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(54) Directionally imaged retroreflective sheeting.

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Description

The present invention provides new forms of directionally imaged sheeting, i.e., sheeting that has been provided with images that are viewable only within limited angles of viewing. The invention also provides novel methods for preparing the new sheeting involving controlled laser irradiation of certain forms of retroreflective sheeting, or of other forms of sheeting patterned after retroreflective sheeting ("retroreflective" sheeting reflects light back toward the source of the light, irrespective of the angle at which the light is incident on the sheeting, within rather wide ranges of incident angles).

Background Art

Retroreflective sheeting in which a graphic image or other mark is built into the sheeting has found a number of important uses, particularly as distinctive labels useful to authenticate an article or document. For example, retroreflective sheetings in which legends are printed into the sheeting, as taught in U.S. Pats. 3,154,872; 3,801,183; 4,082,426; and 4,099,838, have found use as validation stickers for vehicle license plates and as security films for driver's licenses, government documents, phonograph records, tape cassettes, and the like.

Galanos, U.S. Pat. 4,200,875 forms directional images in "high gain retroreflective sheeting of the exposed-lens type" (col. 2, lines 3-4) by laser irradiation of the sheeting through a mask or pattern. The noted "high gain retroreflective sheeting" comprises "a plurality of transparent glass microspheres ... that are partially embedded in a binder layer ... and that are partially exposed above the binder layer, ... with a reflective layer ... adjacent to and disposed behind the embedded surface of each of the plurality of transparent glass microspheres" (col. 1, lines 25-32). The "binder layer, such as 12, FIG. 1, is pigmented in carbon black" (col. 1, line 55). When such "high gain retroreflective sheeting" is irradiated while positioned at a specific angle to a laser light beam, an image is formed which "can be seen thereafter with the naked eye if, and only if, the target (sheeting) is again positioned at that same angle" (col. 2, lines 9-11). When "a plurality of different preselected patterns are individually and separately recorded, at different angles, ... then each of the recorded patterns is visible only when viewed at the angle at which it was recorded by the laser light beam radiation on the target" (col. 2, lines 12-18).

Although the Galanos patent states that the sheeting he used is illustrated in Fig. 1, the pigmented under layer 12 would have prevented one from seeing any images except at approximately 90° to the face of the sheeting. However, the "Scotchlite" brand reflective sheetings "High Gain" No. 7610 and No. 7611, which apparently were used, were of substantially different construction. That is, the back hemisphere of each glass microsphere had a specularly reflective layer and its front hemisphere was open, thus permitting directional images to be formed over a wide range of angles.

The Galanos patent does not explain how a directional image is formed in the described retroreflective sheeting target other than to state that the laser preferably is "a high energy one of the Q-switched type having a power (energy?) of one Joule" and that its beam preferably "has a diameter of 5/8 inch and a pulse width of 90 nanoseconds" (col. 3, lines 34-38). The patent points out that the pattern of the image must be smaller than the target, but "that the diameter of the beam 22 as compared to the size of the pattern is immaterial, because even if the laser light beam (radiation) 22 is smaller than the pattern, the laser 21 can be moved in a scanning action" (sentence bridging col. 3 & 4). Galanos says that the directional image is "recorded on the target by structural alteration, i.e., modification of the target material" (col. 4, lines 32 and 51). From a bare reading of the Galanos patent, one skilled in the art would not know what constituent of the retroreflective sheeting material had been structurally altered. Based on our work in making the present invention, a likely explanation for the image formation observed by Galanos is a modification of the glass microspheres, e.g., by a localized devitrification, melting, or erosion of the glass at the back edges of the microspheres where the laser beam is focused.

Some advantages of the imaged sheeting taught in the Galanos patent are that the images are seen within sharply defined angular ranges, which could be used as an identifying characteristic to help assure that the sheeting is genuine; and the images can be formed in an already manufactured retroreflective sheeting. As compared to procedures of the four patents cited in the first paragraph of this "Background Art" section, the Galanos directional images can be formed in an already manufactured retroreflective sheeting, thereby avoiding the need for inventories of specially printed retroreflective sheeting and the need for long process runs to distribute the costs in setting up a printing operation.

