

SUPERINTENDENCIA DE INDUSTRIA Y COMERCIO	
RAD: 14-93868- -3	FECHA: 2015-06-04 14:32:40
DEP: 2020 DIRECCION DE NUEVAS CREACIONES	EVE: 378 FASE NACIONAL INCLUIDO CAPITULO I
TRA: 11 PCT-PATENTE DE INVENCION CAPITULOS I Y II	FOLIOS: 8
ACT: 430 REQUERSOLICITA	

DIRECCIÓN DE NUEVAS CREACIONES

2020
Bogotá, D.C.,

Abogado(a)/Señor(a)
HUMBERTO RUBIO CAMACHO

Asunto: Radicación: 14-93868- -3
 Trámite: 11
 Evento: 378
 Actuación: 430
 Oficio: 6242
 Folios: 8

Patente de Invención	X			Patente de Modelo de Utilidad	
Vía Nacional					
Vía PCT (Fase Nacional)	X	Capítulo I	X	Capítulo II	
No. Solicitud Internacional	PCT/US2012/062531				
Fecha de Presentación Internacional	30/10/2012				

Como resultado del examen de fondo realizado, con fundamento en el Artículo 45 de la Decisión 486 de la Comisión de la Comunidad Andina, se comunica:

1. Documentos estudiados

Descripción:	Rad. N° 14-093868-00000-0000	02/Mayo/2014
Reivindicaciones:	Rad. N° 14-093868-00000-0000	02/Mayo/2014
Dibujos:	Rad. N° 14-093868-00000-0000	02/Mayo/2014
Prioridad:	US 13/286,505	01/Noviembre/2011

2. Análisis de la Prioridad

Se acepta la reivindicación de prioridad porque ésta solicitud fue presentada dentro del plazo establecido (Art. 9 D 486) y su contenido técnico corresponde con el de la prioridad reivindicada.

3. Objeto de la invención

De acuerdo con lo establecido en el numeral 1.2.2.2 del Capítulo Primero del Título X de la Circular Única para efectos del examen de patentabilidad, se tendrá en cuenta la tasa pagada por el solicitante al momento de comenzar el examen para las reivindicaciones

adicionales; esto es que cuando la solicitud contenga más de diez (10) reivindicaciones y no se haya pagado la tasa complementaria, sólo se estudiarán las cubiertas por la tasa pagada. Por lo tanto, se estudiarán las reivindicaciones 1 a 29.

Título de la solicitud: “Revestimiento retrorreflectante de grupos de prismas multidireccionales rayables” (Fl. 1).

El problema planteado en esta solicitud, consiste en lograr un revestimiento retrorreflectante prismático con el que se obtenga el mismo brillo retrorreflectante observable con independencia de la orientación angular del revestimiento sobre la señal.

Para resolver este problema técnico, la solicitud en estudio propone un revestimiento de prisma retrorreflectante, que comprende una pluralidad de grupos de esquinas de cubo formas a partir de un material transparente que están separadas una de otra en todos los lados por una superficie.

El objeto de la presente solicitud se relaciona con la Clasificación Internacional de Patentes (CIP): G 02 B 5/124.

4. De la solicitud de patente

Reivindicaciones (Art 30 D 486, Art 22 PCT)

El capítulo reivindicatorio no es claro porque:

- La reivindicación 2, y las expresiones: “...donde las esquinas de cubo tienen unas orientaciones diferentes de tal modo que la retrorreflectividad del revestimiento es sustancialmente insensible en sentido rotacional.” (reivindicación 1 y 18), “...que proporciona células de aire por detrás de los grupos.” (reivindicación 16), “... entonces el corte de un segundo conjunto de ranuras en uve para crear reflexión en las esquinas de cubo resultantes que da como resultado una divergencia aumentada de la liza que vuelve del revestimiento.” (reivindicación 27), “...para aumentar la angularidad de observación.” (reivindicación 29); describen funciones, efectos, ventajas o resultados a alcanzar, los cuales no son aspectos susceptibles de patente. Para mayor claridad, el producto reclamado se debe definir técnicamente mediante sus características estructurales. Se sugiere al solicitante eliminar las reivindicaciones y expresiones citadas.
- El término: “sustancialmente” (reivindicaciones 1, 18 y 25), es impreciso, por lo cual no permite distinguir la invención del estado de la técnica. Se sugiere al solicitante eliminar dicho término.

5. Determinación del Estado de la Técnica

El estado de la técnica se determinó con base en la fecha de presentación de la solicitud de prioridad: noviembre 11 de 2011, y se encontraron los siguientes documentos que

anticipan el objeto de esta solicitud:

Ítem	Documento	Título	Fecha de Publicación
D1	US 7'938.549	'Retroreflective article'	10/Mayo/2011
D2	WO 99/28770	'Multi-orientation retroreflective sheet'	10/Junio/1999

El documento D1¹ divulga un artículo retrorreflectivo con excelentes características de ángulo amplio. Características de ángulo de entrada, características de ángulo de observación y características de ángulo de rotación son mejoradas (resumen).

El documento D2² divulga una lámina de estructura retrorreflectiva (40) que tiene elementos de cubo de esquina (41). La estructura incluye un primer arreglo (42) de elementos retrorreflectivos (41) orientados en una primera dirección en un plano y un asegundo arreglo (44) de elementos retrorreflectivos orientados en una segunda dirección en el plano (resumen).

6. Examen de Patentabilidad (Art 14 D486)

Novedad (Art 16 D486)

La reivindicación 1 consiste en: *“Revestimiento de prisma retrorreflectante, que comprende una pluralidad de grupos discretos de esquinas de cubo...”* (Ver página 15 del radicado N° 14-093868-00000-0000).

Comparación de las características técnicas esenciales, con las del estado de la técnica:

Características esenciales	D1	D2
Revestimiento de prisma retrorreflectante caracterizado por:	Artículo retrorreflectivo que comprende:	Lamina retrorreflectiva multi-orientacion que comprende:
Una pluralidad de grupos discretos de esquinas de cubo formadas a partir de un material transparente que están separadas una de otra en todos los lados por una superficie.	Una pluralidad de grupos discretos de esquinas de cubo formadas a partir de un material transparente que están separadas una de otra en todos los lados por una superficie (Fig.7; reivindicación 1).	Una pluralidad de grupos discretos de esquinas de cubo formadas a partir de un material transparente que están separadas una de otra en todos los lados por una superficie (Fig.7).
Cada esquina de cubo tiene una arista de base no colineal o paralela con las aristas de base de esquinas de cubo a cada lado de la misma.	Cada esquina de cubo tiene una arista de base no colineal o paralela con las aristas de base de esquinas de cubo a cada lado de la misma (Figs. 5 a 7).	Cada esquina de cubo tiene una arista de base no colineal o paralela con las aristas de base de esquinas de cubo a cada lado de la misma (Fig. 7; Pág. 13, líneas 4 a 6).
Donde las esquinas de cubo en cada grupo se definen mediante un conjunto de ranuras en uve rectas, teniendo una misma dirección a través de la totalidad de su	Donde las esquinas de cubo en cada grupo se definen mediante un conjunto de ranuras en uve rectas (A1-A8), teniendo una misma dirección a través de la	Donde las esquinas de cubo en cada grupo se definen mediante un conjunto de ranuras en uve rectas, teniendo una misma dirección a través de la totalidad

1 <https://www.google.ca/patents/US7938549?dq=7938549&hl=es&sa=X&ei=U8BgVYukFeiwsAS2zYCICQ&ved=0CB0Q6AEwAA>
2 http://worldwide.espacenet.com/publicationDetails/biblio?DB=EPODOC&II=0&ND=3&adjacent=true&locale=en_EP&FT=D&date=19990610&CC=WO&NR=9928770A1&KC=A1

longitud.	totalidad de su longitud (Figs. 5 a 7).	de su longitud (Figs. 7).
-----------	---	---------------------------

De acuerdo con la tabla anterior, las características esenciales del revestimiento de la reivindicación 1 habían sido divulgadas previamente en los documentos D1 y D2, por lo tanto, la materia reivindicada no es nueva.

Asimismo, los documentos antecedentes divulgan las características de las reivindicaciones dependientes así:

- Reivindicación 3: Donde cuatro o más de las esquinas del cubo en cada grupo tienen unas aristas que convergen en un punto central del centro (B) (D1: Figs. 5 y 6).
- Reivindicación 4: Las esquinas de cubo de los grupos incluyen unos pares simétricos de esquinas de cubo (D1: Figs. 5 y 6).
- Reivindicación 5: Las esquinas de cubo de cada grupo incluyen dos pares simétricos de esquinas de cubo, y donde una de las aristas de las dos esquinas de cubo en los pares simétricos se encuentra en ángulos rectos con respecto a una de las aristas de las dos esquinas de cubo a cada lado de la misma (D1: Figs. 5 y 6).
- Reivindicación 6: Los grupos de esquina de cubo tiene lados rectos (D1: Fig. 5 a 7).
- Reivindicación 7: Las formas de los grupos de esquina de cubos son poligonales, y la totalidad de las esquinas de cubo comparten un vértice común (B) que se encuentra en el centro de la forma poligonal (D1: Fig.7).
- Reivindicación 8: Las esquinas de cubo dentro del grupo están dispuestas en unos pares simétricos de esquinas de cubo alrededor del vértice común (B) (D1: Fig.7).
- Reivindicación 9: La superficie alrededor de los grupos se define mediante una ranura en uve (D1: Figs. 7 y 8).
- Reivindicación 10: La ranura en uve que define la superficie se encuentra a continuación de los lados de esquinas de cubo en diferentes grupos (D1: Fig. 7 y 8).
- Reivindicación 11: La superficie con textura alrededor de los grupos se define mediante una superficie plana (D2: Pág. 13, líneas 4 a 6).
- Reivindicación 12: la superficie alrededor de los grupos se define mediante una superficie curva (D1: Figs.7, 8, 15 y 16).
- Reivindicación 13: Los grupos de esquina de cubo están separados de manera uniforme uno de otro de tal modo que la superficie que separa los grupos forma un patrón uniforme de rejilla (D1: Figs. 7 y 8).
- Reivindicación 14: Las esquinas de cubo en los grupos están inclinadas (D1: Figs. 7

y 8).

- Reivindicación 16 y 17: Película de soporte sellada que proporciona células de aire por detrás de los grupos unida a la superficie que separa los grupos (D1: Col. 7, líneas 4 a 8).

En cuanto a la reivindicación 15, cabe aclarar que es bien conocido en la técnica que aunque en este tipo de láminas no es necesario, puede existir una capa de metal retrorreflectante³. En consecuencia, la reivindicación citada no contiene materia que pueda dar novedad a la invención reclamada.

La reivindicación 18 consiste en: “*Revestimiento de prisma retrorreflectante, que comprende una pluralidad de grupos discretos de esquinas de cubo...*” (Ver página 17 del radicado N° 14-093868-00000-0000).

Comparación de las características técnicas esenciales, con las del estado de la técnica:

Características esenciales	D1	D2
Revestimiento de prisma retrorreflectante caracterizado por:	Artículo retrorreflectivo que comprende:	Lamina retrorreflectiva multi-orientación caracterizada por:
Una pluralidad de grupos discretos de esquinas de cubo formadas a partir de un material transparente , teniendo cada uno de los grupos unos lados rectos y poligonales y estando los grupos separados uno de otro en todos los lados por una superficie con textura.	Una pluralidad de grupos discretos de esquinas de cubo formadas a partir de un material transparente , teniendo cada uno de los grupos unos lados rectos y poligonales y estando los grupos separados uno de otro en todos los lados por una superficie con textura. (Figs. 5 a 7; reivindicación 1).	Una pluralidad de grupos discretos de esquinas de cubo formadas a partir de un material transparente , teniendo cada uno de los grupos unos lados rectos y poligonales y estando los grupos separados uno de otro en todos los lados por una superficie con textura (Fig. 7; Pág. 13, líneas 4 a 6).
Estando las esquinas de cubo en cada grupo definidas mediante un conjunto de ranuras en uve rectas, teniendo cada ranura en uve una misma dirección a través de toda su longitud.	Estando las esquinas de cubo en cada grupo definidas mediante un conjunto de ranuras en uve rectas, teniendo cada ranura en uve una misma dirección a través de toda su longitud (Figs. 5 a 7).	Estando las esquinas de cubo en cada grupo definidas mediante un conjunto de ranuras en uve rectas, teniendo cada ranura en uve una misma dirección a través de toda su longitud (Figs. 5 a 7).
Teniendo cada esquina de cubo una arista de base que no es común con una arista de base de otra esquina de cubo.	Teniendo cada esquina de cubo una arista de base que no es común con una arista de base de otra esquina de cubo. (Figs. 7 y 8).	Teniendo cada esquina de cubo una arista de base que no es común con una arista de base de otra esquina de cubo. Se encuentra un espacio entre los cubos en uno o más bordes (Pág. 12, líneas 26 a 30 y 1 a 6)

Asimismo, el documento D1 divulga las características de las reivindicaciones dependientes así:

- Reivindicación 19: Las esquinas de cubo comparten un vértice común que se encuentra de forma central dentro de la forma poligonal de los grupos definidos mediante los lados rectos y están dispuestas en pares simétricos respecto al vértice

3 http://www.huaweirm.cn/en/jszc_view.asp?Product_id=49&type_parid=41

común (Fig.7).

- Reivindicación 20: La superficie con textura alrededor de los grupos se define mediante una ranura en uve (Fig. 5 a 8).
- Reivindicación 21: La ranura en uve que define la superficie con textura se encuentra a continuación de los lados de esquinas de cubo en diferentes grupos (Figs. 7 y 8).
- Reivindicación 22: La superficie con textura alrededor de los grupos se define mediante una superficie plana (D2: Pág. 13, líneas 4 a 6).
- Reivindicación 23: la superficie alrededor de los grupos se define mediante una superficie curva (Figs.7, 8, 15 y 16).
- Reivindicación 24: Los grupos de esquina de cubo están separados de manera uniforme uno de otro de tal modo que las superficies de textura óptica que rodean los grupos forman un patrón uniforme de rejilla (Figs. 7 y 8).

La reivindicación 25 consiste en: “*Un método para formar un revestimiento de prisma retrorreflectante insensible en sentido rotacional que comprende: formar esquinas de cubo en sustrato ...*” (Ver página 18 del radicado N° 14-093868-00000-0000).

Comparación de las características técnicas esenciales, con las del estado de la técnica:

Características esenciales	D1	D2
Un método para formar un revestimiento de prisma que comprende:	Artículo retrorreflectivo que comprende:	Lamina retrorreflectiva multi-orientación caracterizada por:
Formar esquinas de cubo en un sustrato mediante el corte de una cara del sustrato con un patrón de ranuras en uve rectas, teniendo cada ranura en uve una misma dirección a través de la totalidad de su longitud, donde las esquinas de cubo resultantes tienen unas orientaciones diferentes.	Grupos de esquinas de cubo formadas a partir de un material transparente, teniendo cada uno de los grupos unos lados rectos y poligonales y estando los grupos separados uno de otro en todos los lados por una superficie con textura. Estando las esquinas de cubo en cada grupo definidas mediante un conjunto de ranuras en uve rectas, teniendo cada ranura en uve una misma dirección a través de toda su longitud (Figs. 5 a 7; reivindicación 1).	Grupos discretos de esquinas de cubo formadas a partir de un material transparente, teniendo cada uno de los grupos unos lados rectos y poligonales y estando los grupos separados uno de otro en todos los lados por una superficie con textura (Fig. 7; Pág. 13, líneas 4 a 6). Estando las esquinas de cubo en cada grupo definidas mediante un conjunto de ranuras en uve rectas, teniendo cada ranura en uve una misma dirección a través de toda su longitud (Figs. 5 a 7).
Proporcionar una superficie con textura sobre la cara de uno del sustrato y una réplica del sustrato que define grupos de esquina rodeados por una superficie con textura.	Una superficie con textura sobre la cara de uno del sustrato y una réplica del sustrato que define grupos de esquina rodeados por una (Figs. 5 a 7).	Una superficie con textura sobre la cara de uno del sustrato y una réplica del sustrato que define grupos de esquina rodeados por una (Figs. 7).
Usar uno del sustrato y una réplica del mismo para formar un	Una pluralidad de grupos discretos de esquinas de cubo	Una pluralidad de grupos discretos de esquinas de cubo

revestimiento de prisma retrorreflectante a partir de un material transparente que tiene una pluralidad de grupos discretos de esquinas de cubo que están separadas una de otra en todos los lados por una superficie con textura, donde cada esquina de cubo en lo grupos tiene una arista base no colineal o paralela con las aristas de base de esquinas de cubo a cada lado de la misma, y esquinas de cubo en cada grupo tienen unas orientaciones diferentes.	formadas a partir de un material transparente que están separadas una de otra en todos los lados por una superficie (Fig.7; reivindicación 1). Cada esquina de cubo tiene una arista de base no colineal o paralela con las aristas de base de esquinas de cubo a cada lado de la misma (Figs. 5 a 7).	formadas a partir de un material transparente que están separadas una de otra en todos los lados por una superficie (Fig.7). Cada esquina de cubo tiene una arista de base no colineal o paralela con las aristas de base de esquinas de cubo a cada lado de la misma (Fig. 7; Pág. 13, líneas 4 a 6).
---	--	--

La reivindicación 2 fue afectada en el numeral 4 de la presente comunicación.

7. Conclusión

Los requisitos de Patentabilidad de la presente solicitud están afectados así:

Ítem	Documento	Reivindicaciones afectadas	Requisito que afecta
D1	US 7'938.549	1 a 29	Novedad/Nivel Inventivo
D2	WO 99/28770	1 a 29	Novedad/Nivel Inventivo

En cumplimiento del artículo 45 de la Decisión 486 de la Comisión de la Comunidad Andina, se le indica que debe dar respuesta dentro del término de sesenta (60) días contados a partir del día siguiente de la fecha de notificación de la presente comunicación. En caso de no dar respuesta al presente requerimiento, o si a pesar de la respuesta subsistieran los impedimentos para la concesión, se denegará la patente.

Se invita al solicitante se sirva indicar, si así lo considera, su renuncia al término faltante de sesenta (60) días para dar respuesta a este requerimiento y presentarla por escrito.

Finalmente, se le recuerda al solicitante que si como respuesta a este requerimiento llegara a modificar el capítulo reivindicatorio y éste contenga más de diez (10) reivindicaciones, no pagará la tasa de modificación voluntaria pero sí la correspondiente al pago por reivindicación adicional.

Notifíquese el presente oficio conforme a lo dispuesto en el numeral 5.2, literal e), del capítulo quinto del título primero de la Circular Única No. 10 de 2001.



JESUS FERNEL GARCÍA GARCÍA
Director de Nuevas Creaciones (E)

El anterior requerimiento fue notificado por fijación en lista, de fecha 2015-06-09

Elaboró: Monica Andrea Gutierrez Almonacid
Revisó: Sonia Andrea Diaz Pirazan



US007938549B2

(12) **United States Patent**
Mimura

(10) **Patent No.:** **US 7,938,549 B2**
(45) **Date of Patent:** **May 10, 2011**

(54) **RETROREFLECTIVE ARTICLE**

(75) Inventor: **Ikuo Mimura**, Uozu (JP)

(73) Assignee: **Nippon Carbide Industries Co., Inc.**,
Tokyo (JP)

(*) Notice: Subject to any disclaimer, the term of this
patent is extended or adjusted under 35
U.S.C. 154(b) by 90 days.

(21) Appl. No.: **12/094,801**

(22) PCT Filed: **Nov. 30, 2006**

(86) PCT No.: **PCT/JP2006/324395**

§ 371 (c)(1),
(2), (4) Date: **Aug. 1, 2008**

(87) PCT Pub. No.: **WO2007/064033**

PCT Pub. Date: **Jun. 7, 2006**

(65) **Prior Publication Data**

US 2009/0161217 A1 Jun. 25, 2009

(30) **Foreign Application Priority Data**

Nov. 30, 2005 (JP) 2005-345479

(51) **Int. Cl.**
G02B 5/124 (2006.01)

(52) **U.S. Cl.** **359/530**; 428/167

(58) **Field of Classification Search** 395/529-530;
428/167

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2,265,790 A 12/1941 Young
2,310,790 A 2/1943 Jungersen

3,039,093 A	1/1962	Rockwood
3,365,790 A	1/1968	Brauer
4,588,258 A	5/1986	Hoopman
4,775,219 A	10/1988	Appeldorn et al.
5,022,739 A	6/1991	Bennett et al.
5,132,841 A	7/1992	Bennett et al.
5,138,488 A	8/1992	Szzech
5,171,624 A	12/1992	Walter
5,175,645 A	12/1992	Bennett et al.
5,565,151 A	10/1996	Nilsen
5,706,132 A	1/1998	Nestegard et al.
5,898,523 A	4/1999	Smith et al.
5,936,770 A	8/1999	Nestegard et al.
6,036,322 A	3/2000	Nilsen et al.
6,685,323 B1	2/2004	Mimura et al.
6,883,921 B2	4/2005	Mimura et al.
2007/0109641 A1	5/2007	Mimura et al.
2009/0122405 A1 *	5/2009	Mimura 359/530

FOREIGN PATENT DOCUMENTS

EP	0 137 736	10/1992
EP	0 548 280	9/1994
JP	11-149009	6/1999
WO	03/014779	2/2003
WO	2005/054909	6/2005

* cited by examiner

Primary Examiner — James Phan

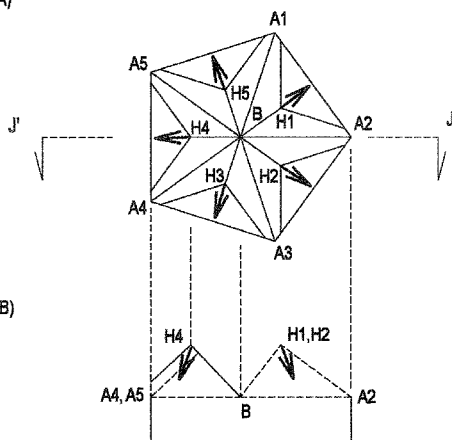
(74) *Attorney, Agent, or Firm* — Fitzpatrick, Cella, Harper &
Scinto

(57) **ABSTRACT**

A retroreflective article with excellent wide-angle characteristics is provided. Entrance angle characteristics, observation angle characteristics, and rotation angle characteristics are improved. In a retroreflective article, an assembly of multidirectional retroreflective elements is formed, in which either five, or seven or more unit elements are formed so as to share two common base edges forming the triangular base face of the unit elements and a common vertex at which the common base edges intersect, with an adjacent retroreflective element.

