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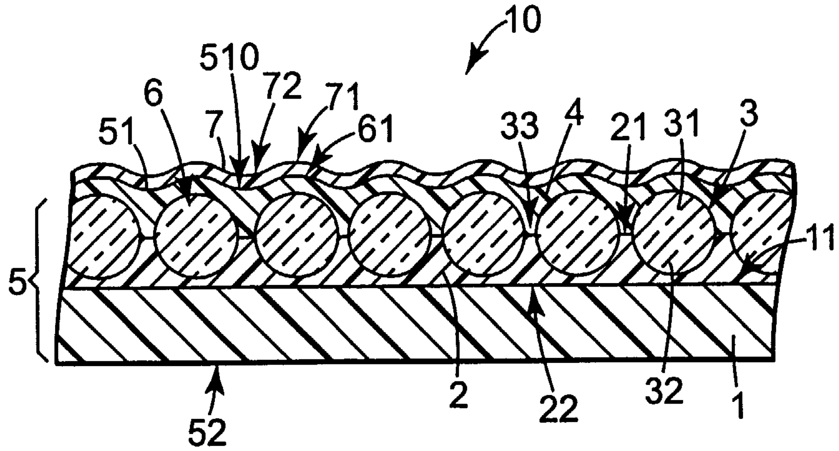
(54) **Title:** REFLECTOR WITH WIDE OBSERVATION ANGLE



(57) **Abstract:** A reflection sheet has a wide observation angle and can control the direction of effectively reflected light in a specific observation angle range while maintaining the wide observation angle characteristics. The sheet provides a bright reflection and is particularly useful as a construction part of an image-displaying sheet.

WO 03/009019 A2

REFLECTOR WITH WIDE OBSERVATION ANGLE

FIELD OF INVENTION

The present invention relates to the improvement of a reflector with a wide observation angle comprising a base layer and a plurality of minute convex mirrors provided on the surface of the base layer with being coadjacent each other. Preferably, the reflector with a wide observation angle forms an uneven reflection surface using a range of a plurality of beads (minute spheres) which are partly embedded in the base layer or a binding layer included in the base layer and arranged substantially in the form of a single layer.

When such a reflector has a sheet-form base layer or a sheet-form binding layer, it can be used as a reflection sheet with a wide observation angle and is useful as a construction part of an image-displaying sheet which is used as an external-illuminating type one to distinctively display information such as signs, guide signs, advertisements, etc.

BACKGROUND

Hitherto, a reflector, which is called a retro-reflective sheet, is conveniently used to form a reflection surface of a sign such as a road sign, a guide sign, etc., since it has good visibility at night. The conventional retroreflective sheets are generally designed so that they glitter most brightly at a low observation angle of about 0.2 to about 1 degree, and thus observers, for example, drivers can observe the reflection surface of the sign from a relatively long distance, because the observers are usually positioned in the range of the low observation angle described above when they are at a long distance from the sign.

However, when the observers approach the retrore-flective sheet to a close distance, they are in a range outside the observation angle range from which the sheet can be seen, and thus it is difficult for them to recognize the displayed information in comparison with the observation from the remote distance.

Under such circumstances, reflection sheets having a wide observation angle range from which the sheets can be seen, that is, a wide observation angle-reflection sheets, are sought, and several types of such wide observation angle-reflection sheets have been proposed.

One of such wide observation angle-reflection sheets is proposed by the present inventors in JP-A-7-281014. The disclosed reflection sheet is an encapsulated or embedded lens type reflection sheet which comprises two types of glass beads having different refractive indices and widens the observation angle up to 20 degrees. The proposed reflection sheet of this JP application can achieve at least 10 CPL (candela/lux/m^2) at an observation angle of 1 to 3 degrees and at least 1 CPL at an observation angle of 8 to 20 degrees. Such a reflection sheet with a wide observation angle is widely used particularly as a road sign which is combined with an external light source, since it can highlight the sign so that the sign can be seen from the remote distance and the short distance.

Nevertheless, a reflection sheet having a wider observation angle is desired as a reflection sheet of a sign.

The above reflection sheets with a wide observation angle and the conventional retroreflective sheets utilize glass beads and a reflection film such as a metal-deposition film, etc. The glass beads are used as lenses, and the reflection film is provided along the spherical surface (focal plane) including the focal point of the lens. As a result of the study of the inventors, it has been concluded that the above structures of the reflection sheets cannot further widen the observation angle.

As a result of the further study of the inventors, it has been found that it is effective to form, over the whole surface of a reflection sheet, a reflection surface having a plurality of convex mirrors comprising convex parts which are adjacently provided on a basic surface such as the surface of a base layer with one end being fixed to the surface and each of which has a convex surface bulging from one end to the other end, and a reflection film adhered to the convex surfaces of the convex parts, where the convex mirrors range in the horizontal direction of the sheet.

A reflection sheet using only such a plurality of the minute convex mirrors is known and disclosed in, for example, JP-A-11-326609. The reflection sheet disclosed in this JP application is characterized in that a binder layer (binding layer), a layer of beads (or irregularly shaped particles) having an average particle size of 5 to 150 μm, and a reflection film layer formed of a deposition film are laminated on one surface of a support in this order. That is, this sheet comprises a plurality of beads which are adjacently provided on the surface of the binding layer in the form of a single layer and partly embedded in the binding layer, while the rest parts are exposed, and the exposed parts of the beads are covered with the reflection film, and the semispherical surfaces (convex surfaces) of the beads covered with the reflection film form a plurality of minute convex mirrors.

Usually, the above beads are embedded in the binder layer so that 50 to 90 % of the particle size is buried. In such a reflection sheet, the deposition film is adhered directly to the exposed parts of the beads, or a solution of a resin is coated on the exposed parts of the beads with a thickness which does not deform the shape of the exposed glass beads and dried to solidify the resin and then the deposition film is adhered to the resin film. That is, the surface of the deposition film forms a reflection surface having the same shape as that of the concave-convex shape formed from the exposed parts of the beads coadjacent each other. In such a way, the observation angle range in which the information is seen can be greatly increased by making use of the diffusion effects achieved by the combination of the minute convex mirrors.

JP-A-61-3129 discloses a diffusive reflection sheet in which a reflection film is formed over the semispheres of a plurality of beads provided in the form of a single layer to form a plurality of minute convex mirrors, like the reflection sheet of the above JP application. The reflection sheet of JP-A-61-3129 is uses as a diffusive reflection screen for a projector such as a vide projector, etc.

US-A-4,712,867 discloses a retroreflector comprising a base having convex and concave surfaces. The disclosed retroreflector has, on the surface of the base, a plurality of convex surfaces which are adjacently disposed, and concave surfaces which sink from the surface towards the back surface of the base and each of which is provided between the adjacent convex surfaces. The base itself, that is, the convex and concave surfaces themselves do not have reflection properties, and thus a reflective coating comprising a binder and a plurality of glass spheres suspended in the binder is provided to cover the convex and concave surfaces.

The glass spheres are entirely buried in the coating layer, and the coating layer is in close contact with the convex and concave surfaces along the contours of those surfaces. The sizes (heights and depths) of the convex and concave surfaces are larger than the diameter of the glass spheres. This type of the reflector can reflect light in a wide incident angle range by making effective use of the waving of the reflective surface (the convex and concave contour) and the diffusive reflection of the glass spheres embedded in the coating layer.

SUMMARY

However, in the case of a reflection sheet having a plurality of minute convex mirrors like the above-described sheets, most of the reflected light diffuses and substantially no reflection directivity is achieved when the arranging density of the convex mirrors is small. Thus, the direction of effectively reflected light cannot be controlled so that the light is reflected as strongly as possible in a specific observation angle range. When the arranging density of the minute convex mirrors is increased, a luminance decreases while the refection directivity may be somewhat improved. The cause for such decrease of the luminance has not bee clarified but may be assumed as follows:

When the arranging density of the minute convex mirrors is increased, the distance between the adjacent beads decreases so that the beads may cluster together. In such a case, a dent is formed between the adjacent beads (between the exposed parts of the adjacent beads). This dent has a shape diminishing from the bead apexes toward the binding layer. Such a diminished shape has a narrower size toward the distal end (toward the binding layer). The distal end of the diminished shape (the bottom of the dent) is on the surface of the binding surface and thus flat. Accordingly, the light which enters such a dent cannot be reflected to provide observable reflected light. Therefore, the reflection luminance may decrease.

In the reflector disclosed in US-A-4,712,867 and comprising the convex and concave surfaces, the coating layer containing the glass spheres does not have mirror reflection and cannot reflect the incident light intensively. Thus, it is difficult to increase reflection luminance. Since those convex and concave surfaces have relatively large sizes, they cannot function as minute convex and concave mirrors. Furthermore, since the glass spheres buried in the coating layer on the concave surfaces tend to diffusively reflect the incident light, it is difficult to increase the reflection directivity on the concave surfaces. Accordingly, the direction of the effective reflected light cannot be controlled.