However, the directionally imaged sheeting taught in the Galanos patent also has important disadvantages which limit its utility. For example, it is not useful to provide retroreflective images in outdoor environments where it may receive precipitation, because such precipitation can alter the optical relationships in the sheeting and obliterate or greatly reduce a retroreflective image. Furthermore Galanos only provides directionally imaged sheetings having dark coloured binder layers.

Disclosure of Invention

The retroreflective sheeting provided by the present invention is defined in the accompanying Claims 1 to 7. The method of the present invention is defined in the accompanying Claims 8 to 10.

The invention concerns retroreflective sheeting comprising a monolayer of transparent microspheres partially embedded in a light coloured binder layer and a specularly reflective layer covering the back surfaces of the microspheres, and the sheeting contains at least one image which is directional in that it is viewable from the front of the sheeting only across a cone, the angle of which preferably is less than 90°. As in Galanos, the retroreflective sheeting may include one or more additional directional images, each viewable from a different angle. Preferably, the cone across which each authenticating image is viewable does not overlap another cone, and hence the angle of each cone should be less than 60°.

The light coloured binder layer of the present invention is preferably rendered opaque by a light-coloured pigment such as TiO_2 as opposed to Galanos' carbon black, to provide a high-contrast background for messages or pictures which may be superimposed over the reflective sheeting.

The retroreflective sheeting of the invention differs from that apparently produced by Galanos in that each of its directional images is provided by tiny cavities, each cavity opening through the back surface of a microsphere, and substantially every opening is smaller than the depth of the cavity.

One advantage over Galanos which is provided by the present invention is that directional images are formed in sheetings with light-coloured binder layers, contrary to the dark coloured binder layers provided by Galanos. The present invention teaches the discovery, for the first time, that an image can surprisingly be formed in a microlens sheeting wherein the binder layer is light-coloured.

A second advantage is that, as discussed below, directional images may be formed in sheetings having a flat cover film in front of the front surfaces of the microspheres. Such cover films, as taught in U.S. Patent No. 3,190,178 (McKenzie), improve the utility of retroreflective sheetings in outdoor environments where the sheeting is likely to have water deposited thereon, e.g., by rain.

Microscopic examination of typical directionally imaged sheeting of the invention reveals that the wall of each cavity is substantially an ellipsoid, the major axis of which extends orthogonally to the surface of the microsphere. Usually every cavity opening also is smaller than the minor axis of the ellipsoid.

The laser beam we have used to form the described cavities is in the near infrared, having a wavelength on the order of one micrometer. Since the retroreflective sheeting is designed for reflecting visible light, its transparent microspheres are selected to focus a beam of visible light substantially at the reflective layer, in which event an infrared beam would be focused slightly beyond the reflective layer, that is, after being reflected. Hence, the energy of an infrared laser beam may be concentrated inside each microsphere at a point close to the reflective layer, with the heat thus absorbed forming a cavity which opens through the back surface of the microsphere at the axis of the laser beam. Photomicrographs of retroreflective sheeting of the invention show that the cavities are ellipsoidal and that every opening is smaller than the maximum width of the cavity, thus suggesting that the heating is more intense inside the bead than at its surface.

While the transparent microspheres of the retroreflective sheeting used by Galanos are uncovered and hence not suitable in outdoor environments in which they may receive precipitation, the retroreflective sheeting we have used in the invention has a transparent protective film as in U.S. Patent No. 3,190,178. As there taught, the protective film may be sealed to the retroreflective sheeting in a grid pattern. Between narrow sealed areas are relatively broad unsealed areas wherein the front surfaces of the microspheres are optically exposed to an air interface. The sealed areas may form geometric patterns such as hexagons, and within the unsealed areas one or more restricted images may be formed in the practice of the invention. Messages or pictures may be imprinted on the protective film for such purposes as highway direction signs or billboards. While it is likely that the directionally imaged retroreflective sheeting of the invention can be made with uncovered sheeting of the type cited by Galanos, there is little reason to do so because of the fact that almost all retroreflective sheeting is used outdoors.