15 Claims, 14 Drawing Sheets

(A)



(B)

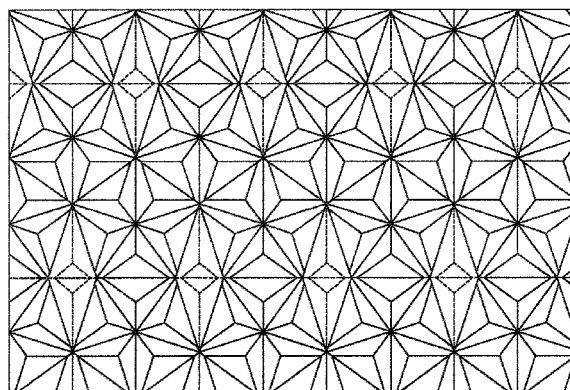
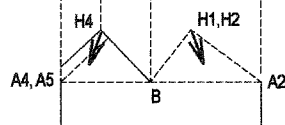


Fig. 1

Prior Art

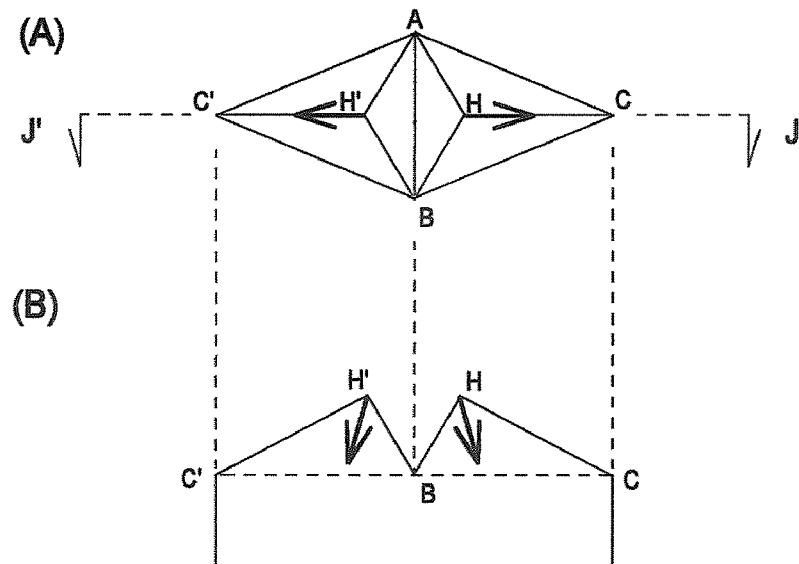


Fig. 2

Prior Art

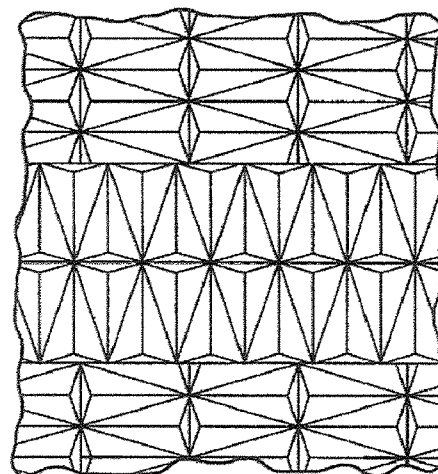


Fig. 3

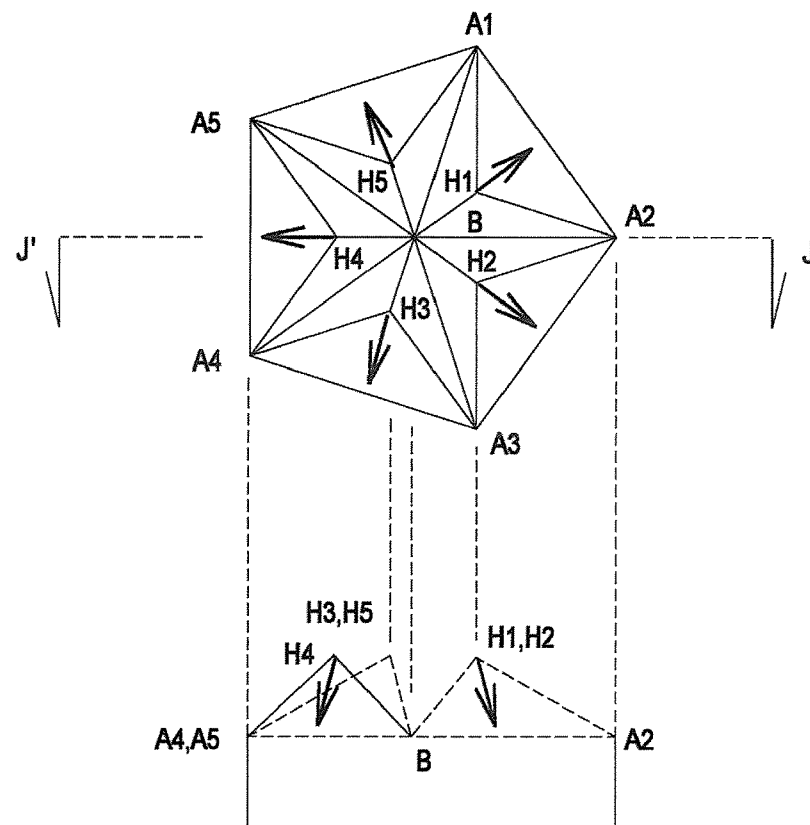


Fig. 4

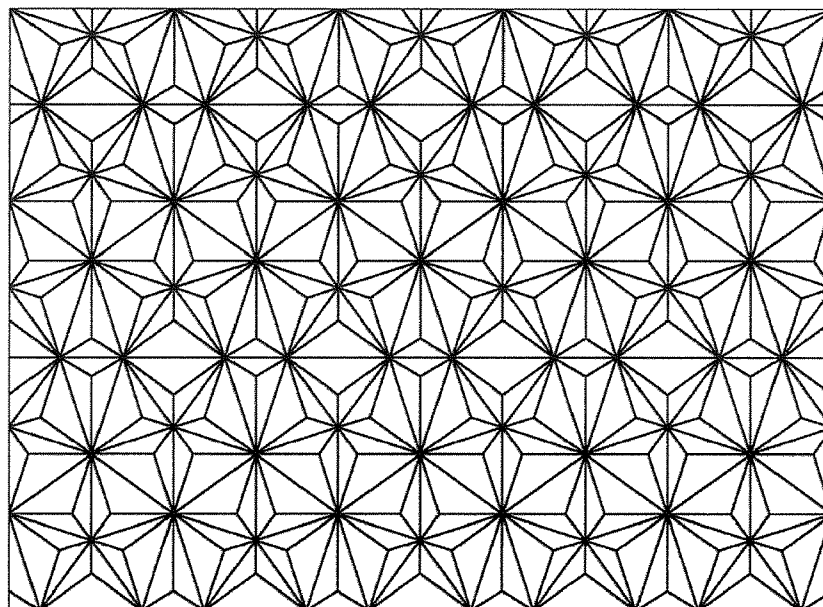


Fig. 5

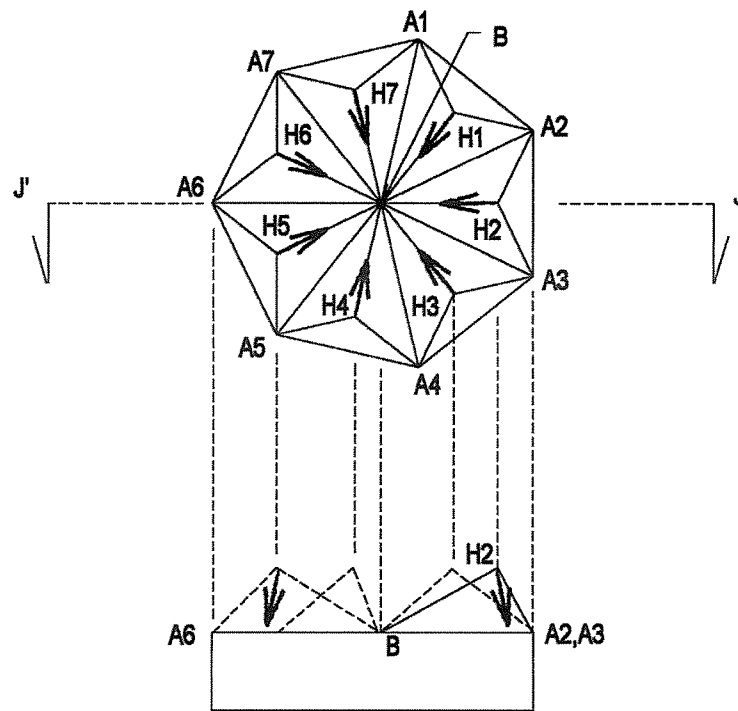


Fig. 6

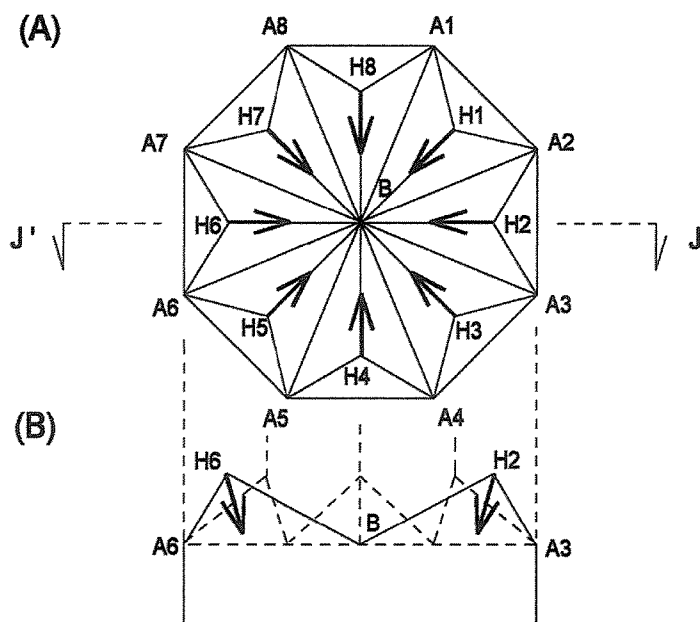


Fig. 7

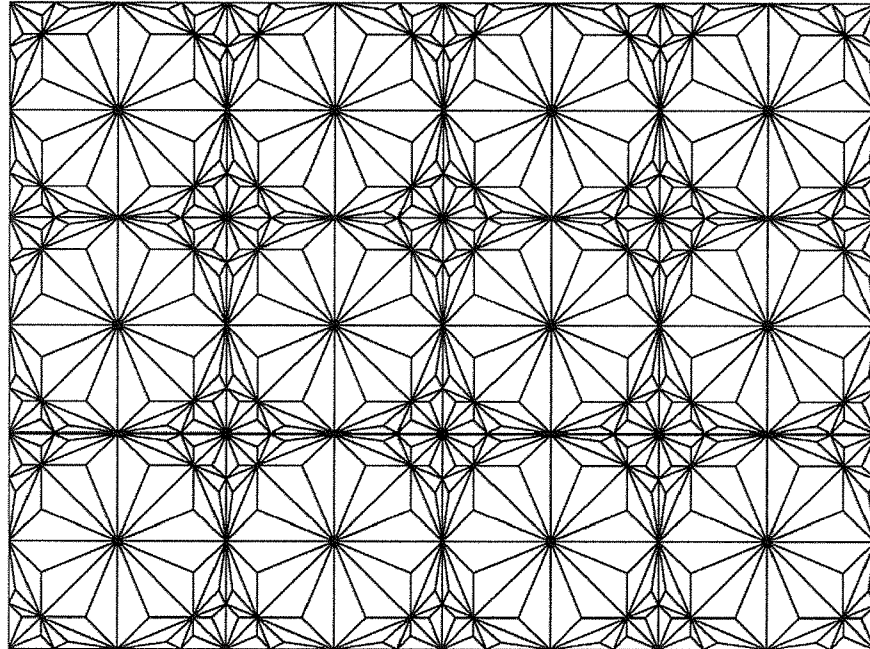


Fig. 8

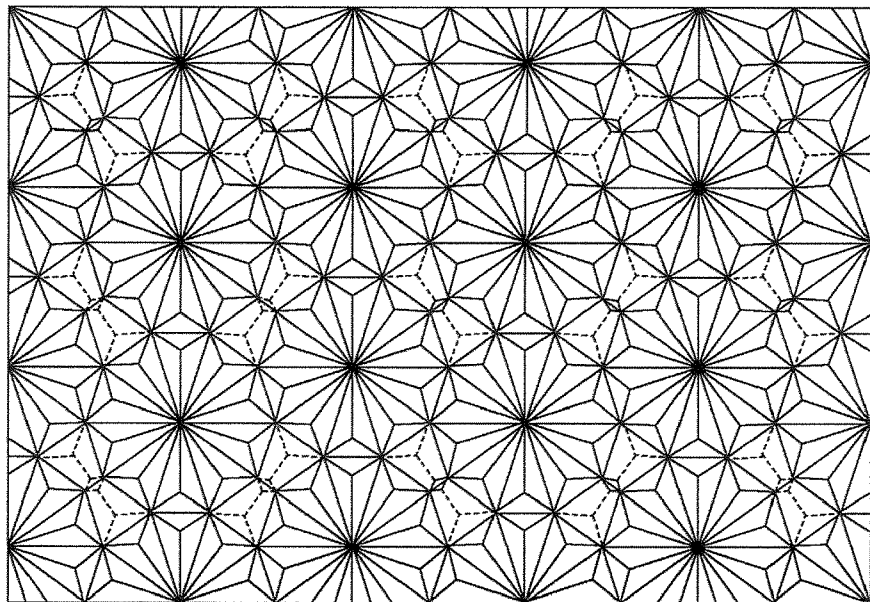


Fig. 9

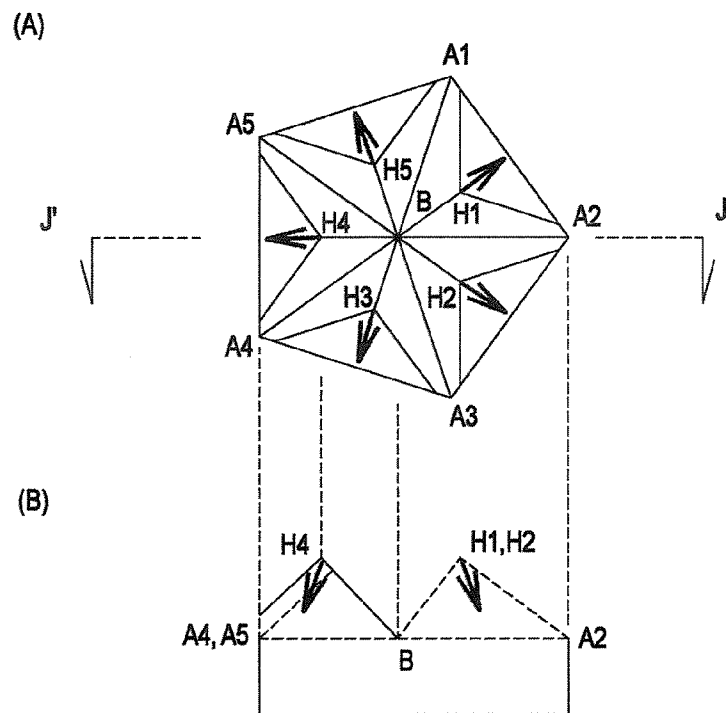


Fig. 10

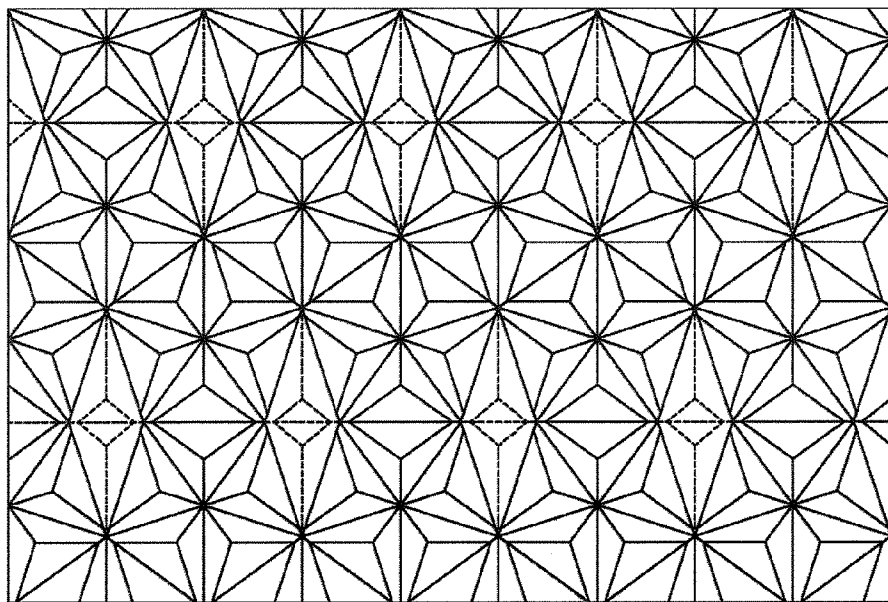


Fig. 11

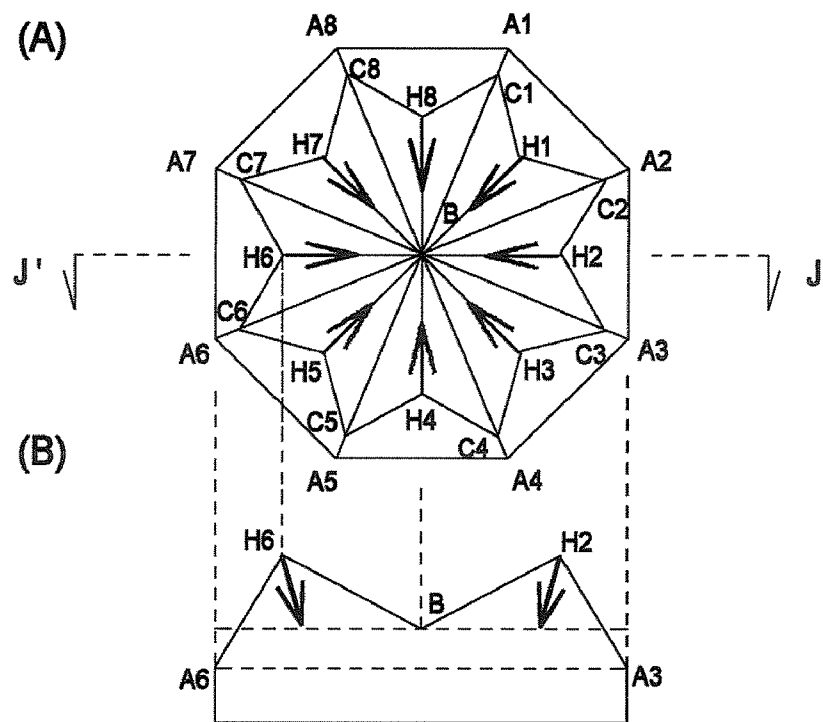


Fig. 12

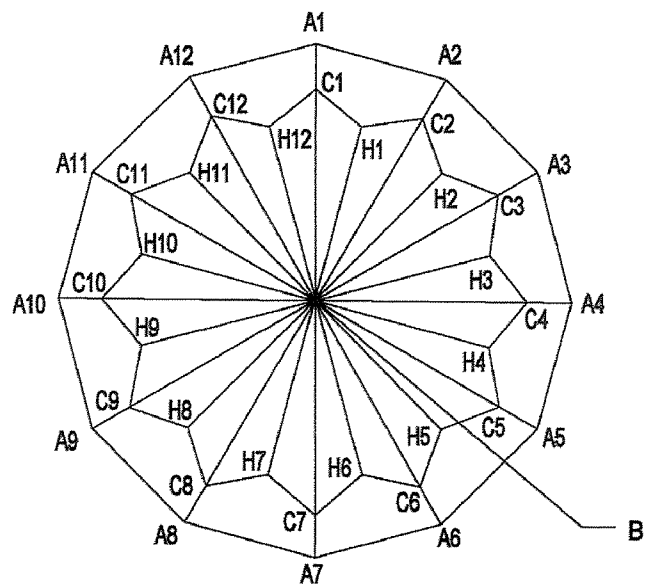


Fig. 13

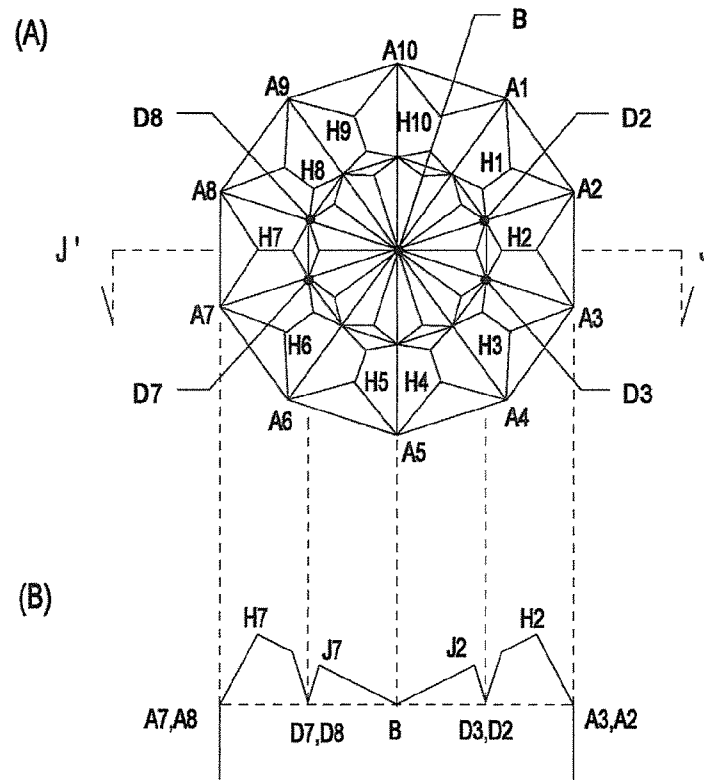


Fig. 14

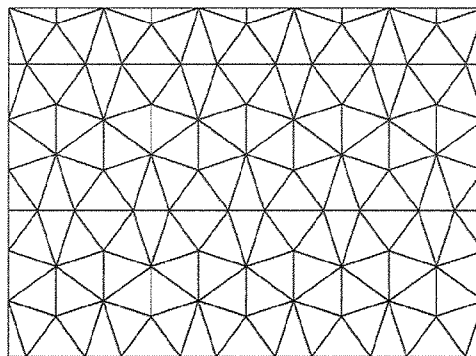


Fig. 15

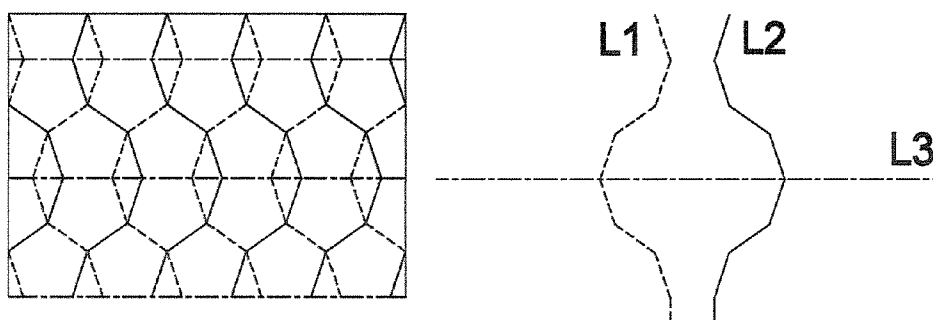


Fig. 16

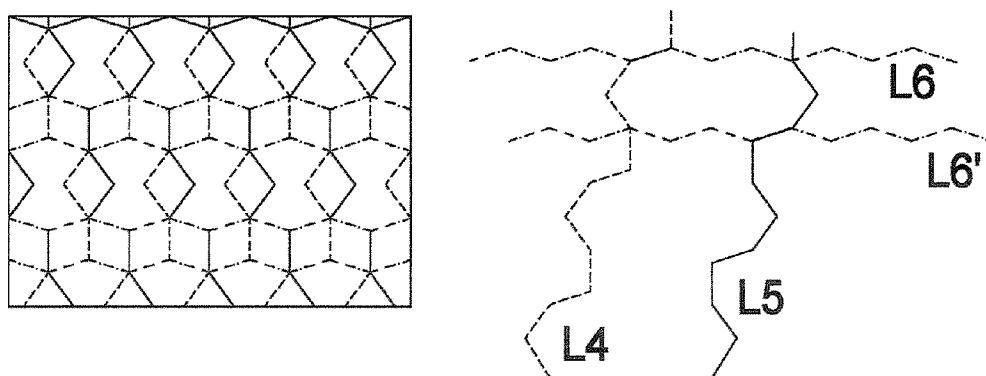


Fig. 17

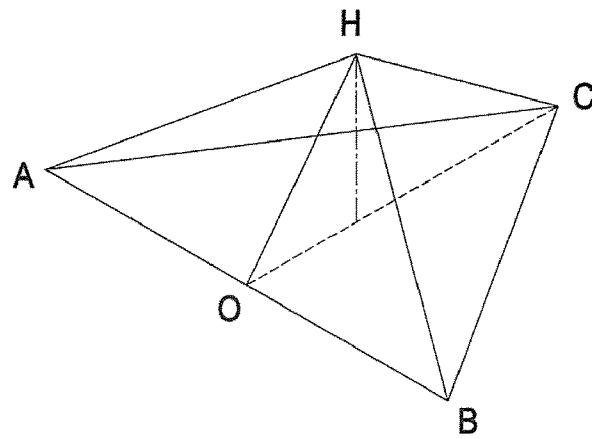


Fig. 18

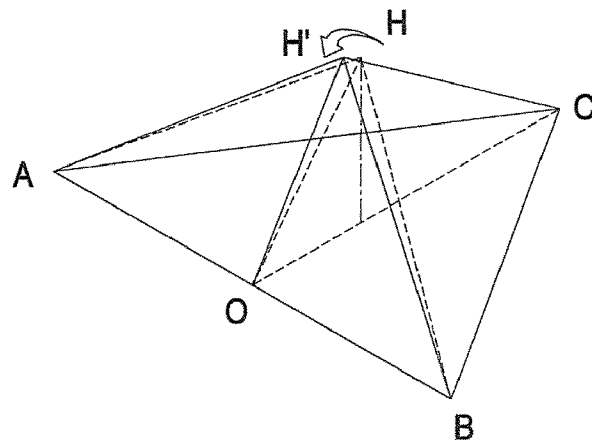


Fig. 19

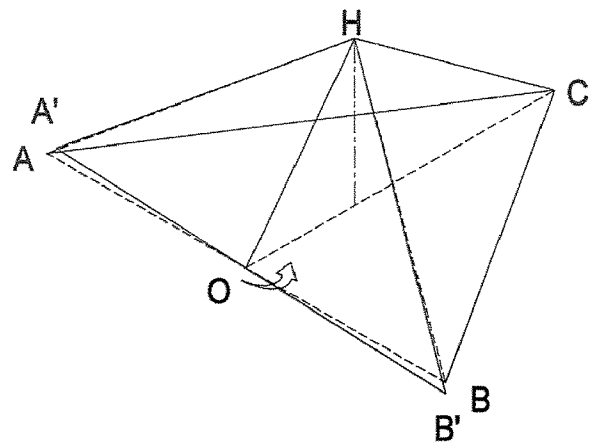


Fig. 20

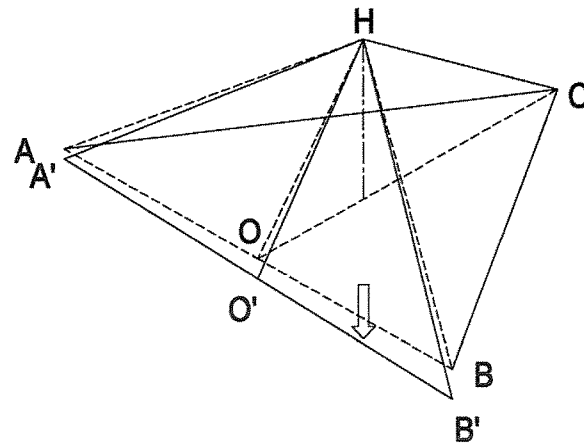


Fig. 21

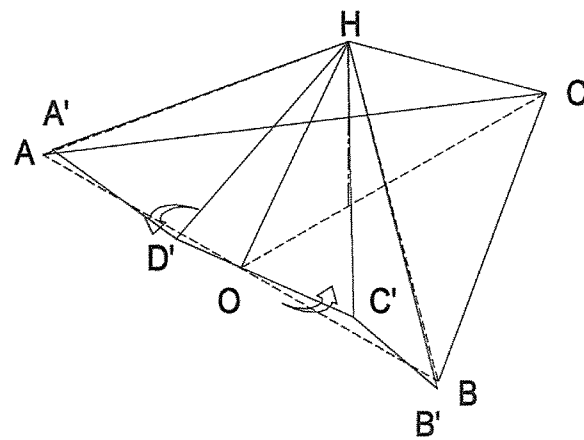


Fig. 22

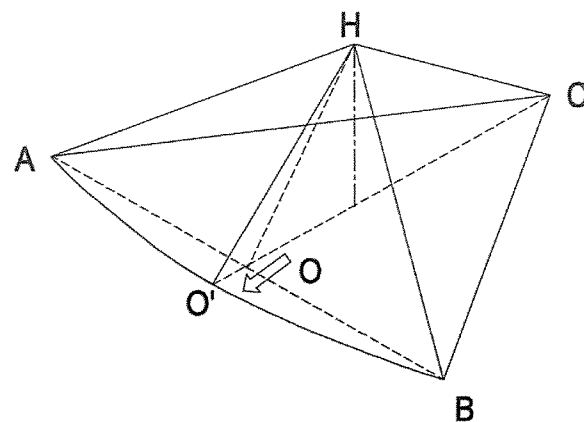


Fig. 23

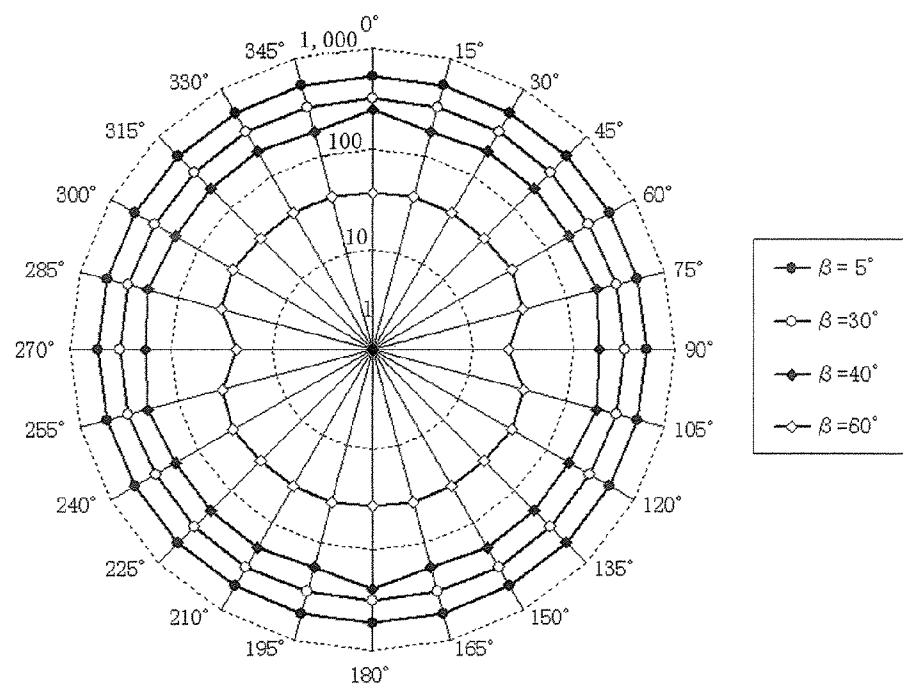


Fig. 24

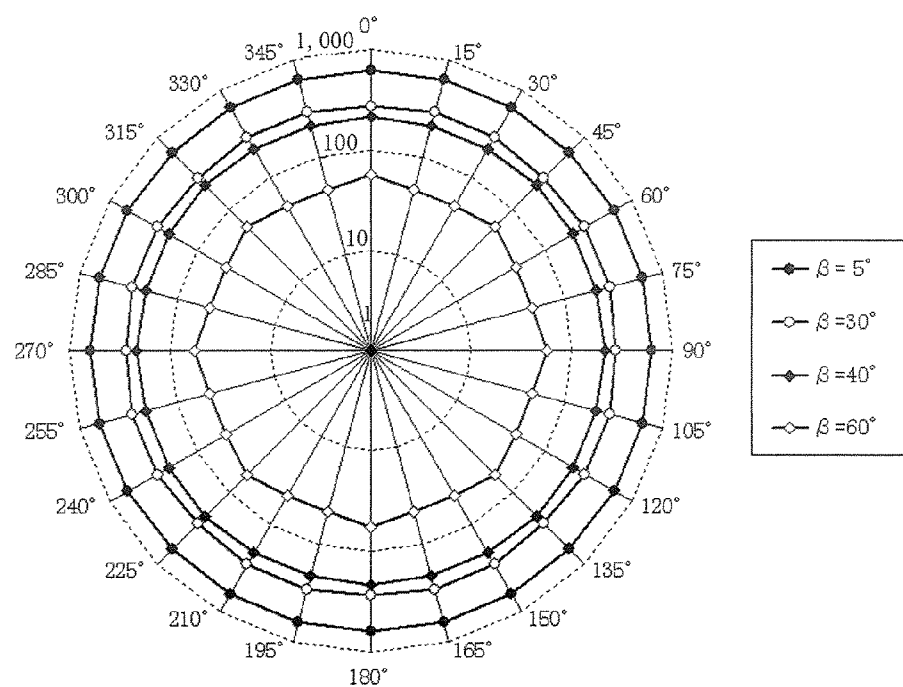


Fig. 25

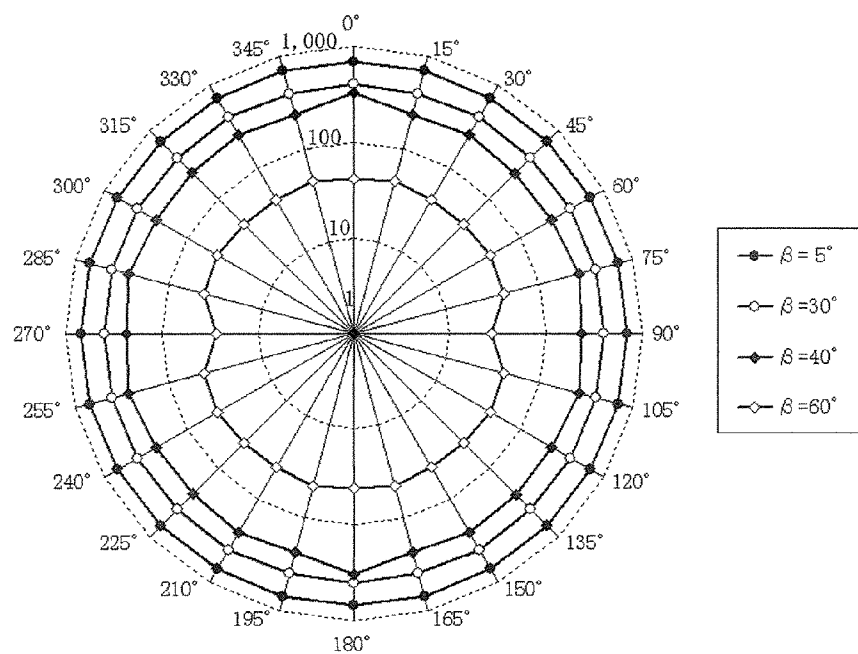


Fig. 26

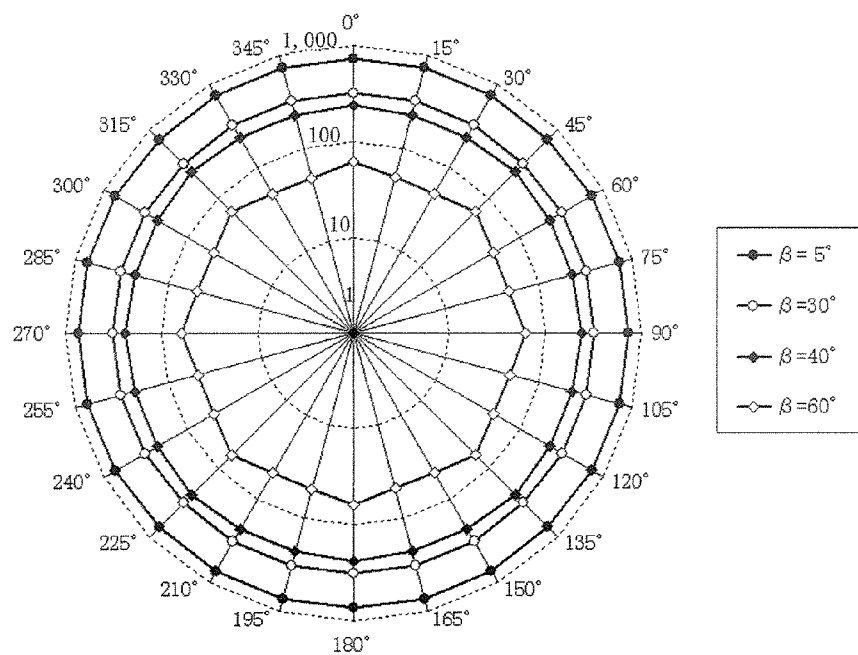


Fig. 27

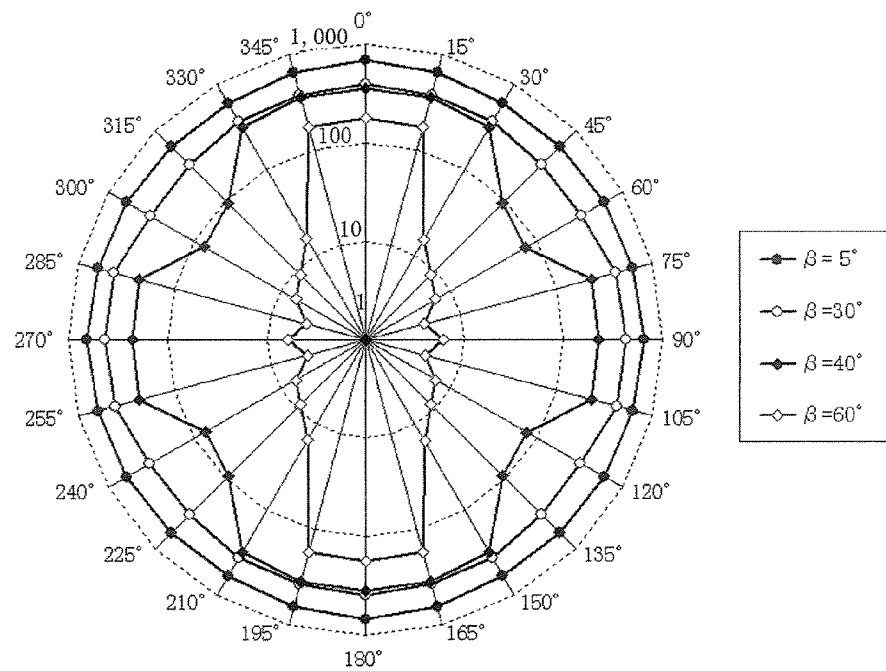


Fig. 28

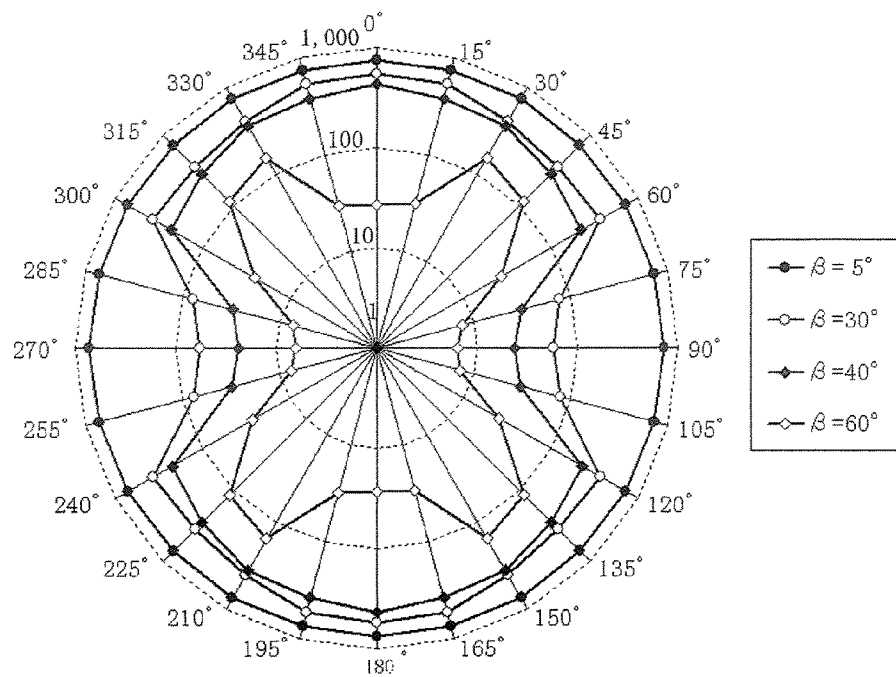
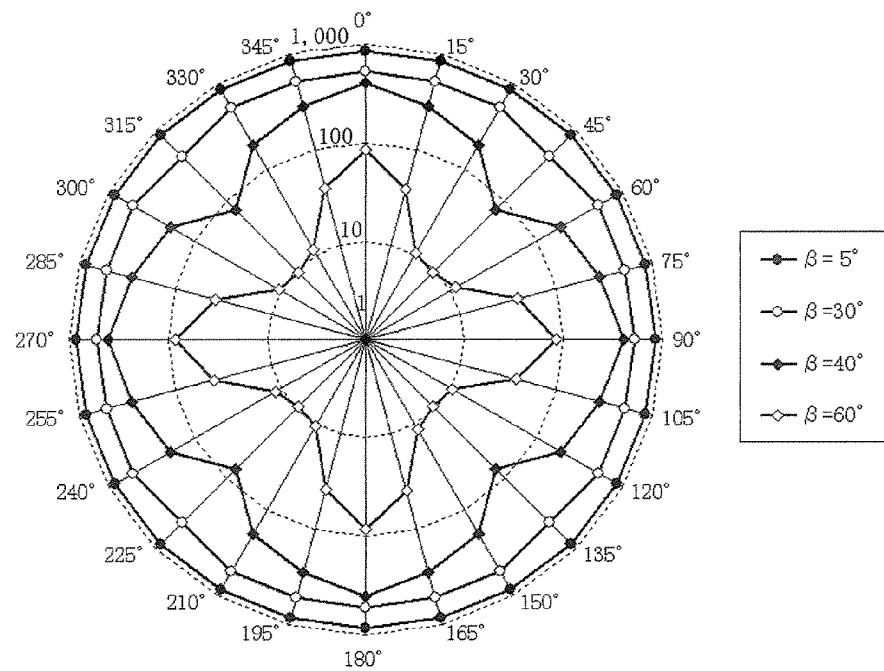


Fig. 29



RETROREFLECTIVE ARTICLE

TECHNICAL FIELD

This invention relates to a retroreflective article which is optimal for use in traffic signs and commercial signs.

Specifically, the invention relates to a retroreflective article which comprises a multidirectional retroreflective element (multidirectional element) assembly having numerous triangular-pyramidal cube-corner retroreflective elements formed therein, and which exhibits excellent retroreflection performance at nighttime.

More specifically, the invention relates to a retroreflective article having excellent wide-angle performance, and having improved entrance angle characteristics, observation angle characteristics, and in particular excellent rotation angle characteristics.

BACKGROUND ART

In the prior art, there have been a number of proposals of retroreflective articles having excellent wide-angle performance, with improved entrance angle characteristics, observation angle characteristics, and rotation angle characteristics.

With respect to improvement of the entrance angle characteristics or observation angle characteristics of such cube-corner type retroreflective sheets and retroreflective articles, and in particular of triangular-pyramidal cube-corner retroreflective sheets and retroreflective articles, various proposals have been made from long ago, and various improvements have been studied. Many of these technologies improve the entrance angle characteristics by inclining the optical axes of some of the retroreflective elements.

For example, in U.S. Pat. No. 2,310,790 by Jungersen, an arrangement of retroreflective elements in various shapes on a thin sheet is described. The triangular-pyramidal reflective elements given as examples in this U.S. Patent include regular-triangular triangular-pyramidal reflective elements, the vertices of which are positioned at the centers of the base triangles, and which have no inclination of the optical axis, as well as isosceles-triangular triangular-pyramidal elements, the vertices of which are not positioned at the centers of the base triangles, and it is stated that light is caused to be reflected effectively (entrance angle characteristics are improved) for approaching vehicles.

Further, it is stated as the size that the depth of the triangular-pyramidal reflecting elements is within $\frac{1}{10}$ inch (2,540 μm). And, in FIG. 15 of this U.S. Patent, a triangular-pyramidal reflecting element pair is shown the optical axis of which is inclined in the positive (+) direction; the angle of inclination (θ) of this optical axis, determined from the ratio of the long edges to the short edge in the base isosceles triangle of the triangular-pyramidal reflecting elements shown in the figure, is estimated to be approximately 6.5° .