Thus, the inventors have made further study to provide a reflection sheet which can be observed brightly (that is, with a high luminance) in a specific observation angle range which is effectively widened, that is the background of the desire for the supply of a wide observation angle reflection sheet, and have completed the present invention.

One object of the present invention is to provide a reflection sheet with a wide observation angle, which can control the direction of effectively reflected light in a specific observation angle range while maintaining the wide observation angle characteristics, which can be observed brightly (that is, with a high luminance), and is particularly useful as a construction part of an image-displaying sheet used as a sign, a signboard, etc.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a schematic cross section of one example of a reflector with a wide observation angle according to the present invention.

Fig. 2 is an enlarged cross section of one example of a reflector with a wide observation angle according to the present invention.

Fig. 3 is a schematic cross section of another example of the reflector with a wide observation angle according to the present invention.

Fig. 4 is a cross section showing a method for producing a reflector with a wide observation angle according to the present invention.

Fig. 5 is a graph reporting the results of the measurement of reflection luminance obtained in Example 3 and Comparative Example 1.

DETAILED DESCRIPTION

To solve the above problem, the present invention provides a reflector comprising

a base layer having a surface and a back surface, and

a plurality of minute convex mirrors which are provided on the surface of said base layer with being coadjacent each other and each of which has a convex surface covered with the first reflection film,

wherein said base layer has a plurality of minute concave mirrors each having a concave surface which falls from the surface to the back surface of said base layer and is covered with the second reflection film, and

said minute concave mirrors are provided between said minute convex mirrors coadjacent each other.

The reflector with a wide observation angle of the present invention has a plurality of minute convex mirrors like the conventional ones, and also has a plurality of minute concave mirrors which are not provided on the conventional reflection sheets. With the reflection sheet having such a structure, the effect to increase the directivity of the minute concave mirrors is achieved in addition to the diffusion effect of the minute convex mirrors, and thus it becomes very easy to control the direction of the effectively reflected light (the reflected light observable with a high luminance) in the specific observation angle range.

One preferred embodiment of the reflector with a wide observation angle of the present invention has the following structure and effectively combines the minute convex mirrors and the minute concave mirrors.

That is, the reflector with a wide observation angle comprises (A) a base layer having a surface and a back surface, (B) a plurality of minute convex parts which are provided on the surface of the base layer with being coadjacent each other, and each of which is fixed to the surface of the base layer at one end and has a convex surface bulging from one end to the other, and (C) the first reflection film fixed to the convex surfaces of said convex parts.

Furthermore, the reflector of this embodiment is characterized in that a concave surface which falls from the surface to the back surface of the base layer is provided between the convex parts adjacent each other and the second reflection film is fixed to the concave surface.

With such a structure, the dent between the adjacent convex parts (between the exposed parts of the beads, when the embedded beads are used) can be used as a reflection surface to effectively prevent the decrease of the luminance.

The functions of the above convex and concave surfaces will be explained more in detail. The convex surfaces having the first reflection film adhered thereto function as the minute convex mirrors, while the concave surfaces having the second reflection film adhered thereto functions as the minute concave mirrors. In the reflector having the above structure, the minute convex mirror and minute concave mirrors are alternately connected on the horizontal plane to form the reflection surface over the whole reflector. Thus, the effect of the minute concave mirrors to increase the directivity of the reflected light is achieved in addition to the diffusion effect of the minute convex mirrors so that the direction of the effectively reflected light can be very easily controlled in the specific observation angle range while maintaining the wide observation angle characteristics.

The surface roughness of the uneven reflection surface formed by connecting the first reflection film and the second reflection film is preferably determined so that the function to widen the observation angle (to which the diffusive reflection contributes) and the function to control the observation angle (the function to increase the directivity) are well balanced. For example, the surface roughness of the uneven reflection surface formed by the first and second reflection films which are connected each other is preferably in the range from 0.02 to 0.25 in terms of a ratio (D/P) of an average depth of the concave mirrors (D: μm) to an average pitch of the convex mirror (P: μm).

When the surface roughness defined above is too large, the diffusing effect may deteriorate, and the observation angle may not be widened. When the surface roughness is too small, the directivity may deteriorate and the function to control the observation angle may not be effectively improved. From such a viewpoint, the surface roughness is preferably from 0.04 to 0.20, more preferably from 0.05 to 0.18.

Here, the above depth D and the pitch P are measured with a three-dimensional laser surface roughness meter or a laser microscope equipped with a three-dimensional surface roughness meter, and defined as follows:

The average depth of the concave mirrors is an average distance between a plane including the deepest point of the concave surface (the minute concave mirror) covered with the reflection film and in parallel with the base layer and planes including the apexes of the convex surfaces (the minute convex mirrors) surrounding the concave surface and in parallel with the base layer. The average depth of the concave mirrors can be obtained by selecting the specific number (e.g. ten or more) of the minute concave mirrors and all the minute convex mirrors surrounding those minute concave mirrors (usually three or four concave mirrors), calculating the above-defined distances and then averaging those distances. The average pitch between the convex mirrors can be obtained by taking a photograph of a sample with a laser microscope and measuring distances between the specific number of the adjacent convex mirrors (for example, 30 to 50 convex mirrors) and averaging the measured distances.

The above-described reflection sheet comprising the minute convex mirrors and the minute concave mirrors preferably has the following structure formed using beads (microspheres).

The reflector comprises (a) a binding layer having a surface and a back surface, (b) a plurality of beads which are fixedly provided on the surface of the binding layer with coadjacent each other, a part of each bead being embedded in the binding layer while the remaining part of each bead being exposed from the binding layer, (c) the first reflection film covering the beads, and is characterized in that

(i) a coating layer with a specific thickness is provided to cover the exposed parts of the beads and fills spaces between the exposed parts of the adjacent beads,

(ii) the coating layer which covers the exposed parts of the beads forms convex parts each having a convex surface bulging from the binding layer toward the coating layer, and the first reflection film is adhered to the convex surfaces of the convex parts, and

(iii) a concave part consisting of the concave surface of the coating layer, which falls from the surface of the coating layer to the binding layer and is provided between the convex parts adjacent each other, and the second reflection film is adhered to the concave surface.

With such a structure, the exposed surfaces of a plurality of the beads partly embedded in the binding layer can be effectively used to form the minute concave mirrors. When the thickness of the coating layer which covers the exposed surfaces of the beads is controlled, the radius of curvature of the concave surfaces (the minute reflection surfaces) is adjusted so that the function to widen the observation angle and the function to control the observation angle can be easily balanced.

In general, the surface of the binding layer between the adjacent beads exposed on the binding layer is flat. Therefore, the simple formation of the reflection film (the second reflection film) between the beads cannot form any minute concave mirrors, and thus the function to control the observation angle cannot be improved. Thus, the coating layer is provided in the spaces between the beads to form the concave surfaces formed of the surfaces of the coating layer, and the second reflection film is provided on such concave surfaces to form the minute concave mirrors. When the thickness of the coating layer which fills the spaces between the beads is controlled, the radius of curvature of the concave surfaces (the minute reflection surfaces) is adjusted so that the function to widen the observation angle and the function to control the observation angle can be easily balanced.

Herein, the term "concave surface" is a surface having a shape functioning as a concave mirror when a reflection film is provided thereon, and means a curved surface having a bowl form, a parabola form, etc.

The coating layer is formed by applying a liquid containing a resin and solidifying it. The solidification includes the hardening of a reactive liquid (including polymerization and crosslinking), drying comprising the evaporation of a solvent in the liquid, cooling of the molten liquid to solidify it, and the like.

The thickness of the coating layer is determined so that the ratio of the thickness of the coating layer to the diameter (average diameter) D of the beads is within a specific range. The ratio of the thickness (t) of the coating layer to the diameter (D) of the beads (t/D) is usually from 0.14 to 0.42, preferably from 0.20 to 0.30. When the coating layer is too thin in relation to the diameter of the beads, the minute concave mirrors may not be formed and thus the function to control the observation angle may not be effectively improved. When the coating layer is too thick, the radius of curvature of the minute convex mirrors may become too large so that the diffusing function tends to deteriorate and thus the observation angle may not be widened.

(Reflector)

One preferred example of the reflector according to the present invention will be explained by making reference to the accompanying drawings, in which Fig. 1 is a schematic cross sectional view of the reflector of the present invention, and Fig. 2 is an enlarged cross sectional view of the reflector of the present invention.