The directional images of the novel retroreflective sheeting can be used as an identifying characteristic to help assure that the sheeting is authentic. An authenticating directional image can be formed to be visible only at an angle at which the sheeting is not normally viewed, thus not interfering with the normal use of the sheeting. Even after the sheeting has so deteriorated in use that it is no longer retroreflective, the cavities provide an authenticating image that can be viewed from the same angle at which it was formed. By using

...ectional images for authenticating purposes, manufacturers and sellers of quality sheeting cannot be unfairly accused of purveying inferior products.

In preferred retroreflective sheeting of the invention, the transparent microspheres are glass and have an average diameter of approximately 50 micrometers. For such sheeting, the laser exposure is preferably adjusted to form cavities having ellipsodial walls, a major axis (depth) of about 7.5 micrometers, and a minor axis (width) about 2.5 micrometers. A directional image provided by cavities of that size is viewable only across a cone of about 15°. Larger cavities afford larger viewing cones, but there seldom would be any reason for a directional image to be viewable across a cone exceeding 30°. On the other hand, a directional image which was viewable only across a cone of less than 10° might be difficult to locate.

The Drawing

In the drawing

Fig. 1 is an enlarged schematic cross-section of a fragment of directionally imaged retroreflective sheeting of the invention;

Fig. 2 is a photomicrograph at a magnification of about 1000X showing a fragment of a monolayer of transparent glass microspheres of directionally imaged sheeting of the invention; and

Fig. 3 is a photomicrograph at a magnification of about 10,000X of the imaged area of a glass microsphere of the directionally imaged sheeting of Fig. 2.

Best Mode of Carrying Out the Invention

The retroreflective sheeting 10 of Fig. 1 comprises a monolayer of glass microspheres 11 partially embedded in a light-coloured binder layer 12. A specularly reflective layer 14 covers the back surface of each microsphere. In the area 16, the binder layer 12 has been forced into intimate hermetically sealed contact with a transparent protective film 18 as taught in the aforementioned U.S. Patent No. 3,190,178. A low-adhesion carrier web 20 underlies the resin matrix 12.

The retroreflective sheeting 10 is equivalent to the sheeting shown in Figs. 1 and 2 of U.S. Pat. 3,190,178 except that the specularly reflective layer 14 makes only hemispherical contact with each of the microspheres 11 and does not extend between adjacent microspheres. The hermetically sealed areas 16 together form geometric grid patterns such as hexagons or squares as illustrated in Fig. 1 of 3,190,178.

To comment on the schematic nature of Fig. 1, glass microspheres rarely will be of uniform size, and the thicknesses of the layers of the retroreflective sheeting may vary from area to area. The protective film 18 may be in tangential contact with some of the underlying microspheres or not, depending on a host of incidental factors. Each hermetically sealed area 16 (although less than 1 mm in breadth) extends across a large number of the microspheres 11.

The sheeting 10 has been irradiated with a laser beam at an angle of about 45° to the exposed surface of the protective film 18 to form a tiny cavity in each microsphere which has been penetrated by the laser beam. The walls of each cavity are substantially ellipsoidal. The opening 24 of substantially every cavity 22 is smaller than the radial depth of the cavity.

To make the photomicrographs of Figs. 2 and 3, retroreflective sheeting as shown in Fig. 1 was directionally imaged at an angle of about 90° to the exposed surface of the protective film. After removing the protective top film using a razor blade, a room-temperature-curing epoxy resin composition was cured in contact with the exposed microspheres. Then the binder layer was softened by soaking in methyl ethyl ketone and removed, thus exposing the specularly reflective layers of the microspheres. A photomicrograph of that area at 1000X as seen in Fig. 2 shows a cavity at approximately the center of the specularly reflective area of each microsphere. At 10,000X as in Fig. 3, it can be seen that molten glass has flowed out of the cavity and has been deposited around the opening of the cavity.

