



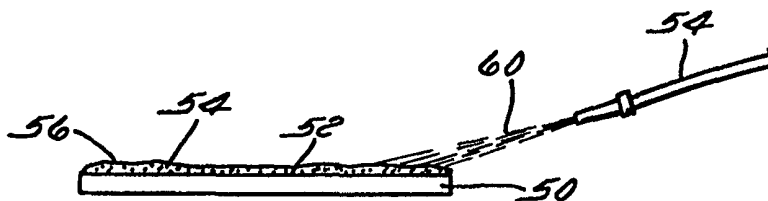
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(54) Title: DIFFUSER MASTER AND METHOD OF MANUFACTURE

(57) Abstract

A diffuser master is provided which is manufactured mechanically instead of holographically. The master can be made from a suitable substrate including relatively hard materials such as plastic, glass or metal. A substrate (30, 50, 70) having a first side (32, 52, 72) is worked to form a diffuser surface relief structure (33, 53, 73) thereon. The substrate can be buffed using a buffing agent (34) of a selected grit in order to form surface scratches in the first side of the substrate. The substrate can also be blasted with shot particles (80) in order to form indentations and depressions in the first side. The substrate can alternatively be acid or alkali etched in order to form surface irregularities in the first side. The scratches, depressions or irregularities can be formed in order to create a desired surface relief and hence desired diffuser output characteristics.



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DIFFUSER MASTER AND METHOD OF MANUFACTURE

Background of the Invention1. Field of the Invention

The present invention relates generally to optical elements, and more particularly to a non-Lambertian diffuser fabricated using mechanical means instead of light and mechanical methods for fabricating the diffuser.

5 2. Description of the Related Art

Methods for manufacturing and replicating optical components such as a master diffuser exhibiting desired light diffusing characteristics are well known. Many of these methods involve creating a master diffuser by exposing a photoresist material to a source of light and then replicating this master diffuser into one or more submasters of a more durable nature. Many of these methods inherently destroy the master diffuser when creating the submasters. There are also other methods of making replicas of a master diffuser which contain the optical features in the master without destroying the master diffuser. With each of these methods, the master diffuser is initially created optically. Submasters are created from these master diffusers utilizing a number of methods whereby the master diffuser surface is replicated into a submaster surface.

One such method involves creating a submaster for an optical product by recording optical features on a photosensitive medium using coherent or incoherent light. The photosensitive medium is then further processed to create a master optical product. A layer of two part silicone epoxy is then poured over the master to replicate the optical surface features of the master photosensitive medium in the silicone epoxy material. The silicone epoxy layer cures at room temperature and becomes rubber. The silicone material is then further cured and separated from the master to obtain a silicone rubber submaster. The soft silicone submaster is then used to make successive generations of submasters or final optical products by covering the soft submaster with a layer of epoxy, covering the layer of epoxy with a plastic substrate, curing the epoxy and separating the epoxy and plastic substrate from the submaster. This particular method of creating a diffuser is

highly labor intensive, requires use of many different materials, requires performing a number of steps, and must be conducted in a sterile environment.

Another method of creating a diffuser involves recording optical features in a photosensitive medium using coherent or incoherent light and then processing the medium to create a master. The photosensitive medium is then coated with a layer of silver. A layer of nickel is electroplated onto the silver layer and then the silver layer and layer of nickel are removed from the photosensitive material or medium to form the submaster. The combined silver and nickel backing form a metal shim submaster which is then replicated to fabricate final optical products by embossing the surface features of the submaster into epoxies, plastics or polycarbonate materials, or by injection molding such materials into a mold carrying the submaster. Again, this process is costly, labor intensive, wasteful of material and requires a sterile environment.

Another significant problem with each of these methods is that the submasters or final optical products created from the master optical elements are made from materials such as plastics, epoxies, or polycarbonate composites and exhibit relatively poor long-term characteristics. These materials are also not suited for use near extremely high temperature light sources because they have relatively low melting or softening temperatures when compared to other more durable materials.

Summary of the Invention

A primary object of the present invention is to provide a method for making a diffuser optical product utilizing conventional mechanical means instead of the aforementioned holographic and complex and costly methods. Another primary object of the present invention is to provide a diffuser from an extremely durable material such as glass or metal. It is another object of the present invention to provide a diffuser which is suitable for use under extreme temperature conditions such as adjacent a high temperature active light source in a liquid crystal display or the like. It is a further object of the present invention to provide a method for producing such a diffuser which requires fewer steps for creating the

diffuser and is less costly in materials, cost of labor and cost of the manufacturing environment.

In accordance with the present invention, these objects are achieved by several methods for producing a diffuser from highly durable materials such as glass or metal and by the resulting diffuser optical products themselves.

