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(54) **METHODS OF CUTTING OR FORMING CAVITIES IN A SUBSTRATE FOR USE IN MAKING OPTICAL FILMS, COMPONENTS OR WAVE GUIDES**

ation No. 09/909,318, filed on Jul. 19, 2001, now Pat. No. 6,752,505, which is a continuation-in-part of application No. 09/256,275, filed on Feb. 23, 1999, now Pat. No. 6,712,481.

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(51) **Int. Cl.<sup>7</sup>** ..... **G02B 6/12**  
(52) **U.S. Cl.** ..... **362/31**

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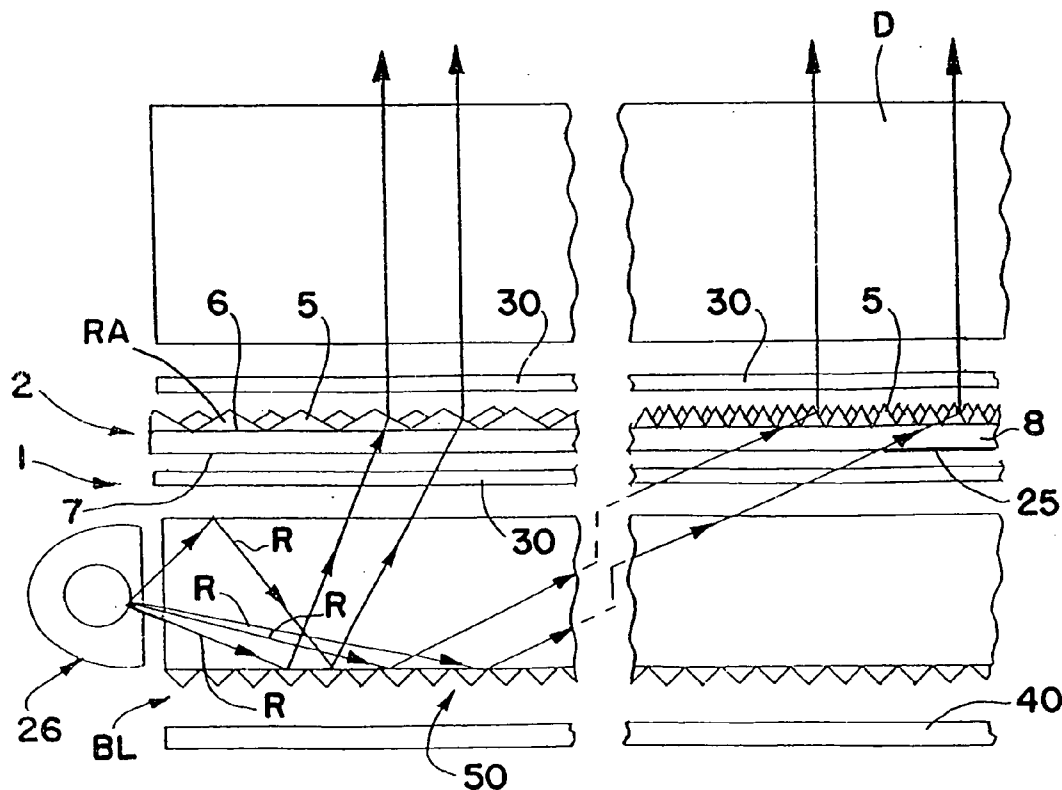
(57) **ABSTRACT**