Example 1

Retroreflective sheeting 10 as illustrated in Fig. 1 (available commercially as 3M high intensity grade reflective sheeting No. 3870 from Minnesota Mining and Manufacturing Company, the assignee of this application) has the following construction:

a monolayer of clear, transparent microspheres 11 having an average diameter of 66 micrometers and a refractive index of about 1.9 embedded to their circumferences in an opaque white polymeric binder layer 12 containing titanium dioxide pigment,

a specularly reflective, vapor-deposited aluminum layer 14 approximately 100 nanometers thick covering the embedded hemisphere of each microsphere,

a transparent polymethylmethacrylate protective film 18, sealed to the binder layer in a hexagonal pattern,

a pressure-sensitive adhesive layer covering the back of the binder layer, and

a protective removable liner covering the back surface of the pressure-sensitive adhesive layer.

The retroreflective sheeting 10 was irradiated from the front using a Q-switched neodymium-yttrium-aluminum-garnet laser which was operated at 100 watts average power, pulse width of about 200 nanoseconds, and pulse repetition frequency of 10 kilohertz. Its wavelength was 1.064 micrometers and its spot diameter was 3 mm. A mask was placed to effect selective irradiation of the sheeting in the pattern of a rectangle, 3.8 by 5.1 cm. The laser beam was scanned across the entire rectangle at normal incidence (90°) at a speed of 1000 cm/sec. At the end of each scan, the sheeting was moved 1.3 mm in a direction normal to the scan. By doing so, a dark rectangular directional image was formed which was conspicuous and visible within a cone of about 22° centered on the angle of irradiation.

Testing

After removing the protective film using a razor blade, a room-temperature curing epoxy resin composition was cured in contact with the exposed microspheres. The cured product was sectioned, polished and then examined with a microscope. This revealed cavities 22 as illustrated in Figure 1. The cavities appeared to have ellipsoidal walls and were typically 8 micrometers deep, 3 micrometers wide at the minor axis of the ellipsoid, and 1-2 micrometers wide at their openings 24.

Claims

1. Retroreflective sheeting (10) comprising a monolayer of transparent microspheres (11) partially embedded in a binder layer (12) with the front surface of said microspheres protruding from said binder layer and a specularly reflective layer (14) covering the back surfaces of the microspheres (11), which sheeting (10) contains at least one pattern viewable from the front of the sheeting only across a conical field of view,

   said binder layer (12) is light-colored, wherein said pattern is provided by tiny cavities (22), each having an opening (24) through a back surface of a microsphere, and substantially every opening is smaller than the depth of the cavity.

2. Retroreflective sheeting as defined in Claim 1 wherein the wall of each cavity (22) is substantially an ellipsoid, the major axis of which extends orthogonally to the surface of the microsphere (11), and each opening (24) is smaller than the minor axis of the ellipsiod.

3. Retroreflective sheeting as defined in Claim 1 or 2 wherein said binder layer (12) is rendered opaque by a light-colored pigment.

4. Retroreflective sheeting as defined in Claim 3 wherein the pigment is TiO_2.

5. Retroreflective sheeting as defined in Claim 1 to which is sealed a transparent protective film (18) in a grid pattern of narrow sealed areas (16) and relatively broad unsealed areas, and within the unsealed areas the front surfaces of the microspheres are optically exposed to an air interface.

6. Retroreflective sheeting as defined in Claim 5 wherein the protective film (18) contains a transparent dye.

7. Retroreflective sheeting as defined in Claim 1 wherein the microspheres are glass.

8. Method of generating a directionally viewable pattern in a retroreflective sheeting (10) containing a monolayer of transparent glass microspheres (11) partially embedded in a light-coloured binder layer (12) with the front surface of said microspheres protruding from said binder layer wherein said microspheres (11) are selected to focus a beam of visible light substantially at a reflective layer (14) which covers the back surfaces of the microspheres, the front surfaces of which are uncovered, said method comprising directing an infrared laser beam at a specific angle toward the front of the sheeting to form tiny cavities (22), each having an opening (24) through the back surface of a microsphere (11) along the axis of the laser beam, substantially every opening (24) being smaller than the depth of the cavity (22).