The reflector (10) comprises the sheet-form support (1) having a surface and a back surface, and the binding layer (2) which is fixedly provided on the surface (11) of the support (1). In general, the binding layer (2) is formed by applying a layer containing a polymer on the support, and has the back surface (22) adhered to the support and the surface (21) in which a plurality of beads (3) are embedded. Here, the support (1) is not drawn in Fig. 2.

On the surface of the binding layer (2), a plurality of the beads (3) are partly embedded in the binding layer (2), and arranged adjacently each other. As shown in Figs. 1 and 2, each bead (3) has the part (32) embedded in the binding layer and the part (31) exposed on the binding layer.

In addition, the coating layer (4) having a specific thickness is provided so that it covers the exposed parts (31) of the beads and fills the spaces (33) between the exposed parts of the beads adjacent each other. Preferably, the coating layer is formed by applying the liquid containing the resin and solidifying it, as described above.

In such a way, the base layer (5) consisting of a laminate having the support (1), the binding layer (2) and the coating layer (4) is formed. Furthermore, a part of each bead is embedded in the base layer (5), while the remaining part of each bead protrudes over the base layer (5), and the protruded part of the bead is covered with the coating layer (4). Thus, a plurality of the convex parts (6), which are formed using the three-dimensional shape of the coating layer (4), are fixed to the base layer (5). As shown in Figs. 1 and 2, the convex parts (6) have the convex surfaces (61) each of which bulges outwardly from the surface of the base layer (5).

The radius curvature and size of the convex surface (61) can be determined by suitably selecting the diameter of the beads embedded, the depth of the beads embedded, the (dry) thickness of the coating layer, the thickness of the resin coated, etc.

For example, the diameter (average diameter) of the beads embedded is usually from 55 to 2,000 μm, preferably from 60 to 1,000 μm, more preferably from 70 to 500 μm. When the diameter of the beads is too large, the diffusing function may deteriorate so that the observation angle may not be widened. When the diameter of the beads is too small, the space between the exposed parts of the adjacent beads becomes too small and the formation of the effective concave surfaces may be difficult so that the directivity may deteriorate and the function to control the observation angle may not be effectively increased.

When the diameter of the beads fluctuates in a certain range, the diffusing function is improved and the observation angle can be easily widened. From such a viewpoint, the fluctuation of the diameter of the beads is usually from 3 to 25 %, preferably from 5 to 20 % in relation to the average diameter of the beads. When the diameter of the bead fluctuates excessively, the effect to control the observation angle may not be improved.

The depth of the bead embedded (the length of the embedded part of the bead in the direction of the diameter) is usually from 20 to 70 %, preferably from 30 to 60 %, of the diameter of the bead. When the depth of the bead embedded is too low, the diffusing function may deteriorate and the observation angle may not be widened. When the depth of the bead embedded is too large, the directivity may deteriorate and the function to control the observation angle may not be effectively increased.

The concave surface (510), which falls from the surface (51) to the back surface (52) of the base layer (5) is formed in the space between the adjacent convex parts (6). The concave surface (510) is a dent with a curved surface as shown in Figs. 1 and 2, which is formed with a physical function such as a surface tension of the resin liquid, etc. in the course of the solidification of the resin liquid, which is applied to fill the spaces (33) between the exposed parts (31) of the adjacent beads, as described above.

For example, when substantially all the beads are regularly arranged at the intersections of a crosshatch which is imaginarily depicted on the surface of the base layer, one dent is formed at the center of the four beads which are positioned at the respective apexes of one square (or rectangle) of the crosshatch. The plane shape of the dent in parallel with the surface of the base layer is substantially a circle. In Fig. 2, the surface of the dent forms the concave surface (510). The concave and convex surfaces formed from the coating layer are connected each other to form the uneven surface, and provide the uneven reflection surface having the specific surface roughness after the formation of the reflection film (7).

When two beads, which are arranged adjacently along one side of the above square, are not in contact with each other, a dent (not shown) is formed between such a pair of the beads. The dent present on the side of the square is usually connected with the dent present at the center of the square. In such a case, the concave surface on the side of the square can be used as a minute concave mirror after the formation of the reflection film.

Apart from the square (or rectangular) arrangement of the beads, the beads can be arranged at the corners of a parallelogram (except a rectangular), and a concave mirror is formed at the center of the four beads arranged at the four corners. The arrangement of the beads may include the rectangular arrangements and the parallelogrammic arrangements. Furthermore, a part of the beads may be irregularly arranged. In addition to the quadrate arrangements, triangular or pentagonal arrangements may be present, and a concave mirror may be formed at the center among the three or five beads.

The radius of curvature and depth of the concave surface (510) may be determined by suitably selecting the (dry) thickness of the coating layer, the thickness of the resin liquid coated, the rheology of the resin liquid, the solidifying conditions of the resin liquid (e.g. drying temperature, drying time, etc.), the shape and size of the space (33), and the like. When the thickness of the coating layer is too low, any dent with a curved surface is not formed. Thus, the thickness of the coating layer is preferably adjusted in the above-described range.

Then, the reflection film (7) is formed so that it integrally covers the convex surfaces (61) and the concave surfaces (510) and it is adhered to those surfaces. Thereby, the first reflection films (71) each comprising the reflection film (7) and being adhered to the convex surface (61), and the second reflection films (72) adhered to the concave surfaces (510) are formed. The convex parts (6) to which the first reflective films (71) are adhered form the reflective convex parts (60) having the minute convex mirrors. The concave surface (510) to which the second reflection film (72) is adhered functions as the minute concave mirror.

The reflection film (7) usually contains a material with metallic luster such as a metal. Such a metallic luster film is, for example, a metal film with a relatively small thickness, which is formed by a thin film-forming method such as deposition or sputtering, as shown in Fig. 2. Alternatively, the reflection film (7) may be a metal luster coating layer formed from a metal luster paint containing a polymer and a metal luster powder such as a metal powder dispersed therein. When the metal layer is relatively thick and the metal layer provided directly on the surface of the binding layer in which the beads are embedded can form the effective convex surfaces, the reflection film functions also as the coating layer, and the coating layer of the resin can be neglected.

Each of the reflection films (71, 72) has a specific radius of curvature. The radius of curvature of the convex surface is not limited insofar as the effects of the present invention are not impaired, and it is usually from 30 μm to 5 mm, preferably from 50 μm to 2 mm. Also the radius of curvature of the concave surface is not limited insofar as the effects of the present invention are not impaired, and it is usually from 15 μm to 5 mm, preferably from 40 μm to 3 mm.

Other sizes of each component constituting the reflector of the present invention are not limited, insofar as the effects of the present invention are not impaired.

The pitch (P) between the adjacent convex parts is usually from 30 to 3,000 μm, preferably from 60 to 1,000 μm, more preferably from 70 to 500 μm. When the beads are used to form the convex parts, preferably the adjacent beads are not in contact with each other to increase the pitch as much as possible in the above range.

The depth (D) of the concave surface is usually from 2 to 600 μm, preferably from 5 to 300 μm.

The thickness of the coating layer is usually from 5 to 300 μm, preferably from 10 to 200 μm. The thickness of the binding layer is usually from 20 to 500 μm, preferably from 30 to 250 μm. The thickness of the support is usually from 20 to 2,000 μm, preferably from 30 to 1,000 μm.

(Production of the reflector)

The reflector of the present invention may be produced by various methods. For example, the reflector having the structure of Fig. 1 or Fig. 2 is usually produced as follows:

Firstly, the support (1) is provided. The support (1) is used to support the binding layer (2) and to increase the mechanical strength of the base layer (5) for the prevention of the breakage of the binding layer in the course of the production of the reflector. When the strength of the reflector as a whole is sufficiently high for the practical use of the reflector, the support (1) may be removed from the reflector (1) after the completion of the reflector.

The support (1) is a film or a sheet made of, for example, a polymeric material or paper. When the support is removed from the reflector after the completion of the reflector, the surface (11) of the support (1) is preferably treated to make it releasable so that the support is easily removed from the binding layer (2). When the support is not removed from the reflector after the completion of the reflector, the surface (11) of the support (1) is preferably treated to make it adhesive with corona treatment or primer coating so that the adhesion strength of the support to the binding layer (2) is increased.

Examples of the polymer used to form the support include polyesters (e.g. PET, PEN, etc.), acrylic polymers, vinyl chloride polymers, olefin copolymers (e.g. ethylene-acrylic acid copolymers, ionomers, etc.), polyurethanes, and the like.

Secondly, the binding layer (2) is provided on the surface (11) of the support (1). The binding layer (2) is preferably a polymer layer comprising a polymer which can adhere and retain the beads. Such a polymer layer may be formed by applying a paint containing the polymer and solidifying it. Alternatively, a molded film comprising a polymer is laminated on the support by extrusion.

