arrays of micro-images or icons positioned within, on, or next to an optical spacer, and

(c) one or more optionally periodic planar arrays of non-cylindrical micro lenses positioned on or next to either an optical spacer or a planar icon array, with each micro-lens having a base diameter of less than 50 microns.

83. A security thread, comprising:
- (a) an optical spacer having opposing upper and lower planar surfaces;
 - (b) a periodic array of micro-images or icons comprising filled recesses formed on the lower planar surface of the optical spacer;
 - 5 (c) a periodic array of non-cylindrical, flat field, aspheric or polygonal base multi-zonal micro-lenses positioned on the upper planar surface of the optical spacer, wherein each micro-lens have a base diameter ranging from about 20 to about 30 microns; and
 - (d) a pigmented sealing or obscuring layer 516 positioned on the icon array.
- 10 84. A method of making a security thread, comprising the steps of:
- (a) applying a substantially transparent or clear radiation curable resin to the upper and lower surfaces of the optical spacer;
 - (b) forming a micro-lens array on the upper surface and an icon array in the form of recesses on the lower surface of the optical spacer;
 - 15 (c) curing the substantially transparent or clear resin using a source of radiation;
 - (d) filling the icon array recesses with a pigmented resin or ink;
 - (e) removing excess resin or ink from the lower surface of the optical spacer, and
 - 20 (f) applying a pigmented sealing or obscuring coating or layer to the lower surface of the optical spacer.

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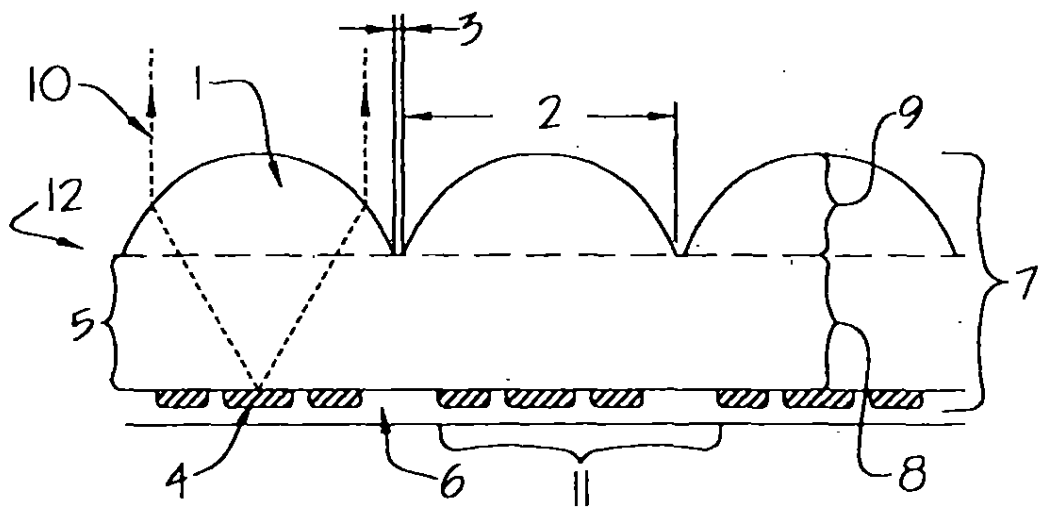


Fig. 1a

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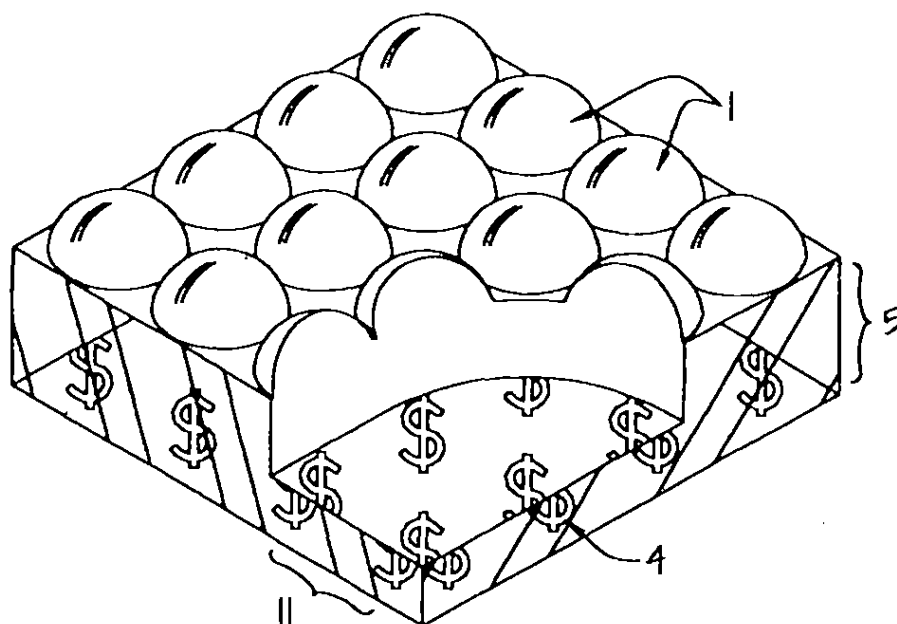


Fig. 1b

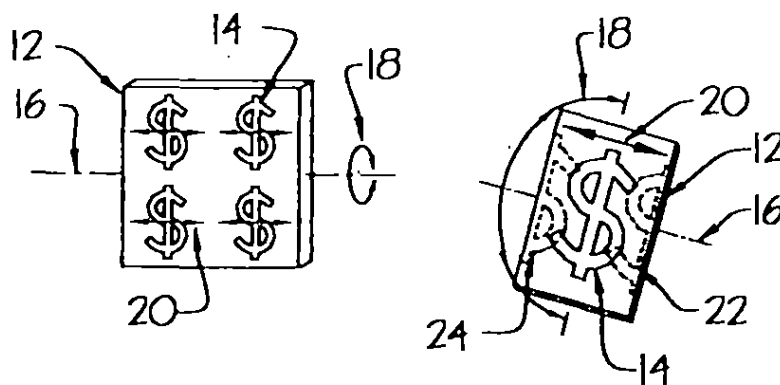
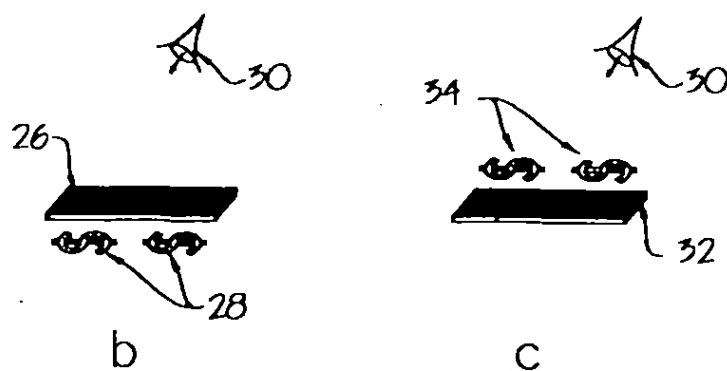


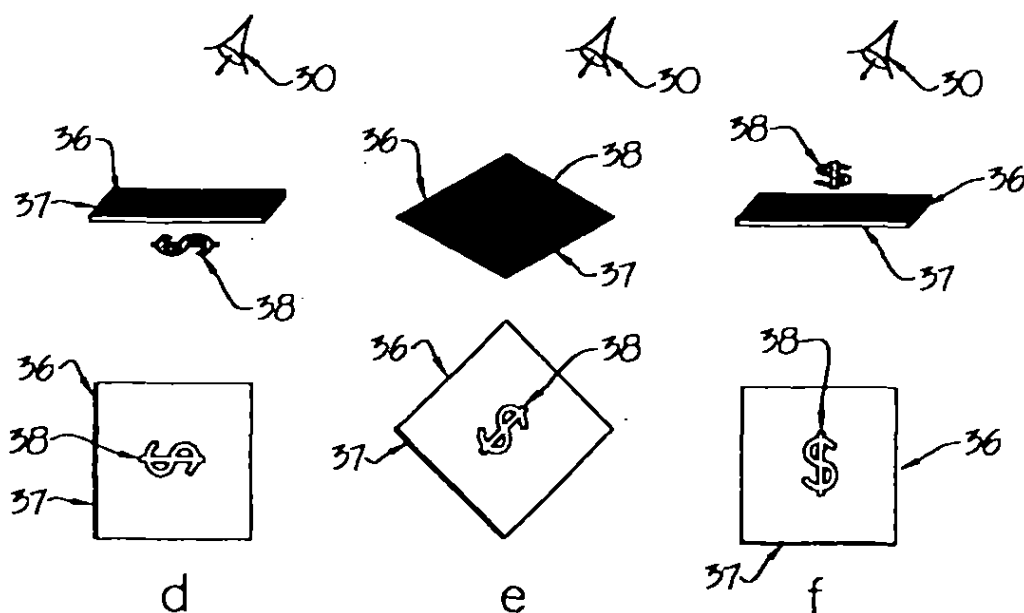
Fig 2a

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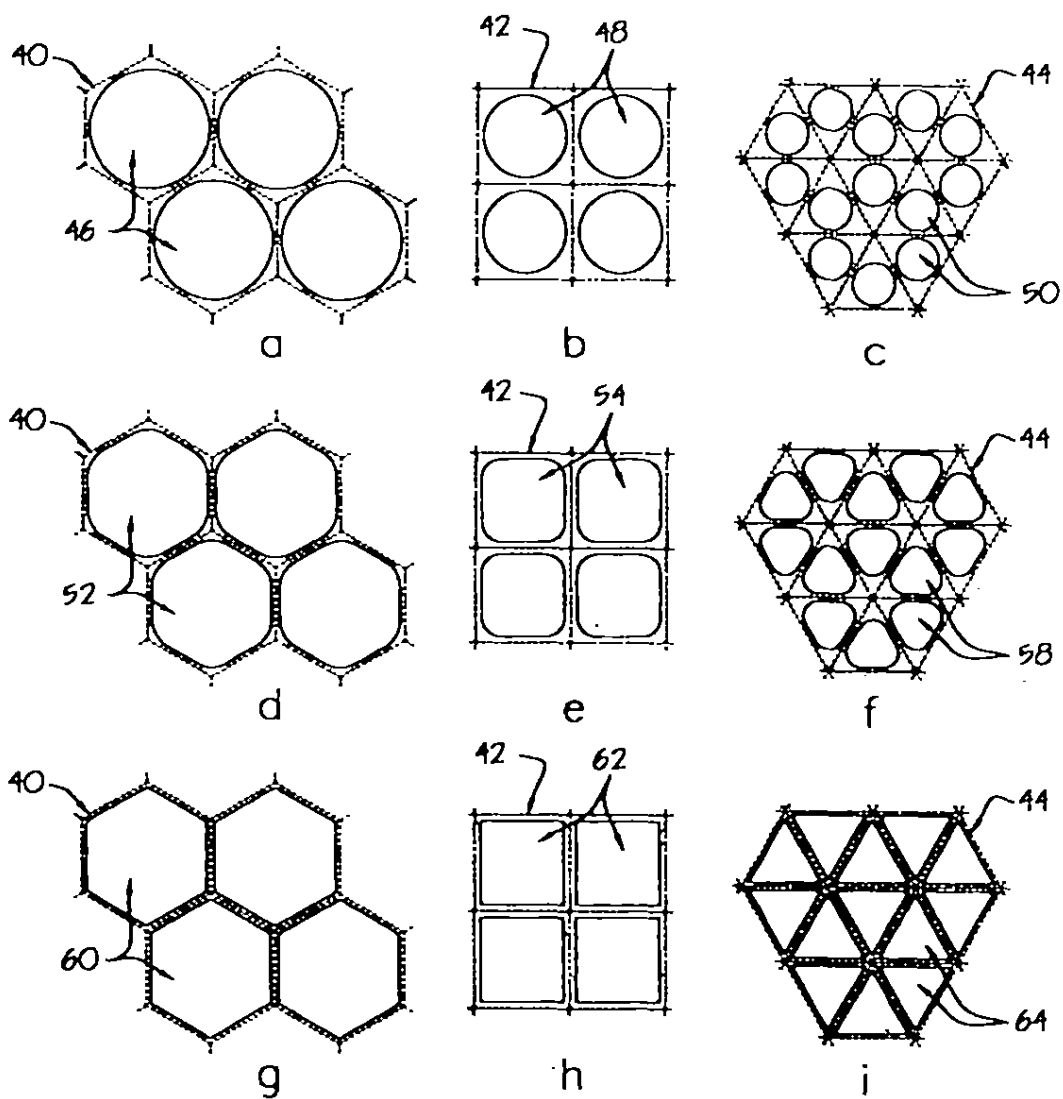
Figs 2b,c