In one embodiment, a method for producing such a diffuser first includes providing a substrate body having at least a first side. A working material is then selected which has desired qualities for altering the characteristics of the first side of the substrate body. The working material is applied to the first side in order to form a plurality of irregularities thereon which define a diffuser surface. The diffuser surface exhibits light propagating characteristics defined by the particular characteristics of the plurality of irregularities.

In one embodiment, the working material is a buffing agent having a desired grit. The first side of the substrate body is buffed utilizing the buffing agent which forms a plurality of scratches in the first side according to the particular grit of the agent. The scratches define the diffuser surface and thereby exhibit light propagating characteristics defined by the orientation, contour, length and depth of the plurality of irregularities.

In another embodiment, the working material is an acid or alkali agent selected to react with a particular substrate body material. The acid or alkali agent is placed on the first side of the substrate body for an etching time duration. The acid or alkali agent etches a plurality of irregularities into the first side of the substrate body. The plurality of irregularities each have at least a size, a depth, and a contour formed according to the reaction between the substrate body and the acid or alkali agent as well as etching time duration. The diffuser surface on the first side exhibits light propagation characteristics defined by the size, depth and contour of the irregularities formed by the etching or acid or alkali agent.

In another embodiment, the acid or alkali etching agent also includes a plurality of particles mixed therein each having a size, a shape and a mass. The particles enhance the etching reaction between the substrate body and the acid or alkali agent by forming deeper depressions where the particles are located on the

first side of the substrate body. In another embodiment, a pressure may be applied to the first side of the substrate body while the acid or alkali agent and particles are disposed thereon to further enhance penetration of the particles into the first side of the substrate body as the acid or alkali agent reacts with the
5 substrate body material.

In one embodiment, a mask having a plurality of openings formed therein is applied to the first side of the substrate body. The acid or alkali agent is placed on the first side over the mask and thereby etches a plurality of irregularities into the first side where the first side is exposed through the openings of the mask.
10 The irregularities each have a size, depth and contour which are essentially determined by the length, width, orientation and shape of the plurality of openings in the mask as well as the particular reaction between the acid agent and the substrate body as well as the etching time duration.

In one embodiment, the working material is a blasting agent which includes
15 a plurality of shot particles each having a size, a shape and a mass. The blasting agent is forced against the first side of the substrate body such as in a sandblasting operation at a predetermined velocity to form a plurality of irregularities or depressions. The depressions are formed according to the size, shape and mass of the shot particles as well as the predetermined velocity. The diffuser surface
20 structure is defined by the depth, contour and size of the plurality of irregularities formed in the first side of the substrate body.

In another embodiment of the invention, a diffuser is disclosed having a substrate body and at least a first side. A diffuser surface relief structure formed non-holographically in the first side defines a plurality of irregularities therein.
25 The irregularities have light propagating characteristics which are defined by at least one of the size, depth, length, width, orientation, and contour of the plurality of irregularities.

In one embodiment, the substrate body is formed from a glass material substrate. In another embodiment, the substrate body is formed from a hard
30 plastic material substrate. In another embodiment, the substrate body is formed from a metallic material substrate.

In one embodiment, the surface relief structure is comprised of a plurality of scratches formed by buffing the first side with a buffing agent having a predetermined grit. In another embodiment, the surface relief structure is comprised of a plurality of closely spaced depressions in the first side formed by forcing a plurality of shot particles at a predetermined velocity against the first side. In a further embodiment, the surface relief structure is acid etched into the first side by an acid agent placed on the first side of the substrate body.

These and other aspects and objects of the present invention will be better appreciated and understood when considered in conjunction with the following description and accompanying drawings. It should be understood, however, that the following description, while indicating preferred embodiments of the present invention, is given by way of illustration and not of limitation. Many changes and modifications may be made within the scope of the present invention without departing from the spirit thereof and the invention includes all such modifications.

Brief Description of the Drawings

A clear conception of the advantages and features of the present invention, and of the construction and operation of typical mechanisms provided with the present invention, will become more readily apparent by referring to exemplary and therefore non-limiting embodiments illustrated in the drawings accompanying and forming a part of this specification, and in which:

Figure 1A illustrates an elevational perspective view of a glass diffuser constructed in accordance with one embodiment of the present invention;

Figure 1B illustrates an elevational perspective view of a metal diffuser constructed in accordance with another embodiment of the present invention;

Figure 1C illustrates an elevational perspective view of a plastic diffuser constructed in accordance with another embodiment of the present invention;

Figure 2 illustrates a schematic view of a buffing process for forming one of the diffusers of Figures 1A-1C;

Figure 3 illustrates a schematic view of an etching process for forming one of the diffusers illustrated in Figures 1A-1C;

Figure 4 illustrates an alternative etching process for forming one of the diffusers illustrated in Figures 1A-1C;

Figure 5A illustrates another alternative etching process for forming one of the diffusers illustrated in Figures 1A-1C;

5 Figure 5B illustrates a perspective view of the diffuser illustrated in Figure 5A;

Figure 6 illustrates a schematic view of a blasting process for forming one of the diffusers illustrated in Figures 1A-1C;

10 Figure 7A illustrates an elevational plan view of the diffuser surface of a diffuser; and

Figure 7B illustrates a cross-sectional view of the diffuser surface taken along lines 7B-7B of Figure 7A.