Examples of the polymer used to form the binding layer include acrylic polymers, polyurethanes, polyesters, vinyl chloride polymers, olefin copolymers (e.g. ethylene-acrylic acid copolymers, ionomers, etc.), and the like.

Next, a plurality of the beads are partly embedded in the binding layer (2). The beads are substantially spherical particles made of various materials such as glass, ceramics, hard polymers, metals, metal oxides, etc.

The beads are embedded by coating a paint for forming the binder layer (2) on the support, and scattering the beads (3) in the form of a single layer before the solidification of the paint applied. After the beads are partly sunk in the unsolidified paint, the paint is solidified. The paint may be solidified by heating and drying when the paint contains a solvent. When the binding layer comprises a polymer which is molten or softened with heat, the binding layer is cooled (including spontaneous cooling) after the beads are partly sunk to finish the embedding of the beads. Furthermore, the binding layer may be heated after the scattering of the beads to make the ratio of the embedded part of each bead (a ratio of the embedded part to the diameter of the bead) as large as possible.

Alternatively, the beads may be embedded using a process substrate having a polyethylene layer on the surface, as is well known in the field of retroreflective sheets, as follows:

Firstly, the beads are provided in the form of a single layer on the polyethylene layer of the process substrate and then partly embedded in the polyethylene layer. The paint for a binding layer is applied so that the paint covers the exposed parts of the beads on the surface of the polyethylene layer, and then dried. After drying, the process substrate is removed, and thus the binding layer carrying the beads which are partly embedded in the layer and partly exposed is obtained.

After finishing the embedding of the beads (3) in the biding layer (2) so that the beads have the exposed parts by any one of the above-described methods, a resin liquid is applied on the surface (21) of the binding layer (2) at a specific thickness and solidified to form the coating layer (4). The resin in the coating layer may comprise an acrylic polymer, polyurethane, polyester, a vinyl chloride polymer, a polyolefin copolymer (e.g. ethylene-acrylic acid copolymer, inonmer, etc.), and the like.

Finally, the reflection film (7) is adhered to the surface of the coating layer (4) which has been formed as described above to finish the reflector of the present invention.

As the material of the reflection film (7), a material with metallic luster is used as described above. Examples of the material with metallic luster include aluminum, silver, nickel, chromium, etc. The thickness of the reflection film is selected so that the reflectance of the reflection film is made as high as possible. The thickness of the reflection film is usually at least 200 Å, preferably at least 400 Å.

The reflector of the present invention may be produced using no coating layer. As shown in Fig. 3, an uneven structure is formed on the surface (51) of the base layer (5), which structure comprises a plurality of the projections (6) consisting of first beads (30) which are partly embedded in the base layer, and a plurality of the dents (511) which are formed by removing the second beads (39). For example, when a metal deposition film is formed on the uneven surface, the uneven reflection surface having the intended three-dimensional surface roughness can be formed.

To form such an uneven structure on the base layer, the following method may be employed:

Firstly, the base layer (5) comprising a thermoplastic polymer is provided. After softening the base layer (5) with heating, a plurality of the first beads (3) and a plurality of the second beads (39) are partly embedded in the base layer (5) so that the heads of the exposed parts of the beads (3) and the beads (39) are on substantially the same level. In this case, the second beads (3) having a relatively small diameter are shallowly embedded and thus easily removed from the base layer, while the first beads having a relatively large diameter are deeply embedded and fixed to the base layer (5). After embedding the two kinds of the beads in the base layer (5), the second beads (39) are removed to form the concave surfaces (510) consisting of the surfaces of the dents (511) from which the beads (39) have been removed.

The second beads may be removed with electrostatic suction or vacuum suction. The second beads are selectively removed with leaving the first beads on the base layer. Furthermore, the second beads may be mechanically removed with a brush, etc. Alternatively, the second beads made of a magnetic material are used together with the first beads made of a non-magnetic material, and the second beads are selectively removed with magnetic suction.

The reflector of the present invention may be produced without the use of the embedding of the beads described above. For example, as shown in Fig. 4, a copying method is employed, in which a negative mold (8) having a plurality of concave and convex parts is used as a negative corresponding to the uneven structure to be formed on the surface (51) of the base layer (5). A curable polymer is applied on the mold (8) to fill the concave and convex parts, and then cured. Alternatively, a polymer, which is molten or softened with heating is applied on the mold (8) and cooled to solidify the polymer. After the curing or solidification of the polymer, the negative mold is removed, and thus the uneven structure as a positive corresponding to the negative is copied on the surface (51) of the base layer. Thereby, a plurality of the convex parts (6), which are fixed to the surface (51) of the base layer and adjacently arranged and each of which has the convex surface (61), and the concave surfaces (510) formed between the adjacent convex parts are formed. Then, the reflection film (7) are adhered to the surface (51) having the uneven structure to finish the reflector of the present invention.

The negative mold (8) is preferably produced from a metal plate by an unevenness-forming processing such as electro-discharging machining.

The curable polymer may comprise an oligomer or a monomer which can be cured with heat or a radiation (e.g. UV rays, electron beams, etc.). For example, a polymer comprising an acrylic monomer or oligomer is preferable.

Examples of the polymer which can be molten or softened include acrylic polymers, polyurethanes, polyesters, vinyl chloride polymers, olefin copolymers (e.g. ethylene-acrylic acid copolymers, ionomers, etc.), polyamides, and the like.

The reflector of the present invention can also be produced by a combined method of the above replication method and the method for forming the convex and concave surfaces with the coating layer (the coating layer method). For example, as shown in Fig. 6, the precursor base layer (53) having the precursor projections (54) on its surface is provided, and a resin liquid like one described above is applied on the surface of the precursor base layer (53) and solidified to form the coating layer (4) having the specific thickness. Thereby, like the case using the beads embedding, the convex parts (6) having the specific convex surfaces (61) and the concave surfaces having the convex surfaces (510) are formed on the surface of the coating layer (4).

Thus, according to the above described method, the precursor reflector (101) can be easily produced, which comprises the precursor base layer (53) having a plurality of the precursor projections (54), which are integrally formed on the surface of the base layer, and the coating layer (4), which is formed to have the specific thickness so that it covers the precursor projections (54) and fills the spaces (55) between the adjacent precursor projections (54), wherein the base layer (5) comprises the precursor base layer (53) and the coating layer (4), the convex parts (6) comprises the precursor projections (54) and the parts of the coating layer (4) covering the precursor projections (54), and the concave surfaces (51) comprises the surface of the coating layer which fills the spaces between the adjacent precursor projections (54). Then, the reflection film is adhered to the convex and concave surfaces of the precursor reflector (101) by the same method as described above to finish the reflector.

The above method can change the sizes and shapes of the convex and concave reflective surfaces easily and control the direction of the effectively reflected light in the specific observation angle range very easily by adjusting the thickness of the coating layer without changing the sizes and shapes of the concave and convex parts of the negative mold. That is, the reflectors having varying reflection characteristics can be produced using a single negative mold.

The precursor base layer described above can also be produced by embossing besides the above replication method. That is, the base layer sheet carrying no precursor projections is embossed with a negative mold having the specific convex and concave parts on its mold surface to obtain the precursor base layer having the precursor projections which are integrally formed on the surface thereof. The embossing can shorten the molding time (the time to form the unevenness on the base layer sheet) relatively easily in comparison with the replication method. On the other hand, like the replication method, the embossing can regularly arrange the convex parts more easily than the bead-embedding method. Accordingly, the reflector, which is produced by the combination of the embossing and the coating layer method is suitable for precisely controlling the direction of the effectively reflected light in the specific observation angle range. In addition, in the course of the embossing, the surface properties of the positive convex and concave parts, which are transferred to the base layer side, deteriorate, and when the reflection film is directly formed directly on the positive convex and concave surfaces as transferred, the surface properties of the reflection surface tends to deteriorate and thus the reflection luminance tends to decrease. However, when the reflection film is formed on the coating layer which covers the surface of the positive convex and concave parts on the base layer side, such deterioration of the surface properties of the reflection surface can be effectively prevented.

The base layer sheet used in the embossing is made of a material, which can be plastically deformed by pressing or pressing while heating, for example, metals or polymers. As the polymers, acrylic polymers, vinyl chloride polymers, polyolefin copolymers (e.g. ethylene-acrylic acid copolymers, ionomers, etc.), polyurethane, etc. can be used. The thickness of the base layer sheet is usually from 50 μm to 5 mm, preferably from 70 μm to 3 mm.

The coating layer may be formed by the same coating method using the same resin liquid as those used in the above beads-embedding method.