Further, in European Patent No. 137,736B1 by Hoopman, a retroreflective sheet and retroreflective article are described in which pairs of inclined triangular-pyramidal cube-corner retroreflective elements, the triangular shapes in the base plane on a thin sheet of which are isosceles triangles, rotated 180° with respect to each other, are arranged with base faces on a common surface in closest-packed fashion. The optical axis of the triangular-pyramidal cube-corner retroreflective elements described in this patent are inclined in what is the negative (-) direction in this Specification, and the angle of inclination is shown to be approximately 7° to 13° .

Further, in U.S. Pat. No. 5,138,488 by Szczech, a retroreflective sheet and retroreflective article are disclosed, in which inclined triangular-pyramidal cube-corner retroreflective elements, the triangular shape in the base plane on a thin sheet of which are isosceles triangles, are similarly arranged with base faces on a common surface in closest-packed fashion. In this U.S. Patent, the optical axis of the triangular-pyramidal reflective elements is inclined in the direction common to two triangular-pyramidal reflective elements facing each other and forming a pair, that is, in the positive (+) direction explained below, the inclination angle is approximately 2° to 5° , and the element size is stipulated to be from $25\ \mu\text{m}$ to $100\ \mu\text{m}$.

Further, in European Patent No. 548,280B1 corresponding to the above patent, it is stated that the direction of inclination of the optical axis comprises the common edge of two elements forming a pair, and that the distance of the vertex of an element and the plane perpendicular to the common plane is equal to the distance between the point at which the element optical axis intersects the common plane and the perpendicular plane, and that the inclination angle is approximately 2° to 5° , and the element size is $25\ \mu\text{m}$ to $100\ \mu\text{m}$.

In this way, in the European Patent No. 548,280B1 of Szczech, the optical axis is in a range from approximately 2° to 5° , comprising both positive (+) and negative (-) directions. However, in the embodiments of the above U.S. Patent and European Patent of Szczech, only triangular-pyramidal reflective elements having an optical axis inclination angle of $(-)8.20^\circ$, $(-)9.2^\circ$, and $(-)4.3^\circ$, and with an element height (h) of $87.5\ \mu\text{m}$, are disclosed.

In addition, various proposals have been made relating to improvement of observation angle characteristics.

In U.S. Pat. No. 4,775,219 of Appeldorn, V-shape grooves forming elements present an asymmetrical shape such as shown in FIG. 17 which explains the present invention, and have a slight deviation with respect to the angle of the theoretical V-shape grooves forming cube corners. Further, by periodically modifying the deviation which imparts asymmetry to adjacent V-shape grooves, an attempt is made to improve observation angle characteristics.

However, periodic modification of the angle of adjacent V-shape grooves increases the difficulty of die machining. Even if this difficulty could be overcome, the combination of deviations which could be imparted is limited, and a uniform reflected light spreading could not be imparted. Further, it has been necessary to prepare several types of diamond bits to form V-shape grooves and other machining tools for one V-shape groove direction. And, high-precision machining technology has also been necessary when forming asymmetric V-shape grooves.

Further, in U.S. Pat. No. 5,171,624 by Walter, a triangular-pyramidal retroreflective element is disclosed, the reflective faces of which are formed using a machining tool having a curve-shape cross-sectional shape, having a fixed quadratic surface cross-sectional shape. In a triangular-pyramidal retroreflective element in which reflective side faces having a quadratic surface are formed, appropriate dispersion of retroreflective light is possible, and improvement of observation angle characteristics is obtained.

However, it is extremely difficult to fabricate machining tools having such curved-surface cross-sectional shapes by design. Hence due to the difficulty of machining such tools, it has been very difficult in the past to obtain quadratic surfaces by design. And, it has not been possible to form quadratic surfaces in various shapes, determined only by the shapes of machining tools used, on the same retroreflective article in given surface shapes.

In U.S. Pat. No. 5,565,151 by Nilsen, a portion of a reflecting side face (A-B-H) is cut away, and an attempt is made to promote the dispersion of retroreflective light and improve observation angle characteristics by means of the triangular-columnar shapes (A-A1-A2-B2-B1-B) formed thereby and the new reflecting side faces (A2-H1-B2).