Detailed Description of the Presently Preferred Embodiments

15 Referring now to the drawings, Figures 1A-1C illustrate several simplified elevational perspective views of diffusers formed by one of the methods of the present invention. The present invention may be utilized to form diffusers from substrate materials such as plastics, glass or metal. The methods are appropriate for forming diffusers from conventional diffuser materials such as epoxy, polycarbonate, polyester, acrylic, nylon, polystyrene, tetrafluoroethylene, 20 polyimide, polyvinyl chloride, polymethyl methacrylate, TPX™, ARTON™, and other plastic materials but also may be utilized to form diffusers from much more durable materials such as glass and metal for which previous methods were not suitable. Glass materials that can be used include light barium crown, phosphate crown, crown, flint, extralight flint, light flint, fused silicon, and borosilicate. 25 Figure 1A illustrates a glass diffuser 20 constructed according to one embodiment of the present invention. Figure 1B illustrates a metal diffuser 22 constructed in accordance with one embodiment of the present invention. Figure 1C illustrates a plastic diffuser 24 constructed in accordance with one embodiment of the present invention. The glass diffuser 20, metal diffuser 22, and plastic diffuser 24 will be 30 described in greater detail below with reference to the processes of the invention.

- 7 -

Figure 2 illustrates a schematic view of a process of forming a random surface relief structure on a diffuser substrate body. The substrate body 30 includes a first side 32 onto which a diffuser surface relief structure will be formed. The substrate 30 is illustrated in the form of a flat rectangular plate and the diffusers 20, 22 and 24 are illustrated in the form of rectangles in Figures 1A-1C. It is intended that the diffusers and the substrate material may take on any number of configurations and constructions without departing from the scope of the present invention. The simple shapes and configurations illustrated herein are shown for simplification of description and not by way of limitation.

10 The substrate 30 of the present embodiment can also be in the form of a glass substrate, a metal substrate, or a plastic substrate without departing from the scope of the present invention. Depending upon the type of substrate material selected, the process shown in Figure 2 may vary slightly in order to produce the desired surface relief structure as described below. The method of the invention is
15 capable of forming a surface relief structure on a common material such as plastic but is also capable of forming such a surface relief structure on hard and highly durable materials such as glass and metal. Prior methods of forming diffuser surface relief structures are not capable of producing suitable surface relief structures on such hard and durable materials.

20 Referring again to Figure 2, the first side 32 of the substrate 30 is facing upward although this orientation can be altered without departing from the scope of the invention. The substrate 30 can also be held in a suitable fixture (not shown) or other apparatus for affixing the substrate in place while it is being worked.

25 As illustrated in Figure 2, a suitable buffing agent 34 is disposed on the first side 32 of the substrate 30. Buffing agents that can be used include agents such as aluminum oxide, silicon carbide, and cerium oxide. A buffing apparatus 36 is disposed over the substrate 30 and is utilized to work the buffing agent 34 against the first side 32 to produce scratches or other such irregularities in the
30 substrate first side 32. Depending upon the materials selected for the substrate 30, the buffing agent is selected including a particular grit in the form of buffing

- 8 -

particles 35 which are suspended within a compound or which are otherwise attached to the buffing apparatus 36. The buffing particles 35 are determined by the type of substrate material 30 selected.

For example, if the substrate 30 is a plastic material, the buffing agent 34
5 may be a buffing compound having suspended therein a plurality of buffing particles 35 in the form of sand or silica of a particular grit or size. Alternatively, the buffing agent can be in the form of what is commonly known as sandpaper which includes a paper substrate having sand or silica particles adhered thereto of a particular grit. In either case, the buffing particles must be suitable for working
10 and abrading the surface of the relatively soft plastic substrate.