When the coating layer is combined with the replication method or the embossing, the surface of each precursor projection of the precursor base layer does not necessarily have a convex shape. In addition, the dent formed among the adjacent precursor projections does not necessarily have a concave shape. For example, in the case of the precursor base layer (53) of Fig. 6, the bottom of the dent formed between the adjacent precursor projections is flat. This is also found in the beads-embedding method, and the bottom of the dent between the beads is usually flat prior to the application of the coating layer (see Figs. 1 and 2).

Even in the case the dent having the flat bottom, when the coating layer having the specific thickness is applied, the convex surface comprising the surface of the coating layer filled in the dent can be easily formed. Similarly, when the surface of the precursor projection does not have a smooth convex surface, as shown in Figs. 7-11, the convex surface comprising the surface of the coating layer which covers the convex part can be easily formed.

In the embodiment of Fig. 6, the precursor projections each having a semispherical shape are positioned in the crosshatch arrangement, that is, they are regularly positioned on the points of intersection of the vertical and horizontal lines of the crosshatch which lie at right angles to each other. Insofar as the dents (spaces 55) are formed between the precursor projections, the peripheral parts of the adjacent precursor projections may be in contact each other. However, as depicted in Fig. 6, preferably the adjacent precursor projections are not in contact each other, and the dents (spaces 55) are provided as if they surround the precursor projection, since the concave surface is easily formed with the coating layer.

The precursor base layer (53) shown in Fig. 7 is the same as that of Fig. 6 except that the shape of the precursor projection (54) is cylindrical. In the embodiment of Fig. 8, the precursor base layer (53) is the same as that of Fig. 6 except that the shape of the precursor projection (54) is conical.

In the embodiment of Fig. 7, the shape of the precursor projection may be prismatic, and in the embodiment of Fig. 8, the shape of the precursor projection may be pyramidal.

Figs. 9-11 show some embodiments, which are particularly suitable when it is desired to easily control the direction of the effectively reflected light. In the case of the precursor base layer (53) of Fig. 9, quarter-spherical precursor projections (54), each of which is the halved semisphere, are positioned in the crosshatch arrangement. The vertical planes of the quarter-spheres (sections 541) usually face the same direction as shown in Fig. 9. Thereby, the directivity of the reflected light can be improved.

The embodiment of Fig. 10 is the same as that of Fig. 9 except that the semiconical precursor projections (54), which are the halved conical projections, are used. The embodiment of Fig. 11 is the same as that of Fig. 9 except that the truncated semiconical precursor projections (54) are used.

In the embodiments of Figs. 6-11, all the precursor projections have the same shape and size, although a plurality of precursor projections having different shapes and/or sizes may be used. The embodiments of the latter case are shown in Figs. 12-15.

In the embodiment of Fig. 12, the semiconical precursor projections (54), which are the halved conical projections, are positioned in the crosshatch arrangement. They contain a plurality of precursor projections, which have different slope angles of the side planes (542) in relation to the precursor base layer (53), and the sections (541) facing different directions. In the embodiment of Fig. 12, the precursor projections having the same shape and the same size are positioned along one line of the crosshatch. The center line divides the precursor projections in two groups of the convex parts the sections (541) of which face each other. With the reflector produced from such a precursor base layer by the coating method, the light incident from the zero degree direction near the center of the base layer tends to be reflected at the relatively large angle. Accordingly, with such as reflector, the directivity can be easily controlled so that the reflection luminance in the direction of the relatively high observation angle is higher than that in the direction of the relatively low observation angle.

The embodiment of Fig. 13 is the precursor base layer (53), in which the two types of semispherical precursor projections (54a, 54b) having different heights and diameters are alternately positioned in the crosshatch arrangement.

In the embodiment of Fig. 14, the first conical precursor projections (54a) and the second semispherical precursor projections (54b), which have different height and diameter from those of the first precursor projections, are alternately positioned in the crosshatch arrangement.

In the embodiment of Fig. 15, the first semispherical precursor projections (54a) and the second pyramidal precursor projections (54b) are alternately positioned in the crosshatch arrangement.

When a plurality of the precursor projections having different shapes and/or sizes are used as described above, the range of directions in which the light can be effectively reflected is widened and thus the reflectance in the wide observation angle can be increased.

To increase the reflectance in the wide observation angle range, the first and second sets of precursor projections, all of which have the same shape and same size but one set of which faces a different direction than the other, can be used as shown in Fig. 16. The embodiment of this figure uses the precursor projections (54c, 54d) each having an ellipsoid shape in the horizontal cross section (the cross section in parallel with the surface of the precursor base layer). All the ellipsoidal precursor projections have the same shape and the same size, and grouped in two sets in which the major axes of the ellipsoids on the horizontal cross section are in the different directions. That is, the direction of the major axis of the first set of the precursor projections (54c) is perpendicular to that of the second set of the precursor projections (54d). To achieve the above described effect, it is preferable to use precursor projections having a horizontal cross section other than a circle of a regular polygon.

The precursor projections are not limited to those described above, and those having various shapes can be used insofar as the effects of the present invention are not impaired.

As shown in Fig. 17, a concave part (56) having a concave surface may be formed between the adjacent precursor projections (54). In the embodiment of Fig. 17, the semiconical precursor projections are used like the embodiment of Fig. 10, and the concave parts (56) and the precursor projections (54) are alternately positioned in the crosshatch arrangement.

In the embossing, the size of the precursor projections on the precursor base layer is not limited insofar as the effects of the present invention are not impaired. For example, the height of the precursor projection is usually from 40 μm to 1 mm, preferably from 50 μm to 600 μm. The distance between the adjacent precursor projections is determined so that the distance between the convex mirrors formed on the surface of the convex parts, and the depth of the concave mirrors formed by the application of the coating layer and the reflection film are in the specified range. The above distance is usually from 40 μm to 4 mm, preferably from 70 μm to 2 mm, more preferably from 80 μm to 1 mm.

The reflector of the present invention may have a protective layer comprising a transparent coating, which covers the surface of the reflector along the convex and concave surfaces of the reflection film. The protective layer has the unevenness resulted from the unevenness of the reflection film. The protective layer may be formed by applying a coating liquid containing a polymer on the surface of the reflection film and drying it to form a film, or by adhering a thermoplastic polymer film while heating to the surface of the reflection film. The polymer film may be pressed against the reflection film with applying vacuum while it is heated and adhered to the reflection film.

The polymer of the protective layer may be an acrylic polymer, polyurethane, a vinyl chloride polymer, a polyolefin copolymer (e.g. an ethylene-acrylic acid copolymer, an ionomer, etc.) a fluoropolymer, a silicone, and the like. Preferably, the polymer is curable with light or heat. The thickness of the protective layer is usually from 1 to 100 μm, preferably from 3 to 50 μm.

(Image-displaying sheet)

As already described, the reflector with a wide observation angle of the present invention is useful as a reflection sheet which is used as a construction part of a reflection type image-displaying sheet.

Preferably, the reflection type image-displaying sheet is produced using the reflector with a wide observation angle of the present invention, and may have the following structure:

That is, the image-displaying sheet comprises the reflector with a wide observation angle (a reflection sheet), a light-transmitting polymer layer which is provided so that it covers the convex surfaces at a specific distance from the convex surfaces of the reflector, and a light-transmitting image which is provided on at least one of the surface and the back surface of the light-transmitting polymer layer. With such an image-displaying sheet, the uneven reflection surface, which is formed from the first reflection film and the second reflection film, reflects the external illumination light entering on the surface of the image-displaying sheet (the light-transmitting polymer layer) to form the reflected light which passes through the light-transmitting polymer layer and the image. The reflected light allows the image to be seen by an observer. Accordingly, the image can be distinctively seen in an as wide as possible observation angle range, that is, from a relatively remote distance and also from a short distance.

In general, a light-transmitting image formed with light-transmitting coloring inks is provided on at least one surface of the light-transmitting polymer layer. The light-transmitting polymer layer is fixed so that a space is left between the uneven reflection surface and the polymer layer. The light-transmitting polymer layer is fixed by adhering the periphery of the back surface of the polymer layer to a frame part for adhesion which is provided around the periphery of the base layer. For adhesion, a conventional adhesive such as an acrylic adhesive, an epoxy adhesive, etc. may be used.

The image-displaying sheet of the present invention may be used as a construction part of a sign, etc. Thus, preferably, the image-displaying sheet is finished with providing an adhesive layer comprising an adhesive, etc. on the back surface of the base layer (the back surface (52) of the support or the back surface of the binding layer) so that the sheet can be adhered and fixed to an adherent such as a sign substrate.

In general, the light-transmitting layer is formed of a film or a sheet comprising a polymer such as an acrylic polymer, polyester, polyurthane, polyolefin, polyamide, etc. Preferably, white dots are printed on the surface or the back surface of the light-transmitting layer to provide the whiteness as a foundation of the image, since the visibility of the image is effectively increased. To achieve the same effect, a light-diffusion film can be partly used as a light-transmitting layer. The thickness of the film or sheet used as the light-transmitting polymer layer is not limited, and is usually from 10 to 800 μm.