However, in the invention of Nilsen there is no description of the kind of triangular columnar shape which is preferable for installation, nor of the kind of angle at which new reflecting side faces are to be formed. Further, special tools are required to cut away a portion of reflecting side faces and form a portion of the triangular columnar shape. And, elements with the newly formed triangular columnar shape do not have retroreflection functions, but are simply designed to obtain spreading of retroreflective light through dispersion of light in various directions.

However, in the above-described technology to improve entrance angle characteristics and observation angle characteristics, there is no attainment of improved rotation angle characteristics.

Various proposals relating to improvement of rotation angle characteristics have been made; in all such proposals, an attempt is made to improve rotation angle characteristics by partitioning the directions of retroreflective elements, the base faces of which have triangular shapes, into various regions and combining regions.

Examples include U.S. Pat. No. 5,022,739, U.S. Pat. No. 5,132,841, and U.S. Pat. No. 5,175,645, by Bennett et al; U.S. Pat. No. 6,036,322, by Nilsen et al; U.S. Pat. No. 5,706,132 and U.S. Pat. No. 5,936,770, by Nestegard et al; and U.S. Pat. No. 5,898,523, by Smith.

However, although the shapes into which element regions are partitioned and the directions of triangular-pyramidal cube-corner elements are different, all of the technologies of these patents can be said to employ the same basic technique.

DISCLOSURE OF THE INVENTION

An object of this invention is the provision of a retroreflective article having excellent wide-angle characteristics, and improvement of entrance angle characteristics, observation angle characteristics, and rotation angle characteristics.

In particular, an object is to provide a retroreflective article having excellent rotation angle characteristics, as well as a retroreflective article provided with excellent entrance angle characteristics and observation angle characteristics.

A further object is to provide a retroreflective sheet, which can be used in such specific applications as traffic signs, construction signs, commercial signs, vehicle license plates, and similar, and which can be cut freely in any direction and utilized due to excellent rotation angle characteristics.

This invention provides a triangular-pyramidal cube-corner retroreflective article, comprising numerous triangular-pyramidal cube-corner retroreflective elements formed by cutting away a group of grooves having a substantially V-shape cross-section, and is characterized in that an assembly of multidirectional retroreflective elements (hereafter called "multidirectional elements") is formed, in which either five, or seven or more triangular-pyramidal cube-corner retroreflective elements (hereafter called "unit elements") are formed so as to share two base edges (hereafter called "common base edges") forming triangular base faces of the unit elements as well as vertexes (hereafter called "common vertexes") at which the common base edges intersect, with an adjacent retroreflective element.

In this invention, a multidirectional element is formed by combining triangular-pyramidal cube-corner elements hav-

ing optical axes direction in various directions, so that the multidirectional element exhibits excellent retroreflective efficiency regardless of the direction from which light is incident. Further, in practical terms, excellent retroreflective efficiency is obtained regardless of the rotation angle (meaning the direction of either the retroreflective article, or the retroreflective sheet) at which a retroreflective article of this invention is installed.

Further, a multidirectional element in which unit elements are combined in various directions also exhibits excellent entrance angle characteristics. In particular, a unit element used in this invention has a shape in which the optical axis is inclined, so that entrance angle characteristics are also improved.

It is preferable that a multidirectional element of this invention be formed from five or seven to twelve unit elements. If four or fewer unit elements are used, the unit elements cannot form a cube-corner shape, and a combination of six unit elements is equal to a reflective element group comprising triangular-pyramidal cube-corner reflecting elements of the prior art.

Further, combinations of multidirectional elements in which 13 or more unit elements are combined exist, but the ratio of the lengths of common edges and outer peripheral base edges becomes too great. Hence the ratio of the area of reflecting side faces having common base edges to the area of reflecting side faces having outer peripheral base edges becomes too great, so that the retroreflective efficiency declines, which is not preferable.

Further, in the case of combinations in which the number of unit elements is an odd number, by forming a retroreflective article in which multidirectional elements are combined by combining a multidirectional element with the multidirectional element rotated by 180°, a combination is obtained in which the number of unit elements is twice as great, and rotation angle characteristics are made still more uniform.

Further, in the case of combinations in which the number of unit elements is an even number, die formation is facilitated, which is preferable.

Further, retroreflective articles in which two or more types of multidirectional elements are combined are also possible. By combining a plurality of multidirectional elements in this way, rotation angle characteristics can be further improved.

In this invention, it is preferable that the lengths of two common base edges forming a unit element be equal. The shape of the base face of such a unit element is an isosceles triangle, and the shape of a multidirectional element thus formed has an external periphery in the shape of a regular polygon. A retroreflective article which combines multidirectional elements having an external periphery with such a regular polygonal shape has a higher closest-packing density of multidirectional elements, and so the retroreflective efficiency can be improved.

In a method of forming a multidirectional element in this invention, the multidirectional element can be formed such that the locus of base portions defined by the intersection of two side faces of grooves having a substantially symmetrical V-shape cross-section forms straight lines, bent lines, curves and repeated line groups comprising combinations of these line groups.

In this invention, in a groove with a substantially symmetrical V-shape, the angle of the V-shape groove can be determined such that the three side faces of a triangular-pyramidal shape remaining when the V-shape groove is cut out are mutually perpendicular. Further, a slight inclination can be imparted to mutually perpendicular side faces to improve the observation angle characteristics as well. Consequently, a

slight inclination can be imparted to the angle of the V-shape groove from the angle of perpendicular formation, and asymmetrical V-shape grooves can be used as well.

V-shape grooves are formed continuously, and the locus of the base portion defined by the intersection of the two side faces of the V-shape grooves is formed continuously. The locus of the base portion describes a straight line or a bent line in order to form a multidirectional element. Further, in order to improve the observation angle characteristics, the loci can be bent lines, curves, or combinations of these lines obtained by imparting slight modifications to the base edges of the original straight lines. It is preferable that the nonlinearity be such that the deviation from straight lines is, for example, approximately 5 to 1000 nm/ μ m.

Further, by making the line group forming the locus of the base portions curve groups defined by trigonometric functions, inverse trigonometric functions, elliptic functions, circular functions, and composite functions of these functions, the observation angle characteristics can be improved.

It is preferable that the nonlinearity be such that the deviation of these curves from straight lines is, for example, approximately 5 to 1000 nm/ μ m.

In this invention, bent lines are formed by substantially combining straight lines; but it is preferable that bending portions be curves the radius of curvature of which is 2 to 20 μ m. If the radius of a bending portion is too large, exceeding 20 μ m, then a ridgeline of a unit element may be cut away and reflection efficiency may decline, or other problems readily occur. Further, if the radius is less than 2 μ m, then an excessive load is applied to the cutting tool, and tool breakage or wear, or other problems readily occur, which is not preferable.

Numerous line groups comprising straight lines, bent lines, curves, and combinations of these line groups, to form a retroreflective article of this invention in which numerous multidirectional elements are formed, are formed through repeated patterns at an equal pitch.

Further, repeated line groups which form the locus of base portions of the above V-shape grooves are in a common plane, defined by the triangular base faces of unit elements.

Moreover, in order to improve the retroreflective efficiency, positioning is also possible such that at least one line group of the repeated line groups is not in the common plane. For example, among the repeated line groups forming the outer-periphery base edges of unit elements in a pentagonal multidirectional element, by making the repeated line group forming the common base edges more shallow, the areas of the three reflecting side faces of unit elements can be made equal.

Further, in the case of a multidirectional element in the shape of a heptagon or higher-order polygon, by making the repeated line group forming the shared base edges deeper than the repeated line groups forming the outer-peripheral base edges of the unit elements, the areas of the three reflecting side faces of unit elements can be made equal.

That is, by forming at least one line group among the repeated line groups so as not to be in the common plane, but such that the depth of the V-shape groove, determined by the distance between a plane defined by the line group and the vertex of the unit element, is $\pm(5$ to $200)$ % of the element height defined by the distance between the vertex of the unit element and the common plane, and still more preferably is $\pm(5$ to $40)$ %, the retroreflective efficiency can be increased.

Further, in order to improve the retroreflective efficiency, it is preferable that in the three base edges of the triangular base face of a unit element, when the depth of the V-shape groove forming the shortest base edge is assumed as ds , and the depth of the V-shape groove forming the longest base edge is

assumed as de , an inequality $1.05 \leq (ds/de) \leq 3.00$ (1) be satisfied, and still more preferable that an inequality $1.05 \leq (ds/de) \leq 1.40$ (2) be satisfied.

In order to improve the observation angle characteristics, it is preferable that the multidirectional elements be formed comprising at least one type of unit element having a prism side face in which at least one prism apex angle among three prism apex angles formed by three reflecting side faces forming the unit element and perpendicular to one another has a deviation from perpendicular of from 0.0001 to 0.01°.

It is still more preferable that the multidirectional elements be formed comprising at least one type of unit element having a prism side face in which at least one prism apex angle among three prism apex angles formed by three reflecting side faces forming the unit element and perpendicular to one another has a deviation from perpendicular of from 0.0001 to 0.01°.

Further, in order to improve the observation angle characteristics, it is preferable that at least one reflecting side face of the three retroreflective side faces of the unit element forms a curved surface, and that the maximum deviation of the curved surface from a virtual plane for which the unit element forms a theoretical cube-corner element is from $1/1000$ to $200/1000$ of the length of the base portion forming the curved surface.

By imparting a slight deviation to the prism apex angles of unit elements by the various methods described above, the retroreflective light spreading can be increased, and observation angle characteristics can be improved. The degree of deviation can be selected appropriately according to the observation angle for which improvement is desired.

Further, in the case of a multidirectional element formed from seven or more unit elements, because the optical axis inclination is large, in order to improve the retroreflective efficiency, it is preferable that V-shape grooves forming common base edges be cut by means of one or more V-shape subgrooves, parallel to the V-shape grooves forming base edges of unit elements forming the outer periphery of the multidirectional element, and having an angle substantially equal to the angle of the V-shape grooves, and that unit reflective elements be formed by a square-shape cube-corner retroreflective element with at least one base face and by one triangular-pyramidal cube-corner retroreflective element.

Further, in cases in which retroreflective articles of this element are used as sheet-shape products, it is preferable that the height of the unit elements be from 25 to 2000 μ m, in order to obtain flexibility of the sheet product. If the height is less than 25 μ m, elements are small, so that spreading of retroreflective light due to diffraction effects becomes excessive, which is not preferable; if the height exceeds 2000 μ m, sheet flexibility is not obtained, which is not preferable.

Any material which has excellent light transparency and a high refractive index can be used as optical media of a retroreflective element of this invention, and no limits in particular are imposed. For example, glass materials, transparent resins, and similar can be used preferable. As transparent resins, acrylic resins, polycarbonate resins, vinyl chloride resins, styrene resins, epoxy resins, urethane resins, and copolymer resins, modified resins, combinations and similar of these resins, can be used. Retroreflective articles formed from resins have excellent flexibility, are lightweight, are colorable, and have other excellent properties, and are preferable.

Further, by adding coloring agents, ultraviolet ray absorption agents, light stabilizers, oxidation inhibitors, and similar as appropriate to such transparent resins, excellent coloring, durability, weather resistance, and other properties can be

7

imparted. These properties can also be attained by laminating retroreflective articles onto other resin layers, or by other methods.

Further, in order to attain reflection by the principle of total internal reflection in a retroreflective article of this invention, an air layer can be provided in the back face of retroreflective elements, to adopt a sealed structure which prevents the intrusion of water, moisture, and similar.

Further, a light-reflecting mirror-surface reflecting layer, such as of aluminum or similar, can be provided on the reflecting faces of retroreflective elements. A retroreflective article provided with such mirror-surface reflecting layers efficiently reflects over a broad range of incidence angles and so is preferable, but has the drawback that the external appearance of the article is dark due to the mirror-surface reflecting layer.

In this way, by means of this invention, retroreflective articles can be provided with improved wide-angle characteristics, that is, with improved entrance angle characteristics, observation angle characteristics, and rotation angle characteristics.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a triangular-pyramidal cube-corner element pair of the prior art;

FIG. 2 is a triangular-pyramidal cube-corner element group of the prior art;

FIG. 3 shows a multidirectional element of the invention;

FIG. 4 is a plane view showing a multidirectional element group of the invention;

FIG. 5 shows a multidirectional element of the invention;

FIG. 6 shows a multidirectional element of the invention;

FIG. 7 is a plane view showing a multidirectional element group of the invention;

FIG. 8 is a plane view showing a multidirectional element group of the invention;

FIG. 9 shows a multidirectional element of the invention;

FIG. 10 is a plane view showing a multidirectional element group of the invention;

FIG. 11 shows a multidirectional element of the invention;

FIG. 12 shows a multidirectional element of the invention;

FIG. 13 shows a multidirectional element of the invention;

FIG. 14 shows the locus of groove base portions forming multidirectional elements of this invention;

FIG. 15 shows the locus of groove base portions forming multidirectional elements of this invention;

FIG. 16 shows the locus of groove base portions forming multidirectional elements of this invention;

FIG. 17 is a cubic diagram used to explain reflecting elements in this invention;

FIG. 18 is a cubic diagram used to explain reflecting elements in this invention;

FIG. 19 is a cubic diagram used to explain reflecting elements in this invention;

FIG. 20 is a cubic diagram used to explain reflecting elements in this invention;

FIG. 21 is a cubic diagram used to explain reflecting elements in this invention;

FIG. 22 is a cubic diagram used to explain reflecting elements in this invention;

FIG. 23 is a radar chart of retroreflective coefficients of the retroreflective article in Embodiment 1 of the invention;

FIG. 24 is a radar chart of retroreflective coefficients of the retroreflective article in Embodiment 2 of the invention;

FIG. 25 is a radar chart of retroreflective coefficients of the retroreflective article in Embodiment 3 of the invention;

8

FIG. 26 is a radar chart of retroreflective coefficients of the retroreflective article in Embodiment 4 of the invention;

FIG. 27 is a radar chart of retroreflective coefficients of the retroreflective article in Comparative Example 1 of the invention;

FIG. 28 is a radar chart of retroreflective coefficients of the retroreflective article in Comparative Example 2 of the invention; and,

FIG. 29 is a radar chart of retroreflective coefficients of the retroreflective article in Comparative Example 3 of the invention.

BEST MODE FOR CARRYING OUT THE INVENTION

Preferred modes of multidirectional retroreflective articles of the invention are explained, citing the drawings.

FIG. 1 shows a plane view and cross-sectional view of triangular-pyramidal cube-corner retroreflective elements (A-B-C and A-B-C') of the prior art. These triangular-pyramidal cube-corner retroreflective elements are two elements with left-right symmetry, formed in closest-packing mode with one common base edge (A-B).

In general, the optical axis of an element is inclined for the purpose of improving the entrance angle characteristics; the two optical axes of an element pair are inclined so as to be directed in opposite directions by the same angle. However, the optical axes are inclined only in the plane perpendicular to the common base edge (A-B), and are not inclined in the plane parallel to the common base edge (A-B), so that there is the problem that the entrance angle characteristics are not improved for this direction.

On the other hand, regions are partitioned and combined such that the directions of triangular-pyramidal cube corners which form a pair in the element group shown in FIG. 2 are mutually perpendicular. This combination of element groups averages the performance for azimuth angles of 0° and 90°, so that the rotation angle characteristics can be improved; but at azimuth angles other than 0° and 90°, fluctuations in reflection performance remain. At the 45° azimuth angle in particular, the improvement in reflection performance, and in particular in entrance angle characteristics, is unsatisfactory.

Examples of such element forms include U.S. Pat. No. 5,022,739, U.S. Pat. No. 5,132,841, and U.S. Pat. No. 5,175,645, by Bennett et al; U.S. Pat. No. 6,036,322, by Nilsen et al; U.S. Pat. No. 5,706,132 and U.S. Pat. No. 5,936,770, by Nestegard et al; and U.S. Pat. No. 5,898,523, by Smith; in all these cases, improvement of rotation angle characteristics is inadequate.

FIG. 3 shows a plane view and cross-sectional view of a multidirectional element, formed such that five unit elements in this invention each have two base edges (A1-B, A2-B, A3-B, A4-B, and A5-B) and one vertex (B) in common. The arrows shown in FIG. 3 indicate the directions of inclination of the optical axes of elements; because of uniform dispersion in five directions, excellent rotation angle characteristics can be obtained. Further, the inclination angle of the optical axes is 11.333°, and directions are inclined toward the outer-periphery base edges, so that entrance angle characteristics are also improved.

FIG. 4 is a plane view of a retroreflective article of this invention, in which many of the pentagonal multidirectional elements shown in FIG. 3 are arranged. Elements having a triangular-pyramidal shape are formed between the multidirectional elements; these triangular-pyramidal shapes do not form cube-corner elements, and so do not contribute to retroreflection. The element group which forms the multidirectional

9

tional retroreflective article shown in FIG. 4 is formed by V-shape groove groups having a continuous bent-line shape bottom portion locus.

FIG. 5 shows a plane view and cross-sectional view of a multidirectional element, formed such that seven unit elements of this invention have two base edges (A1-B, A2-B, A3-B, A4-B, A5-B, A6-B, A7-B) and one vertex (B) in common. The optical axes of the unit elements shown in FIG. 5 are inclined, and the directions are dispersed uniformly in seven directions, so that excellent rotation angle characteristics can be obtained. Further, the inclination angle of the optical axes is 6.476° , inclined in the direction of the common vertex (B), so that entrance angle characteristics are also improved.

FIG. 6 shows a plane view and cross-sectional view of a multidirectional element, formed from eight unit elements of this invention having two base edges (A1-B, A2-B, A3-B, A4-B, A5-B, A6-B, A7-B, A8-B) and one vertex (B) in common. The arrows shown in FIG. 6 indicate the direction of inclination of the optical axes of the elements; because the directions are dispersed uniformly in eight directions, excellent rotation angle characteristics are obtained. Further, the angle of inclination of the optical axes is 10.790° , and inclination is in the direction of the common vertex (B), so that the entrance angle characteristics are also improved.

FIG. 7 shows a plane view of a retroreflective article of this invention, in which many of the octagonal multidirectional elements shown in FIG. 6 are arranged. Elements having a triangular-pyramidal shape are formed between the multidirectional elements, but because triangular-pyramidal cube-corner elements are not formed, these do not contribute to retroreflection. The element group forming the multidirectional retroreflective article shown in FIG. 7 is formed by V-shape grooves having the base portion locus of a continuous bent line shape. Octagonal multidirectional elements with a smaller shape are formed between the octagonal multidirectional elements, so that the packing density of the element group is raised, and the retroreflective efficiency is increased. Further, the observation angle characteristics of the small multidirectional elements are improved through a large diffraction effect.

FIG. 8 shows a plane view of a retroreflective article of this invention, in which numerous decagonal multidirectional elements are arranged. Between the multidirectional elements, elements with a triangular-pyramidal shape, with one vertex cut away, are formed, but these do not form triangular-pyramidal cube-corner elements, and so do not contribute to retroreflection. The element group forming the multidirectional retroreflective article shown in FIG. 8 are formed by a V-shape groove pattern having a base portion locus with a continuous bent-line shape.

FIG. 9 shows a plane view and cross-sectional view of a multidirectional element, formed from five unit elements of this invention having two base edges (A1-B, A2-B, A3-B, A4-B, A5-B) and one vertex (B) in common, the outer-periphery base edges of which are formed more shallowly than the common base edges (A1-B, A2-B, A3-B, A4-B, A5-B), and portions of the outer-periphery base edges of which are cut away by common base edges. For this reason, elements are formed such that the areas of the three reflecting side faces of the unit elements are equal, and the retroreflective efficiency is raised.

The optical axes of the unit elements forming the multidirectional element shown in FIG. 9 are dispersed uniformly in five directions, so that excellent rotation angle characteristics can be obtained. Further, the optical axis inclination angle is 11.333° , and inclination is in the directions of the outer-

10

periphery base edges (A1-A2, A2-A3, A3-A4, and A5-A1), so that entrance angle characteristics are also improved.

FIG. 10 shows a plane view of a retroreflective article of this invention, in which many of the shallow-groove type pentagonal multidirectional elements such as shown in FIG. 9 are arranged. Elements having a triangular-pyramidal shape are formed between the multidirectional elements, but these triangular-pyramidal shapes do not form cube-corner elements, and so do not contribute to retroreflection. The element group forming the multidirectional retroreflective article shown in FIG. 10 is formed by a V-shape groove group having a base portion locus with a continuous bent-line shape.

FIG. 11 shows a plane view and cross-sectional view of a multidirectional element, formed such that eight unit elements have in common two base edges (A1-B, A2-B, A3-B, A4-B, A5-B, A6-B, A7-B, A8-B) and one vertex (B); the outer-periphery base edges (A1-A2, A2-A3, A3-A4, A4-A5, A5-A6, A6-A7, A7-A8, and A8-A1) are formed so as to be deeper than the common base edges (A1-B, A2-B, A3-B, A4-B, A5-B, A6-B, A7-B, A8-B). Hence the unit elements are formed such that the areas of the three reflecting side faces of the unit elements are equal, and the retroreflective efficiency is raised.

Because the optical axes of the unit elements forming the multidirectional element shown in FIG. 11 are dispersed uniformly in eight directions, excellent rotation angle characteristics can be obtained. Further, because the optical axis inclination angle is 10.790° , and inclination is in the direction of the common vertex (B), the entrance angle characteristics are also improved.

Because the optical axes of the unit elements forming the multidirectional element shown in FIG. 12 are dispersed uniformly in 12 directions, excellent rotation angle characteristics can be obtained. And, the optical axis inclination angle is 19.720° , and inclination is in the directions of the outer-periphery base edges (A1-A2, A2-A3, A4-A5, A5-A6, A6-A7, A7-A8, A8-A9, A9-A10, A10-A11, A11-A12, A12-A1), the entrance angle characteristics are also improved.

FIG. 13 shows a multidirectional element in which ten unit elements are combined. In this multidirectional element, V-shape grooves forming common base edges are cut by means of one V-shape subgroove parallel to the V-shape grooves forming the outer-periphery base edges, and having an angle substantially equal to the angle of the V-shape grooves; unit elements are formed by cube-corner retroreflective elements the base face of which is square in shape and triangular-pyramidal cube-corner retroreflective elements. An element in which such a subgroove is formed has higher retroreflective efficiency, and so is particularly preferable.

FIG. 14, FIG. 15, and FIG. 16 are diagrams used to explain a method of forming multidirectional elements in a retroreflective article of this invention.

FIG. 14 shows only the locus of the base portions of grooves, the cross-section of which is a V-shape, which form pentagonal multidirectional elements shown in FIG. 4. The locus of these grooves forms a pattern in which continuous bent lines are repeated.

FIG. 15 shows, as L1, L2, and L3, the loci of grooves forming the outer-periphery base edges, among the loci of the V-shape grooves shown in FIG. 14. The angle of the V grooves of these three types of base portion loci are all the same angle.

FIG. 16 shows, as L4, L5 and L6, the loci of grooves forming common base edges, among the loci of the V-shape grooves shown in FIG. 14. The angle of the V grooves of these three types of base portion loci are all the same angle.

By forming these six types of V-grooves, a retroreflective article is formed, in which is formed an assembly of multidirectional elements having the pentagonal shape shown in FIG. 4.

Further, in order to impart observation angle characteristics to a multidirectional element in this invention, a slight deviation can be added to the prism apex angles. FIG. 17 shows a cubic diagram of a cube-corner element of the prior art, in which there is no deviation of the prism apex angles. Here, "prism apex angle" refers to the angles made by the three reflecting side faces (ABH, BCH, and CAH); in order to effect retroreflection, these three reflecting side faces must be mutually perpendicular. If a deviation is imparted to a prism apex angle, then retroreflective light no longer returns parallel to the incident light, so that the retroreflective light spreads while returning, and the observation angle characteristics are improved.

FIG. 18 shows a conceptual diagram of a method for adding a deviation to a V-groove angle, which is one method of adding an apex angle deviation. In order to add a deviation to a V-groove angle, such methods can be adopted as adding a deviation in advance to the theoretical value of the knife-edge angle of a cutting tool, or inclining a cutting tool by a slight amount from the perpendicular to cut with an asymmetrical shape, or similar.