Figure 2 illustrates that a buffing agent 34 including suspended silica particles is disposed on the first side 32 of the substrate 30. The buffing apparatus 36 includes a buffing pad 38 that is brought into contact with the buffing compound 34 and rotated or otherwise moved against the buffing compound 34.
15 The buffing pad 38 works the buffing agent 34 including the suspended silica particles into the first side 32 to form a plurality of surface irregularities in the form of scratches and indentations in the surface. In an alternative embodiment, the buffing apparatus 36 may have a sheet or pad of sandpaper mounted to the pad 38, where the sheet includes the silica particles adhered thereto. In this
20 embodiment, the buffing compound 34 is not necessary and is replaced by the sandpaper carried on the buffing pad 38.

Figure 2 illustrates that the buffing pad 38 is rotated about a rotary shaft 40 in order to work the buffing agent 34 into the first side 32. The buffing pad 38 can alternatively be a surface which moves back and forth across the first side 32
25 in order to produce the scratches and indentations. In a further alternative, the buffing pad 38 can be connected via a mechanism (not shown) and electronic means to a computer system 42 for guiding the buffing pad 38 over the first side 32. In such an embodiment, the particular surface scratches and indentations are preprogrammed into the computer and replicated onto the first side 32 as desired.

30 In this embodiment, the surface irregularities, indentations or scratches are formed in the first side 32 of the substrate 30 by the silica or buffing particles of

the buffing agent 34 physically cutting into the first side 32. The depth, cross-sectional contour, length and shape of the scratches depends on the direction of rotation and/or linear movement of the buffing pad 38 of the buffing apparatus 36 relative to the first side of the substrate.

5 If the substrate body 30 is alternatively formed from a material such as glass or a very hard plastic or a soft metal such as gold, the buffing agent 34 may include a more durable type of sand or silica particle 35 is suitable for forming scratches and indentations and otherwise deforming such hard materials. Alternatively, if the substrate material is any type of glass including extremely
10 hard composite glass, the buffing agent 34 may include buffing particles 35 in the form of a diamond powder or diamond particles suitable for scratching or otherwise deforming such a hard surface. The type of buffing agent 34 as well as the particular construction of the buffing apparatus 36 is selected and designed according to the desired diffuser characteristics and the substrate 30 material.

15 Referring now to Figure 3, a substrate body 50 includes a first side onto which a surface relief structure is to be formed. Again, the substrate material can be any suitable material but preferably is a metal or glass substrate material. Additionally, the substrate 50 can be supported in a suitable fixture or machine (not shown) in order to perform the process of the invention.

20 An acid or alkali etching agent 54, such as hydrochloric acid, hydrofluoric acid, ammonium fluoride, potassium hydroxide or sodium hydroxide is poured on or otherwise disposed over the first side 52 of the substrate 50. The etching agent 54 reacts with the substrate material and forms irregularities or depressions in the first side 52 to define the diffuser surface relief structure as is described in more
25 detail below. The etching acid or alkali can be any type of acid or alkali that is selected to react as desired with a particular substrate material from which the substrate body 50 is manufactured. The etching acid in one preferred embodiment is a solution containing either hydrofluoric acid or ammonium fluoride. The etching alkali in one preferred embodiment is a solution containing either
30 potassium hydroxide or sodium hydroxide. Depending on the amount of time the acid or alkali is left on the first side of the substrate and on the concentration of

- 10 -

the acid or alkali, the etching agent 54 reacts with the first side to form the irregularities thereon. The etching acid or alkali essentially eats away at the surface of the substrate body 50 where it is located and where it is most concentrated. For example, the etching acid or alkali can be applied to the first
5 side 52 for less than 2 minutes on a glass or metal substrate body 50 to produce the desired result.

After the desired duration of acid or alkali etching has expired, the first side 52 is washed with water or another cleaning solution in order to remove all of the remaining etching agent 54. A suitable hose 58 connected to a reservoir of
10 water other solution 60 can be retained near the substrate 50 in order to wash the etching agent 54 from the substrate.

In the present embodiment, a plurality of solid particles 56 are suspended in the acid or alkali etching agent 54 to further enhance the etching process and to produce a more desirable surface relief structure in the first side 52 of the
15 substrate. Alternatively, the particles can be first placed on top of the substrate body 50, such as a glass substrate, and then the etching agent 54 poured over the first side 52 and the particles 56 to produce the desired surface relief. The particles 56 enhance the surface relief structure by penetrating deeper into the first
20 side 52 according to the mass and size of each particle and according to the chemical reaction between the etching agent 54 and the substrate body 50 beneath each particle. The greater the mass of each particle 56, the deeper the depression left beneath each particular particle.

Figure 4 illustrates another alternative embodiment of the acid or alkali etching process whereby a pressure plate or pressing tool 62 is placed over the
25 first side 52 sandwiching therebetween the acid or alkali etching agent 54 and the particles 56. A force in the direction of arrows F is applied to the pressure plate or pressing tool 62 to increase penetration of the particles deeper into the first side 52. The more force applied to the plate 62, the deeper the particles 56 will embed into the first side 52 thereby enhancing the surface relief structure.