Figs 2d,e,f

SUBSTITUTE SHEET (RULE 26)

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Figs 3a-i

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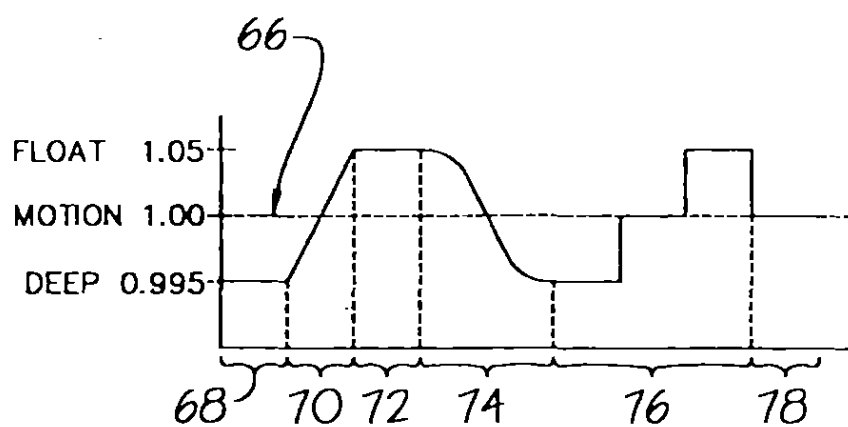
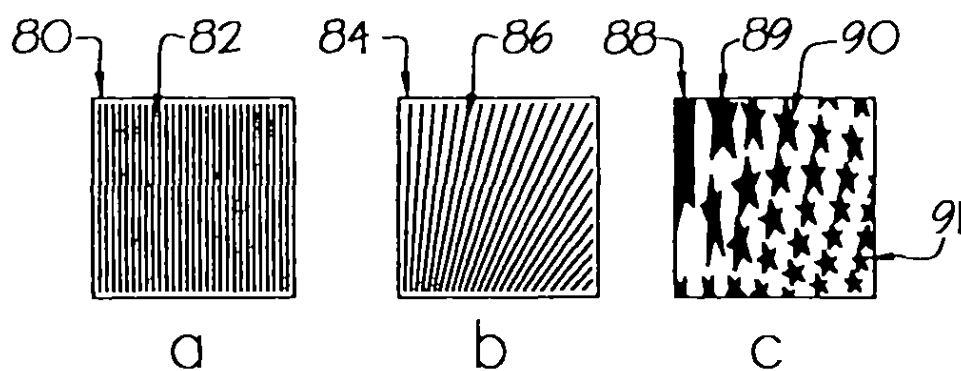
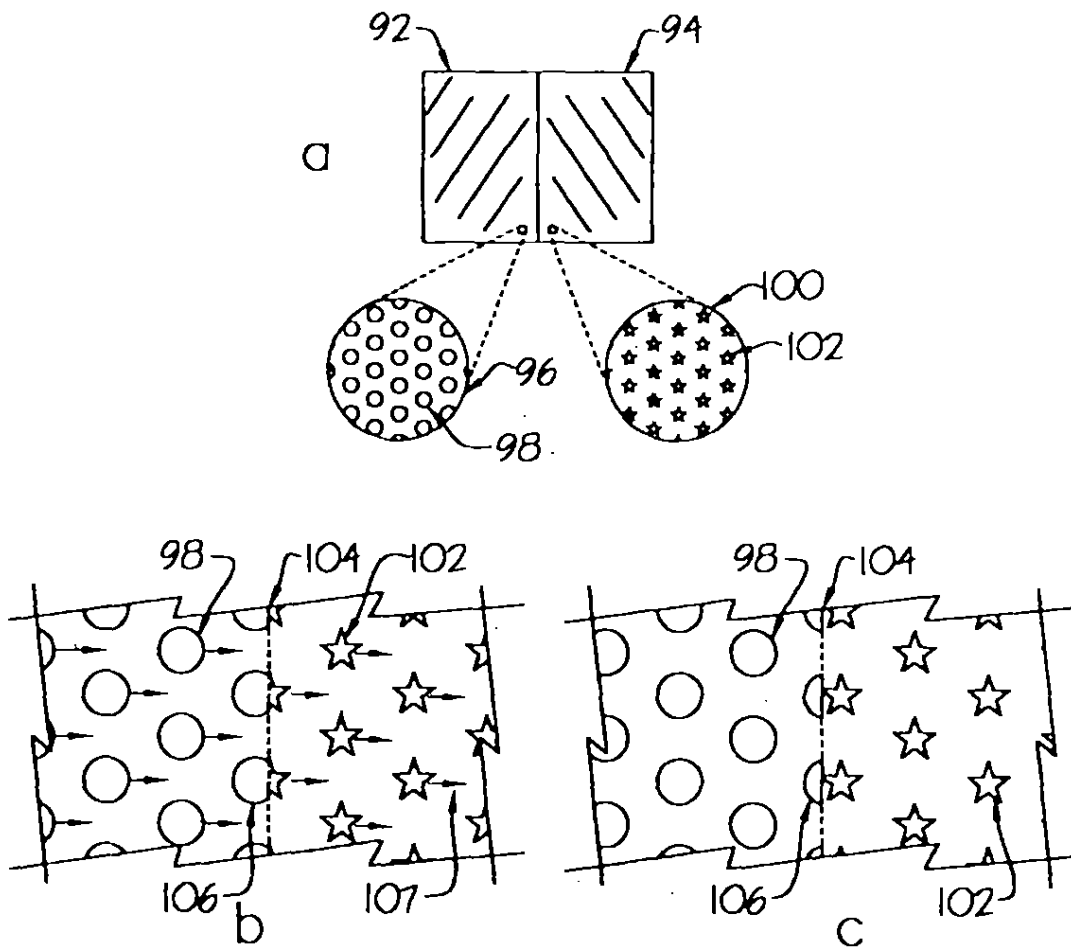


Fig. 4



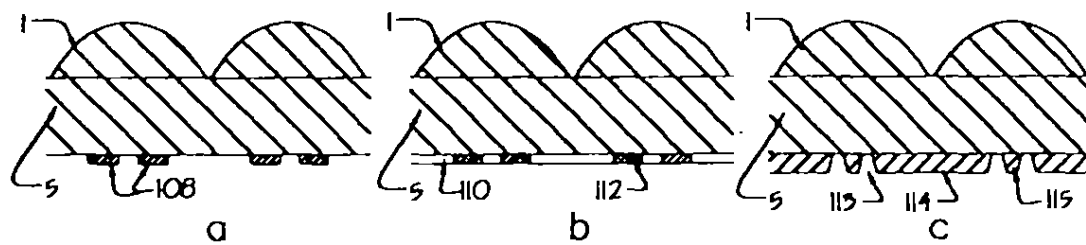
Figs. 5a-c

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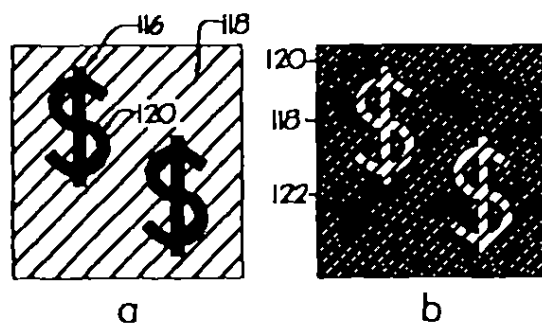


Figs. 6a-c

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Figs. 7a-c



Figs. 8a-b

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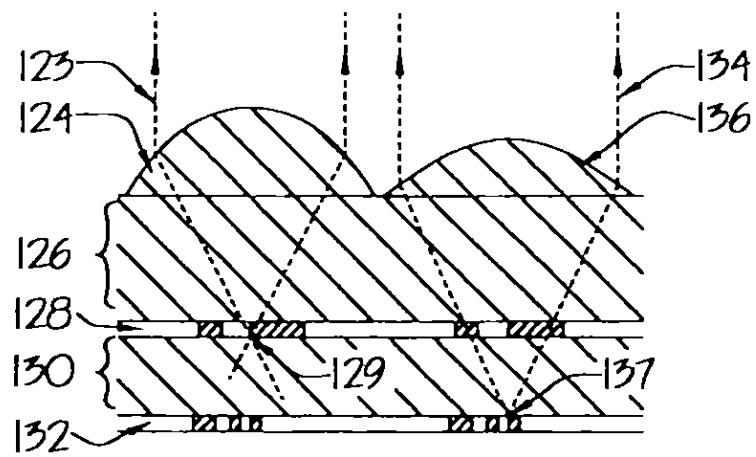


Fig. 9

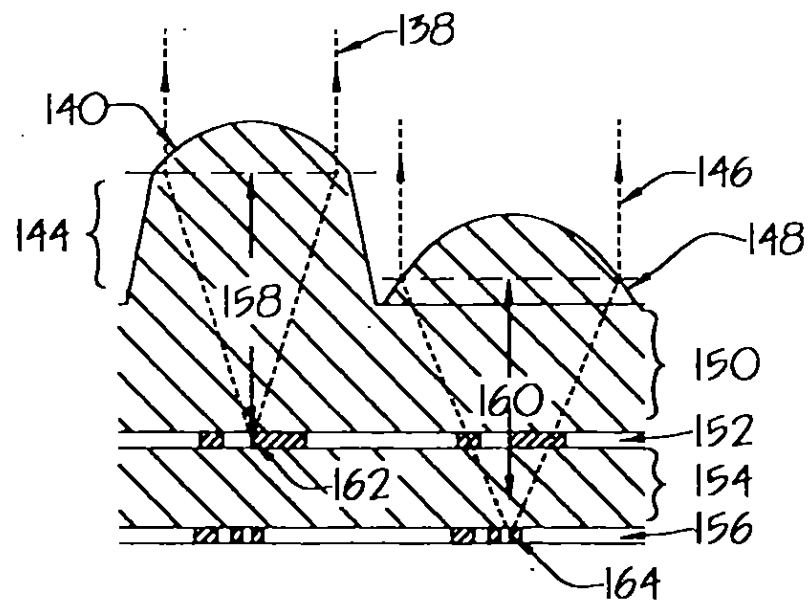
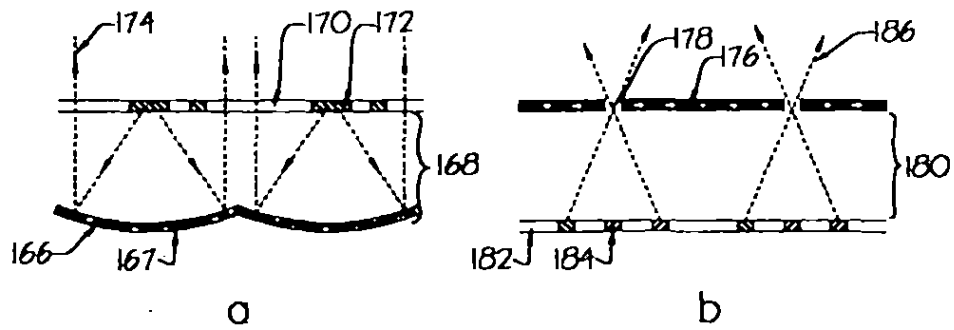