The light-transmitting polymer layer may have a back surface with the unevenness adhered to the uneven reflection surface and a surface on which the light-transmitting image is formed without providing any space between the polymer layer and the uneven reflection surface. The light-transmitting image may be formed by a suitable method such as printing directly on the uneven reflection surface using no light-transmitting polymer layer.

Furthermore, the reflector of the present invention may be used as a projection screen to display an image by projecting the image including information of the sign or guide sign with a projector.

(Exterior lighting image-displaying system)

The reflector or the image-displaying sheet of the present invention is suitable for assembling an exterior lighting image-displaying system in combination with external lighting equipment having a light source. In such a system, the reflector (or the reflection included in the image-displaying sheet) reflects the light from the external lighting equipment, and can be observed in a wide observation angle range as large as possible in which the reflected light is observed even from a remote distance. Thus, the image-displaying system according to the present invention is particularly useful as a lighting system for illuminating a signboard set on a rooftop of a building or a sign posted above a road.

For example, a preferred embodiment for illuminating the signboard on the rooftop of the building is schematically illustrated in Fig. 18. In this embodiment, the image-displaying sheet comprising the reflector of the present invention is fixed to the surface of the signboard. The sheet may be fixed to the signboard with an adhesive. In the case of the signboard illustrated, the external lighting equipment is preferably positioned so that the surface of the image-displaying sheet is illuminated from the vertically upside of the signboard. In addition, the direction of the light reflected on the surface of the image-displaying sheet is preferably controlled in the vertically downward direction and in the wide observation angle range as large as possible in relation to an observer on a ground (or a road) near the building. To control the direction of the reflected light as described above, the convex parts of the reflector are preferably formed using the precursor projections having the cross sections vertical to the surface of the precursor base layer, like the embodiment depicted in Fig. 9. In this case, the cross sections of the precursor projections are preferably positioned so that they face vertically upwards.

Fig. 19 schematically shows a preferred embodiment where the sign posted above the road is illuminated. In this embodiment, an image-displaying sheet comprising a reflector of the present invention is fixed to the surface of the sign substrate. Preferably, lighting equipment is placed on a roadside (a shoulder, etc.) and projects light in an obliquely upward direction against the surface of the image-displaying sheet. In this case, the light returning to the lighting equipment cannot be seen by a driver of an automobile traveling on the road. Thus, the amount of such light should be decreased as much as possible. To control the direction of the reflected light so that the driver of the automobile can catch the reflected light, like the embodiment of Fig. 18, preferably, the reflector comprising the convex parts, which are formed from the precursor projections having the sections vertical to the surface of the precursor base layer, is used. In the embodiment of Fig. 19, the sections of the precursor projections are positioned so that they faces horizontally the lighting equipment (to the left side in the figure).

The external lighting equipment may be a conventional projector lamp for illuminating the signboard or sign. Specific examples of such a projector lamp include Projector "OPL-250" (manufactured by Sumimoto 3M Limited, and a projector lamp disclosed in Japanese Patent No. 2910868.

The external lighting image-displaying system according to the present invention can effectively increase the brightness and contrast of the image formed thereon in comparison with an image-displaying system comprising a white sheet which is colored with a white pigment. When the image-displaying sheet is placed at a position higher than an eye of an observer outdoors, the background of the image-displaying sheet comprising the reflector of the present invention is seen white brightly even in cloudy days or at the twilight when the conventional white sheet is seen grayish.

(Other applications)

The reflector of the present invention can be used as a reflector for indirect lighting or a projection screen.

The reflector for indirect lighting is used to illuminate an object with light reflected by the reflector without directly illuminating the object with the light from a light source. In the case of the reflector for indirect lighting, effective observation angles and the distribution of intensity of reflected light in the observation range are preferably designed in desired ranges. With the reflector of the present invention, in particular, the reflector produced by the replication method is suitable as the reflector for indirect lighting, since the shapes and sizes of the convex and concave mirrors are easily designed.

The reflector of the present invention may be used as the reflector for indirect lighting as follows:

For example, the reflector is attached to a ceiling of a room, and lighted with a light source from below so that the reflected light from the reflector illuminates the room interior. In this case, when the light source is hidden from the observer, the illumination with mild impression is achieved. In addition, the room can be illuminated with light which comes from a place where the light source cannot be installed, for example, the ceiling, wall, etc. Furthermore, when it is desirable to light the room interior with light coming from a high position or a place which one cannot reach such as the ceiling, the light source can be installed on the floor or a position near the floor, and thus the light source can be easily replaced.

The indirect lighting can be used to illuminate the interior of a room in a special circumstance where a conventional light source cannot be used. For example, the special circumstance may be the room interior at high or low temperature, at high humidity, or in water, or the room requires ant-explosion or dust-proofing means. In such a case, the light source is placed outdoors while the reflector for indirect lighting is placed indoors, and the light is introduced in the room to illuminate the reflector, so that the room interior is illuminated with reflected light. In this case, at least a part of the wall of the room which separates outdoor and indoor is formed with a transparent plate (glass, etc.), and the light from the light source can be introduced in the room through the transparent plate. Alternatively, an elongate light-guiding means such as an optical fiber is used, light from the light source is introduced in the light-guiding means from one end thereof and light is emitted in the room from the other end of the light-guiding means.

When the reflector of the present invention is used as the projection screen, the high luminance observation angle of the reflector is controlled in a relatively narrow range (for example, the one-third maximum luminance observation angle being ±30 degrees in the horizontal direction). In such a case, two different images can be projected on the screen with two projectors, one of which is from the left side and the other from the right side in the horizontal direction. That is, each of two observers who are on the right and left sides in relation to the center line of the screen can correctly observe the image projected with one projector without the interference with the other image projected with the other projector (without the overlap of two images). Such a projection system is suitable for providing projected images having different information to two observes who are approaching the screen from the left and right directions in relation to the center of the information-displaying plate.

EXAMPLES

Examples 1-5

In these Examples, a reflector of the type shown in Figs. 1 and 2 was produced.

Firstly, a paint for a binding layer was applied with a bar coater on the surface of a support made of a polyester film. The thickness of the paint was adjusted so that the dry thickness was 35 µm. The paint was prepared by mixing 100 wt. parts of a polyvinylbutyral resin ("B90" manufactured by Monsanto Company), 23.3 wt. parts of an alkyd resin (Aroplaz® manufactured by Ashland Chemical Company), solvents (193 wt.

parts of xylene and 310 wt. parts of n-butanol) and 40 wt. parts of a urea-formaldehyde resin as a crosslinking agent (Uformite® F240 manufactured by Reichhold Chemicals).

Secondly, glass beads having an average diameter of 74 μm ± 10 μm were uniformly scattered on the surface of the paint coated before the paint is dried. Then, the paint was dried at 90°C for 10 minutes. Thereby, the glass beads were embedded in the binding layer so that about 40 to 50 % of the average diameter was in the binding layer.

Next, a mixture of a resin liquid containing a polyurethane resin with 25 wt. % of non-volatiles (containing 100 wt. parts of Desmolac 4125 available from Sumitomo Bayer Urethane Co., Ltd.) and 5 wt. parts of a polyisocynate as a crosslinking agent (Sumidur® N3300 available from Sumitomo Bayer Urethane Co., Ltd.) was applied on the binding layer with a bar coater at a specific bar set for each Example (100 to 300 μm) and dried to form a coating layer. Thus, a plurality of convex parts each comprising one bead and the coating layer covering the exposed part of the bead and having a convex surface consisting of the surface of the coating layer, and a plurality of dents with concave surfaces each of which was formed among the adjacent convex parts.

Finally, aluminum was vacuum deposited on the uneven surface formed from the convex parts and the dents to form a reflection film having a thickness of about 500 Å. Thereby, the reflector with a wide observation angle of the present invention was completed, which comprised the first reflection film adhered to the convex surfaces and the second reflection film adhered to the concave surfaces.

Example 6

A reflector with a wide observation angle of the present invention was produced in the same manner as in Example 1 except that the resin liquid was applied at a bar set of 50 μm.

Comparative Example 1

A reflector with a wide observation angle was produced in the same manner as in Example 1 except that no coating layer was formed. Thus, no concave surface was formed among the adjacent convex parts since no coating layer was formed.

Comparative Example 2

In this Comparative Example, a white reflection sheet with an intensive diffusive reflection property (that is, a copying paper) was used as a reflector for comparison.

Evaluation of the reflector

With each of the reflectors of Examples (except Comparative Example 2), the average depth of the concave mirrors (D: μm) and the average pitch of the convex mirrors (P: μm) were measured with a laser microscope, and then the ratio D/P was calculated.