30 The size, shape and mass of the particular particles 56 can vary considerably depending on the desired surface relief characteristics formed in the

first side 52. In one embodiment, a powder such as a ceramic powder including very fine particles can be utilized and placed on the first side 52 of the substrate body 50. The ceramic powder particles are particularly useful for etching a substrate of glass. Particular examples of suitable powder particles include silicon carbide and boron carbide. Such powder particles can either be in the form of irregular and randomly shaped particles in a range of sizes from about 4 mm to about 0.045 mm. Alternatively, particles can have a general shape of hexagonal, rhombohedral, spherical, or any other suitable shape and range in sizes from about 4 mm to about 0.045 mm. The larger the particle size, the deeper the impression made in the first side 52. Spherical particles 56 will leave essentially semi-circular or spherical depressions in the first side 52.

Figures 5A and 5B illustrate another alternative embodiment which can be utilized to etch a surface relief structure in a substrate body 50. Figure 5B illustrates a perspective view of substrate body 50 and the mask 64. In this embodiment, a mask 64 made of a material such as polyester or polycarbonate is placed over the first side 52 of the substrate body 50. A portion of the first side 52 is exposed through a plurality of openings 66 formed in the mask 64. The openings 66 can be randomly produced in the mask or can be computer generated in order to produce a particular and predetermined surface relief structure in the substrate body 50.

In this embodiment, the etching agent 54 does not necessarily include particles 56 therein but may instead be a purely liquid solution. The etching acid solution 54 is then poured over the mask 66 and etches the first side 52 of the substrate body 50 only where exposed through the openings 66. The surface contour and configuration of the surface relief structure formed on the first side 52 is determined by the length, width, contour, spacing and shape of the openings 66 provided in the mask 64 as well as the acid concentration, duration and etching and acid and substrate compositions. Virtually any pattern of openings can be produced in the mask 64 to form any number of surface relief structures in the substrate body 50.

- 12 -

Referring now to Figure 6, another alternative embodiment for producing a surface relief structure in a substrate body is disclosed. In this embodiment, a substrate body 70 is provided having a first side 72 onto which a diffuser surface relief structure is to be formed. The substrate body 70 is placed adjacent a blasting apparatus 74 having a nozzle 76 from which a blasting material is ejected at a high velocity in the direction of the arrows B toward the first side 72 of the substrate. A hose 78 is connected to a supply (not shown) of blasting material or particles 80 drawn into the hose 78 of the apparatus 74 and ejected toward the substrate. The particles 80 can be in the form of shot particles and may be provided from any number of materials such as spherical metal balls or sand or silica particles of various sizes and shapes. The particles 80 are ejected from the blasting apparatus 74 and bombard the first side 72 of the substrate. Upon impact with the substrate, the particles 80 form small depressions or pits in the first side. These depressions or pits define the surface relief structure of the diffuser created on the substrate 70. The shape, size and contour of the depressions or pits are defined by the mass, size and shape of the shot particles 80, the velocity of the particles exiting the nozzle 76, and the material which forms the particles and the substrate body 70. Additionally, the angle of incidence of the nozzle 76 relative to the first side 72 and the path of travel of the shot particles 80 relative to the first side 72 also affects the structure formed on the first side. Additionally, the size and shape of the nozzle 76 may also be varied in order to change the surface relief structure characteristics formed on the first side of the substrate.

Referring now to Figure 7A, an elevation plan view of a diffuser and a diffuser surface formed by any of the above embodiments is illustrated. The diffuser has a substrate 30, 50, or 70 and a diffuser surface 33, 53, or 73 formed by the buffing, etching, and blasting embodiments, respectively. Figure 7B illustrates a cross-sectional view of the diffuser surface taken along lines 7B-7B of Figure 7A.

The shape and orientation of the scratches and indentations determine the light output characteristics of the diffuser, including non-Lambertian output. For example if the scratches are long and narrow in one direction the light output from

the diffuser will be a distribution which is long and narrow in the perpendicular direction. If, for example, a circular light distribution is desired, scratches or indentations of a more circular shape, such as might be achieved by pressing the buffing material into the surface in the presence of acid, are preferably used.

5 Though the invention was described referring to particular embodiments, many other changes and modifications may be made to the invention as described without departing from the spirit and scope thereof. The scope and spirit of these changes and modifications will become apparent from the appended claims. The scope of the invention is therefore intended only to be limited by the appended
10 claims.