FIG. 19 shows another method of adding an apex angle deviation. In this method, a deviation can be added by inclining the groove locus from its theoretical position, which is the line segment A-B.

FIG. 20 also shows another method of adding an apex angle deviation. In this method, by deeply cutting the groove loci within the face defined by the base edge group, that is, with respect to the reference face A-B-C, a deviation can be added.

FIG. 21 is a method of adding deviations to apex angles, by causing bending multiple times within the face in which the groove base portion loci are defined by the base edge group, that is, in the same plane as the reference face A-B-C, to add deviations. In this method, reflecting side faces are formed as numerous polyhedra, and uniform observation angle characteristics are attained, which is particularly preferable.

Further, in FIG. 22, a method of adding apex angle deviation by taking groove loci to be curves is shown. In this method, the reflecting side faces are formed as curved surfaces, and uniform observation angle characteristics are attained, which is particularly preferable.

Methods of obtaining uniform observation angle characteristics based on the methods shown in FIG. 21 and FIG. 22 include, apart from methods in which changes are made within the reference face A-B-C defined by the base edge group, methods of changing the depth as shown in FIG. 19, to obtain similar advantageous results. When changing the groove depth, the depth may be deeper than, or shallower than, the reference face. Further, in changing the depth, groove loci may be bent, or changes may be made continuously over the curve loci.

EMBODIMENTS

Below, details of the invention are explained with greater specificity using embodiments; however, this invention is of course not limited to only these embodiments.

[Retroreflective Coefficient]

In the embodiments, and in this Specification, retroreflective coefficients are measured by the method described below. As a retroreflective coefficient measurement device, a Gamma Scientific "Model 920" was used, and measurements of the retroreflective coefficients of a retroreflective sheet 100

mm on a side were performed at five appropriate locations, conforming to the measurement method stipulated in ASTM E810-91, under angular conditions in which the observation angle (α) was 0.2°, the entrance angle (β) was 5°, 30°, 40°, and 60°, and the rotation angle (ω) ranged from 0 to 345° in 15° increments; the average value was taken to be the retroreflective coefficient for the retroreflective article.

[Method of Forming Retroreflective Article]

The retroreflective elements explained in the following embodiments and comparative examples were formed by directly cutting a commercially available colorless polymethyl methacrylate resin sheet, of thickness 200 μm , using a diamond bit having a prescribed angle.

Embodiment 1

In the element shown in FIG. 3, all of the five unit elements forming the multidirectional element are formed such that the length of the common base edges (A1-B, A2-B, and similar) is 247.60 μm , the length of the outer-periphery base edges (A1-A2, and similar) is 291.07 μm , and the height from the base face of the elements (A1-B-A2) to the vertex H1 of the unit element is 100 μm .

In order to form elements in this way, as the angles of the V-shape grooves to form each of the reflecting side faces, the angle of the V-shape grooves forming the reflecting side face A1-A2-H1 is 93.195°, and the angle of the V-shape groove forming the reflecting side face A1-B-H1 and the reflecting side face A2-B-H1 is 58.139°.

The inner angles of the triangular shape A1-A2-B of the element base face are 72.00° for $\angle\text{A1-B-A2}$, and 54.00° for $\angle\text{B-A1-A2}$ and for $\angle\text{B-A2-A1}$; the base edges A1-B, A2-B, and A1-A2 are all positioned within the same plane. As the reference direction for rotation, the direction to point A1 centered on the common vertex B was taken to be rotation angle 0°.

The five unit elements were formed such that the respective optical axes were inclined by 11.333° in the direction opposite the common vertex B, that is, in the direction of the outer-periphery base edge; the optical axes were all arranged equally to form azimuth angles of 72°.

Embodiment 2

In the element shown in FIG. 6, all of the eight unit elements forming the multidirectional element are formed such that the length of the common base edges (A1-B, A2-B, and similar) is 287.07 μm , the length of the outer-periphery base edges (A1-A2, and similar) is 219.75 μm , and the height from the base face of the elements (A1-B-A2) to the vertex H1 of the unit element is 100 μm .

In order to form elements in this way, as the angles of the V-shape grooves to form each of the reflecting side faces, the angle of the V-shape grooves forming the reflecting side face A1-A2-H1 is 48.949°, and the angle of the V-shape groove forming the reflecting side face A1-B-H1 and the reflecting side face A2-B-H1 is 80.117°.

The inner angles of the triangular shape A1-A2-B of the element base face are 45.00° for $\angle\text{A1-B-A2}$, and 67.50° for $\angle\text{B-A1-A2}$ and for $\angle\text{B-A2-A1}$; the base edges A1-B, A2-B, and A1-A2 are all positioned within the same plane. As the reference direction for rotation, the direction to point H1 centered on the common vertex B was taken to be rotation angle 0°.

The eight unit elements were formed such that the respective optical axes were inclined by 10.790° in the direction of the common vertex B, that is, in the direction opposite the

13

outer-periphery base edge; the optical axes were all arranged equally to form azimuth angles of 45° .

Embodiment 3

In the element shown in FIG. 9, all of the five unit elements forming the multidirectional element are formed such that the length of the common base edges (A1-B, A2-B, and similar) is $247.60\text{ }\mu\text{m}$, the length of the outer-periphery base edges (A1-A2, and similar) is $291.07\text{ }\mu\text{m}$, and the height from the base face of the elements (A1-B-A2) to the vertex H1 of the unit element is $100\text{ }\mu\text{m}$.

In order to form elements in this way, as the angles of the V-shape grooves to form each of the reflecting side faces, the angle of the V-shape grooves forming the reflecting side face A1-A2-H1 is 93.195° , and the angle of the V-shape groove forming the reflecting side face A1-B-H1 and the reflecting side face A2-B-H1 is 58.139° . However, for the reflecting side face A1-A2-H1, the V-shape groove is formed to be $20\text{ }\mu\text{m}$ shallower than in Embodiment 1.

The inner angles of the triangular shape A1-A2-B of the element base face are 72.00° for $\angle\text{A1-B-A2}$, and 54.00° for $\angle\text{B-A1-A2}$ and for $\angle\text{B-A2-A1}$; the base edges A1-B and A2-B are all positioned within the same plane. As the reference direction for rotation, the direction to point A1 centered on the common vertex B was taken to be rotation angle 0° .

The five unit elements were formed such that the respective optical axes were inclined by 11.333° in the direction opposite the common vertex B, that is, in the direction of the outer-periphery base edge; the optical axes were all arranged equally to form azimuth angles of 72° .

Embodiment 4

In the element shown in FIG. 11, all of the eight unit elements forming the multidirectional element are formed such that the projected length of the edges of the triangle defining the element outer periphery (A1-B, A2-B, and similar) is $287.07\text{ }\mu\text{m}$, the lengths of the outer-periphery base edges (A1-A2 and similar) is $219.75\text{ }\mu\text{m}$, and the height from the element reference base face (C1-B-C2) to the unit element vertex H1 is $100\text{ }\mu\text{m}$.

In order to form elements in this way, as the angles of the V-shape grooves to form the reflecting side faces, the angle of the V-shape grooves forming the reflecting side face A1-A2-H is 48.949° , and the angle of the V-shape groove forming the reflecting side face C1-B-H1 and the reflecting side face C2-B-H1 is 80.117° .

However, for the reflecting side face A1-A2-H1, the V-shape groove is formed to be $40\text{ }\mu\text{m}$ deeper than in Embodiment 2. That is, at the three base edges of the triangular base face of a unit element, if the depth of the V-shape groove forming the shortest base edge A1-A2 is d_s , and the depth of the V-shape grooves forming the longest edges (B-C1 and B-C2) is d_e , then $d_s/d_e=1.40$.

The inner angles of the projected triangle A1-A2-B defining the outer periphery of the element are 45.00° for $\angle\text{C1-B-C2}$, and 67.5° for $\angle\text{B-A1-A2}$ and for $\angle\text{B-A2-A1}$; the base edges C1-B, C2-B are all positioned within the same plane. As the reference direction for rotation, the direction to vertex H1 centered on the common vertex B was taken to be rotation angle 0° .

The eight unit elements were formed such that the respective optical axes were inclined by 10.790° in the direction of the common vertex B, that is, in the direction opposite the

14

outer-periphery base edge; the optical axes were all arranged equally to form azimuth angles of 45° .

Embodiment 5

As shown in FIG. 12, a multidirectional element was formed from 12 unit elements. The 12 unit elements all were formed to have a shape such that the projected length of the edges of the triangular defining the outer periphery of the element (A1-B, A2-B, and similar) were $401.03\text{ }\mu\text{m}$, the length of the outer-periphery base edges (A1-A2 and similar) was $207.59\text{ }\mu\text{m}$, and the height from the element reference base face (C1-B-C2) to the unit element vertex H1 was $100\text{ }\mu\text{m}$.

The angle of the V-shape grooves to form each of the reflecting side faces in order to form such an element are 31.085° for the angle of the V-shape groove forming the reflecting side face A1-A2-H1, and 85.883° for the angle of the V-shape grooves to form the reflecting side faces C1-B-H1 and C2-B-H1.

However, the reflecting side face A1-A2-H1 is formed to be $200\text{ }\mu\text{m}$ deeper than the V-shape groove in Embodiment 2. That is, in three of the base edges of the triangular base face of a unit element, if the depth of the V-shape groove forming the shortest base edge A1-A2 is d_s , and the depth of the V-shape grooves forming the longest base edges (B-C1 and B-C2) is d_e , then $d_s/d_e=3.0$.

The inner angles of the projected triangular shape A1-A2-B defining the outer periphery of the element are 30.00° for $\angle\text{C1-B-C2}$, and 75° for $\angle\text{B-A1-A2}$ and for $\angle\text{B-A2-A1}$; the base edges C1-B and C2-B are positioned within the same plane. As the reference direction for rotation, the direction to point H1 centered on the common vertex B was taken to be rotation angle 0° .

The 12 unit elements were formed such that the respective optical axes were inclined by 19.72° in the direction of the common vertex B, that is, in the direction opposite the outer-periphery base edge; the optical axes were all arranged equally to form azimuth angles of 30° .

Embodiment 6

In Embodiment 6, when forming a multidirectional element comprising the eight unit elements fabricated in Embodiment 2, while forming V-shape grooves, cutting of V-shape grooves was performed such that the locus of groove base portions was curved shapes, according to the method shown in FIG. 22.

As the curve shapes, sinusoidal curve approximations were used, based on the straight-line loci of base edges of the element in Embodiment 2. The amplitude of the sinusoidal curves was 0.005 of the length of each edge (A1-B, A2-B, A1-A2, and similar). Hence because the length of edges A1-B and A2-B in Embodiment 2 is $287.07\text{ }\mu\text{m}$, the amplitude is $1.44\text{ }\mu\text{m}$, and because edge A1-A2 has length $219.75\text{ }\mu\text{m}$, the amplitude is $1.10\text{ }\mu\text{m}$.

Further, the period of the sinusoidal curves was taken to be four times the edge length. Hence because edges A1-B and A2-B in Embodiment 2 have length $287.07\text{ }\mu\text{m}$, the period is $1148.27\text{ }\mu\text{m}$, and because edge A1-A2 has length $219.75\text{ }\mu\text{m}$, the period is $879.98\text{ }\mu\text{m}$. In addition, the positions at which the amplitude is a maximum value and is zero were adjusted so as to be at end portions of each edge.

In addition, Comparative Examples, based on well-known technology of the prior art, are explained for the purpose of comparison with retroreflective articles of this invention.

15

Comparative Example 1

A pair of triangular-pyramidal cube-corner retroreflective elements, mutually opposed and with one base edge in common as shown in FIG. 1, was used as a retroreflective article in a comparative example. The elements are formed such that the length of the common base edge (A-B) was 291.07 μm , the length of the other two edges (A-C and B-C) was 247.60 μm , and the height from the element reference base face (A-B-C) to the vertex H of the unit elements is 100 μm .

In order to form such an element, the angle of the V-shape grooves to form the reflecting side faces were 93.195° for the V-shape groove forming the reflecting side face A-B-H, and 58.139° for the V-shape grooves forming the reflecting side faces A-C-H and B-C-H.

The inner angles of the triangular shape A-B-C of the element base face are 72.00° for $\angle\text{A-C-B}$, and 54.00° for $\angle\text{B-A-C}$ and for $\angle\text{A-B-C}$; the base edges A-B, C-B, and B-C are all positioned within the same plane. That is, the retroreflective elements in Comparative Example 1 have the same shape as the unit elements used in Embodiment 1. As the reference direction for rotation, the direction to point C centered on the center point of the common base edge A-B was taken to be rotation angle 0°.

The two reflecting elements are formed such that the optical axes of the two reflecting elements are inclined 11.333° in the direction of the common base edge A-B, and such that the two optical axes have azimuth angles at 180° to each other. A retroreflective article in which such triangular-pyramidal retroreflective element pairs are formed in closest-packed fashion was taken to be Comparative Example 1.

Comparative Example 2

A pair of triangular-pyramidal cube-corner retroreflective elements, mutually opposed and with one base edge in common as shown in FIG. 1, was used as a retroreflective article in a comparative example. The elements are formed such that the length of the common base edge (A-B) was 219.75 μm , the length of the other two edges (A-C and B-C) was 287.07 μm , and the height from the element reference base face (A-B-C) to the vertex H of the unit elements is 100 μm .

In order to form such an element, the angle of the V-shape grooves to form the reflecting side faces were 48.949° for the V-shape groove forming the reflecting side face A-B-H, and 80.117° for the V-shape grooves forming the reflecting side faces A-C-H and B-C-H.

The inner angles of the triangular shape A-B-C of the element base face are 45.00° for $\angle\text{A-C-B}$, and 67.50° for $\angle\text{B-A-C}$ and for $\angle\text{A-B-C}$; the base edges A-B, C-B, and B-C are all positioned within the same plane. That is, the retroreflective elements in Comparative Example 2 have the same shape as the unit elements used in Embodiment 2. As the reference direction for rotation, the direction to point C centered on the center point of the common base edge A-B was taken to be rotation angle 0°.

The two reflecting elements are formed such that the optical axes of the two reflecting elements are inclined 10.79° in the direction opposite the common base edge A-B, and such that the two optical axes have azimuth angles at 180° to each other. A retroreflective article in which such triangular-pyramidal retroreflective element pairs are formed in closest-packed fashion was taken to be Comparative Example 2.

Comparative Example 3

A pair of triangular-pyramidal cube-corner retroreflective elements, mutually opposed and with one base edge in com-

16

mon as shown in FIG. 1, was used as a retroreflective article in a comparative example. The elements are formed such that the length of the common base edge (A-B) was 274.65 μm , the length of the other two edges (A-C and B-C) was 242.91 μm , and the height from the element reference base face (A-B-C) to the vertex H of the unit elements is 100 μm .

In order to form such an element, the angle of the V-shape grooves to form the reflecting side faces were 86.529° for the V-shape groove forming the reflecting side face A-B-H, and 61.983° for the V-shape grooves forming the reflecting side faces A-C-H and B-C-H.

The inner angles of the triangular shape A-B-C of the element base face are 68.851° for $\angle\text{A-C-B}$, and 55.575° for $\angle\text{B-A-C}$ and for $\angle\text{A-B-C}$; the base edges A-B, C-B, and B-C are all positioned within the same plane. That is, the retroreflective elements in Comparative Example 1 have the same shape as the unit elements used in Embodiment 1. As the reference direction for rotation, the direction to point C centered on the center point of the common base edge A-B was taken to be rotation angle 0°.

The two reflecting elements are formed such that the optical axes of the two reflecting elements are inclined 8.00° in the direction of the common base edge A-B, and such that the two optical axes have azimuth angles at 180° to each other.

In Comparative Example 3, a retroreflective article was formed by combining element pairs such as those above with the optical axes inclined 8° in two zones, with element rotation directions at 0° and 90°, as shown in FIG. 2, as Comparative Example 3.

As a retroreflective coefficient measurement device, a Gamma Scientific "Model 920" was used in measurements, at five appropriate locations, of the retroreflective coefficients of retroreflective sheets 100 mm on a side which were the objects of Embodiments 1 through 4 and Comparative Examples 1 through 3, conforming to the measurement method stipulated in ASTM E810-91, under angular conditions in which the observation angle (α) was 0.2°, the entrance angle (β) was 5°, 30°, 40°, and 60°, and the rotation angle (ω) ranged from 0 to 345° in 15° increments; the average value was taken to be the retroreflective coefficient for the retroreflective articles, as shown in the radar charts of FIG. 22 through FIG. 28.

In the radar charts of FIG. 22 through FIG. 28, the retroreflective coefficients for entrance angles (β) of 5°, 30°, 40°, and 60° are plotted, on a logarithmic scale in the clockwise direction on the radar charts, varying the element rotation angle from 0 to 345° in 15° increments.

In the Comparative Examples 1 through 3 based on well-known technology of the prior art, the rotation angle dependence of the retroreflective coefficients with increasing entrance angle is prominent. This rotation angle dependence has been extremely inconvenient when observing the retroreflective article from different azimuth angles, as in the case of traffic signs and similar.

In Comparative Example 1, the difference in retroreflective performance is especially prominent for rotation angles of 0° and 90°, and FIG. 26 shows that the difference in retroreflective coefficients between rotation angles of 0° and 90° at an entrance angle of 60° is a factor of 80 or more, and that the difference in reflection performance is a factor of 1.5 or more at an entrance angle of 40° as well.

In Comparative Example 2 also, this tendency remains the same, and as shown in FIG. 27, the rotation angle dependence is prominent. A difference with Comparative Example 1 is the fact that for the retroreflective article of Comparative

Example 2, an increased retroreflective performance is seen for rotation angles of 30 to 45°, 135 to 150°, 210 to 225°, and 315 to 330°.

Because the design of elements in Comparative Example 3 is divided between azimuth angles of 0° and 90°, the retroreflective performance can be made equal for 0° and 90°, but the decline in retroreflective performance at 45° remains pronounced, and such a retroreflective article is not preferable for use in traffic signs.

As shown in FIG. 22 and FIG. 23, the rotation angle dependence of the retroreflective articles in Embodiment 1 and Embodiment 2, compared with the retroreflective articles of the prior art as described in Comparative Examples 1 through 3, clearly have smaller rotation angle dependences at all entrance angles.

Further, as shown in FIG. 24 and FIG. 25, the rotation angle dependence of the retroreflective articles in Embodiment 3 and Embodiment 4 is clearly small at all entrance angles, compared with the well-known retroreflective articles of the prior art described in Comparative Examples 1 through 3. Similarly advantageous results have been confirmed for the retroreflective article of Embodiment 5.

Also, in Embodiment 3, the reflecting side face A1-A2-H1 is formed to be 20 μm shallower than the V-shape groove in Embodiment 1, and in Embodiment 4 the reflecting side face A1-A2-H1 is formed to be 40 μm deeper than the V-shape groove in Embodiment 2, so that the retroreflective efficiency is enhanced, and improved retroreflective coefficients result.

Further, in Embodiment 5, the reflecting side face A1-A2-H1 is formed to be 200 μm deep, so that the retroreflective efficiency is enhanced, and an improved retroreflective coefficient results.

Upon comparing observation angle characteristics for the retroreflective articles of Embodiments 2 and 6, at an entrance angle of 5° and observation angles of 0.2°, 0.33°, and 1.0°, superior observation angle characteristics were obtained for the retroreflective article of Embodiment 6 at all rotation angles compared with the retroreflective article of Embodiment 2, as indicated by Table 1 below.

That is, it was confirmed that retroreflected rays in the forward direction of the retroreflective article of Embodiment 2, that is, at an observation angle of 0.2°, were broadened to the directions of larger observation angles through formation of grooves in curve shapes.

TABLE 1

	Observation angle		
	0.2°	0.33°	1.0°
Embodiment 2	790	567	46
Embodiment 6	528	634	90

INDUSTRIAL APPLICABILITY

Specific applications for retroreflective articles of this invention include retroreflective articles and retroreflective sheets which can be used in traffic signs, construction signs, commercial signs, vehicle license plates, and similar, and sheets which can be cut freely in any direction and utilized due to excellent rotation angle characteristics.

The invention claimed is:

1. A triangular-pyramidal cube-corner retroreflective sheet, comprising numerous triangular-pyramidal cube-corner light-transparent retroreflective elements formed by cutting away a group of grooves having a substantially V-shape

cross-section, characterized in that an assembly of retroreflective multidirectional elements is formed, in which either five, or seven or more triangular-pyramidal cube-corner retroreflective unit elements are formed so as to share two common base edges forming triangular base faces of the unit elements as well as common vertexes at which the common base edges intersect, with an adjacent retroreflective element.

2. The triangular-pyramidal cube-corner retroreflective article according to claim 1, wherein the multidirectional element is formed from five, or seven to twelve unit elements.

3. The triangular-pyramidal cube-corner retroreflective article according to claim 1 or claim 2, wherein lengths of two common base edges forming the unit elements are equal.

4. The triangular-pyramidal cube-corner retroreflective article according to claim 3, wherein the multidirectional element is formed such that the locus of a base portion defined by the intersection of two side faces of a groove having a substantially symmetrical V-shape cross-section forms straight lines, bent lines, curves or repeated line groups comprising a combination of these line groups.

5. The triangular-pyramidal cube-corner retroreflective article according to claim 4, wherein repeated line groups forming the locus of the base portion are in a common plane defined by the triangular base faces of the unit elements.

6. The triangular-pyramidal cube-corner retroreflective article according to claim 4, wherein at least one line group among the repeated line groups is not in the common plane defined by the triangular base faces of the unit elements.

7. The triangular-pyramidal cube-corner retroreflective article according to claim 4, wherein at least one line group among the repeated line groups is not in the common plane, and that a depth of the V-shape groove, determined by a distance between a plane defined by the line group and a vertex of the unit element, is $\pm(5 \text{ to } 200) \%$ of an element height, defined by a distance between the vertex of the unit element and in the common plane defined by the triangular base faces of the unit elements.

8. The triangular-pyramidal cube-corner retroreflective article according to claim 6, wherein the radius of curvature of bending portions of the bent line-shaped locus of the base portion is from 2 to 50 μm.

9. The triangular-pyramidal cube-corner retroreflective article according to claim 6, wherein the line groups forming the locus of the base portion are curve groups defined by trigonometric functions, inverse trigonometric functions, elliptic functions, circular functions, and composite functions of these functions.

10. The triangular-pyramidal cube-corner retroreflective article according to claim 6, wherein in the three base edges of the triangular base face of the unit element, when a depth of the V-shape groove forming the shortest base edge is assumed as d_s and a depth of the V-shape groove forming the longest base edge is assumed as d_e , an inequality $1.05 \leq (d_s/d_e) \leq 3.00$ (1) is satisfied.

11. The triangular-pyramidal cube-corner retroreflective article according to claim 6, wherein the multidirectional elements are formed comprising at least one type of unit element having a prism side face in which at least one prism apex angle among three prism apex angles formed by three reflecting side faces forming the unit element and perpendicular to one another has a deviation from perpendicular of from 0.0001 to 0.01°.

12. The triangular-pyramidal cube-corner retroreflective article according to claim 11, wherein the multidirectional elements are formed comprising at least three types of unit elements having a prism side face in which at least one prism apex angle among three prism apex angles formed by three

19

reflecting side faces forming the unit element and perpendicular to one another has a deviation from perpendicular of from 0.0001 to 0.01°.

13. The triangular-pyramidal cube-corner retroreflective article according to claim 11, wherein at least one reflecting side face of the three retroreflective side faces of the unit element forms a curved surface, and that the maximum deviation of the curved surface with a virtual plane forming the unit element all reflecting side faces of which are planar is from $\frac{1}{1000}$ to $\frac{200}{1000}$ of the length of the base portion forming the curved surface.

14. The triangular-pyramidal cube-corner retroreflective article according to claim 13, wherein V-shape grooves forming common base edges are cut by means of one or more

20

V-shape subgrooves, parallel to the V-shape grooves forming base edges of unit elements forming the outer periphery of the multidirectional element (hereafter called “outer-periphery base edges”), and having an angle substantially equal to the angle of the V-shape grooves, and in that unit reflective elements are formed by a square-shape cube-corner retroreflective element with at least one base face and by one triangular-pyramidal cube-corner retroreflective element.