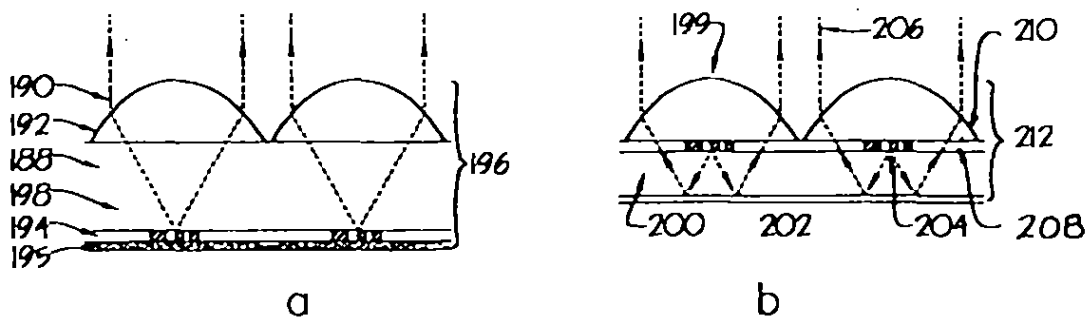
Fig. 10

SUBSTITUTE SHEET (RULE 26)

122



Figs. 11a-b



Figs. 12a-b

223
423

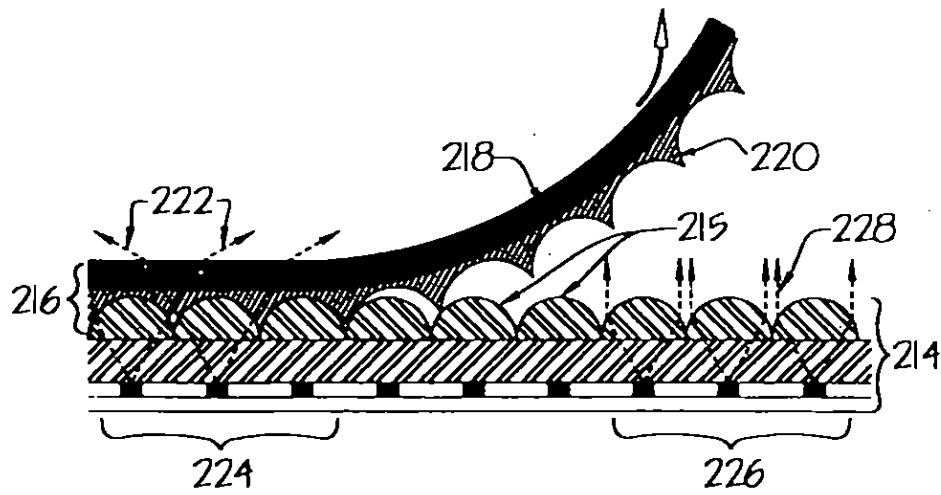


Fig. 13

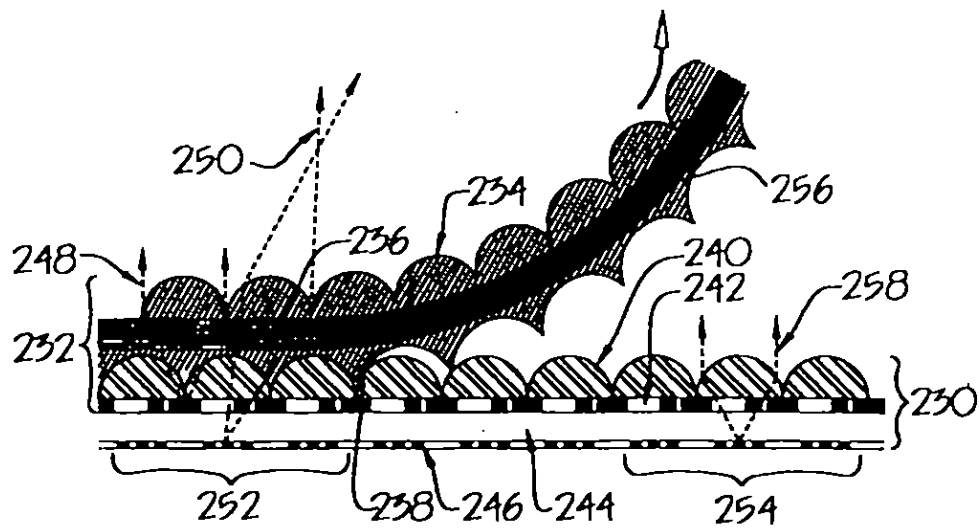
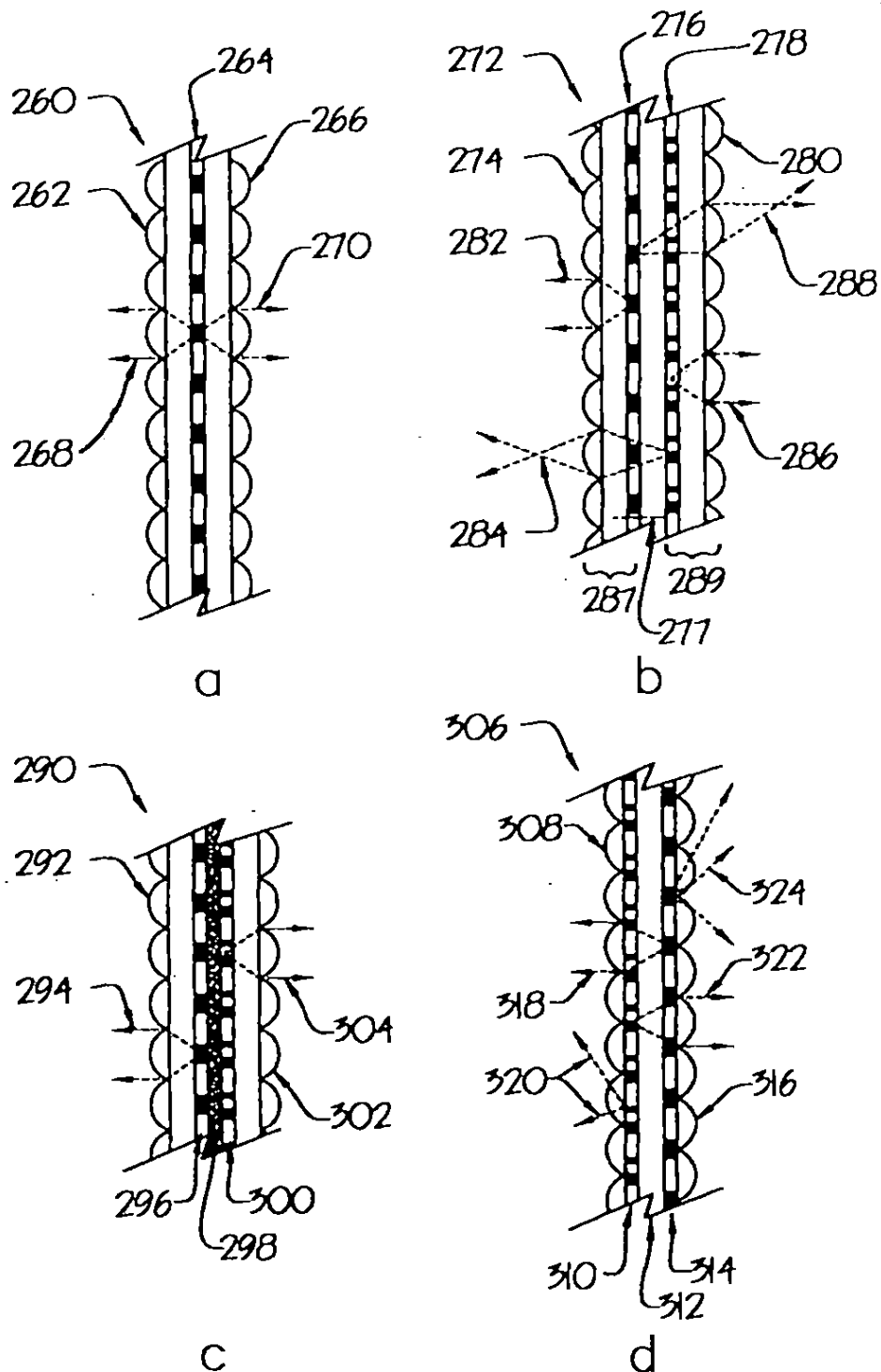


Fig. 14

SUBSTITUTE SHEET (RULE 26)