What is claimed is:

1. A method of making a non-Lambertian diffuser, the method comprising the steps of:
 - providing a substrate body having at least a first side;
 - selecting a buffing agent having a desired grit; and
 - 5 buffing the first side of the substrate body with the buffing agent to form a plurality of irregularities in the first side according to the grit of the buffing agent to thereby form a diffuser surface having light propagating characteristics defined by the orientation, contour and depth of the plurality of irregularities.
2. The method according to claim 1, wherein the step of providing further
10 includes providing a substrate body from a plastic material selected from one of the group consisting of at least polycarbonate, polyester, acrylic, nylon, polystyrene, tetrafluoroethylene, polyimide, polyvinyl chloride, polymethyl methacrylate, TPX™, and ARTON™.
3. The method according to claim 1, further comprising the step of:
15 placing the buffing agent directly on the first side of the substrate body prior to the step of buffing.
4. The method according to claim 1, further comprising the steps of:
 - placing the buffing agent on a buffing apparatus;
 - moving the buffing apparatus into contact with the first side of the substrate
20 body; and
 - buffing the first side with the buffing apparatus.
5. The method according to claim 1, wherein the step of selecting further includes selecting a buffing agent from at least one of the group consisting of aluminum oxide, silicon carbide, and cerium oxide.

- 15 -

6. A method of making a non-Lambertian diffuser, the method comprising the steps of:
- providing a substrate body having at least a first side;
 - selecting an etching agent;
 - 5 placing the etching agent on the first side of the substrate body for an etching time duration; and
 - etching a plurality of irregularities into the first side, the plurality of irregularities having at least a size, a depth and a contour formed according to a reaction between the substrate body and the etching agent and according to the etching time duration to thereby form a diffuser surface on the first side having
 - 10 light propagation characteristics defined by the size, depth and contour of the irregularities.
7. The method according to claim 6, wherein the step of providing further includes providing a substrate body formed from a glass material.
- 15 8. The method according to claim 6, wherein the step of providing further includes providing a substrate body formed from a glass material selected from at least one of the group consisting of light barium crown, phosphate crown, crown, flint, extralight flint, light flint, fused silica, and borosilicate.
9. The method according to claim 6, wherein the step of selecting further
- 20 includes selecting an etching agent from at least one of the group consisting of sodium hydroxide, potassium hydroxide, hydrofluoric acid, and ammonium fluoride.
10. The method according to claim 6, further comprising the steps of:
- mixing a plurality of solid particles with the acid agent to form a working
 - 25 compound, each of the plurality of particles having a size, a shape and a mass;
 - and

etching the plurality of irregularities into the first side, the size, depth and contour of the plurality of irregularities determined by the size, shape and mass of the plurality of particles as well as the reaction between the etching agent and the substrate body and the etching time duration.

- 5 11. The method according to claim 10, further comprising the step of:
applying pressure against the first side after the step of placing the working
compound thereon in order to increase the depth of the plurality of irregularities.
12. The method according to claim 10, wherein the step of mixing further
10 includes providing a plurality of particles each having a general shape selected
from the group consisting of hexagonal, rhombohedral, and spherical, and a
diameter within a range of diameters from about 4 mm to about 0.045 mm.
13. The method according to claim 11, wherein the plurality of particles are
provided having a number of different diameters, the diameter of each of the
plurality of particles being within the range of diameters.
- 15 14. The method according to claim 10, wherein the step of mixing further
includes providing the plurality of particles selected from at least one of the group
consisting of silicon carbide and boron carbide.
15. The method according to claim 6, further comprising the steps of:
selecting a mask having a plurality of openings passing through the mask,
20 each of the plurality of openings having a length, a width, an orientation and a
shape;
securing the mask flush against the first side of the substrate body;
placing the etching agent over the mask on the first side; and
etching the plurality of irregularities into the first side of the substrate body
25 whereby the size, depth and contour of the plurality of irregularities are
determined by the length, width, orientation and shape of the plurality of openings

- 17 -

in the mask as well as the reaction between the etching agent and the substrate body and the etching time duration.

16. The method according to claim 15, wherein the step of selecting a mask further includes selecting a mask made from a material selected from the group
5 consisting of polyester and polycarbonate.

17. A method of making a non-Lambertian diffuser, the method comprising the steps of:
providing a substrate body having at least a first side;
selecting a blasting agent including a plurality of shot particles each having
10 a size, a shape and a mass; and
forcing the blasting agent against the first side of the substrate body at a predetermined velocity to form a plurality of irregularities in the first side according to the size, shape and mass of the plurality of shot particles and the predetermined velocity to thereby form a diffuser surface structure in the first side
15 according to a depth, contour and size of the plurality of irregularities.

18. The method according to claim 17, wherein the step of providing further includes providing a substrate body formed from a glass material.

19. The method according to claim 17, wherein the step of providing further includes providing a substrate body formed from a glass material selected from at
20 least one of the group consisting of light barium crown, phosphate crown, crown, flint, extralight flint, light flint, fused silica, and borosilicate.