15. The triangular-pyramidal cube-corner retroreflective article according to claim 14, wherein the height of the unit elements is from 25 to 2000 μm .

* * * * *



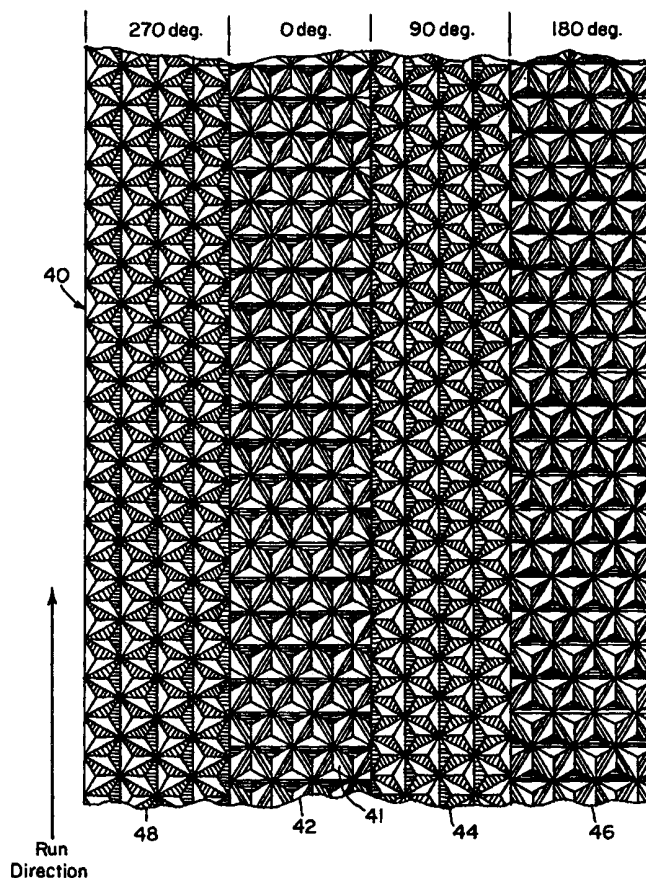
INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification ⁶ : G02B 5/124		A1	(11) International Publication Number: WO 99/28770
			(43) International Publication Date: 10 June 1999 (10.06.99)
(21) International Application Number: PCT/US98/25138 (22) International Filing Date: 24 November 1998 (24.11.98) (30) Priority Data: 08/980,707 1 December 1997 (01.12.97) US (71) Applicant (for all designated States except US): REFLEXITE CORPORATION [US/US]; 120 Darling Drive, Avon, CT 06001-4217 (US). (72) Inventors; and (75) Inventors/Applicants (for US only): NILSEN, Robert, B. [US/US]; 11 Aspenwood Drive, Weatogue, CT 06089 (US). LU, Xiao, Jing [US/US]; 1637 Summit Street, Yorktown Heights, NY 10598 (US). GAUER, Gary, J. [US/US]; 476 Graham Road, South Windsor, CT 06074 (US). (74) Agents: REYNOLDS, Leo, R. et al.; Hamilton, Brook, Smith & Reynolds, P.C., Two Militia Drive, Lexington, MA 02421 (US).		(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG). Published <i>With international search report.</i>	

(54) Title: MULTI-ORIENTATION RETROREFLECTIVE SHEET

(57) Abstract

A retroreflective sheet structure (40) is disclosed that has cube corner retroreflective elements (41). The structure includes a first array (42) of retroreflective elements (41) oriented in a first direction within a plane and a second array (44) of retroreflective elements oriented in a second direction within the plane, wherein said second direction being about 90° to said first direction. The structure further includes a third array (46) of retroreflective elements oriented in a third direction within the plane, wherein said third direction being about 180° to said first direction and a fourth array (48) of retroreflective elements oriented in a fourth direction being about 270° to said first direction. In one embodiment, the retroreflective structure includes the retroreflective elements having cube corner elements having a pitch between elements in the range of between about 0.0035 and 0.0045 inches (0.088 and 0.114 millimeters). In a preferred embodiment, the retroreflective structure includes a metalized layer on the facet side of the retroreflective elements for specular reflection, and the retroreflective elements are tilted by about -3 degrees.



MULTI-ORIENTATION RETROREFLECTIVE SHEET

BACKGROUND OF THE INVENTION

Retroreflective sheeting has the ability to redirect light incident upon a major surface of the sheeting toward its originating source. This unique ability has led to the wide-spread use of retroreflective sheeting in a wide variety of conspicuity enhancement applications relating to traffic and personal safety marking. Typical examples of uses of retroreflective sheeting include the placement of such sheetings on road signs, traffic cones and barricades to enhance their conspicuity, particularly under poor lighting conditions, such as night-time driving conditions or in conditions of inclement weather. These uses typically allow the sheeting to be adhered to relatively flat and rigid surfaces, thereby allowing the sheeting to be relatively inflexible. Additionally, sign applications are characterized by relatively predictable, standardized viewing geometries.

There are essentially two types of retroreflective sheeting, beaded sheeting and cube corner sheeting. Beaded sheeting employs a multitude of independent glass or ceramic microspheres to retroreflect incident light. From the optics perspective, beaded sheeting typically exhibits favorable rotational symmetry and entrance angularity performance because of the symmetrical nature of the beads. Additionally, beaded sheeting typically exhibits relatively good flexibility because the beads are independent from one another. However, beaded sheeting tends to exhibit relatively low brightness when compared to cube corner sheeting.

Cube corner retroreflective sheeting typically employs an array of rigid, interconnected cube corner elements to retroreflect light incident on a major surface of the sheeting. The basic cube corner element is a generally tetrahedral structure having three mutually substantially perpendicular lateral faces which intersect at a single reference point, or apex, and a base triangle opposite the apex. The symmetry axis, or optical axis, of the cube corner element is the axis which extends

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	ES	Spain	LS	Lesotho	SI	Slovenia
AM	Armenia	FI	Finland	LT	Lithuania	SK	Slovakia
AT	Austria	FR	France	LU	Luxembourg	SN	Senegal
AU	Australia	GA	Gabon	LV	Latvia	SZ	Swaziland
AZ	Azerbaijan	GB	United Kingdom	MC	Monaco	TD	Chad
BA	Bosnia and Herzegovina	GE	Georgia	MD	Republic of Moldova	TG	Togo
BB	Barbados	GH	Ghana	MG	Madagascar	TJ	Tajikistan
BE	Belgium	GN	Guinea	MK	The former Yugoslav Republic of Macedonia	TM	Turkmenistan
BF	Burkina Faso	GR	Greece			TR	Turkey
BG	Bulgaria	HU	Hungary	ML	Mali	TT	Trinidad and Tobago
BJ	Benin	IE	Ireland	MN	Mongolia	UA	Ukraine
BR	Brazil	IL	Israel	MR	Mauritania	UG	Uganda
BY	Belarus	IS	Iceland	MW	Malawi	US	United States of America
CA	Canada	IT	Italy	MX	Mexico	UZ	Uzbekistan
CF	Central African Republic	JP	Japan	NE	Niger	VN	Viet Nam
CG	Congo	KE	Kenya	NL	Netherlands	YU	Yugoslavia
CH	Switzerland	KG	Kyrgyzstan	NO	Norway	ZW	Zimbabwe
CI	Côte d'Ivoire	KP	Democratic People's Republic of Korea	NZ	New Zealand		
CM	Cameroon			PL	Poland		
CN	China	KR	Republic of Korea	PT	Portugal		
CU	Cuba	KZ	Kazakstan	RO	Romania		
CZ	Czech Republic	LC	Saint Lucia	RU	Russian Federation		
DE	Germany	LI	Liechtenstein	SD	Sudan		
DK	Denmark	LK	Sri Lanka	SE	Sweden		
EE	Estonia	LR	Liberia	SG	Singapore		

-2-

cube apex and trisects the internal space of the cube corner element. In conventional cube corner elements which have an equilateral base triangle, the optical axis of the cube corner element is perpendicular to the plane which contains the base triangle. In operation, light incident on the base of the cube corner element is reflected from
5 each of the three lateral faces of the element and is redirected toward the light source. Retroreflective sheeting generally incorporates a structured surface including at least one array of cube corner reflective elements to enhance the visibility of an object. When compared with beaded sheeting, cube corner retroreflective sheeting exhibits relatively greater brightness in response to light
10 incident at relatively low entrance angles, for example, near normal light. However, cube corner retroreflective sheeting also exhibits relatively poor rotational symmetry performance at high entrance angles. In addition, cube corner retroreflective sheeting is typically stiffer than beaded sheeting because the cube corner elements are usually all interconnected.

15 The optics of cube corner retroreflective sheetings can be designed to exhibit optimal performance at a specific orientation. This can be accomplished by forming the cube corner elements of the retroreflective sheeting such that their optical axes are canted relative to an axis perpendicular to the base plane of the sheeting. U.S. Patent 4,588,258, issued to Hoopman on May 13, 1986 ('258 Patent), the teachings
20 of which are incorporated by reference herein, discloses retroreflective sheeting which employs optics having canted cube corner elements which form opposing matched pairs. The sheeting disclosed in the '258 Patent exhibits a primary plane of improved retroreflective performance at high entrance angles, identified as the x-plane in the '258 Patent, and a secondary plane of improved retroreflective
25 performance at high entrance angles, identified as the y-plane in the '258 Patent. In use, it is recommended that sheeting manufactured with the '258 Patent be oriented such that its principal plane of improved retroreflective performance, for example the x-plane, is coincident with an expected entrance plane. Thus, sheeting in accordance with the '258 Patent has a single preferred orientation. The '258 Patent
30 discloses cube-corner retroreflective articles in which the optical axis of the

-3-

elements in an array of prism element pairs are tilted toward one edge of the elements, when considered from the front surface of the article on which light to be retroreflected images. This tilt direction is herein defined as "positive" type tilt.

In another patent, U.S. Patent 2,380,447, issued to Jungersen on July 31, 1945 ('447 Patent), the teachings of which are incorporated by reference herein, discloses in Figure 15 of the '447 Patent the optical axis of prism pairs tilting away from the common edge.

In another patent, U.S. Patent 5,171,624, issued on December 15, 1992 to Walter, the teachings of which are incorporated herein in its entirety by reference) discloses micropism reflective sheeting in which prism pairs are tilted with respect to one another at an angle of in the range of between about three and ten degrees, prism size of 0.15-0.64 mm (0.006-0.025 inches) (space between apices) and wherein at least one prism side surface is arcuate.

However, a need still exists for a retroreflective structure that provides a more uniform distribution of light.

SUMMARY OF THE INVENTION

The present invention is directed to a retroreflective structure having cube corner retroreflective elements. The structure includes a first array of retroreflective elements oriented in a first direction within a plane and a second array of retroreflective elements oriented in a second direction within the plane, wherein said second direction being about 90° to said first direction. The structure further includes a third array of retroreflective elements oriented in a third direction within the plane, wherein said third direction being about 180° to said first direction and a fourth array of retroreflective elements oriented in a fourth direction being about 270° to said first direction. In one embodiment, the retroreflective structure includes the retroreflective elements having cube corner elements having a pitch between elements in the range of between about 0.0035 and 0.0045 inches (0.088 and 0.114 millimeters) and a negative tilt between prism pairs. In a preferred

embodiment, the retroreflective structure includes a metalized layer on the facet side of the retroreflective elements for specular reflection.

The invention has many advantages including providing a more uniform retroreflection profile than a single or double orientation cube corner prism sheeting.

- 5 The invention is useful for truck conspicuity enhancement marking.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 shows a perspective view of a cube-corner retroreflective element in a retroreflective structure.

- 10 Figures 2, 3 and 4 show side elevational views of the lateral faces of the cube-corner retroreflective element.

Figure 5 shows a plan view of a retroreflective sheeting with an array of cube-corner elements as shown in Figures 1, 2, 3 and 4.

Figure 6 shows a sectional view taken along line 6-6 of Figure 5.

- 15 Figure 7 shows a plan view of a retroreflective sheeting having cube corner retroreflective elements rotated about the optical axis at 0, 90, 180 and 270 degree orientations respective to the casting direction.

- Figure 8 shows a plot of the X and Y profiles of a diffraction pattern generated by an array of corner cubes having a pitch of 0.004 inches (0.101 millimeters) and a tilt of -3 degrees that is illuminated by a light beam with a center
20 wavelength of 550 nm at a range of observation angles between -2 and 2 degrees.

Figure 9 shows a plot of a corresponding contour map constructed from a set of diffraction patterns, which are produced by a set of illumination angles (SIA) also known as entrance angles.

- 25 Figure 10 shows a plot of SIA's at 0 and 0.33 degrees versus orientation angles for cube corner arrays having pitches of 2, 2.5, 3, 3.5, 4, 4.5, 5, 5.5 and 6 mils (0.05, 0.063, 0.076, 0.089, 0.101, 0.114, 0.127, 0.14 and 0.152 millimeters).

Figure 11 shows a plot of curves that represents SIA's at 0.33 degrees in 0° direction versus beta 2 entrance angles, for corner cube arrays having pitches of 3.5, 3.7, 3.9, 4.0 and 4.3 mils (0.089, 0.094, 0.099, 0.101 and 0.109 millimeters).

-5-

Figure 12 shows a plot of curves that represents SIA's at 0.33 degrees in 90° direction versus beta 2 entrance angles for corner cube arrays having pitches of 3.5, 3.7, 3.9, 4.0 and 4.3 mils (0.089, 0.094, 0.099, 0.101 and 0.109 millimeters).

Figure 13 shows a plot of curves that represents SIA's at 0.33 degrees as a
5 function of orientation angles for cube corner arrays having pitches of 2.5, 3, 3.5, 4, 4.5, 5 and 5.5 mils (0.063, 0.076, 0.089, 0.101, 0.114, 0.127 and 0.14 millimeters).

Figure 14 shows a plot of curves that represents SIA's at 0.33 degrees in 0° direction versus beta 2 entrance angles for corner cube arrays with tilt angles of -7, -5, -3, 0, 3, 5 and 7 degrees having pitches of 0.0035 inches (0.089 millimeters).

10 Figure 15 shows a plot of curves that represents SIA's at 0.33 degrees in the 90° direction versus beta 2 entrance angles for corner cube arrays with tilt angles of -7, -5, -3, 0, 3, 5 and 7 degrees having pitches of 0.0035 inches (0.089 millimeters).

DETAILED DESCRIPTION OF THE INVENTION

The foregoing and other objects, features and advantages of the invention
15 will be apparent from the following more particular description of preferred embodiments of the invention, as illustrated in the accompanying drawings in which like reference characters refer to the same parts throughout the different views. The drawings are not necessarily to scale, emphasis instead being placed upon illustrating the principles of the invention. It will be understood that the particular
20 embodiments of the invention are shown by way of illustration and not as limitations of the invention. The principal features of this invention can be employed in various embodiments without departing from the scope of the invention. All percentages and parts are by weight unless otherwise indicated.

A cube-corner retroreflective element useful in a retroreflective article of the
25 invention is shown in perspective view in Figure 1 and in side elevation views in Figures 2, 3 and 4. As shown, element 10 has three mutually perpendicular lateral faces 12, 14, 16 which meet at apex 18. Base edges 20 of lateral faces 12, 14, 16 are linear and lie in a single plane, that is, base plane 22 of element 10. Element 10 also has a central or optical axis 24, which is a trisector of the internal angle defined by

the lateral faces 12, 14, 16 and which is tilted with respect to a line 26 perpendicular to the base plane 22. Retroreflection occurs when light incident on the base plane 22 of the element is internally reflected by one of the three lateral faces to a second face, then to a third face, and then back through the base toward the source of light.

5 In retroreflective articles, a cube-corner element as shown in Figures 1, 2, 3 and 4 is generally used with at least one other cube-corner element as part of a matched pair, and commonly is used with an array of such elements. The other cube-corner elements, such as they might appear in an array of elements, are shown in plan view of Figure 5 which shows the back of a representative retroreflective
10 article 28. The elements are joined together, for example, by being formed as a part of a single integral sheet material or by being attached at base plane 22 to film 36.

Figure 6 shows in a section view a portion of the retroreflective article pictured in Figure 5 and shows film 36 of a material, such as a polymeric film, connecting the elements 39a, 39b together. Because base edges 20 of retroreflective
15 element 10 are linear and in a common plane, an array of such elements is defined by intersecting sets of grooves. Referring to Figure 5, element 10 is defined by three V-shaped grooves 30, 32, 34 which are each one member of three sets of grooves which cross the array in an intersecting pattern to form matched pairs of prism elements. Matched pair of prisms 37a, 37b has a height (h) dimension and a length
20 (l) dimension. In a preferred embodiment with a -3° tilt, the height dimension has a range of between about 0.0035 and 0.0045 inches (0.088 and 0.114 millimeters). The length dimension has a range of between about 0.0032 and 0.0043 inches (0.812 and 0.109 millimeters).

As shown in Figure 6, light ray (R) from light source (L) is incident on and
25 passes through film 36 to retroreflective element 10 where it is internally reflected and returns through film 36. The matched pair of retroreflective elements 10 has center line 38 that is parallel with lines 26. The shown match pair has a negative tilt from center line 38 as indicated by angle α between optical axis 24 and line 26. The optical axis 24 diverges from center line 38 in the direction of light source L.
30 Conversely, for a positive tilt matched pair, the optical axis converges with the

-7-

center line in the direction toward the light source. In one embodiment, the tilt can range from about -7° to 7° . In a preferred embodiment, the tilt is about -3° . The matched prisms can have a space (s) between the prisms. In one embodiment, the space has a length of between about 0.00002 and 0.004 inches (0.0005 and 0.102 millimeters).

Generally, the prisms are made by forming a master on a flat surface of a metal plate or other suitable material. To form the cube corners, three series of parallel equidistance intersecting V-shaped grooves 60 degrees apart are inscribed in the flat plate. The female replicant die is then used to process the desired cube-corner array into a rigid flat plastic surface.

When the groove angle is 70 degrees, 31 minutes, 43.6 seconds, the angle formed by the intersection of two cube faces (the dihedral angle) is 90 degrees and the incident light is reflected back to the source. For automobile headlight reflectors, the dihedral angle is changed so that the incidental light is reflected non-orthogonally towards the driver instead of the source.

The efficiency of a retroreflective structure is a measure of the amount of incidental light returned within a cone diverging from the axis of retroreflection. Distortion of the prismatic structure adversely affects the efficiency.

Further details concerning the structures and operation of cube-corner microprisms can be found in U.S. Patent 3,684,348, issued to Rowland on August 15, 1972, the teachings of which are incorporated by reference herein. A method for making retroreflective sheeting is also disclosed in U.S. Patent 3,689,346, issued to Rowland on September 5, 1972, the teachings of which are incorporated by reference herein. The disclosed method is for forming cube-corner microprisms in a cooperatively configured mold. The prisms are bonded to sheeting which is applied thereover to provide a composite structure in which the cube-corner formations project from one surface of the sheeting. The preferred materials for forming the sheetings can be any transparent polymer film. Polycarbonate, polyester, polyvinyl chloride, polyurethane are most commonly used.

Figure 7 shows a plan view of retroreflective sheeting 40 having cube corner retroreflective elements rotated about the optical axis at 0, 90, 180 and 270 degree orientations respective to a casting or run direction. Retroreflective sheeting 40 has first array 42 of retroreflective elements 41 oriented in a first direction. First array
5 42 can be in the form of a strip. In one embodiment, first direction is the same as the run direction, which is the direction the film is processed continuously through the manufacturing equipment, also known as the web direction. Second array 44 of retroreflective elements 41 abuts first array 42. Second array 44 has an orientation in a second direction, which is different than the first direction. In one embodiment,
10 second direction is at 90 degrees to first direction. Third array 46 of retroreflective elements abuts second array 44. Third array 46 has an orientation in a third direction which is different than the first direction and second direction. In one embodiment, third direction is at 180 degrees to first direction. Fourth array 48 of retroreflective elements 41 abuts first array 42. Fourth array 48 has an orientation in
15 a fourth direction which is different than the first direction, second direction and third direction. In one embodiment, fourth direction is at 270 degree to first direction.

Due to problems when forming the mold for the cube-corner retroreflective prisms, the arrays are not fully symmetrical. For example, the V-shaped grooves
20 may be slightly different because of temperature at the time of cutting or of a change in the sharpness of the cutting blades. This non-symmetry results in a non-symmetrical pattern at 0° and 180° and at 90° and 270° and at orientation angles in between.

Two factors or specifications of corner cubes (or prismatic sheets) affect
25 their performance mostly. One factor is the single corner cube size on a prismatic sheet, which is described in terms of the pitch of the corner cube. There can be three different pitches in three directions for a prismatic sheet. Each one of them represents a cutting spacing in the corresponding direction. For a regular prismatic material, these three directions form sixty degree angles among any two of them.
30 Thus, one pitch is usually chosen as the main pitch to represent the corner cube size

in most cases. The pitch is shown in Figure 5 as dimension (h) for matched pair of prisms 37a, 37b. The corner cube pitch is small and ranges from about 0.001 to 0.01 inches (0.025 and 0.25 millimeters). In one embodiment, the pitch ranges from between about 0.002 and 0.006 inches (0.05 and 0.15 millimeters). In a preferred
5 embodiment, the pitch ranges from between about 0.0035 and 0.0045 inches (0.088 and 0.114 millimeters). It generates a diffraction pattern in a far field when it is illuminated by an incoming light beam. The diffraction effect influences the performance of the prismatic sheet when measuring photometric data at specified observation and entrance angles. The observation angle is the angle between the
10 incidence (entrance) axis and observation axis. Incidence (entrance) axis is the axis defined by the path of incident light from a light source. The observation axis is the axis defined by the path of retroreflected light from the point of incidence on an article to an observation point. The entrance angle is the angle between the reference axis, which is the line normal to the retroreflective article at the point
15 where light is incident thereto, and the incident axis.

The second factor that affects performance is the direction of the corner cube optical axis which is described by the tilt angles. Two angles are needed to define the optical axis. One angle is defined as an angle formed between the optical axis and the main pitch direction (or machine direction of a prismatic sheet casting
20 process) that is named the X direction. This angle is called the tilt angle. The second is defined as an angle by which a plane containing the optical axis and the actual pitch direction is rotated with respect to the X direction. In most design cases of corner cubes or prismatic materials, the second angle is selected to be zero so that it is sufficient to utilize a tilt angle to describe its optical direction. The tilt angle is
25 usually categorized as positive and negative tilts.

The diffraction pattern that is the returned light pattern by a prismatic material at a far field can be obtained by a photometric measurement of the prismatic material in a test step and can usually be represented by a data table and a contour map. It can also be obtained in the design step by a theoretical calculation of corner
30 cubes with given specifications. The results can be represented as a data table

similar like the measured one, a three dimensional plot, X and Y profiles, and a contour map as the same as a photometric one. Figure 8 shows X, Y profiles and Figure 9 shows a corresponding contour map.

An optimum of prism configuration, in combination with the multiple arrays,
5 can be designed by calculating the diffraction patterns of corner cubes with different pitches and tilts. A corner cube design is optimized in terms of SIA at 0.33° observation angle at 0 and 90 degrees of orientation angles versus entrance angles. The two parameters in this optimization are pitch and tilt angle. Such a retroreflective structure when illuminated with a CIE Standard illuminant A and
10 measured as recommended by CIE Publication No. 54 (1982), the teachings of which are incorporated herein by reference, and having a white sheeting with a pitch of between about 0.0035 and 0.0045 inches (0.088 and 0.114 millimeters), can have a coefficient of retroreflection of at least 450 candelas/lux/m² at an observation angle of 0.33° and entrance angles of β_1 equal to 0° and of β_2 equal to 5° . For β_1 equal to
15 0° and β_2 equal to 30° , the coefficient of retroreflection can be at least 200 candelas/lux/m². For β_1 equal to 0° and β_2 equal to 40° , the coefficient of retroreflection can be at least 90 candelas/lux/m². For β_1 equal to 0° and β_2 equal to 60° , the coefficient of retroreflection can be at least 16 candelas/lux/m².