9. Method as defined in Claim 8 wherein the wavelength of the laser beam is approximately one micrometer.

10. Method as defined in Claim 8 wherein, prior to directing said laser beam toward said sheeting, a transparent protective film (18) is sealed to the retroreflective sheeting (10) in a grid pattern of narrow sealed areas (16) and relatively broad unsealed areas within which the front surfaces of the microspheres (11) are optically exposed to an air interface.

Revendications

1. Matériel en feuille rétroréfléchissant (10) com-

prenant une seule couche de microsphères transparentes (11) partiellement noyées dans une couche de liant (12), la surface avant de ces microsphères se présentant en saillie par rapport à cette couche de liant, et une couche à réflexion spéculaire (14) recouvrant les surfaces arrière des microsphères (11), ce matériel en feuille (10) comportant au moins un dessin ne pouvant être vu sous forme d'un motif ou d'une image depuis l'avant du matériel en feuille, que suivant un champ conique de vision, dans lequel la couche de liant susdite (12) est de couleur claire, le dessin susdit est formé par de minuscules cavités (22), chacune d'elles présentant une ouverture (24) à travers une surface arrière d'une microsphère, et pratiquement chaque ouverture est plus petite que la profondeur de la cavité.

2. Matériel en feuille rétroréfléchissant suivant la revendication 1, dans lequel la paroi de chaque cavité (22) est sensiblement un ellipsoïde, dont l'axe principal s'étend perpendiculairement à la surface de la microsphère (11), et chaque ouverture (24) est plus petite que le plus petit axe de l'ellipsoïde.

3. Matériel en feuille rétroréfléchissant suivant la revendication 1 ou 2, dans lequel la couche de liant (12) est rendue opaque par un pigment de couleur claire.

4. Matériel en feuille rétroréfléchissant suivant la revendication 3, dans lequel le pigment est formé par le TiO_2.

5. Matériel en feuille rétroréfléchissant suivant la revendication 1, sur lequel est scellée une pellicule protectrice transparente (18) suivant un dessin à grille de zones scellées étroites (16) et de zones non scellées, relativement larges, les surfaces avant des microsphères étant exposées optiquement à une interface d'air dans les zones non scellées.

6. Matériel en feuille rétroréfléchissant suivant la revendication 5, dans lequel la pellicule protectrice (18) comporte un colorant transparent.

7. Matériel en feuille rétroréfléchissant suivant la revendication 1, dans lequel les microsphères sont en verre.

8. Procédé de formation d'un motif pouvant être vu de manière directionnelle dans un matériel en feuille rétroréfléchissant (10) comportant une couche unique de microsphères en verre transparentes (11) partiellement noyées dans une couche de liant de couleur claire (12), la surface avant de ces microsphères se présentant en saillie par rapport à la couche de liant susdite, les microsphères (11) étant choisies pour concentrer un faisceau de lumière visible sensiblement à l'endroit d'une couche réfléchissante (14) qui recouvre les surfaces arrière des microsphères, dont les surfaces avant ne sont pas recouvertes, ce procédé comprenant l'envoi d'un faisceau laser à infrarouge suivant un angle particulier vers l'avant du matériel en feuille pour former de minuscules cavités (22), présentant chacune une ouverture (24) à travers la surface arrière d'une microsphère (11) le long de l'axe du faisceau laser, pratiquement chaque ouverture (24) étant plus petite que la profondeur de la cavité (22).

9. Procédé suivant la revendication 8, dans lequel la longueur d'onde du faisceau laser est d'environ 1 micromètre.

10. Procédé suivant la revendication 8, dans lequel, avant l'envoi du faisceau laser vers le matériel en feuille précité, une pellicule protectrice transparente (18) est scellée sur le matériel en feuille rétroréfléchissant (10) suivant un dessin en forme de grille de zones scellées étroites (16) et de zones non scellées, relativement larges, dans les limites desquelles les surfaces avant des microsphères (11) sont exposées optiquement à une interface d'air.