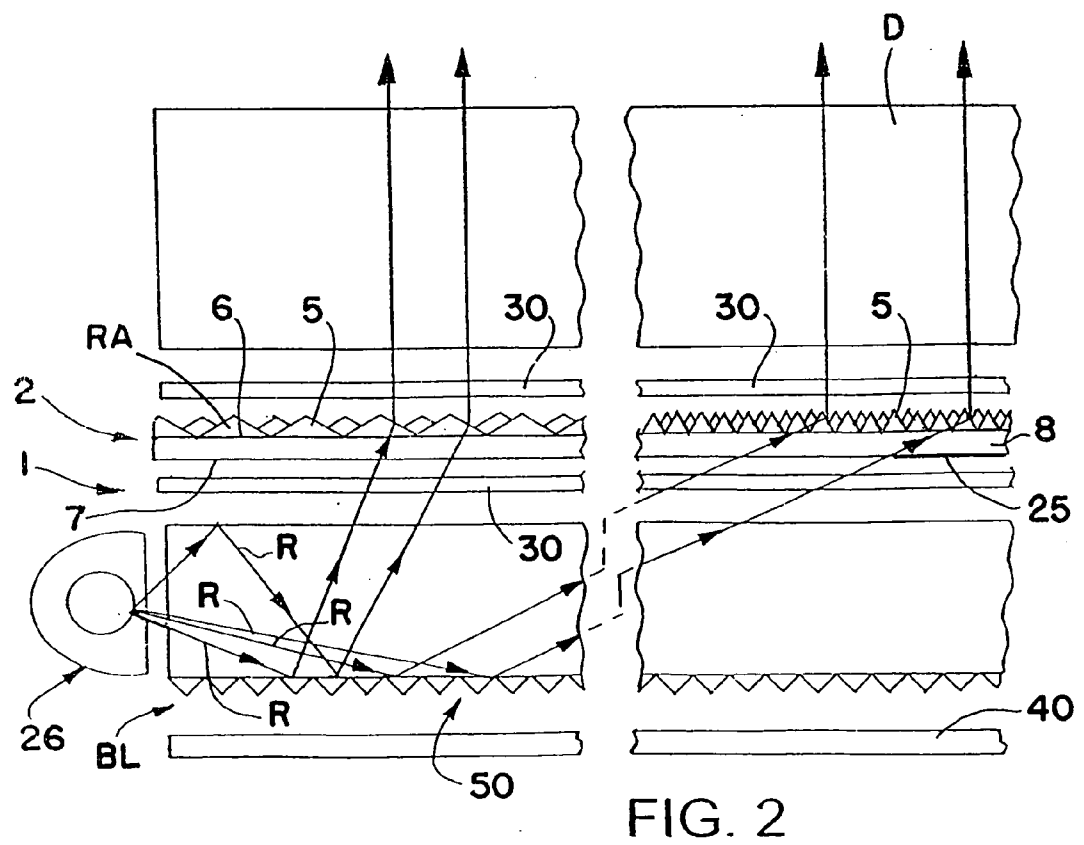
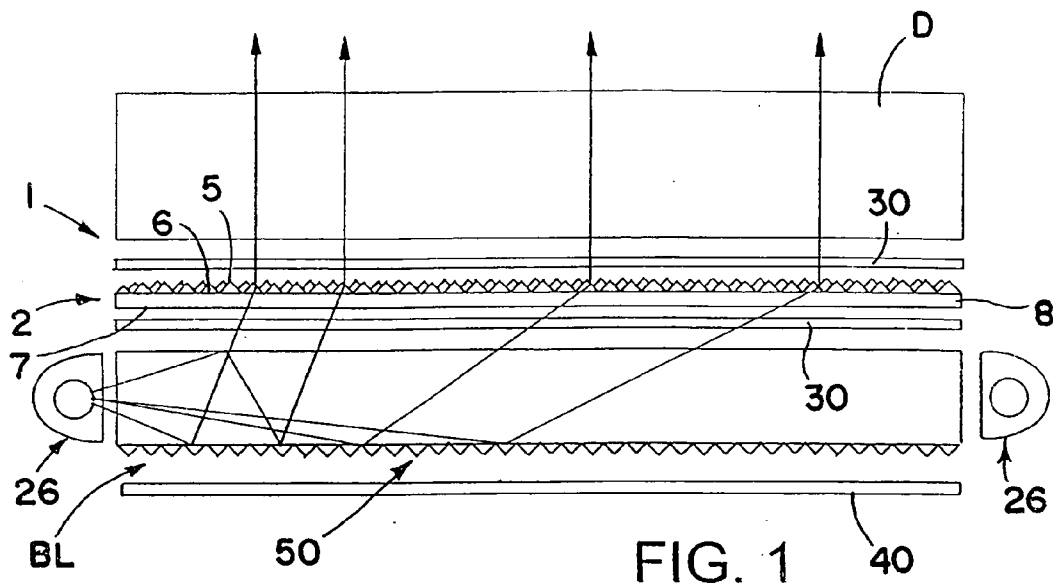
The methods involve using a tool to cut or form multiple optical element shaped cavities in a surface of a substrate without rotating the tool or substrate during the cutting or forming process. At least some of the cavities are cut or formed to have at least two surfaces that come together to form a ridge and that are quite small relative to the length and width of the substrate. Thereafter the substrate is used to form optical films, components or wave guides having multiple optical elements on at least one surface corresponding to the cavities in the substrate.