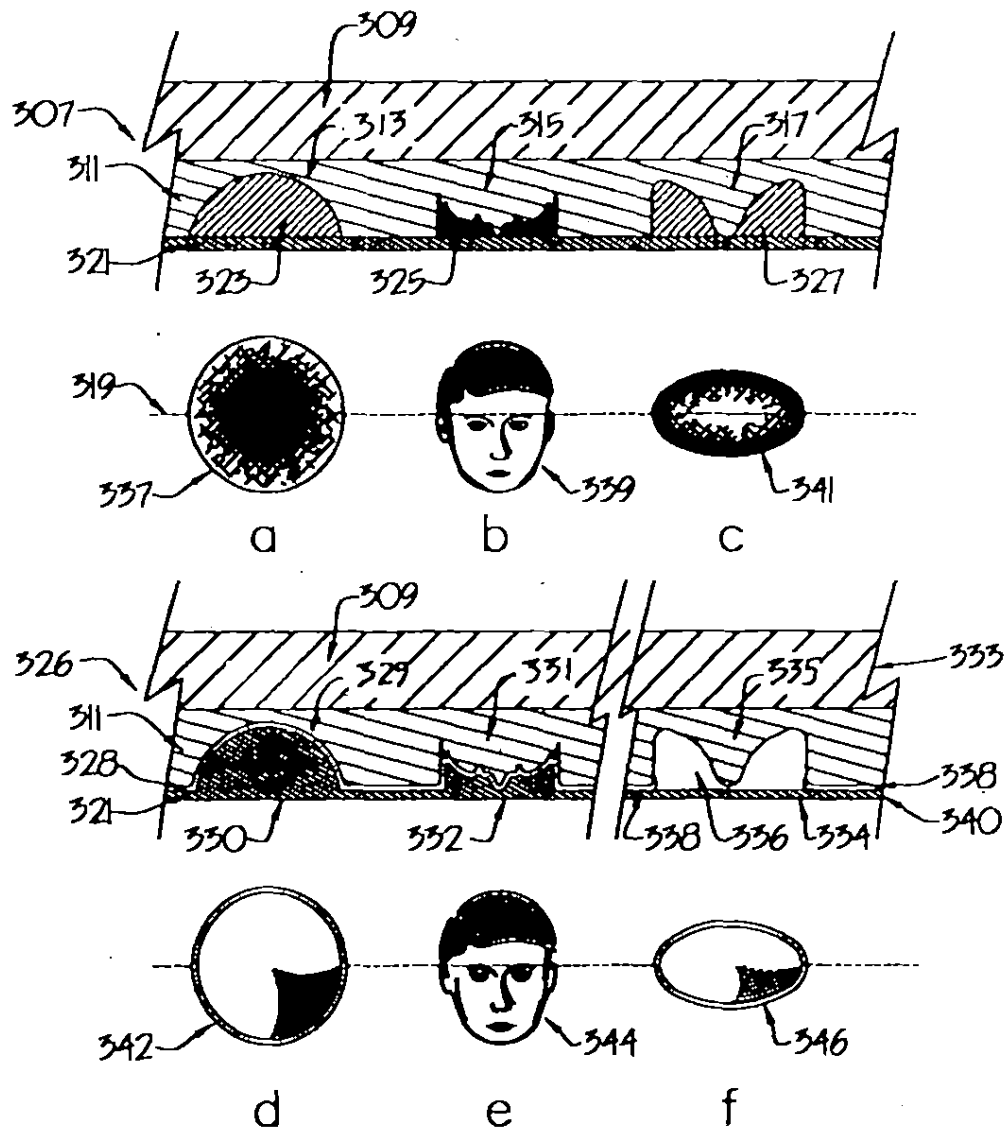
424



Figs. 15a-d

SUBSTITUTE SHEET (RULE 26)

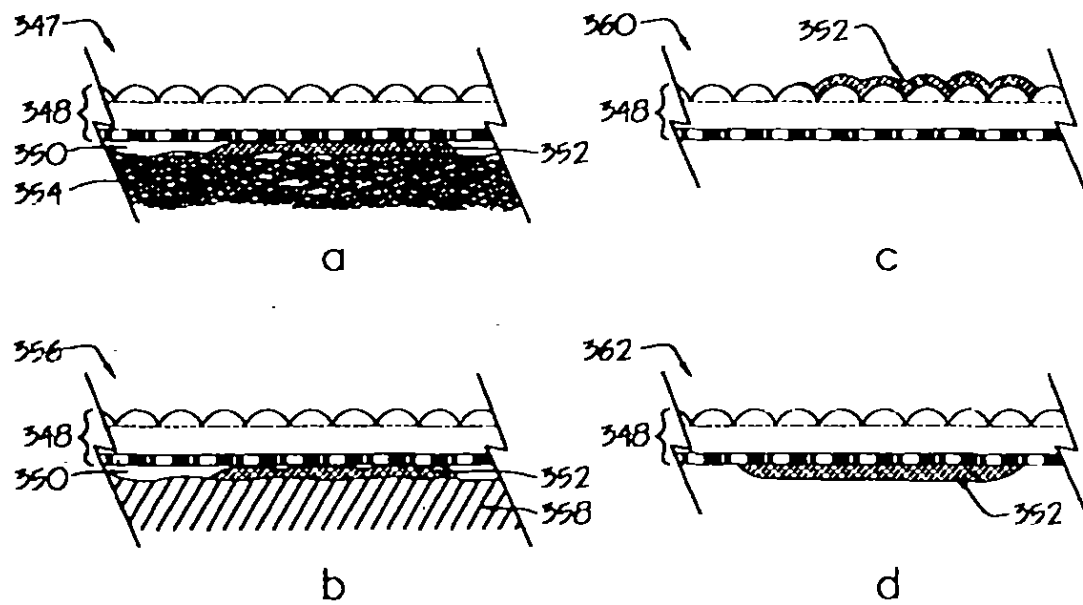
225



Figs. 16a-f

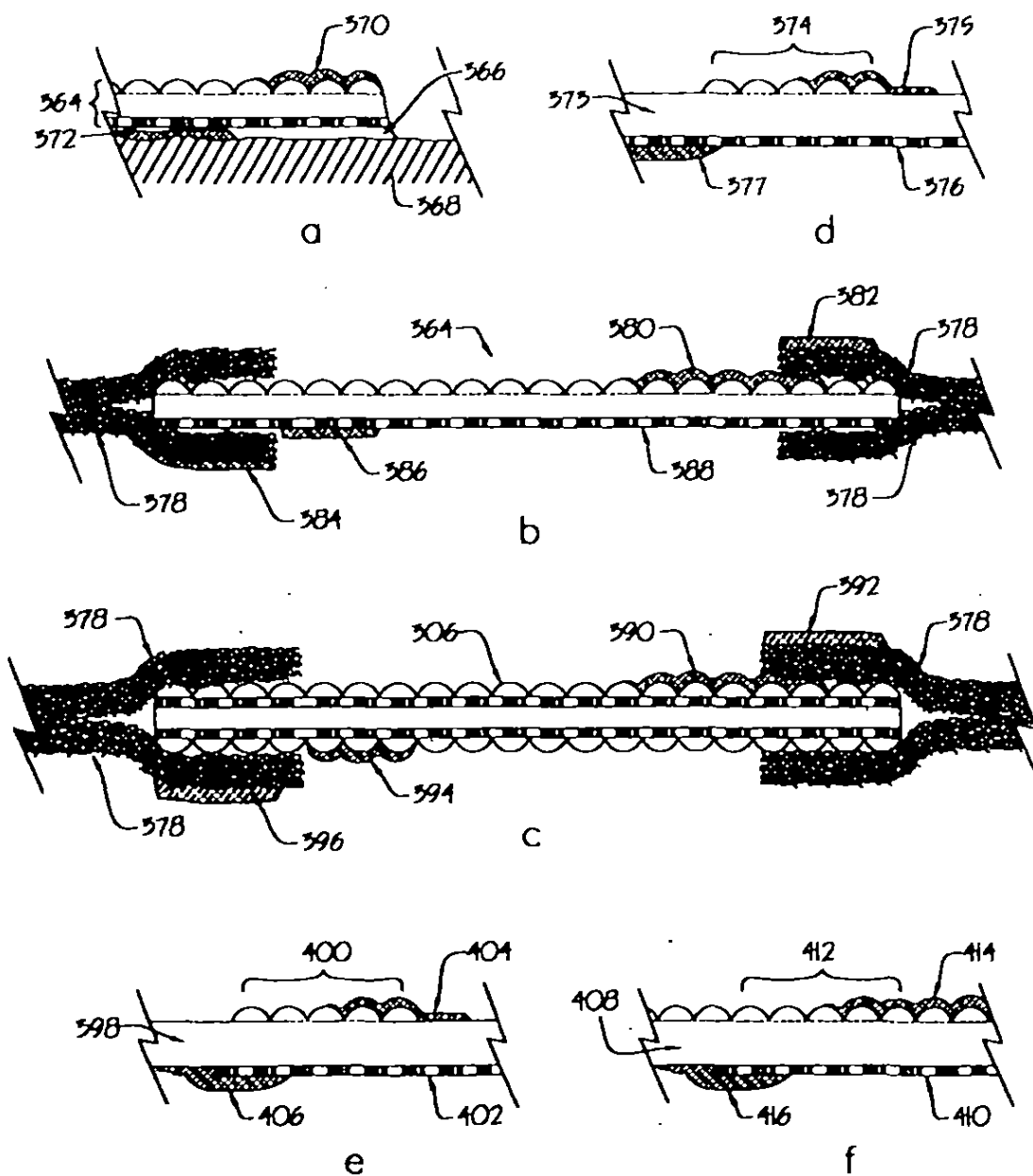
SUBSTITUTE SHEET (RULE 28)