Similarly, for yellow sheeting, the coefficient of retroreflection at an
20 observation angle of 0.33° and entrance angles of β_1 equal to 0° and β_2 equal to 5° is at least 300 candelas/lux/m². For β_1 equal to 0° and β_2 equal to 30° , the coefficient is at least 130 candelas/lux/m². For β_1 equal to 0° and β_2 equal to 40° , the coefficient is at least 75 candelas/lux/m². For β_1 equal to 0° and β_2 equal to 60° , the coefficient is at least 10 candelas/lux/m².

25 The color of the sheeting measured with a spectrophotometer in accordance with the provisions of CIE Document No. 15 (1971), the teachings of which are incorporated herein by reference, and illuminated with CIE Standard illuminant D65 at angle of 45° to the normal and viewed along the normal ($45^\circ/0^\circ$ geometry) the color of the material is located in a region defined by the chromaticity coordinates
30 and comply with the luminance factor β . For the color white, the chromaticity

coordinates are coordinate 1, $x=0.300$, $y=0.270$; coordinate 2, $x=0.385$, $y=0.355$; coordinate 3, $x=0.345$, $y=0.395$; and coordinate 4, $x=0.260$, $y=0.310$. The luminance factor is greater than or equal to 0.25. For the color yellow, the chromaticity coordinates are coordinate 1, $x=0.545$, $y=0.454$; coordinate 2, $x=0.487$, $y=0.423$; coordinate 3, $x=0.427$, $y=0.483$; and coordinate 4, $x=0.465$, $y=0.534$. The luminance factor is greater than or equal to 0.16.

Alternatively, the color can be measured by the CIE Standard illuminant A at entrance angle $\beta_1=\beta_2=0^\circ$, or if this produces colorless surface reflection, angle $\beta_1=0^\circ$ and $\beta_2=+5^\circ$, and is measured at an observation angle of $\alpha=0.33^\circ$. For the color white, the chromaticity coordinates are coordinate 1, $x=0.373$, $y=0.402$; coordinate 2, $x=0.417$, $y=0.359$; coordinate 3, $x=0.450$, $y=0.513$; and coordinate 4, $x=0.548$, $y=0.414$. For the color yellow, the chromaticity coordinates are coordinate 1, $x=0.585$, $y=0.385$; coordinate 2, $x=0.610$, $y=0.390$; coordinate 3, $x=0.520$, $y=0.480$; and coordinate 4, $x=0.505$, $y=0.465$.

Figure 10 shows a set of curves, which are the functions of SIA at 0 and SIA at 0.33 observation angles versus orientation angles from 0 to 180 degrees while the entrance angle is 5 degrees ($\beta_1=+5$ and $\beta_2=0$). The parameter of the curves is the corner cube pitch at 0.002, 0.0025, 0.003, 0.0035, 0.004, 0.0045, 0.005, 0.0055 and 0.006 inches (0.05, 0.063, 0.076, 0.089, 0.101, 0.114, 0.127, 0.14 and 0.152 millimeters). The theoretical calculation allows one to obtain the SIA at 0 degree, or the center value of the diffraction pattern of corner cubes. As can be seen, a small range from 0.0035 to 0.0045 inches (0.088 and 0.114 millimeters) produces much better performance (a flatter but higher profile over angles -30 to 180 degrees) at 0.33 degree observation angle.

The optimized design for a cube corner retroreflector specifically about the 0.33 degree observation angle appears to be approximately 0.0037 inches (0.094 millimeters) in length by 0.0035 inches (0.089 millimeters) in height pitch at a tilt of approximately -3 degrees. This is preferably designed for a metalized products. These dimensions characterize the specifics of the cube corner designs which show

an improved photometric performance at the 0.33 degree observation angle along with increased performance at entrance angles.

The performance is not uniform at the orientation angles. The typical application is at 0 degrees and 90 degrees respective to the run direction of the material. These geometries can also be extended to 180 and 270 degrees, respectively.

In order to provide a more uniform sheeting, retroreflective structure utilizes strips or arrays of prisms at these specific orientations. The arrays are oriented such that a smoothing action occurs yielding premium performance at each of these geometries. Although two orientations provide an improvement over one orientation, to eliminate or smooth any manufacturing errors, the four orientations provide the preferred effect.

The parquet of arrays can be formed by a number of methods with differing level of accuracies dependent upon method utilized. In one embodiment, an electroform or a casting mold can be machined into pieces, then reassembled to the desired arrangement of cubes. Other practices include mastering of individual pieces or arrays of individual pieces. In one embodiment, the arrays have a width of between about 0.25 and 0.5 inches (6.35 and 12.7 millimeters). Preferably, the width is about 0.33 inches (8.38 millimeters). The parqueting technique can run either perpendicular or parallel to the run direction of the sheeting. Any angle in between can be utilized to provide substantially the same effect.

The sheeting is preferably coated with a specular reflective coating on the prism facets to enhance retroreflective performance and to aid in manufacture of a thin product. The coatings can be aluminum, silver, gold or similar which aid in similar desired properties.

The spacing (s) in between the cubes on one or more edges, as shown in Figure 6, is for the purpose of enhancing specular reflection of the sheeting. The space can be either flat or of a specific optical shape. The improvement in the luminance factor can be substantial. To enhance the specular reflection from this surface even further, the surface can be etched, lapped, abraded, bead blasted, laser

written, compression molded, or any other type of material removal or deforming process which creates a non-uniform surface. A buffed flat surface can double the luminance value of an aluminum metalized part with only a ten percent loss in retroreflected brightness values. The buffing adds textures to the flat surface. The spacing can be created in the mastering process or in subsequent processes from the lifts of the master.

Figures 11 and 12 represent two sets of curves, which are the functions of SIA at 0.33 observation angles versus entrance angles at beta 2 direction from 5 to 60 degrees. The set of curves shown in Figure 11 is for a zero degree orientation angle and the curves in Figure 12 are ninety degrees. The pitches for the comparison are chosen to cover a range from 0.0035 to 0.0043 inches (0.89 and 0.109 millimeters). In these two figures, a -3 degrees tilt is selected for all pitches.

A comparison of the SIA's at 0.33 degree at all orientation angles for pitches 0.0025, 0.003, 0.0035, 0.004, 0.0045, 0.005 and 0.0055 inches (0.063, 0.076, 0.089, 0.101, 0.114, 0.127 and 0.14 millimeters) is shown in Figure 13. Figure 13 shows that the pitches from 0.0035 to 0.004 inches (0.088 to 0.101 millimeters) can produce a much better performance among the range 0.0025-0.0055 inches (0.063-0.14 millimeters). The 0.0035 and 0.004 inch (0.088 and 0.101) prisms provide a greater average and flatter retroreflectivity profile over a 360° orientation angle.

Two sets of curves in Figures 14 and 15 disclose the variations of SIA at 0.33 observation angle as the entrance angle changes from 5 to 60 degrees at beta 2 direction for a representative pitch size of 0.0035 inches (0.089 millimeters). The tilt angles in the range -7 degrees to 7 degrees are used as parameters to compare the SIA's at 0.33 degrees. Negative tilts give higher SIA in the first group of curves, which are at 0 degree orientation angle. Minus 3 degree tilt produces the highest SIA's. The second group shown in Figure 15 at a 90 degree orientation angle provides higher SIA on positive tiles. Three and five degree tilts provide the favorable performances along the beta 2 direction.

-14-

CLAIMS

What is claimed is:

1. A retroreflective structure having cube corner retroreflective elements comprising:
 - 5 a) a first array of retroreflective elements oriented in a first direction within a plane;
 - b) a second array of retroreflective elements oriented in a second direction within the plane, wherein said second direction being about 90° to said first direction;
 - 10 c) a third array of retroreflective elements oriented in a third direction within the plane, wherein said third direction being about 180° to said first direction; and
 - d) a fourth array of retroreflective elements oriented in a fourth direction being about 270° to said first direction.
- 15 2. The retroreflective structure of Claim 1 wherein the retroreflective elements comprise cube corner elements having a pitch between elements in the range of between about 0.0035 and 0.0045 inches.
3. The retroreflective structure of Claim 1 wherein the retroreflective elements include a metalized layer on the facet side of the elements for specular
20 reflection.
4. The retroreflective structure of Claim 1 wherein the first direction is the casting direction.
5. The retroreflective structure of Claim 1 wherein the structure includes white sheeting having a coefficient of retroreflection of at least 450

-15-

candelas/lux/m² at an observation angle of 0.33° and entrance angles of β_1 equal to zero and of β_2 equal to 5°.

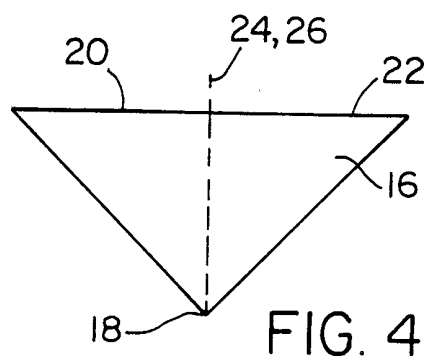
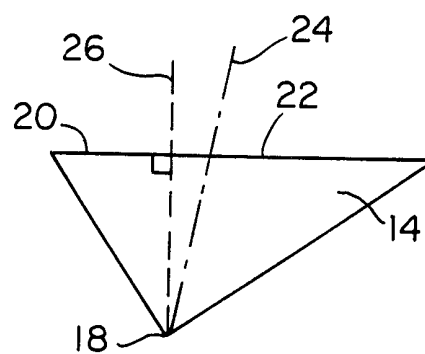
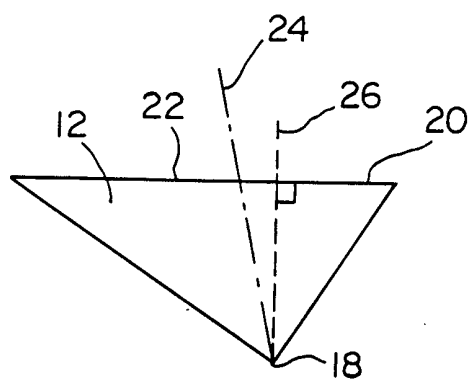
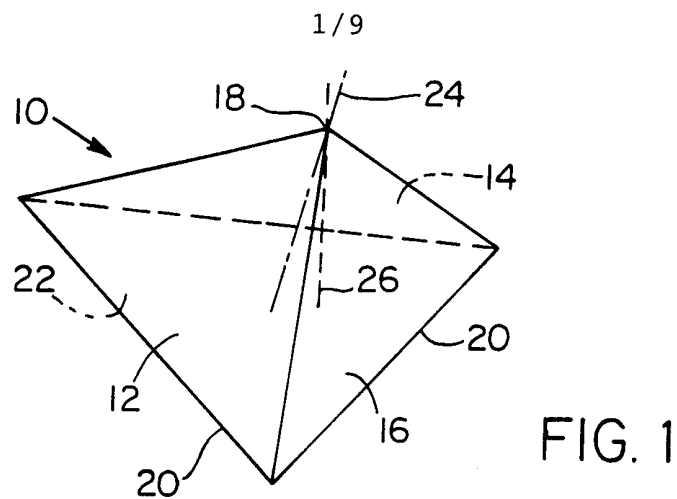
6. The retroreflective structure of Claim 1 wherein the structure includes white sheeting having a coefficient of retroreflection of at least 200
5 candelas/lux/m² at an observation angle of 0.33° and entrance angles of β_1 equal to zero and of β_2 equal to 30°.
7. The retroreflective structure of Claim 1 wherein the structure includes white sheeting having a coefficient of retroreflection of at least 90 candelas/lux/m²
10 at an observation angle of 0.33° and entrance angles of β_1 equal to zero and of β_2 equal to 40°.
8. The retroreflective structure of Claim 1 wherein the structure includes white sheeting having a coefficient of retroreflection of at least 16 candelas/lux/m²
at an observation angle of 0.33° and entrance angles of β_1 equal to zero and of β_2 equal to 60°.
- 15 9. The retroreflective structure of Claim 1 wherein the retroreflective cube corner elements include a separation between elements on one or more edges by a spacing in the range of between about 0.00002 and 0.004 inches.
10. The retroreflective structure of Claim 9 wherein the spacing between the prisms includes a textured surface.
- 20 11. The retroreflective structure of Claim 1 wherein the retroreflective cube corner elements in a height in the range of between about 0.002 and 0.02 inches.

-16-

12. The retroreflective structure of Claim 1 wherein the cube corner elements are tilted at a negative angle.
13. The retroreflective structure of Claim 1 wherein the cube corner elements are tilted within the range of -7 degrees to +7 degrees.
- 5 14. The retroreflective structure of Claim 1 wherein the cube corner elements are tilted at about -3 degrees.
15. A retroreflective structure comprising an array of retroreflective cube-corner elements having a pitch between elements in the range of between about 0.0035 and 0.0045 inches.
- 10 16. The retroreflective structure of Claim 15 wherein the retroreflective elements include a metalized layer on the facet side of the elements.
17. A retroreflective structure having cube-corner retroreflective elements comprising:
 - 15 a) a first array of retroreflective elements oriented in a first direction within a plane;
 - b) a second array of retroreflective elements oriented in a second direction within the plane, wherein said second direction being about 90° to said first direction;
 - c) a third array of retroreflective elements oriented in a third direction 20 within the plane, wherein said third direction being about 180° to said first direction; and
 - d) a fourth array of retroreflective elements oriented in a fourth direction being about 270° to said first direction, wherein the retroreflective elements are cube-corner elements having a pitch in the range of 25 between about 0.0035 and 0.0045 inches and a negative tilt.

-17-

18. The retroreflective structure of Claim 17 wherein the retroreflective elements include a metalized layer on the facet side of the elements for specular reflection.
19. A retroreflective structure having cube-corner retroreflective elements comprising:
- 5 a) a first array of retroreflective elements oriented in a first direction within a plane; and
- b) a second array of retroreflective elements oriented in a second direction within the plane, wherein said second direction being about
- 10 90° to said first direction, wherein the retroreflective elements are cube-corner elements having a pitch in the range of between about 0.0035 and 0.0045 inches and a negative tilt and includes a metalized layer on the facet side for the elements for specular reflection.



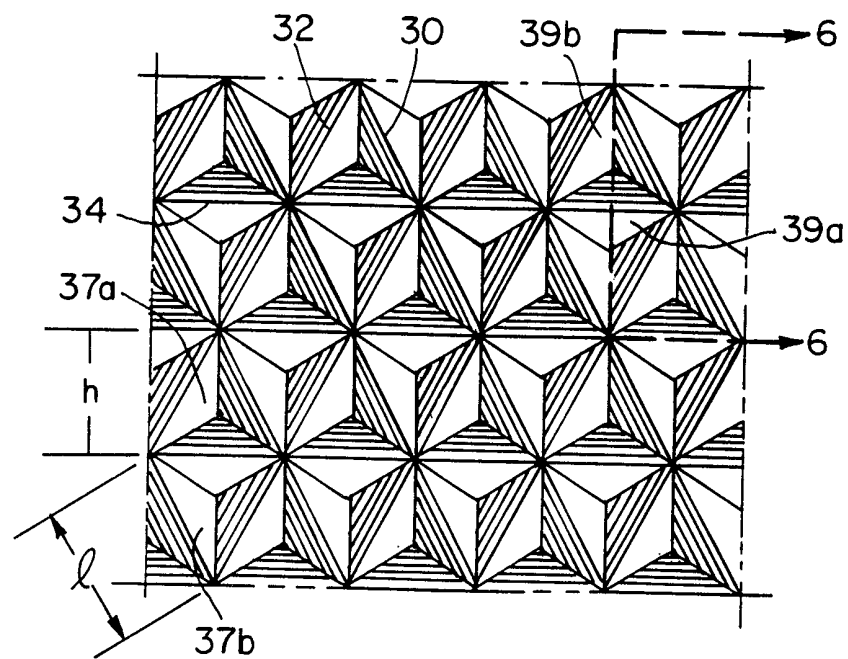


FIG. 5

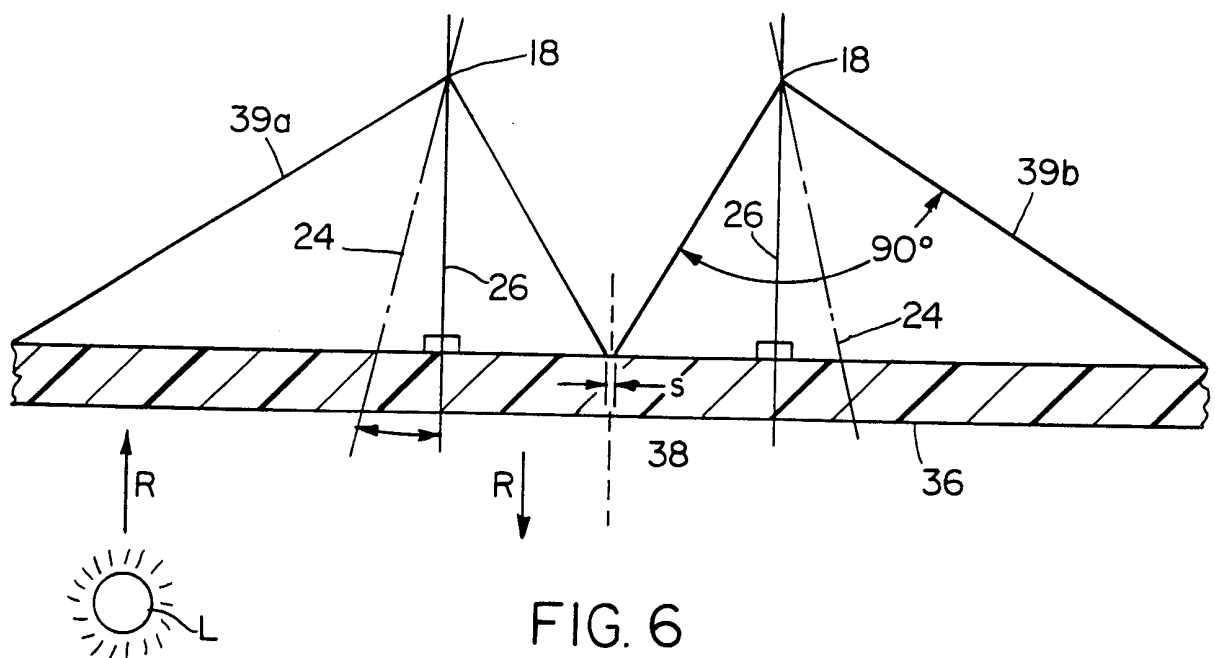


FIG. 6

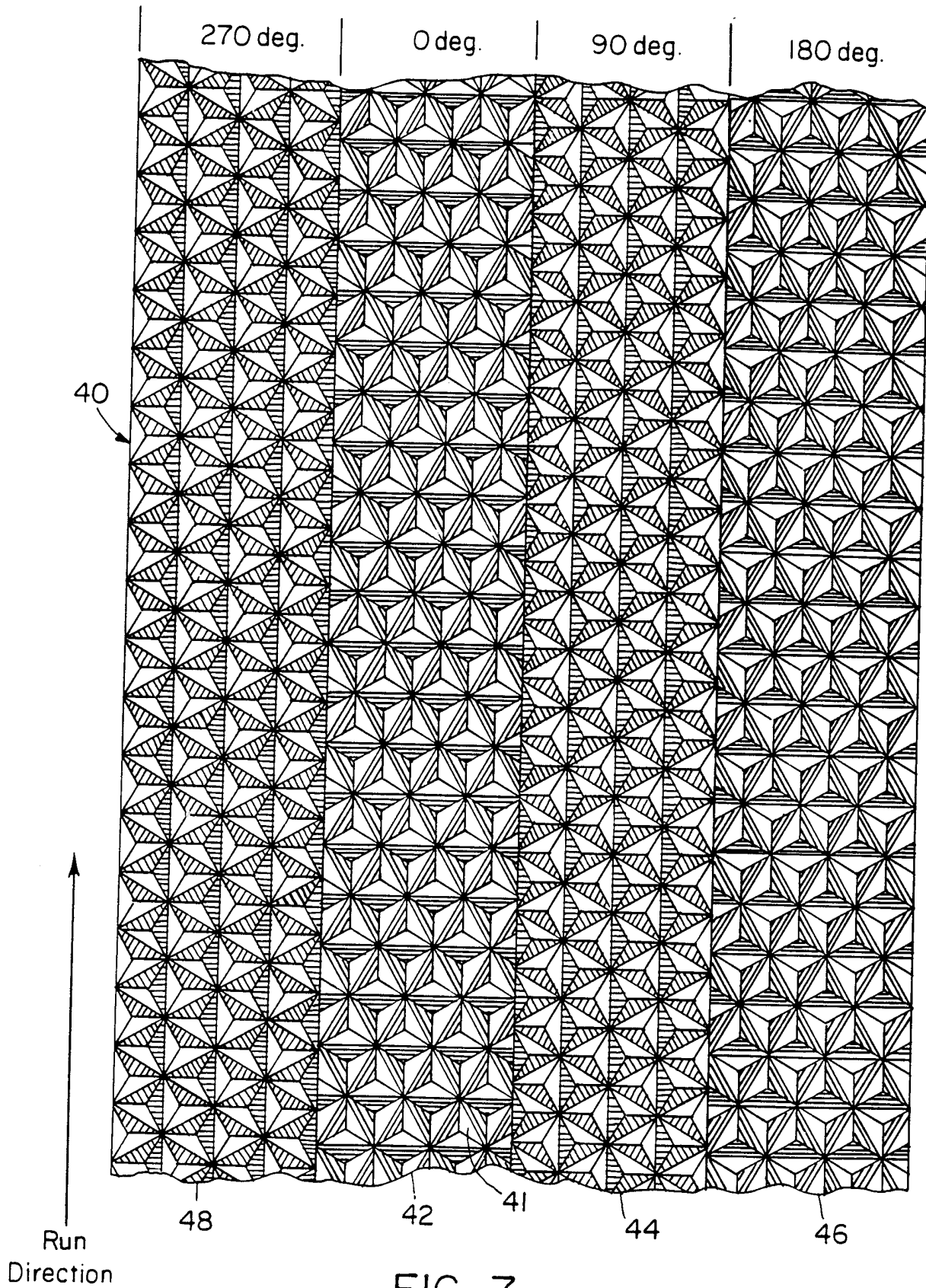


FIG. 7

SUBSTITUTE SHEET (RULE 26)