20. The method according to claim 17, wherein the step of providing further includes providing a substrate body formed from a metal material.

21. The method according to claim 17, wherein the step of selecting further
25 includes selecting the plurality of shot particles each having a diameter within a

range from about 4 mm to about 0.045 mm and a general shape selected from the group consisting of hexagonal, rhombohedral, and spherical.

22. The method according to claim 17, wherein the step of selecting further includes selecting the plurality of shot particles from shot particles made from a metal material.
- 5
23. A non-Lambertian diffuser comprising:
a substrate body having at least a first side; and
a diffuser surface relief structure formed non-holographically in the first side, the surface relief structure defining a plurality of irregularities in the first side and
10 having light propagating characteristics defined by at least one of the size, depth, length, width, orientation, and contour of the plurality of irregularities.
24. The diffuser according to claim 23, wherein the substrate body is a glass material substrate.
25. The diffuser according to claim 23, wherein the substrate body is a plastic material substrate.
- 15
26. The diffuser according to claim 23, wherein the substrate body is a metallic material substrate.
27. The diffuser according to claim 23, wherein the surface relief structure comprises a plurality of scratches in the first side formed by buffing the first side with a buffing agent having a predetermined grit, each of the plurality of scratches
20 having a depth, a contour, a length, a width, and a shape.
28. The diffuser according to claim 23, wherein the surface relief structure comprises a plurality of closely spaced depressions in the first side each having a depth and a contour and each formed by forcing a plurality of shot particles at a

- 19 -

predetermined velocity against the first side, the shot particles each having a predetermined size, shape and mass.

29. The diffuser according to claim 23, wherein the surface relief structure is etched into the first side by an etching agent carrying a plurality of particles each
5 having a size, shape and mass.

30. The diffuser according to claim 29, wherein the surface relief structure is further etched into the first side by pressing the plurality of particles into the first side.

31. The diffuser according to claim 23, wherein the surface relief structure is
10 further etched into the first side by an etching agent contacting the first side through a plurality of openings in a mask, the plurality of openings each having a length, a width, an orientation and a shape.