The average depth of the concave mirrors was measured as follows:

A square sample of about 3 cm square was cut from the reflector near its center, and the average depth was measured with ten minute concave mirrors, which were randomly selected, and all the minute convex mirrors which surrounded the selected minute concave mirrors (usually 3 or 4 convex mirrors). The average pitch of the convex mirrors was measured by taking the photograph of each sample with the laser microscope and measuring the average distance between 40 adjacent convex mirrors. The observation conditions with the laser microscope were as follows:

Laser microscope: 1LM21 manufactured by LASERTEC

Objective lens: 50 times magnification

Scanning rate: Normal

Gain: Twelve o'clock direction

Stage moving speed: 30-80 μm/30 sec.

Averaging processing: 9 x 9

Pretreatment of sample: None

The reflection luminance of the reflector of each Example was measured as follows:

The reflector sample was illuminated with white light from the direction of 0 (zero) degree from the normal direction to the sample surface so that the plane illumination on the sample surface was 300 luces, and the reflection luminance was measured with varying the measuring angle (observation angle). The luminance was measured with a color luminance meter BM-5A (manufactured by TOPCON Co., Ltd.). The unit of the luminance was cd/cm^2. The distance between the light source and the luminance meter was about 10 m.

The results are shown in Table 1. Fig. 5 shows the graphs obtained in Example 3 and Comparative Example 1 as the examples of the graphs depicted from the results measured.

The effective observation angle range is a rage of the observation angles at which the absolute value of the luminance is at least 5 cd/cm^2 including zero degree of the observation angle. The observation angle range in which the 1/3 maximum luminance (one third of the maximum luminance) is attained (the 1/3 maximum luminance observation angle) is also an important parameter to evaluate the wide observation angle characteristics.

For example, when the 1/3 maximum luminance observation angle is less than 10 degrees, the diffusing function is low. When the 1/3 maximum luminance observation angle exceeds 80 degrees, the diffusing function is increased but the angle range in which the reflector is brightly observed cannot be widened. When the 1/3 maximum luminance observation angle is at least 10 degrees and no more than 80 degrees, preferably no more than 75 degrees, the angle range in which the reflector is brightly observed can be widened.

Even when the 1/3 maximum luminance observation angle satisfies the above requirements, the reflector cannot be observed brightly in a wide observation angle range, if the effective observation angle is less than 50 degrees. Accordingly, the reflector has the excellent wide observation angle property and can be seen brightly in the wide observation angle, when the both observation angles defined above are no more than 80 degrees, and the effective observation angle is at least 50 degrees, preferably at least 55 degrees.

Preferably, the effective observation angle is at least 50 degrees and the both observation angles defined above are no more than 75 degrees, preferably no more than 70 degrees to control the direction of the effectively reflected light in the specified observation angle range. For example, in the case of the reflector of Example 6, the thickness of the coating layer was relatively low, and the radius of curvature of the concave surfaces, which were formed on the surface of the coating layer among the adjacent convex parts, was insufficient to control the direction of the effectively reflected light in the specified observation angle range. The reflection directivity and the luminance were lower than those of other Examples, although the wide observation angle characteristics was better than the reflector of Comparative Example 1 (having no minute concave mirrors).

Table 1

	Bar set (μm)	Av. depth of concave mirrors P (μm)	Av. pitch of convex mirrors D (μm)	D/P	Maximum luminance (cd/m^2)	Effective obser-vation angle (deg.)	1/3 maximum obser-vation angle (deg.)
Ex. 1	100	15	95	0.16	60	±100	±70
Ex. 2	150	13	95	0.14	75	±75	±50
Ex. 3	200	9	95	0.09	190	±70	±33
Ex. 4	250	7	95	0.07	300	±60	±23
Ex. 5	300	5	95	0.05	930	±50	±12
Ex. 6	50	19	95	0.20	50	---	±80
C. E. 1	---	33	95	0.35	150	±40	±19
C. E. 2	---	---	---	---	50	---	>±80

Example 7

A reflector of this Example was produced in the same manner as in Example 1 except that the embossing was employed in place of the beads-embedding method. That is, in this Example, a base layer having convex parts was produced as follows:

A base layer sheet comprising a vinyl chloride resin was provided and embossed to obtain a precursor base layer having the structure of Fig. 6. Then, in the same manner as in Example 1, the coating layer was formed so as to cover the precursor projections and fill the spaces between the precursor projections to obtain a precursor reflector. Thereafter, a reflection film was formed to finish the reflector of this Example. In the course of the application of the resin liquid, the bar set was 300 μm.

The height of the semispherical precursor projection (the height of the convex part projected from the surface of the precursor base layer) was 365 μm, the diameter of the horizontal cross section of the precursor projection on the surface of the precursor base layer was 1 mm, the shortest distance between the adjacent two precursor projections (the distance measured along the line of the crosshatch) was 100 μm, and the radius of curvature of the surface of the precursor projection was 530 μm.

The surface roughness of the precursor base layer was 9.68 μm in terms of Rz (ten point average roughness), which was measured with a laser microscope equipped with a three-dimensional surface roughness meter (Laser Microscope manufactured by Laser Tech Co., Ltd.) at a magnification of 200 times.

The surface roughness of the precursor reflector was 5.95 μm in terms of Rz (ten point average roughness), which was measured with the above laser microscope at a magnification of 200 times.

In the reflector of this Example, each concave mirror was formed among the four convex mirrors positioned in the crosshatch arrangement. The average depth D of the concave mirrors was 55 μm, and the average pitch P between the two convex mirrors surrounding the concave mirror was 675 μm. Thus, the ratio D/P was 0.08.

The reflection characteristics of the reflector of this Example were measured. When the incident angle of light was 0 (zero) degree and 20 degrees, the maximum luminance was 520 [cd/m^2] and 1,150 [cd/m^2] respectively. When the incident angle of light was 0 (zero) degree and the reflection angle (observation angle) was 30 degrees, the luminance was 230 [cd/m^2], while when the incident angle was -20 degrees and the reflection angle was 50 degrees, the luminance was 450 [cd/m^2]. These results showed that the reflector has the very wide effective observation angle.

As a reference example, the reflection characteristics were measured with a reflector having no concave mirrors, in which the reflection film was formed on the precursor base layer having no coating layer was used as it was.

The results are as follows:

The maximum luminance was 330 [cd/m^2] at an incident angle of 0 degree and 560 [cd/m^2] at an incident angle of 20 degrees. When the incident angle was 0 (zero) degree and the reflection angle was 30 degrees, the luminance was 100 [cd/m^2], while when the incident angle was -20 degrees and the reflection angle was 50 degrees, the luminance was 120 [cd/m^2]. The measured values were lower than those of the reflector having the concave mirrors, which means that the reflection directivity was low.

The reflector of the reference example as a whole had the lower luminance than the reflector of Example 7. This may be because the reflection surface of the reflector of the reference example, in which the reflection film was formed directly on the positive convex and concave surfaces of the precursor base layer transferred from the negative mold, has the lower surface smoothness than the reflection surface of the reflector of Example 7.

When the coating layer was used, the decrease of the reflection luminance was effectively prevented.

The reflection luminance was measured by the same method under the same conditions as those in Example 1. Fig. 20 schematically shows the measuring apparatus, in which the relative positions of the light source and the luminance meter (the incident angle and the observation angle) is variable.

EFFECTS OF THE INVENTION

As can be seen from the above explanations, with the reflector of the present invention, the direction of the effectively reflected light can be very easily controlled in the specific observation angle range while maintaining the wide observation angle characteristics, and the reflector can be observed brightly, that is, with high luminance. Furthermore, the reflector of the present invention is particularly useful as a construction part of an image-displaying sheet which is used as a sign, a signboard, etc.

WHAT IS CLAIMED:

1. A reflector comprising

a base layer having a surface and a back surface, and

a plurality of minute convex mirrors which are provided on the surface of said base layer with being coadjacent each other and each of which has a convex surface covered with the first reflection film,

wherein said base layer has a plurality of minute concave mirrors each having a concave surface which falls from the surface to the back surface of said base layer and is covered with the second reflection film, and

said minute concave mirrors are provided between said minute convex mirrors coadjacent each other.

2. The reflector according to claim 1 wherein the surface roughness of the uneven reflection surface formed by the first and second reflection films which are connected each other is in the range from 0.02 to 0.25 in terms of a ratio (D/P) of an average depth of the concave mirrors (D: μm) to an average pitch of the convex mirror (P: μm).