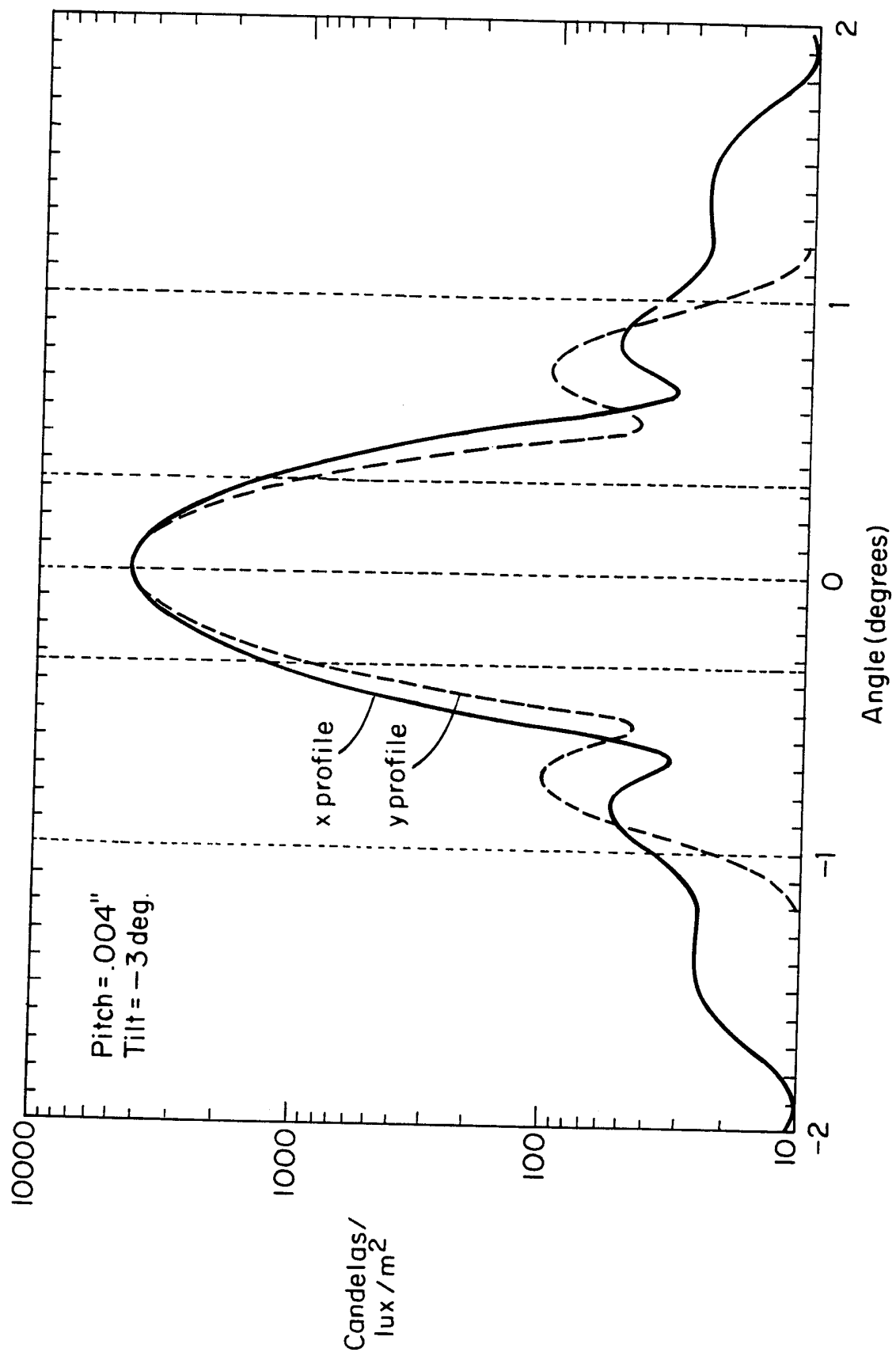


FIG. 8

5/9

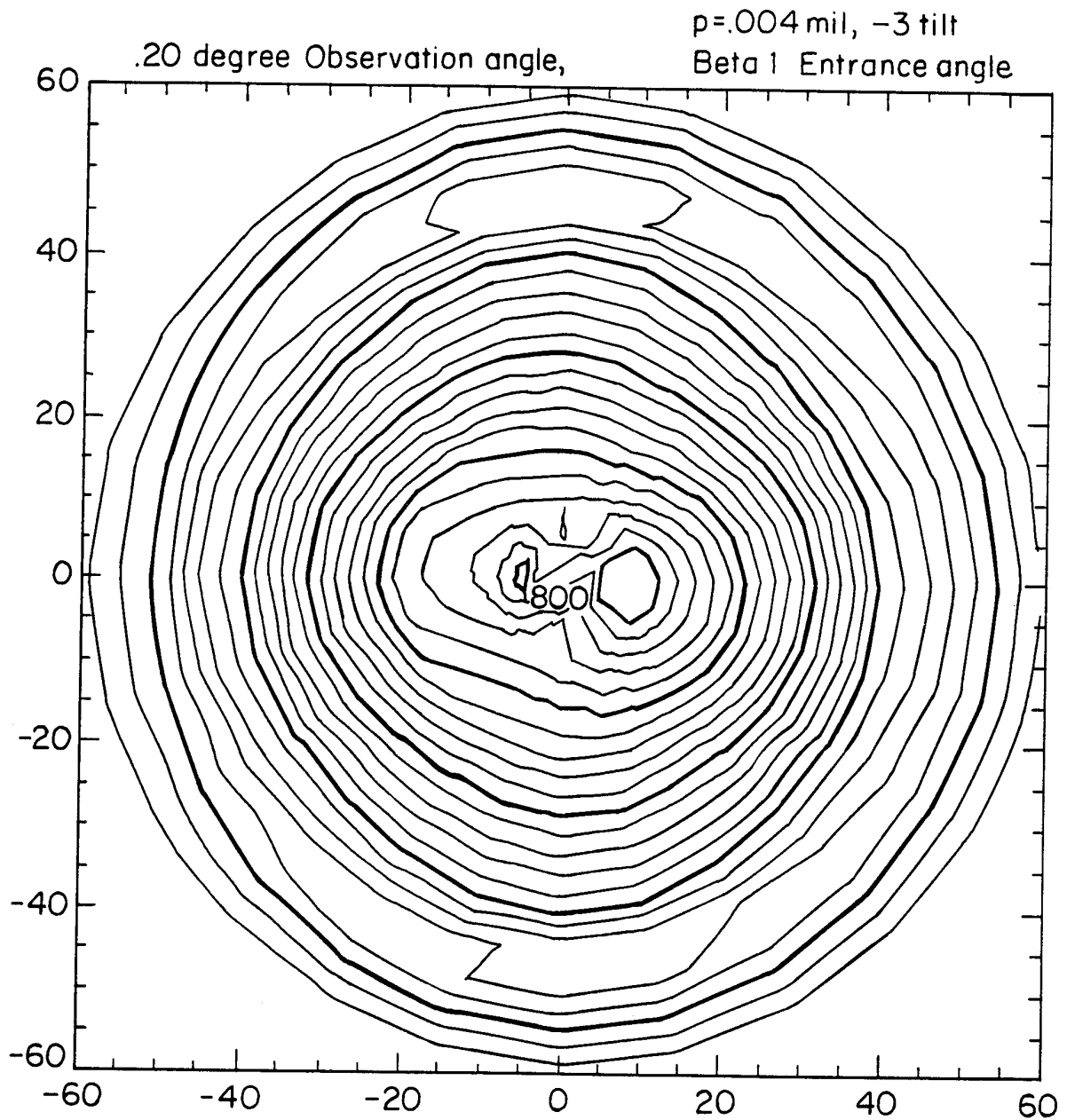
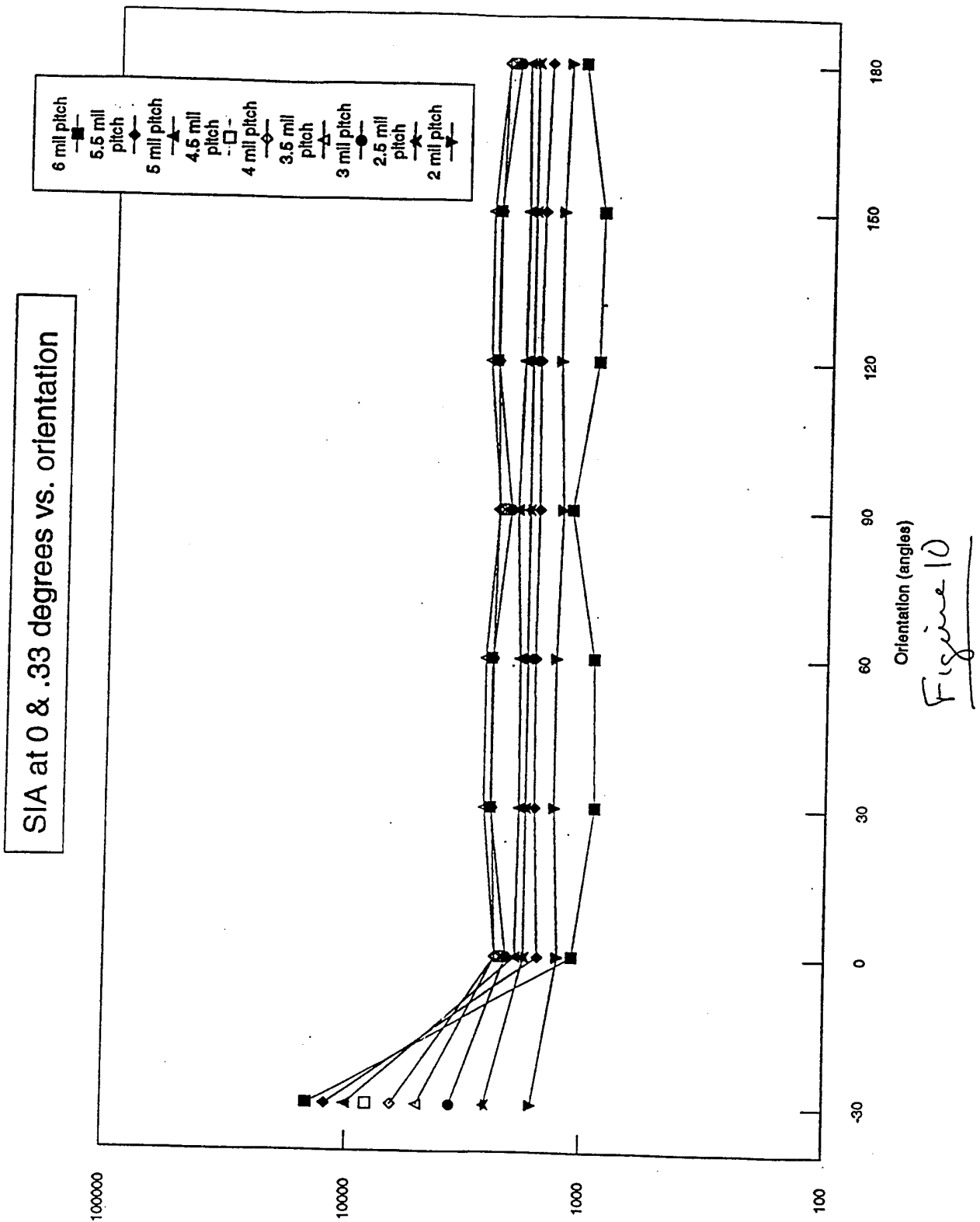
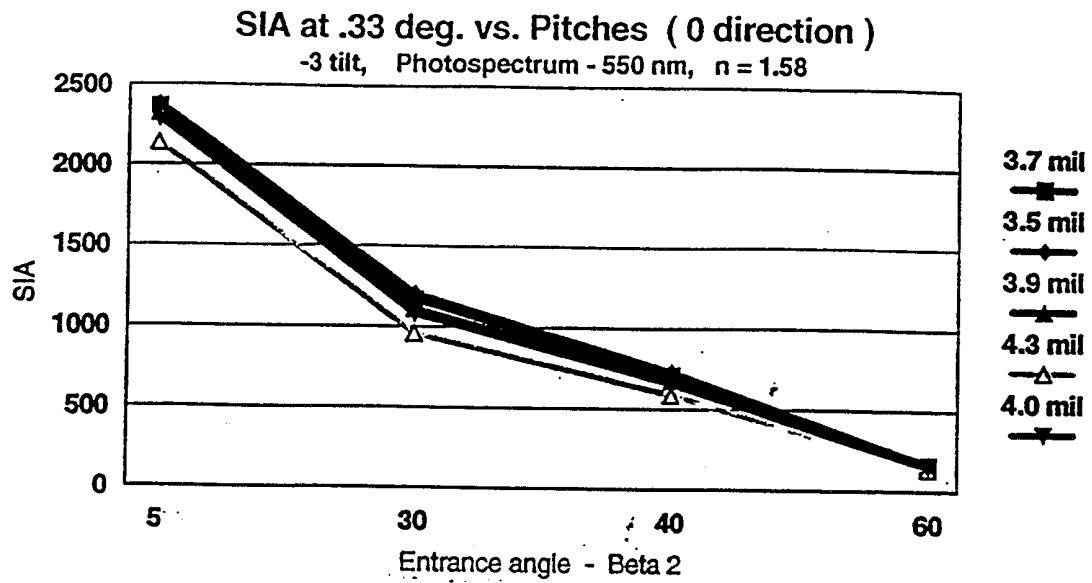
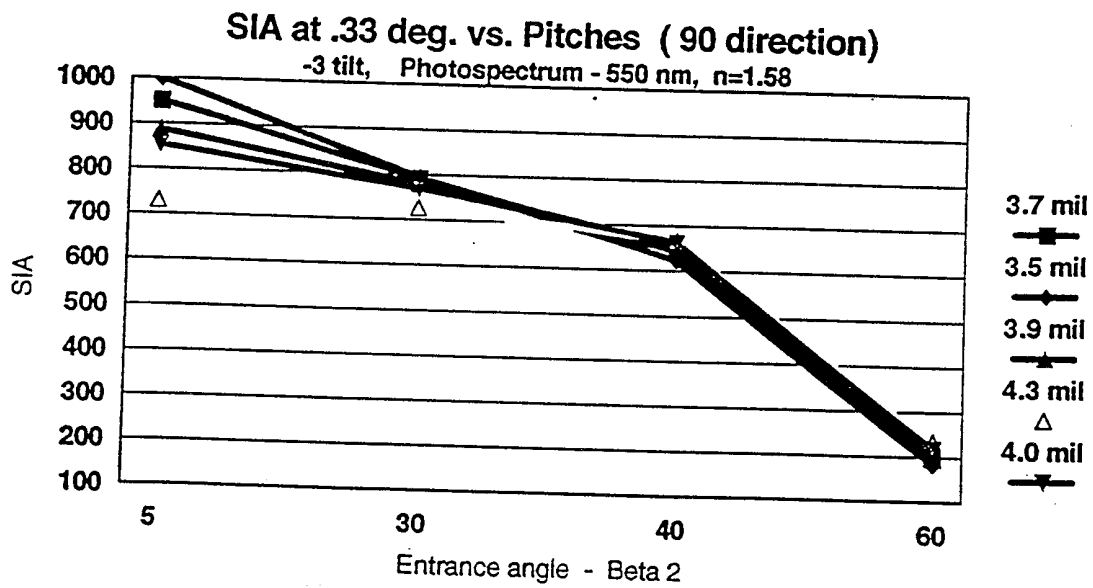


FIG. 9



Figure 11Figure 12

SIA at .33 deg. vs. orientation
 $p = 2.5$ to 5.5 mil

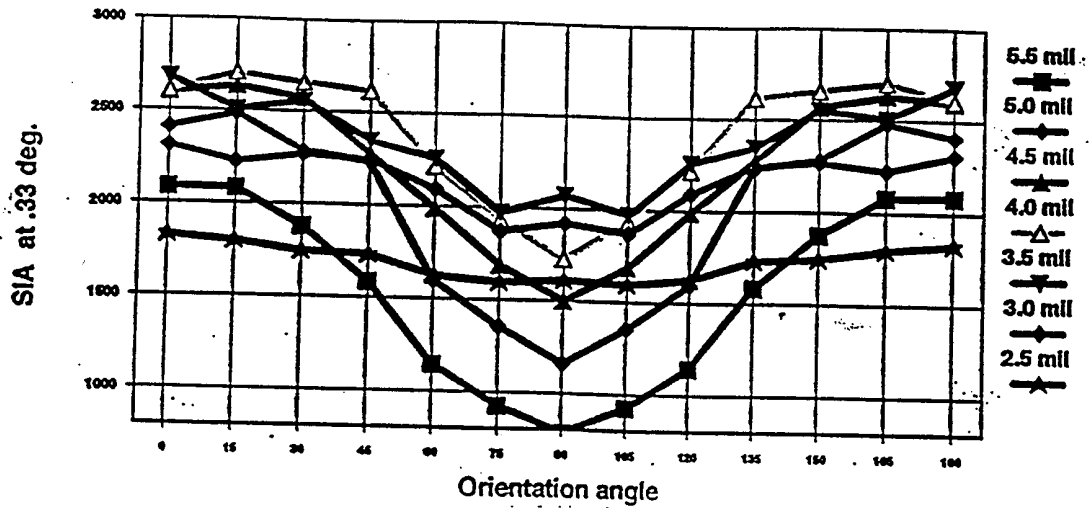


Figure 13

SIA at .33 deg. vs. entrance angles
Orientation angle = 0, pitch = 3.5 mil

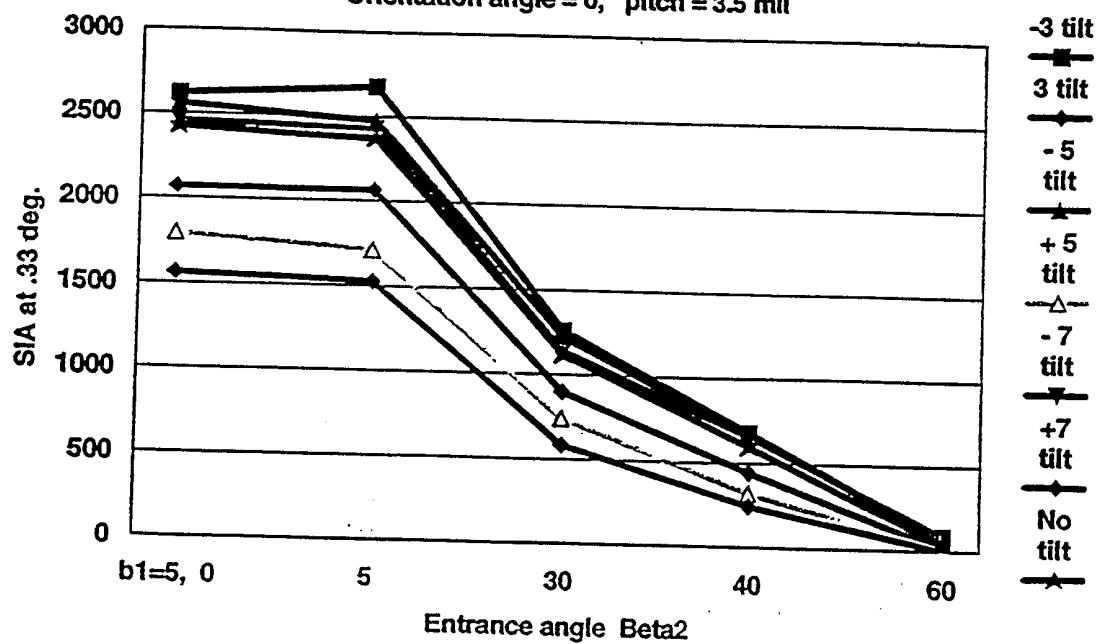


Figure 14

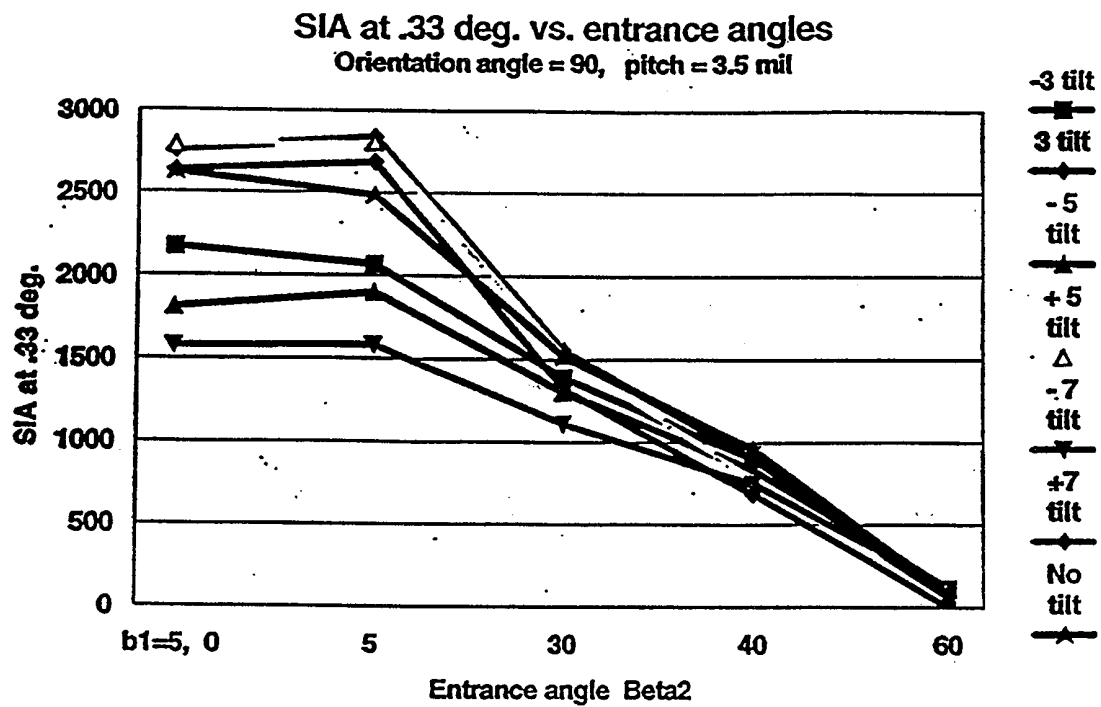


Figure 15.

INTERNATIONAL SEARCH REPORT

Intern: al Application No

PCT/US 98/25138

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 G02B5/124

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)

IPC 6 G02B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	WO 97 26567 A (MINNESOTA MINING & MFG) 24 July 1997 see figure 1 see claims 10-13; figure 3 see page 11, line 16 - line 24 --- -/--	1,3,5-8, 11 2,9, 12-14, 17-19

☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"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

"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

"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.

"&" document member of the same patent family

Date of the actual completion of the international search

23 February 1999

Date of mailing of the international search report

02/03/1999

Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,
Fax: (+31-70) 340-3016

Authorized officer

Ciarrocca, M

INTERNATIONAL SEARCH REPORT

International Application No.

PCT/US 98/25138

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	WO 96 10197 A (REFLEXITE CORP) 4 April 1996 see page 13, line 1 - line 15; figure 13 see page 18, line 9 - line 25; figures 14,19 see page 20, last line - page 21, line 3 see page 22, line 2 - line 5 ---	15,16 2,9, 12-14, 17-19
X A	FR 795 186 A (NEUHAUS JEAN) 6 March 1936 see figure 3 ---	1 17,19
X A	FR 748 391 A (LERAY GUSTAVE) 30 June 1933 see claim 4; figure 4 ---	1,3 17,19
X A	DE 42 40 680 A (GUBELA SEN HANS ERICH) 9 June 1994 see column 3, line 36 - line 44; figure 6 see claims 1,7 ---	1,11 9,17,19
A	WO 92 04647 A (MINNESOTA MINING & MFG) 19 March 1992 see page 8, line 19 - line 25 ---	11-14
A	FR 2 386 059 A (BAYER AG) 27 October 1978 see page 6, line 31 - page 7, line 8; figure 3 ---	9
A	EP 0 390 344 A (MINNESOTA MINING & MFG) 3 October 1990 see page 8, line 40 - line 44; tables 2A,2B see figure 1A ---	9
A	WO 96 30786 A (REFLEXITE CORP) 3 October 1996 see abstract -----	9,10

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/US 98/25138

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 9726567 A	24-07-1997	US 5706132 A AU 1146397 A CA 2242771 A EP 0875008 A	06-01-1998 11-08-1997 24-07-1997 04-11-1998
WO 9610197 A	04-04-1996	US 5565151 A AU 3555095 A EP 0787311 A JP 10506726 T US 5840406 A	15-10-1996 19-04-1996 06-08-1997 30-06-1998 24-11-1998
FR 795186 A	06-03-1936	NONE	
FR 748391 A	30-06-1933	NONE	
DE 4240680 A	09-06-1994	NONE	
WO 9204647 A	19-03-1992	US 5138488 A AT 112067 T AU 652001 B AU 8750191 A CA 2089571 A DE 69104214 D DE 69104214 T DK 548280 T EP 0548280 A ES 2060409 T IE 66898 B JP 6501111 T	11-08-1992 15-10-1994 11-08-1994 30-03-1992 11-03-1992 27-10-1994 13-04-1995 17-10-1994 30-06-1993 16-11-1994 07-02-1996 27-01-1994
FR 2386059 A	27-10-1978	NONE	
EP 0390344 A	03-10-1990	US 5122902 A AT 129077 T AU 616100 B AU 4977590 A CA 2010201 A DE 69022870 D DE 69022870 T JP 2285301 A	16-06-1992 15-10-1995 17-10-1991 04-10-1990 30-09-1990 16-11-1995 23-05-1996 22-11-1990
WO 9630786 A	03-10-1996	NONE	