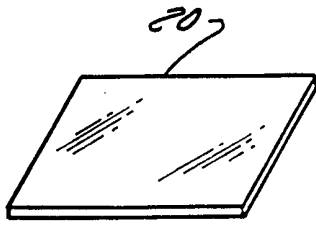


FIG. 1A

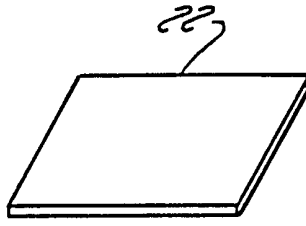


FIG. 1B

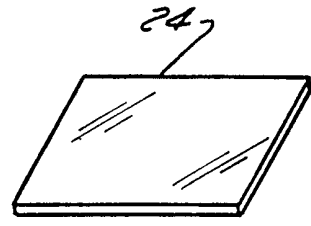


FIG. 1C

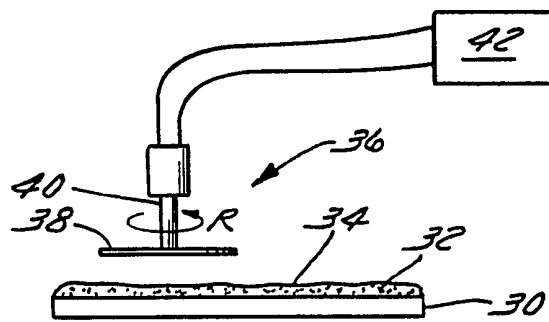


FIG. 2

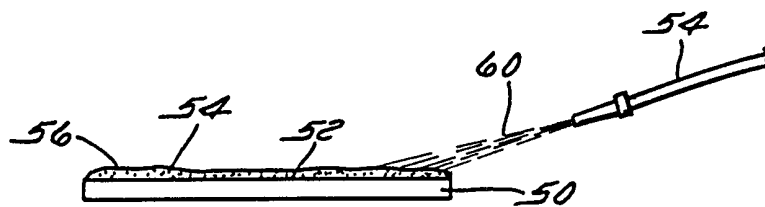


FIG. 3

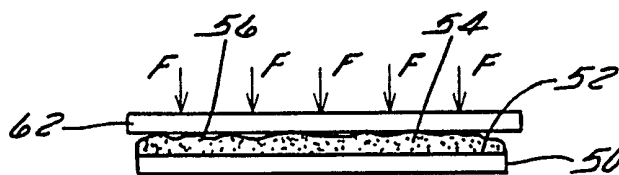


FIG. 4

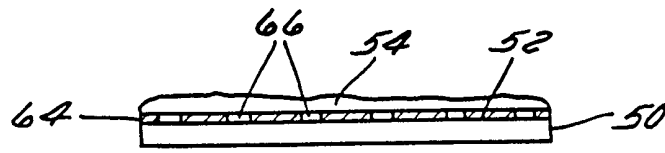


FIG. 5A

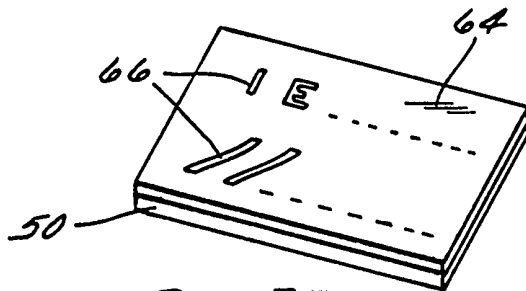


FIG. 5B

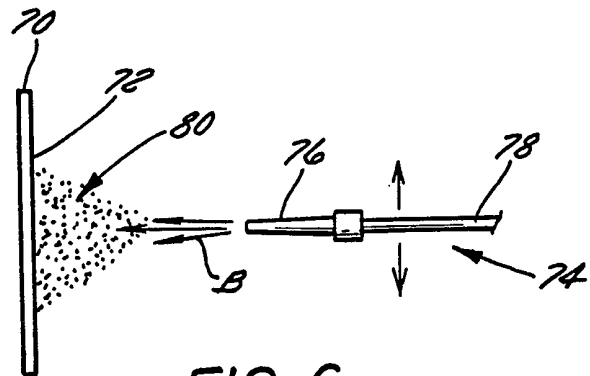


FIG. 6

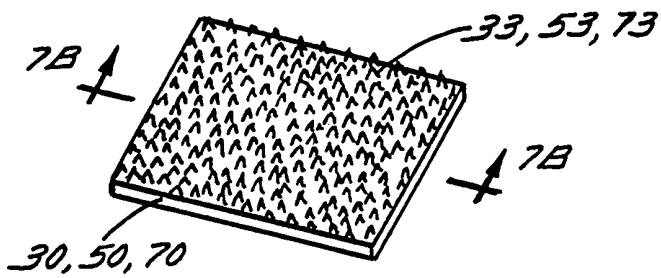


FIG. 7A

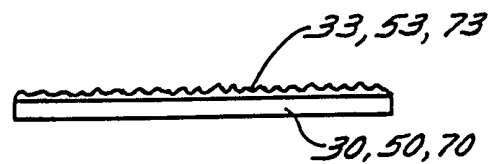


FIG. 7B

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US99/19293

A. CLASSIFICATION OF SUBJECT MATTER
 IPC(6) : G02B 5/02
 US CL :359/599
 According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED
 Minimum documentation searched (classification system followed by classification symbols)
 U.S. : 359/599; 349/84, 112; 353/38; 362/35

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
 USPAT DERWENT, JPO, EPO
 diffuse, reflect, optic, scattering, lambertian, etch, ablate, gring, buff, blast, shot, grit, glass, flint, crown

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5,046,793 A (HOCKLEY et al.) 10 Sept 1991, see: figs, 1-2; col. 2, lines 26-34; col. 4, line 54 - col. 5, line 20.	1, 6, 17, 23
X	US 5,024,953 A (UMEATSU et al.) 18 June 1991, see: col. 6, lines 4-20; col. 8, lines 26-32; col. 11, lines 14-53;	1, 2, 6, 7, 15, 17, 18, 20, 23-26
X	US 6,623,137 A (POWERS et al.) 22 April 1997, see, col. 10, lines 27-44.	1, 2, 6, 7, 17,, 18, 20, 23-26
X, P	US 5,808,713 A (BROER et al.) 15 September 1998, see: col. 10, lines 33-43.	1, 2, 17, 18, 20, 23-26.
X	GB 2,028,529, A (CASTLEBERRY) 05 March 1980, see: page 1, lines 57 -84	1, 2, 6, 7, 23-26

Further documents are listed in the continuation of Box C. See patent family annex.

* Special categories of cited documents:	*T* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
A document defining the general state of the art which is not considered to be of particular relevance	*X* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
E earlier document published on or after the international filing date	*Y* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
L document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	*G* document member of the same patent family
O document referring to an oral disclosure, use, exhibition or other means	
P document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search 22 NOVEMBER 1999	Date of mailing of the international search report 22 DEC 1999
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Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 305-3230	Authorized officer ALLAN OLSEN Telephone No. (703) 308-0661	<i>pat</i> DEBORAH THOMAS PARALEGAL SPECIALIST
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