(21) Appl. No.: **10/915,632**  
(22) Filed: **Aug. 10, 2004**

**Related U.S. Application Data**

(60) Continuation-in-part of application No. 10/729,113, filed on Dec. 5, 2003, which is a division of appli-





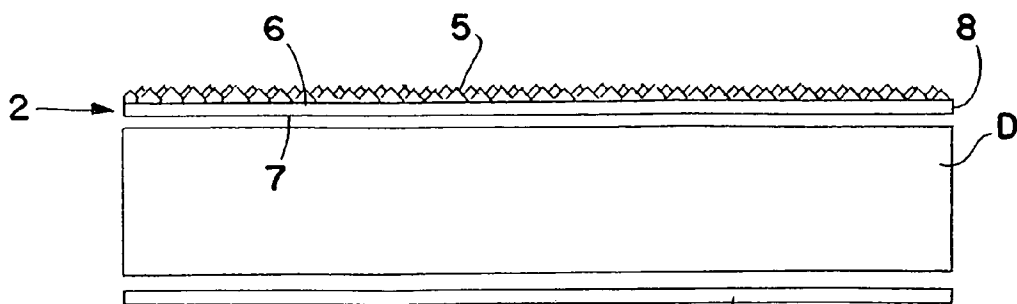


FIG. 3

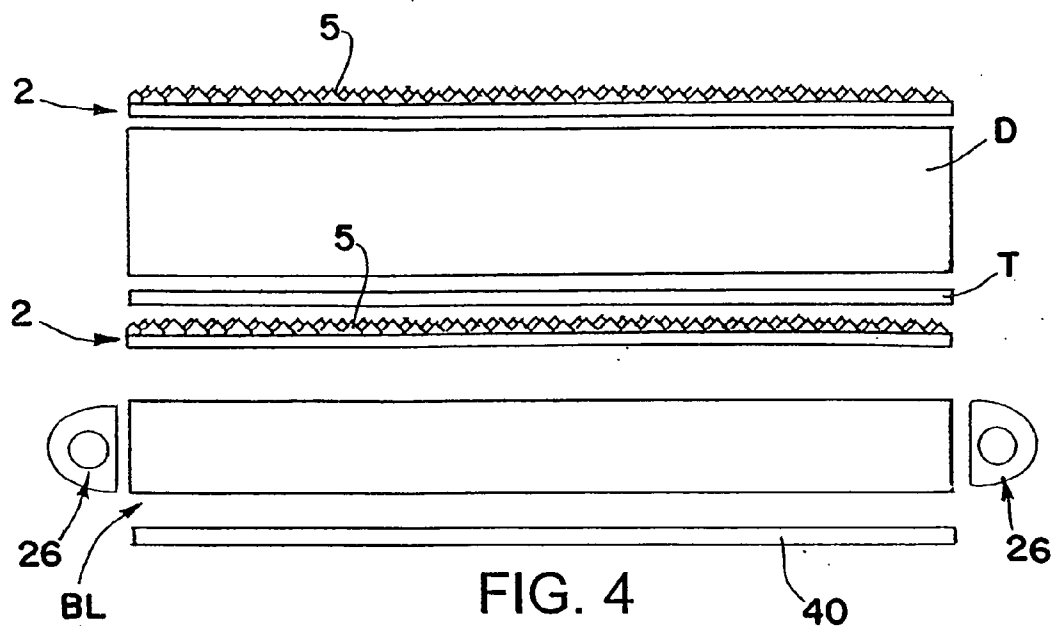


FIG. 4

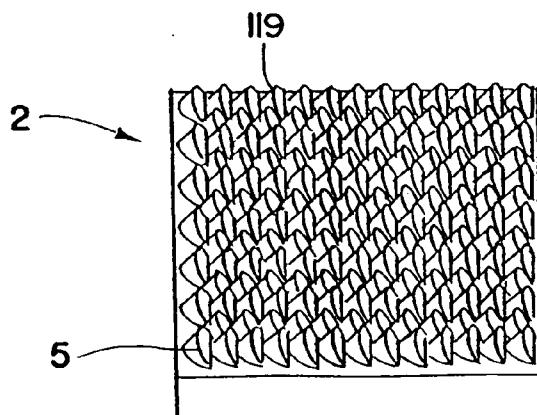


FIG. 5

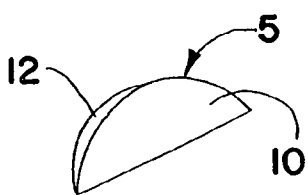