55
426



Figs. 17a-d

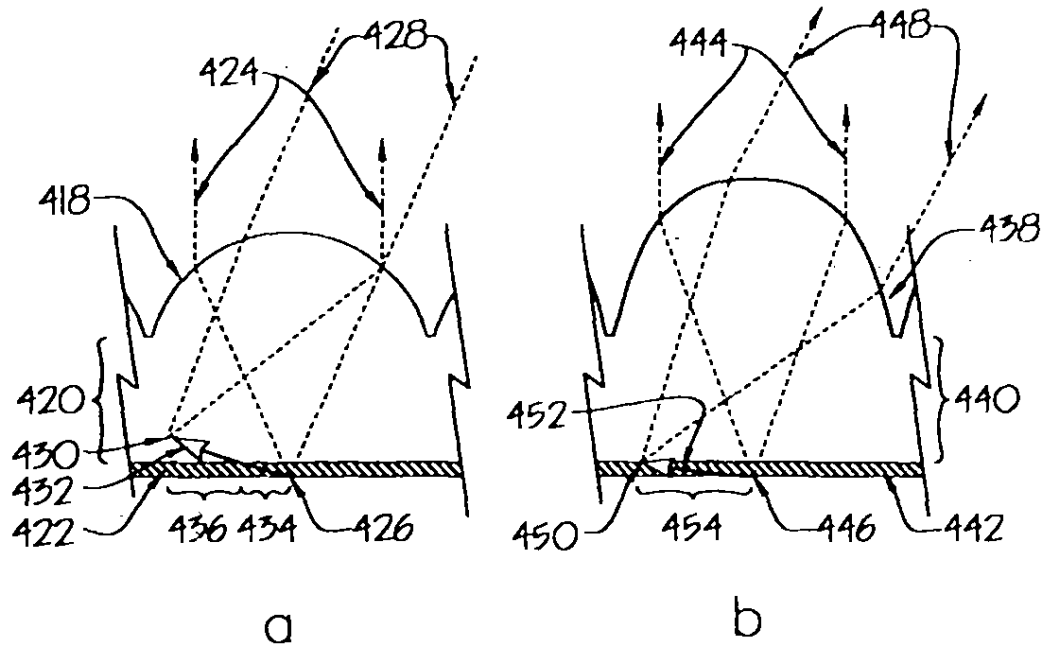
223
423



Figs. 18a-f

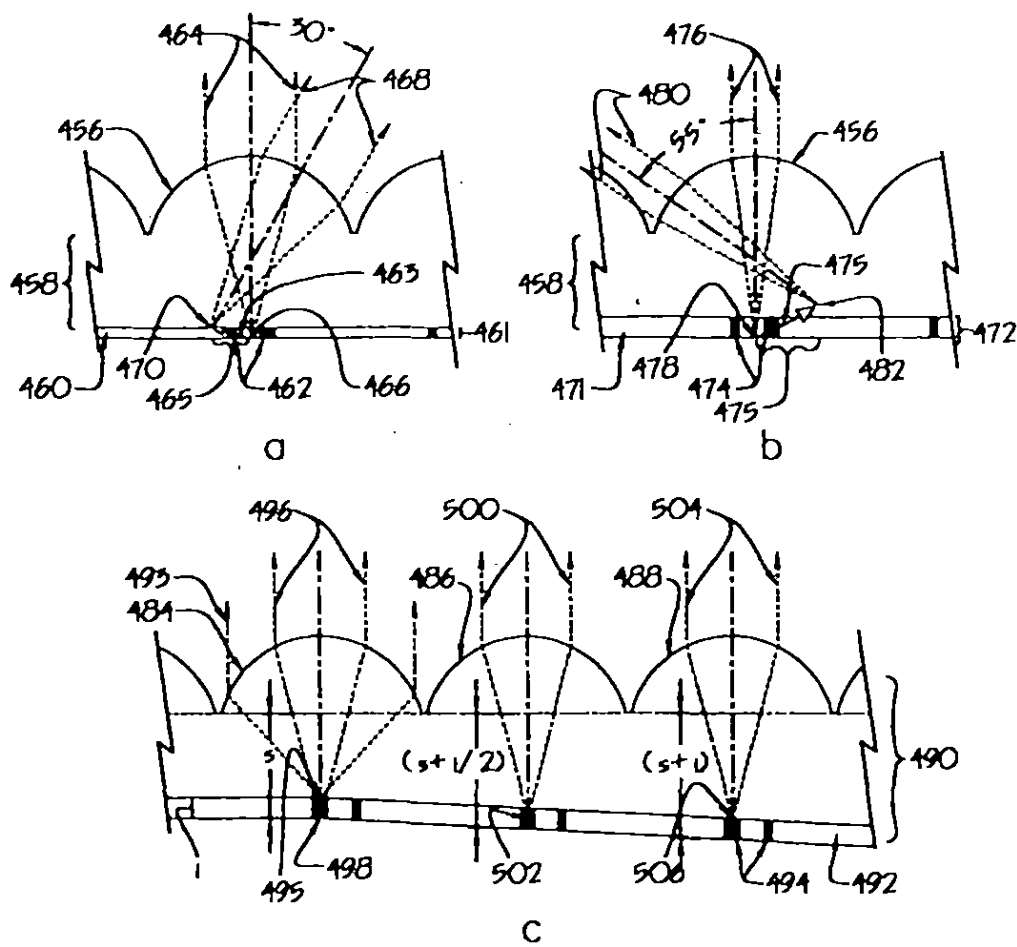
SUBSTITUTE SHEET (RULE 26)

428



Figs. 19a-b

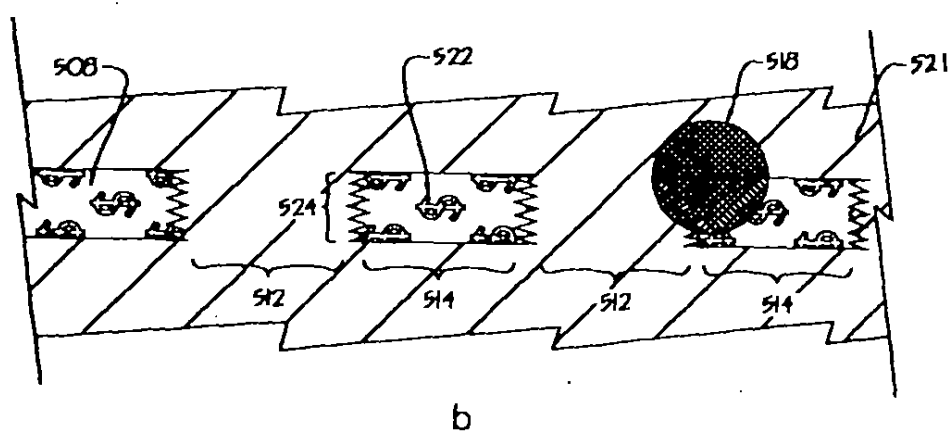
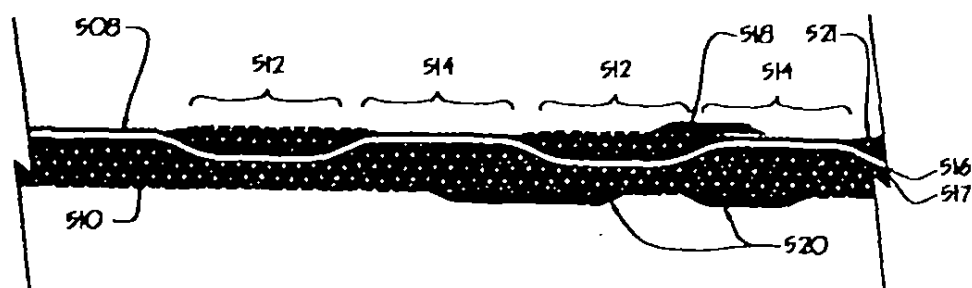
429



Figs. 20a-c

SUBSTITUTE SHEET (RULE 26)

430

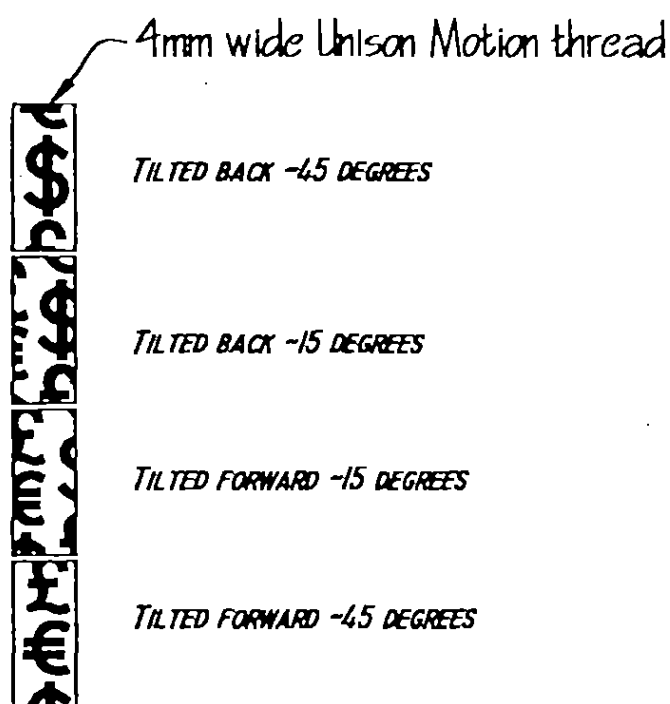


b

Figs. 21a,b

SUBSTITUTE SHEET (RULE 26)