Patentansprüche

1. Rückstrahlendes Blattmaterial (10) mit einer Monolage von durchsichtigen Mikroperlen (11), die teilweise in einer Bindemittelschicht (12) einnehettet sind, von der die vordere Fläche der Mikroperlen vorsteht, und mit einer die rückseitigen Flächen der Mikroperlen (11) bedeckenden, direktreflektierenden Schicht (14), wobei das Blattmaterial (10) mindestens ein nur aus einem konischen Betrachtungsfeld als Bild betrachtbares Muster besitzt und die Bindemittelschicht (12) hellfarben ist, das Muster von winzigen Hohlräumen (22) gebildet wird, die je eine die rückseitige Fläche einer Mikroperle durchsetzende Mündung (24) besitzen, und im wesentlichen jede Mündung kleiner ist als die Tiefe des Hohlraumes.

2. Rückstrahlendes Blattmaterial nach Anspruch 1, dadurch gekennzeichnet, daß die Wandung jedes Hohlraums (22) im wesentlichen ein Ellipsoid ist, dessen Hauptachse zu der Oberfläche der Mikroperle (11) rechtwinklig ist, und daß jede Mündung (24) kleiner ist als die Ne-

benachse des Ellipsoids.

3. Rückstrahlendes Blattmaterial nach Anspruch 1 oder 2, dadurch gekennzeichnet, daß die Bindemittelschicht (12) durch ein dank eines hellfarbenen Pigments opak ist.

4. Rückstrahlendes Blattmaterial nach Anspruch 2, dadurch gekennzeichnet, daß das Pigment TiO_3 ist.

5. Rückstrahlendes Blattmaterial nach Anspruch 1, an das eine durchsichtige Schutzfolie (18) in einem Gittermuster von schmalen gesiegelten Flächen (16) und relativ breiten ungesiegelten Flächen angesiegelt ist, und daß in den ungesiegelten Flächen die Vorderflächen der Mikroperlen zu einer Luftgrenzfläche hin optisch freiliegen.

6. Rückstrahlendes Blattmaterial nach Anspruch 5, dadurch gekennzeichnet, daß die Schutzfolie (18) einen durchsichtigen Farbstoff enthält.

7. Rückstrahlendes Blattmaterial nach Anspruch 1, dadurch gekennzeichnet, daß die Mikroperlen aus Glas bestehen.

8. Verfahren zum Erzeugen eines richtungsabhängig betrachtbaren Musters in einem rückstrahlenden Blattmaterial (10), das eine Monolage von durchsichtigen Mikroperlen (11) aus Glas enthält, die teilweise in einer hellfarbenen Bindemittelschicht (12) eingebettet sind, von der die vordere Fläche der Mikroperlen vorsteht, wobei die Mikroperlen (11) so ausgewählt sind, daß sie ein Strahlenbündel sichtbaren Lichtes im wesentlichen auf eine reflexionsfähige reflektierende Schicht (14) fokussieren, die die rückseitigen Flächen der Mikroperlen bedeckt, deren vordere Flächen freiliegen, wobei in dem Verfahren ein Infrarotlaserstrahlenbündel unter einem bestimmten Winkel auf die Vorderseite des Blattmaterials gerichtet wird, so daß winzige Hohlräume (22) gebildet werden, die je eine Mündung (24) haben, die die rückseitige Fläche einer Mikroperle (11) auf der Achse des Laserstrahlenbündels durchsetzt, und im wesentlichen jede Mündung (24) kleiner ist als die Tiefe des Hohlraums (22).

9. Verfahren nach Anspruch 8, dadurch gekennzeichnet, daß die Wellenlänge des Laserstrahlenbündels etwa 1 Mikrometer beträgt.