3. A reflector with a wide observation angle comprising

(A) a base layer having a surface and a back surface,

(B) a plurality of minute convex parts which are provided on the surface of said base layer with being coadjacent each other, and each of which is fixed to the surface of said base layer and has a convex surface bulging outwardly from the surface of said base layer, and

(C) the first reflection film fixed to the convex surfaces of said convex parts,

wherein a concave surface which falls from the surface to the back surface of said base layer is provided between the convex parts adjacent each other and the second reflection film is adhered to said concave surface.

4. The reflector according to claim 3 comprising a precursor base layer having a plurality of precursor projections which are integrally formed with the surface thereof, and a coating layer with a specific thickness which is provided to cover said precursor projections and fills spaces between the adjacent precursor projections,

wherein the base layer comprises said precursor base layer and said coating layer, the convex parts comprises said precursor projections and the parts of said coating layer covering said precursor projections, and the concave surface comprises the surface of said coating layer which fills the spaces between said precursor projections.

5. A reflector with a wide observation angle comprising

(a) a binding layer having a surface and a back surface,

(b) a plurality of beads which are fixedly provided on the surface of said binding layer with coadjacent each other, a part of each bead being embedded in said binding layer while the remaining part of each bead being exposed from the binding layer, and

(c) the first reflection film covering said beads

wherein a coating layer with a specific thickness is provided to cover the exposed parts of said beads and to fill spaces between the exposed parts of the adjacent beads,

the coating layer which covers the exposed parts of said beads forms convex parts each having a convex surface bulging from said binding layer toward said coating layer,

said first reflection film is adhered to the convex surfaces of said convex parts, and

a concave part consisting of the concave surface of said coating layer, which falls from the surface of said coating layer to said binding layer, and is provided between said convex parts adjacent each other, and the second reflection film, is adhered to said concave surface.

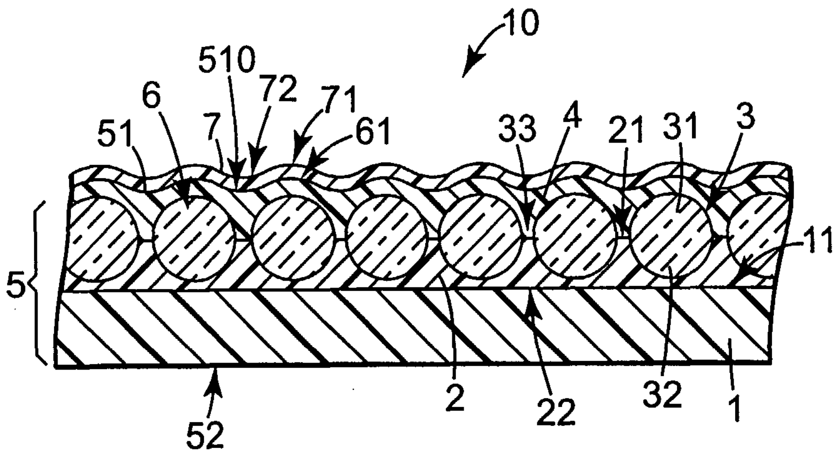

10
510
72
71
6
7
61
51
33
4
21
31
3
11
5
2
22
32
1
52

Fig. 1

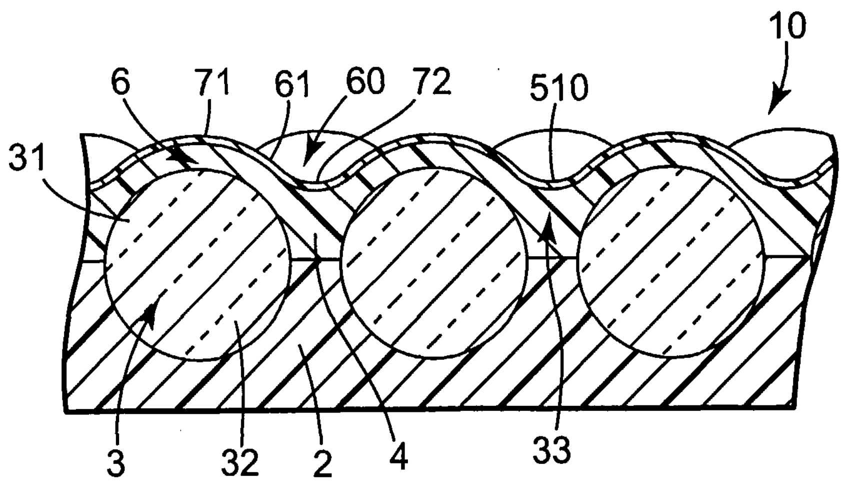

10
6
71
61
60
72
510
31
3
32
2
4
33

Fig. 2

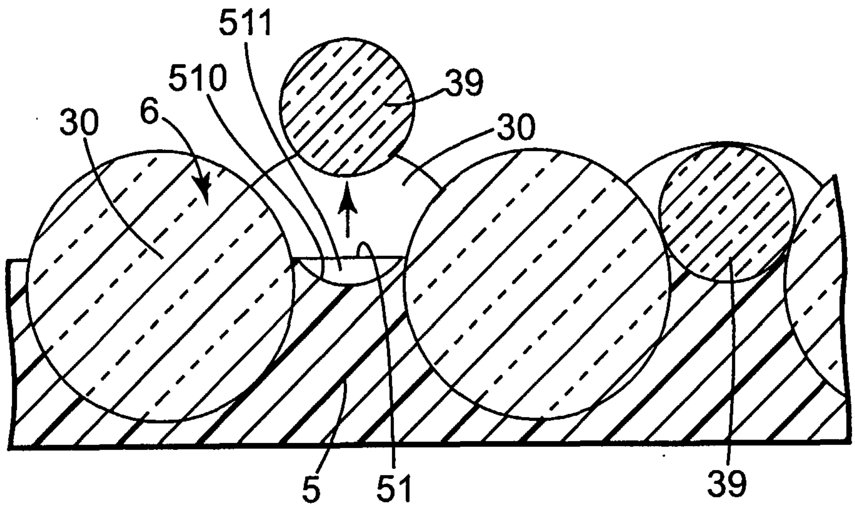


Fig. 3

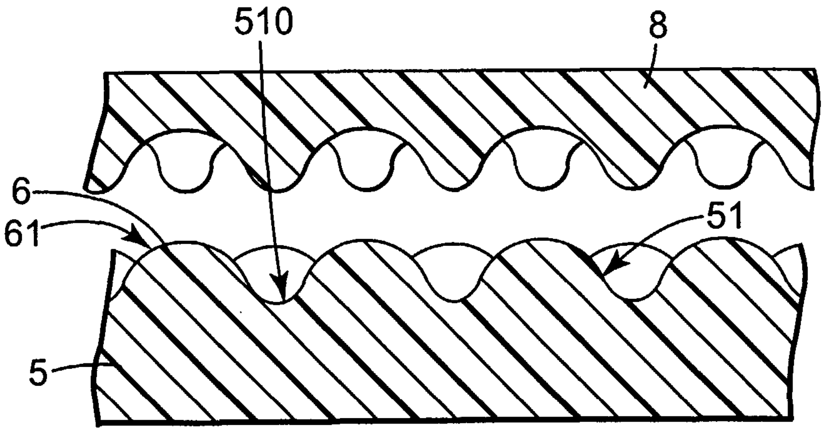


Fig. 4

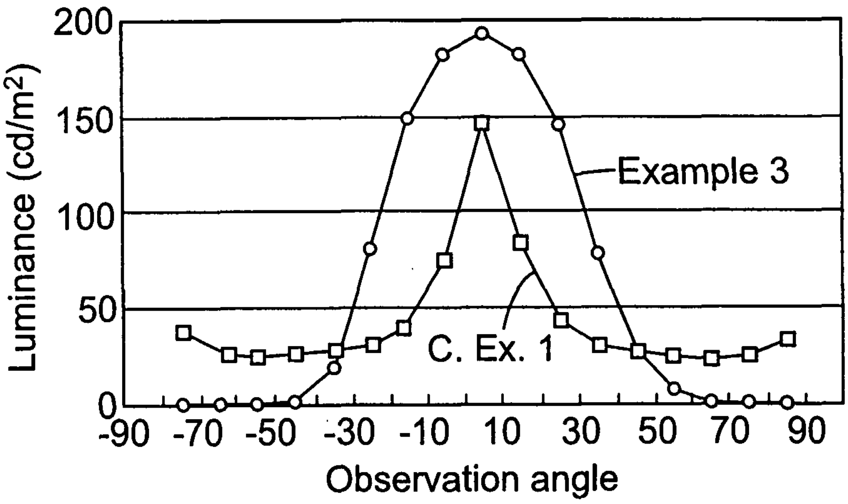

200
150
100
50
0
Luminance (cd/m²)
Example 3
C. Ex. 1
-90 -70 -50 -30 -10 10 30 50 70 90
Observation angle

Fig. 5