431



Unison Motion ortho-parallax

Fig. 22

432

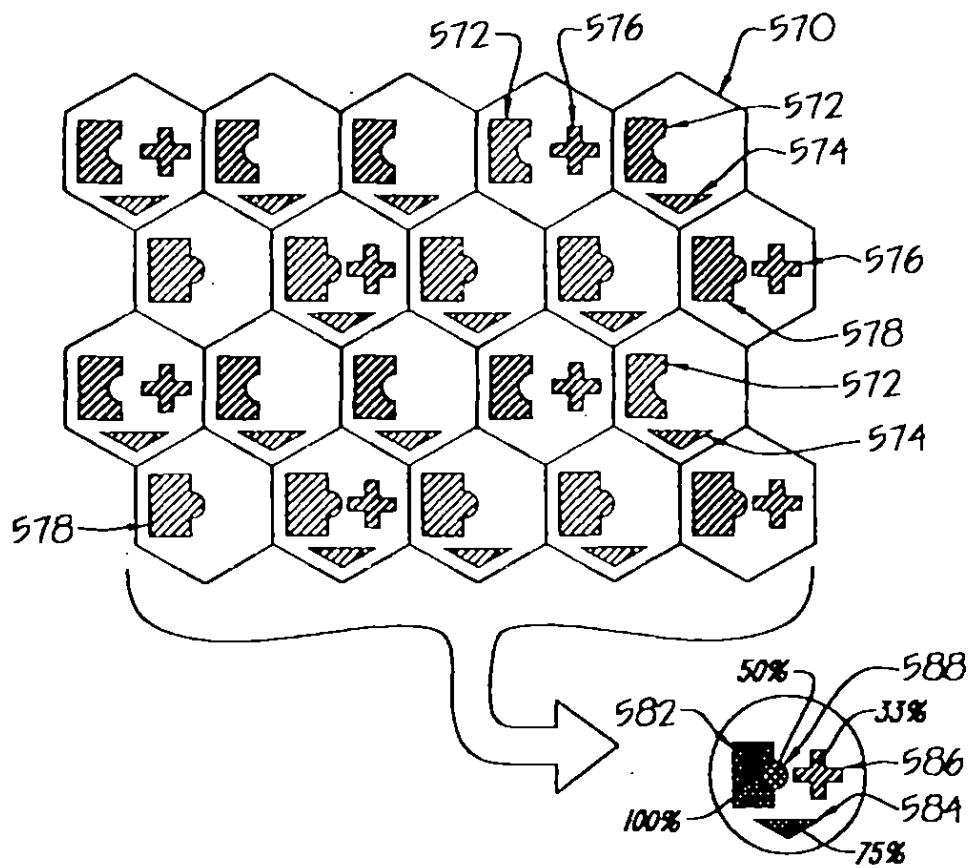


Fig. 23

256
433

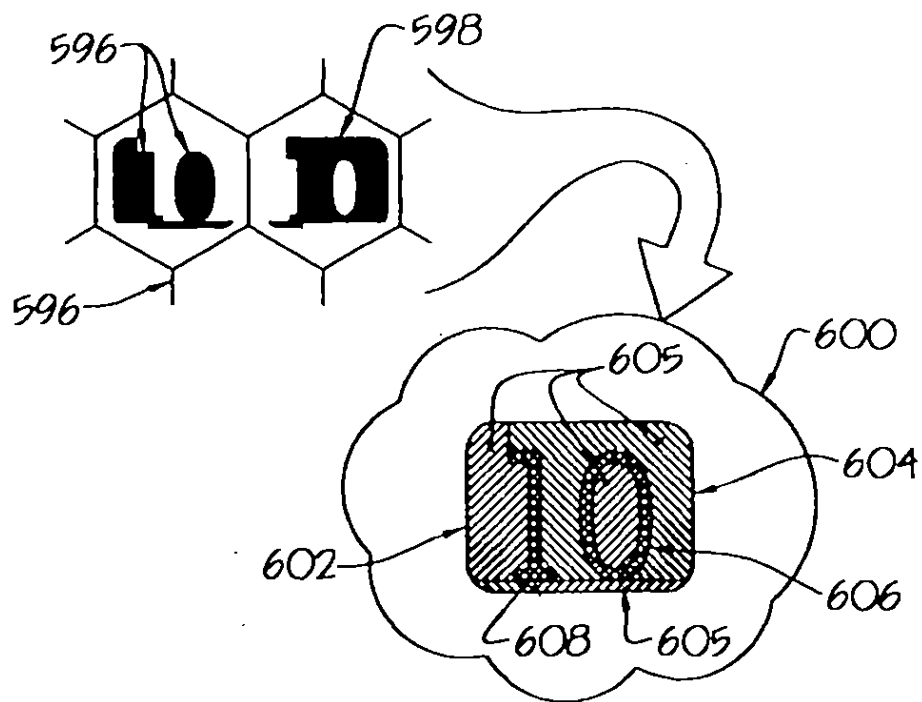


Fig. 24a

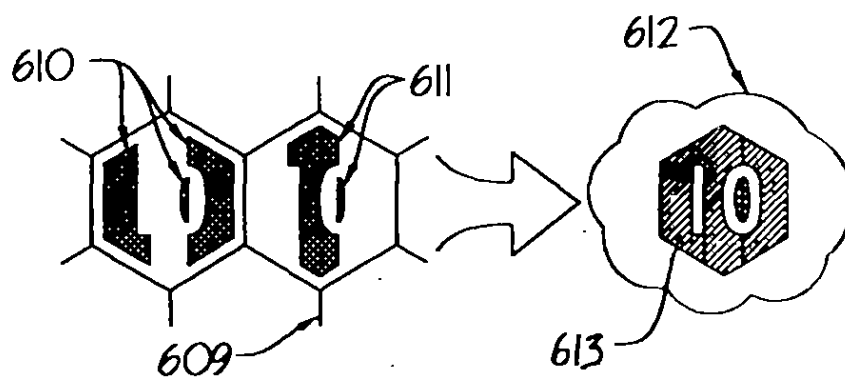


Fig. 24b

434

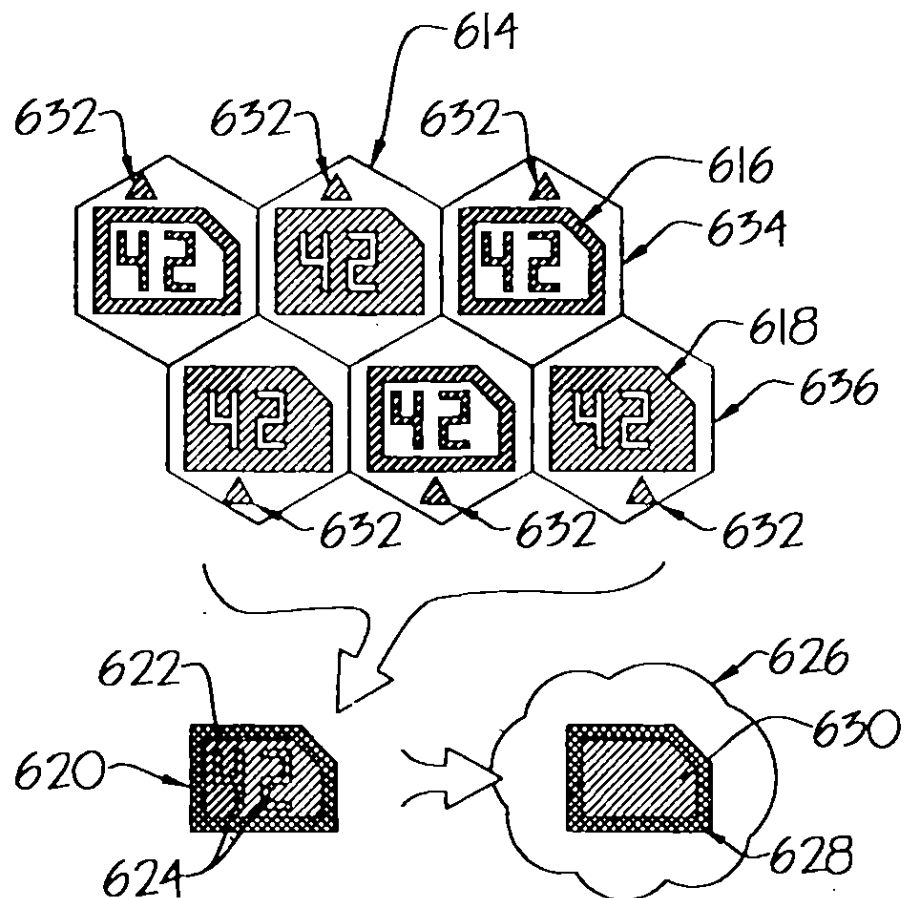


Fig. 25

435

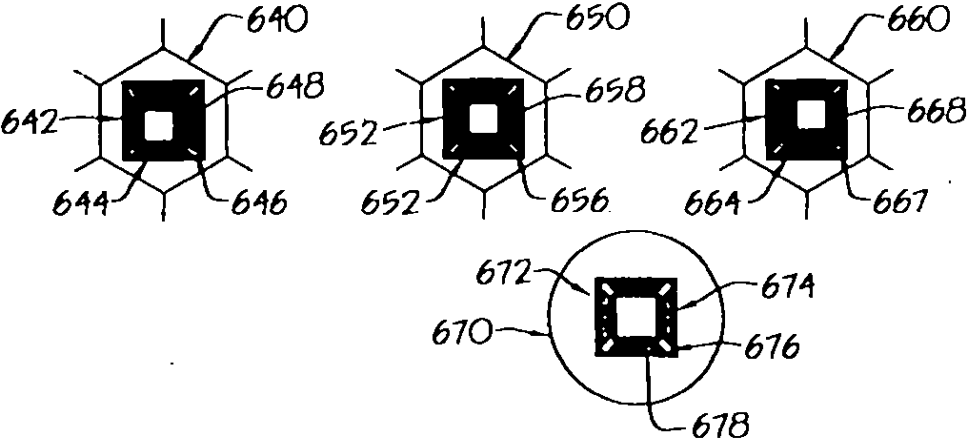


Fig. 26

436

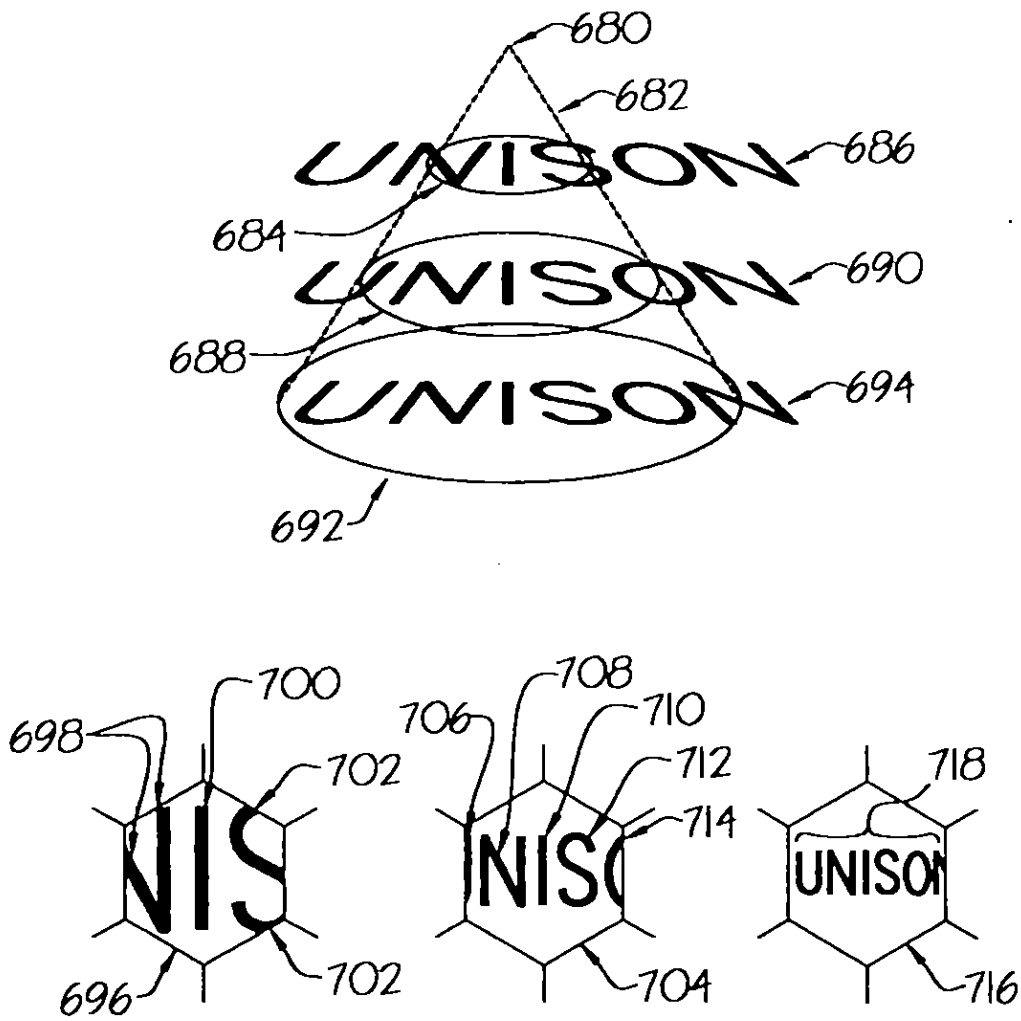


Fig. 27

4328