FIG. 5a

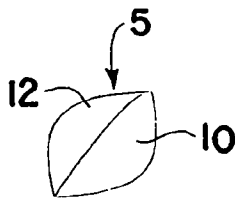


FIG. 5b

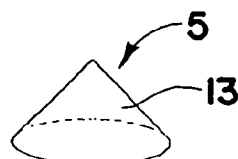


FIG. 5c

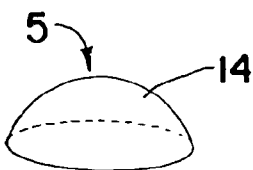


FIG. 5d

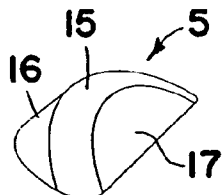


FIG. 5e



FIG. 5f

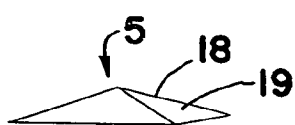


FIG. 5g

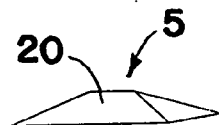


FIG. 5h

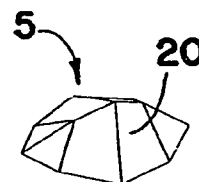


FIG. 5i

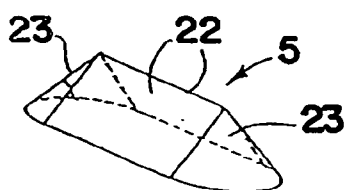


FIG. 5j

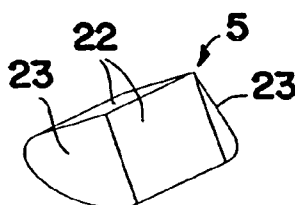


FIG. 5k

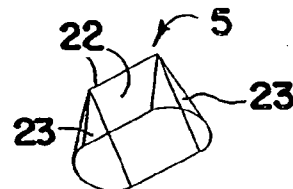


FIG. 5l

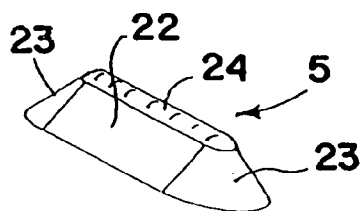


FIG. 5m

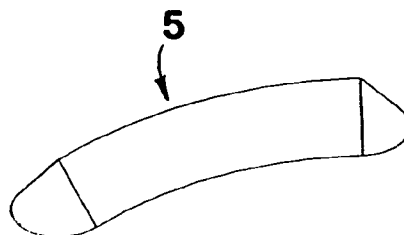
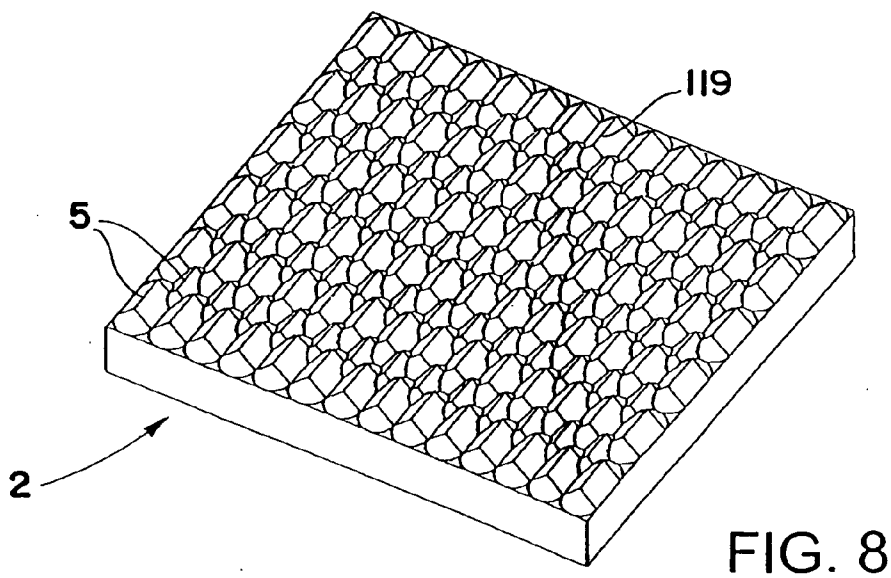
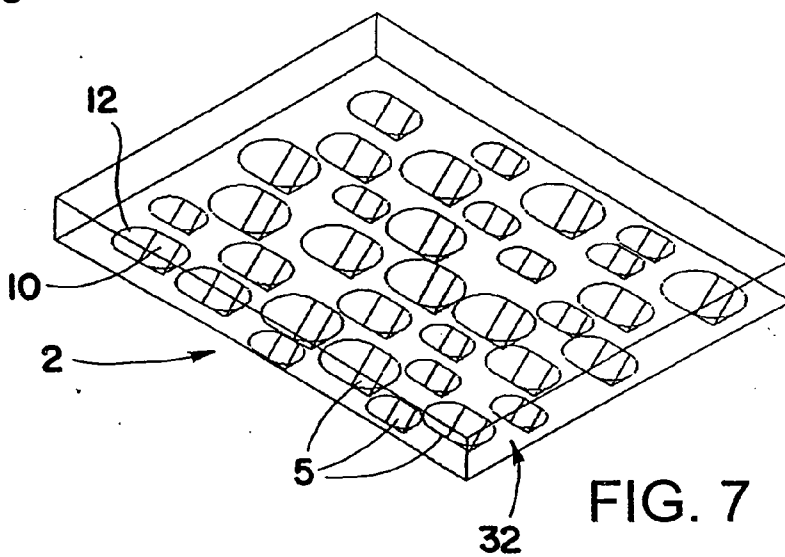
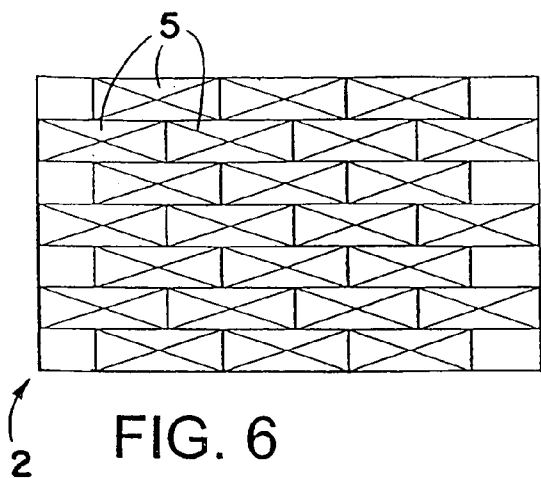