10. Verfahren nach Anspruch 8, dadurch gekennzeichnet, daß vor dem Beaufschlagen das Blattmaterials mit dem Laserstrahlenbündel eine durchsichtige Schutzfolie (18) an das rückstrahlende Blattmaterial (10) in einem Gittermuster von schmalen gesiegelten Flächen (16) und relativ breiten ungesiegelten Flächen angesiegelt wird, in denen die vorderen Flächen der Mikroperlen (11) zu einer Luftgrenzfläche hin optisch freiliegen.

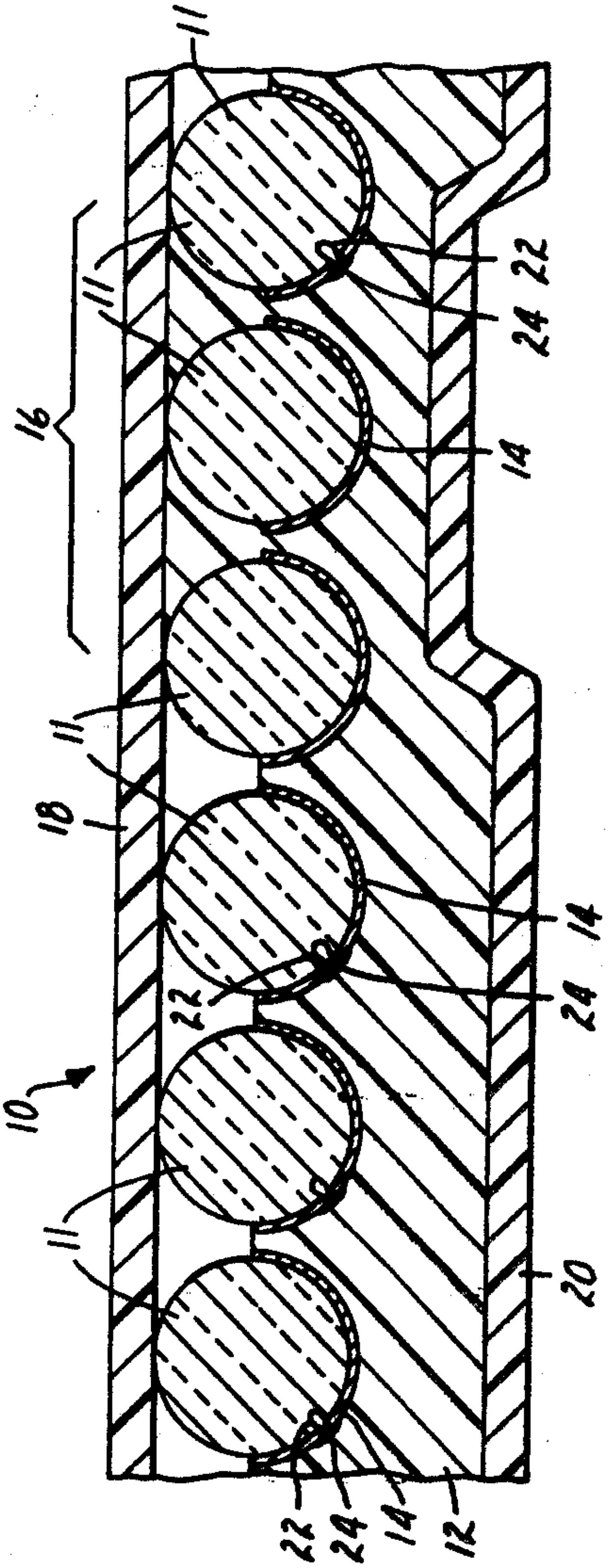

FIG.1

FIG. 2

FIG. 3

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Title DIRECTIONALLY IMAGED RETROREFLECTIVE SHEETING

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**** END OF REGISTER ENTRY ****

RENEWAL DETAILS

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PROPRIETOR(S)

MINNESOTA MINING AND MANUFACTURING COMPANY, 3M Center, P.O. Box 33427, St. Paul, Minnesota 55133-3427, United States of America

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