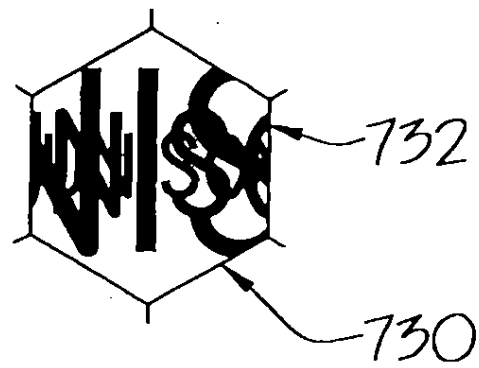


Fig. 28

438

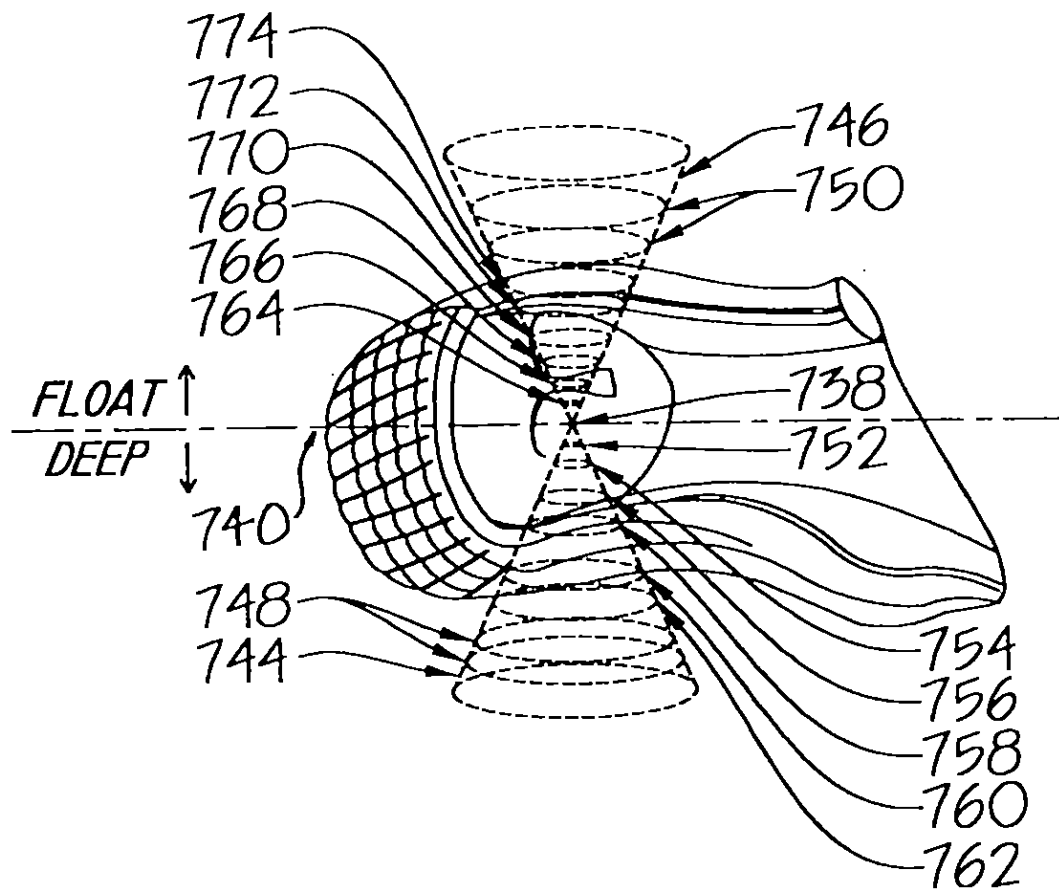


Fig. 29

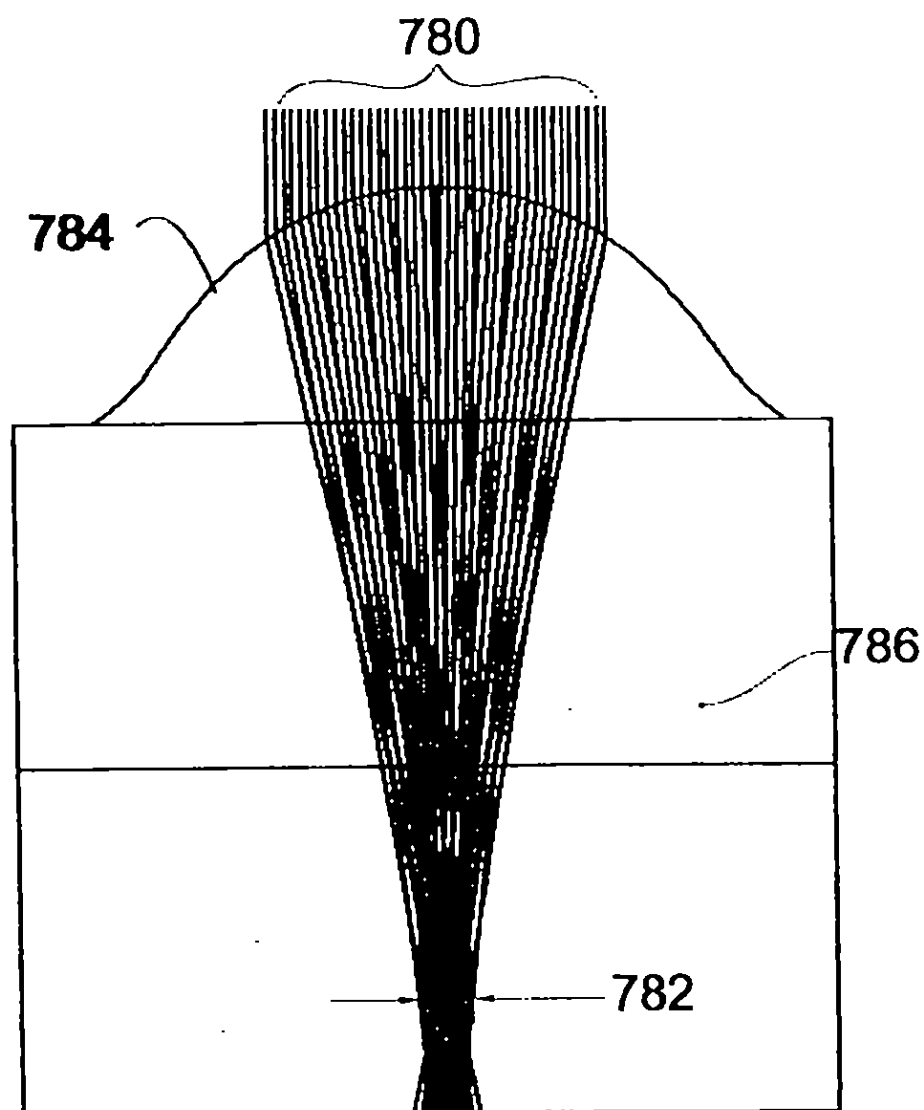
85
439

Fig. 30

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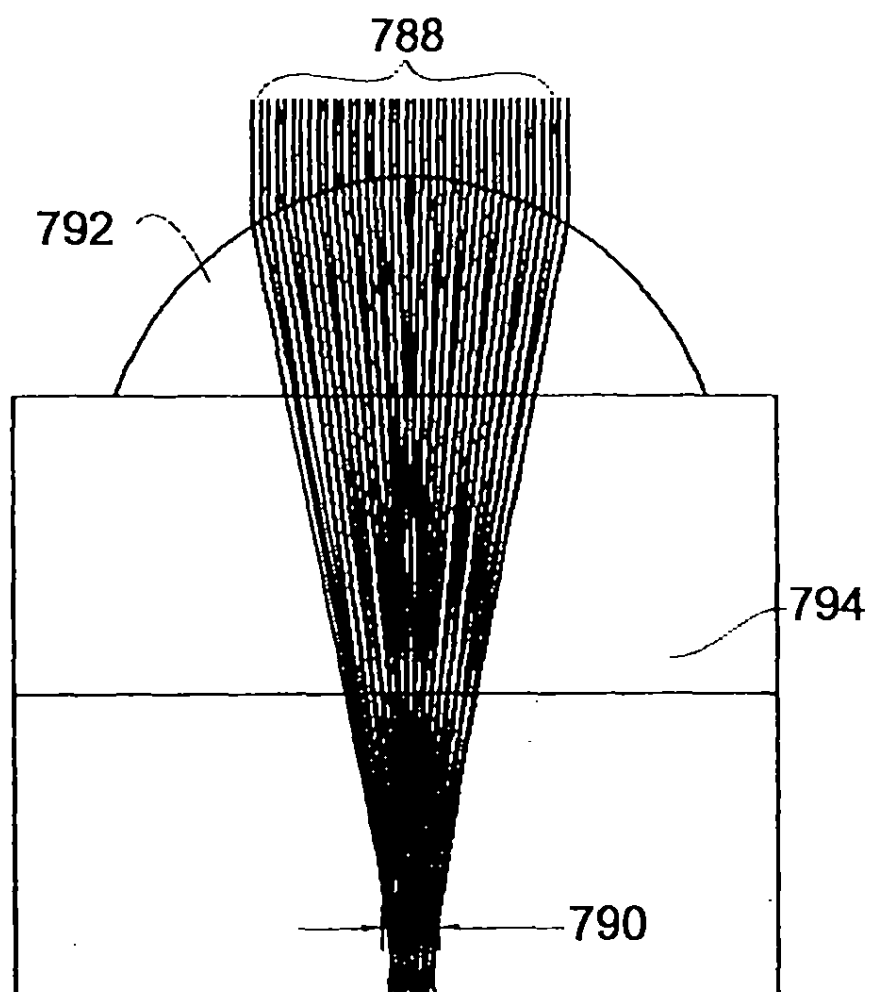
53
440

Fig. 31

SUBSTITUTE SHEET (RULE 26)

441

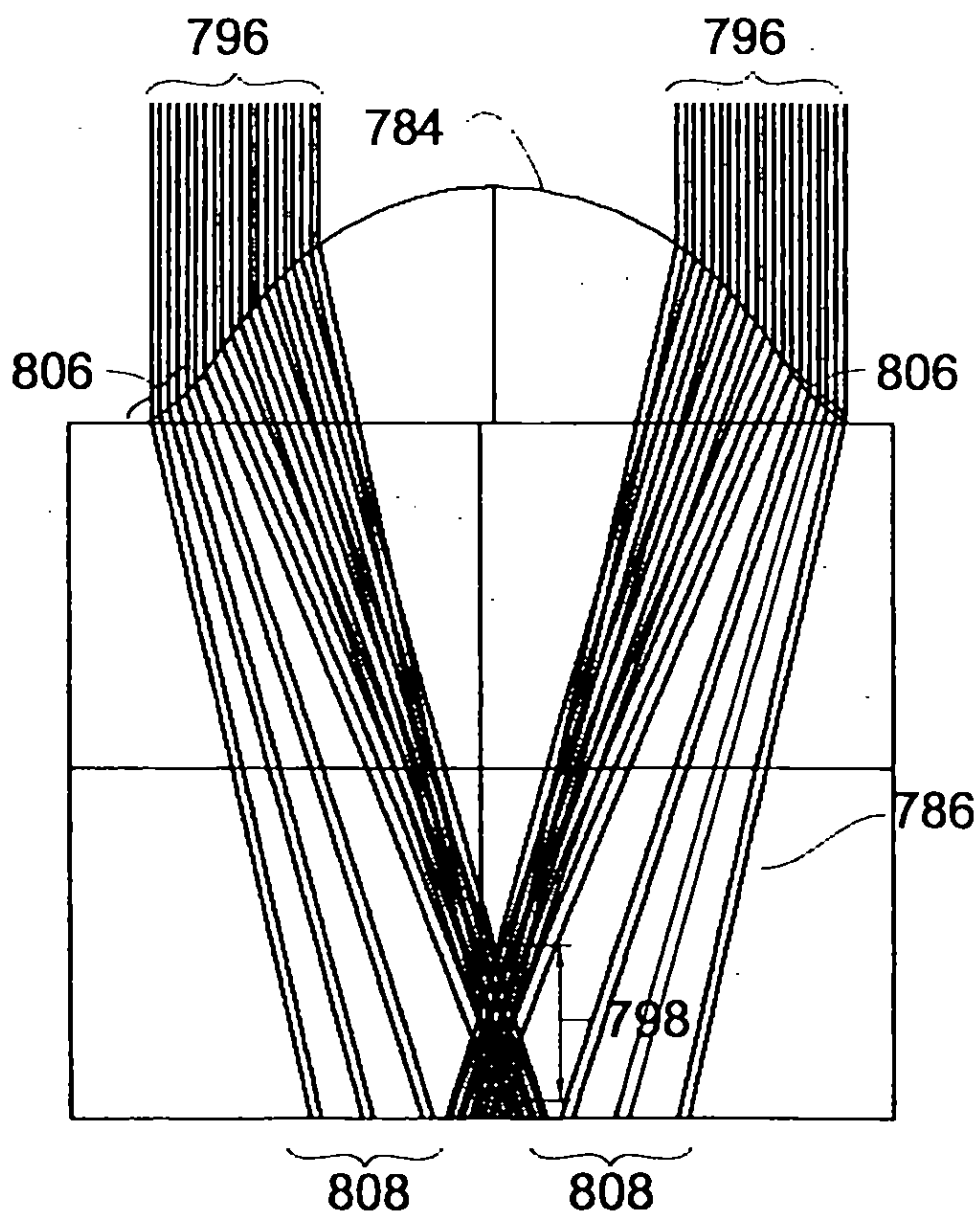


Fig. 32

SUBSTITUTE SHEET (RULE 26)