FIG. 5n



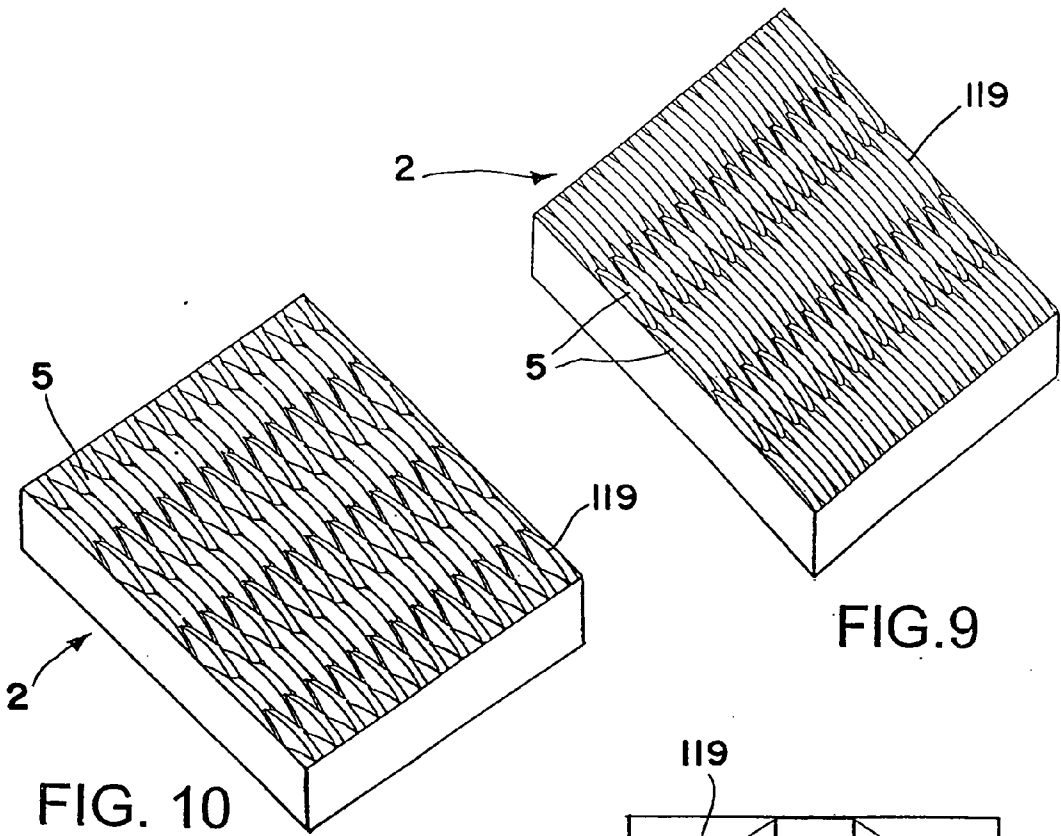


FIG. 9

FIG. 10

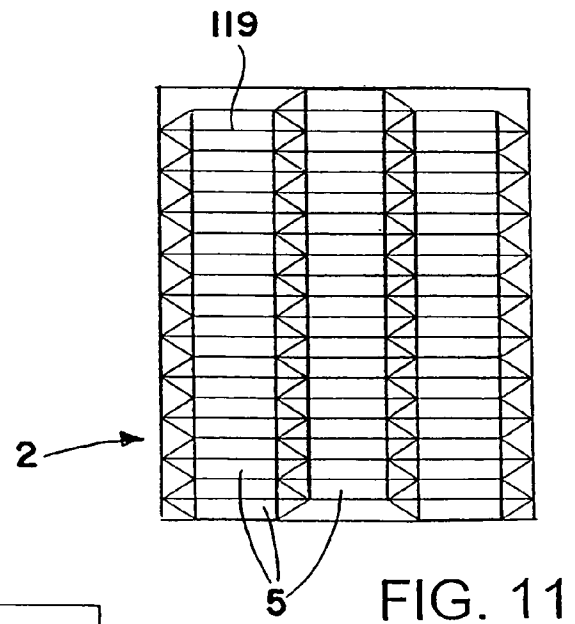


FIG. 11