442

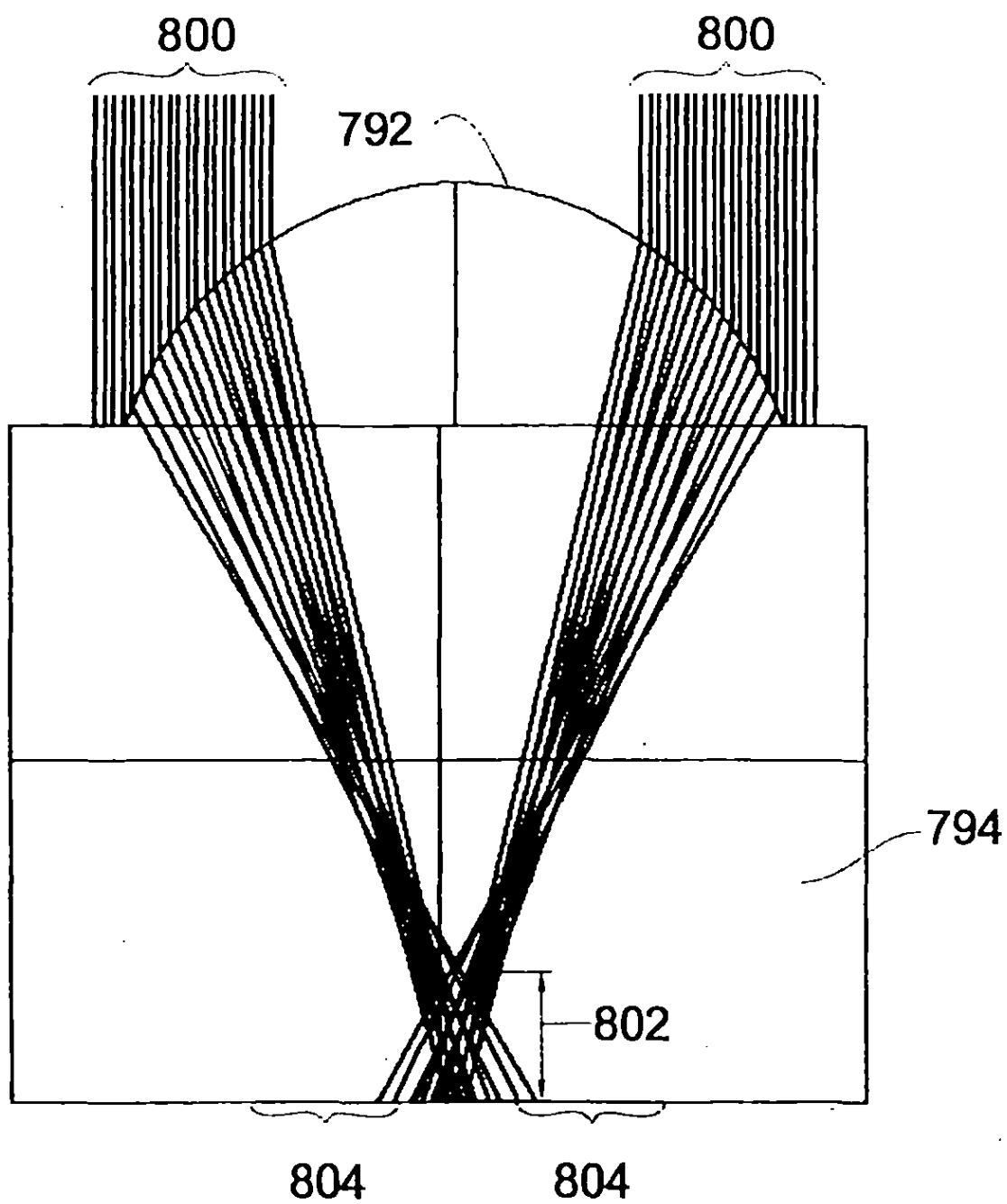


Fig. 33

MODELO DE UTILIDAD [1]

- INCOMPLETA []

INCOMPLETA []

INCOMPLETA []

Carrera 13 No. 27-00 Piso 5, 7 y 10
Conmutador: 3 82 08 40
Fax: 350 52 20
E-mail: info@sic.gov.co
www.sic.gov.co
Bogotá, D.C., Colombia

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SUPERINTENDENCIA DE INDUSTRIA Y COMERCIO
 Edif. 05-050/05C - 00000-0000
 Tel: 2000-05-20 16:00:50 Dep. 2020 NUECREACIONES
 Trá: 11 PATENTEYN
 Eje: 370 FASENACIONALN
 Act 411 PRESENTACION Folios: 441

**FORMULARIO ÚNICO DE SOLICITUD DE PATENTE
 PCT
 ENTRADA EN FASE NACIONAL**

1) SOLICITUD DE:			
☒ Patente de invención		☐ Patente de Modelo de Utilidad	
☐ Capítulo I.		☒ Capítulo II.	
2) SOLICITANTE (71)	 Dilia María Rodríguez D'Aleman LUGAR DE NACIMIENTO: GA, USA		IDENTIFICACIÓN C.C. ☐ NIT: ☒ C.E. ☐ OTRO ☐ Cual _____ NÚMERO _____
Teléfono: _____ Fax: _____ E. Mail: _____			
3) REPRESENTANTE O APODERADO	Nombre: DILIA MARÍA RODRÍGUEZ D'ALEMAN Dirección: Carrera 11 N°. 86-53 Piso 6 Bogotá D.C. Teléfono: 6181088 Fax: 6350824 E. Mail: info@clarkemodet.com.co		IDENTIFICACIÓN C.C. ☒ NIT: ☐ C.E. ☐ OTRO ☐ NÚMERO: 41.654.882 TP: 20824 CSJ
4) INVENTOR (ES) (72)	Nombre: 1. STEENBLIK, Richard, A.; 2. HURT, Mark, J.; 3. JORDAN, Gregory, R. Dirección: 1. 240 Seale Lane, Alpharetta, GA 30022, USA; 2. 3816 Turnberry Court, Duluth, GA 30096 USA; 3. 1293 Dalesford Drive, Alpharetta, GA 30004, USA Nacionalidad o Domicilio: Todos los anteriores, estadounidenses		
5) PCT (86) Solicitud Internacional No. PCT/US2004/039315 Fecha: Nov. 22, 2004 Publicación Internacional No. WO 2005/052650 A2 Fecha: Junio 9, 2005			
6) Título (54) SISTEMA DE PRESENTACIÓN DE IMÁGENES Y SEGURIDAD MICRO-ÓPTICA			
7) Clasificación Internacional: G02B			
8) PRIORIDAD	33) País de Origen	(32) Fecha	(31) Número de Solicitud
SI ☒ NO ☐	Estados Unidos	Nov. 21, 2003	60/524,281
	Estados Unidos	Ene. 22, 2004	60/538,392
	Estados Unidos	Nov. 12, 2004	60/627,234
9) Comprobante de pago N°. 06-42,854 Fecha: Junio 8, 2006			
Instrucciones para el diligenciamiento del presente formulario Ver reverso de esta pagina			

NOVEDAD DE LA INVENCION

Habiendo descrito el presente invento, se considera como una novedad y, por lo tanto, se reclama como prioridad lo contenido en las siguientes:

REIVINDICACIONES

1.- Un sistema micro-óptico de magnificación sintética que comprende:

a) uno o más separadores ópticos;

b) una micro-imagen compuesta de una disposición plana periódica de una pluralidad de iconos de imagen que tienen un eje de simetría por lo menos alrededor de uno de sus ejes planos, y colocada en o junto al separador óptico;

y

c) una disposición plana periódica de elementos de enfoque de iconos de imagen que tienen un eje de simetría por lo menos alrededor de sus ejes planos, el eje de simetría es el mismo eje plano que el de la disposición plana de micro-imagen, cada elemento de enfoque tiene un diámetro efectivo de menos de 50 micras y se asocia con un icono de imagen y provee un campo de visión agrandado sobre el ancho del icono de imagen asociado de forma que los bordes periféricos del icono de imagen asociado no se salen

de visión.

2.- El sistema micro-óptico de magnificación sintética de conformidad con la reivindicación 1, caracterizado porque los elementos de enfoque son seleccionados del grupo que consiste de lentes no cilíndricos y reflectores de enfoque no cilíndricos.

3.- El sistema micro-óptico de magnificación sintética de conformidad con la reivindicación 2, caracterizado porque los elementos de enfoque son elementos de enfoque esféricos.

4.- El sistema micro-óptico de magnificación sintética de conformidad con la reivindicación 3, caracterizado porque los elementos de enfoque tienen geometrías base en el plano de su disposición plana seleccionadas del grupo que consiste de una base circular, una base hexagonal, una base hexagonal redondeada, una base cuadrada, una base triangular, una base triangular redondeada, y mezclas de las mismas.

5.- El sistema micro-óptico de magnificación sintética de conformidad con la reivindicación 2, caracterizado porque los elementos de enfoque tienen un F número equivalente a 4 o menos.

6.- El sistema micro-óptico de magnificación sintética de conformidad con la reivindicación 3, caracterizado porque los elementos de enfoque tienen un F

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REPUBLICA DE COLOMBIA
SUPERINTENDENCIA DE INDUSTRIA Y COMERCIO

Bogotá,
2020

Doctor(a)
RODRIGUEZ D' ALEMAN DILIA MARIA

for

REFERENCIA	Radicación No.	6 59796
	Solicitud internacional	US2004/039315
	Fecha inicio fase nacional	21/06/2006
	Trámite	11
	Evento	379
	Actuación	430
	Oficio No.	8074

Como resultado del examen de forma, realizado con fundamento en el artículo 38 de la Decisión 486 de la Comisión de la Comunidad Andina, artículo 27 del Tratado de Cooperación en Materia de Patentes (PCT), regla 51 bis del Reglamento y Circular Única de la Superintendencia de Industria y Comercio, se le comunica que:

1. Si fuere el caso, el solicitante debe adjuntar la traducción de los anexos del reporte de examen preliminar internacional (Art. 36.2.b) del tratado PCT.
2. La traducción de los capítulos descriptivo y reivindicatorio deberán estar acompañadas de los respectivos dibujos
3. La solicitud no contiene la copia del documento en que consta la cesión del derecho a la patente del inventor al solicitante o a su causante. (Art. 26-k) Decisión 486.
4. La solicitud no contiene el poder debidamente otorgado, con el lleno de los requisitos exigidos por los artículos 63 y subsiguientes del Código de Procedimiento Civil. Adicionalmente, deberá presentar el documento que acredita la existencia y representación legal de la sociedad solicitante, cuando ésta fuere persona jurídica.

En cumplimiento de lo dispuesto por el artículo 39 de la Decisión 486, se le requiere para que dentro del término de dos meses siguientes a la fecha de notificación del presente oficio, complete los requisitos anteriormente enunciados. En caso de no dar cumplimiento al presente requerimiento, la solicitud se considerará abandonada y perderá su prelación.

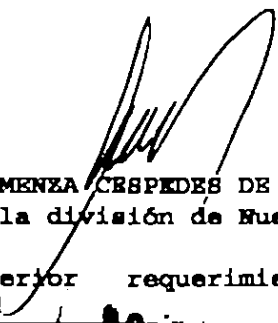
Notifíquese el presente oficio conforme a lo dispuesto en el numeral 5.2, literal e), del capítulo quinto del título primero de la Circular Unica No.10 de 2001.

Continúa en la página siguiente...

REPUBLICA DE COLOMBIA
SUPERINTENDENCIA DE INDUSTRIA Y COMERCI

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Radicación No.: 6 59796



ALIX CARMENZA CESPEDES DE VERGEL
Jefe de la división de Nuevas Creaciones

El anterior requerimiento fue notificado por fijación en lista de
fecha 28 JUL 2006
adpall