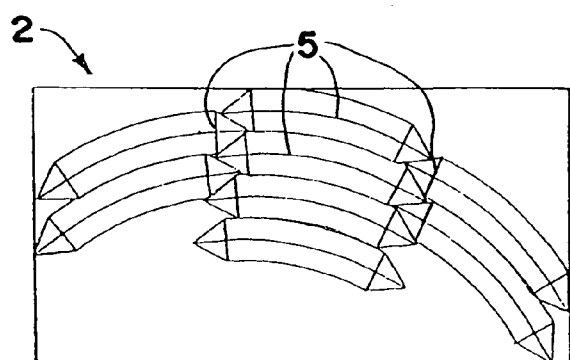
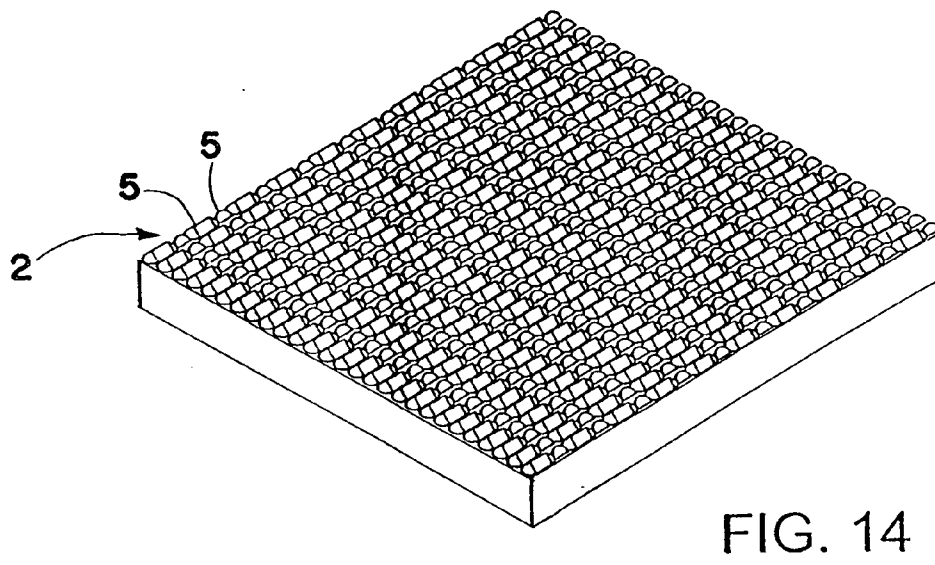
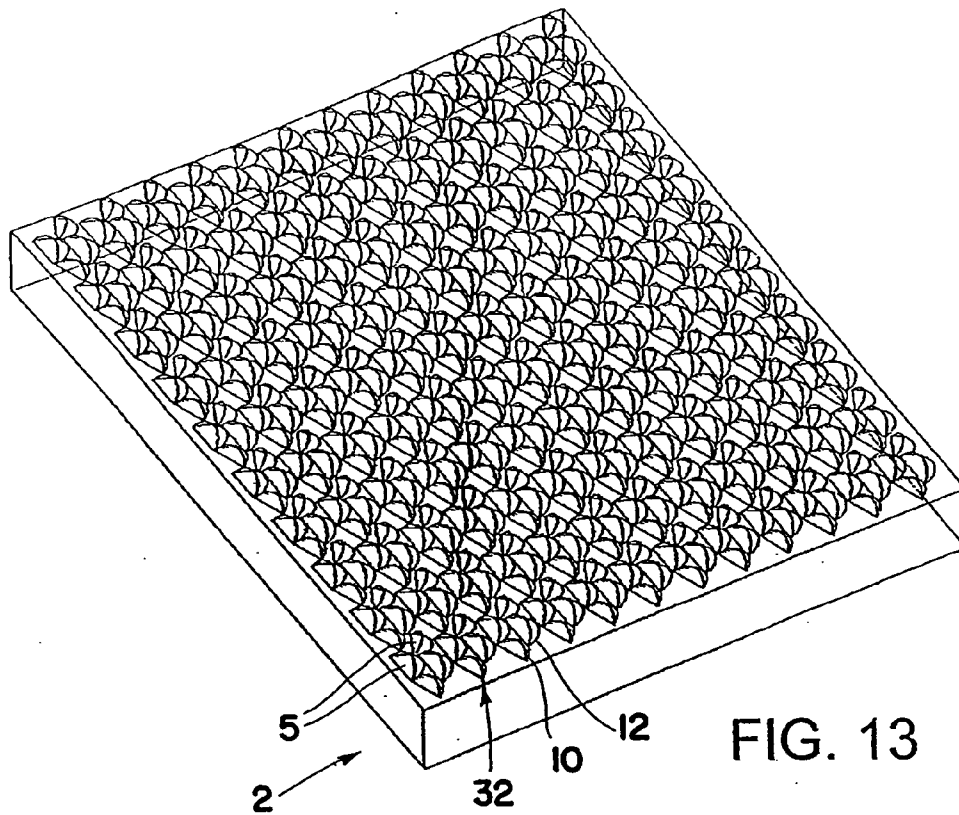


FIG. 12



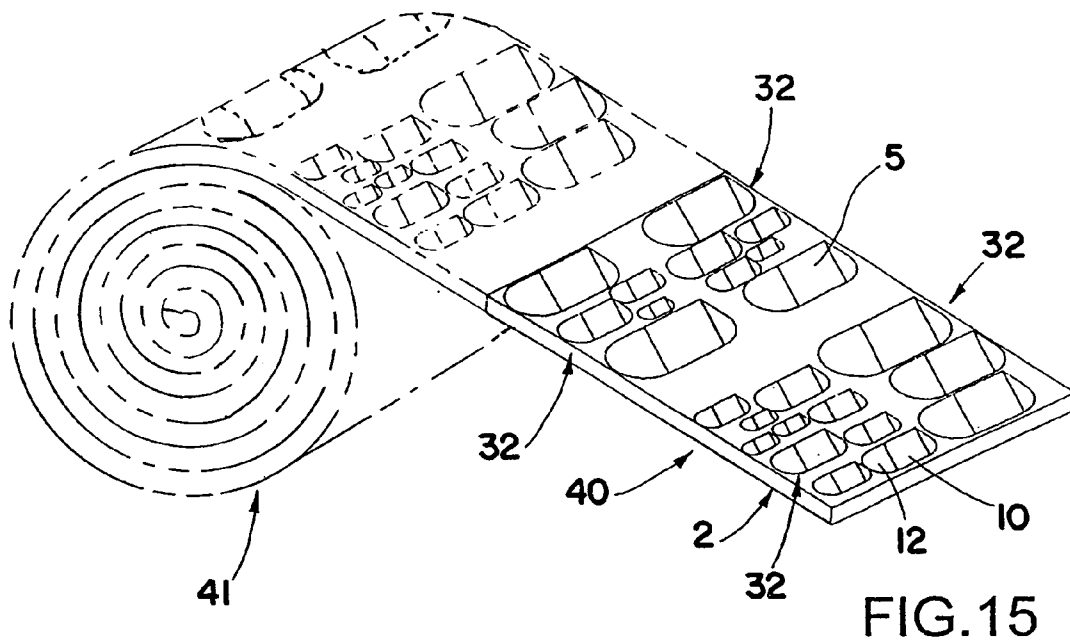


FIG. 15

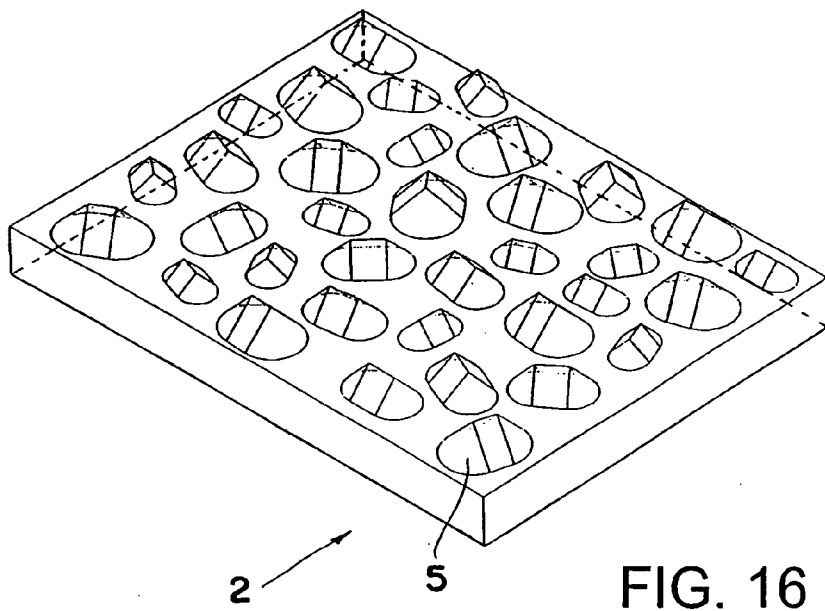
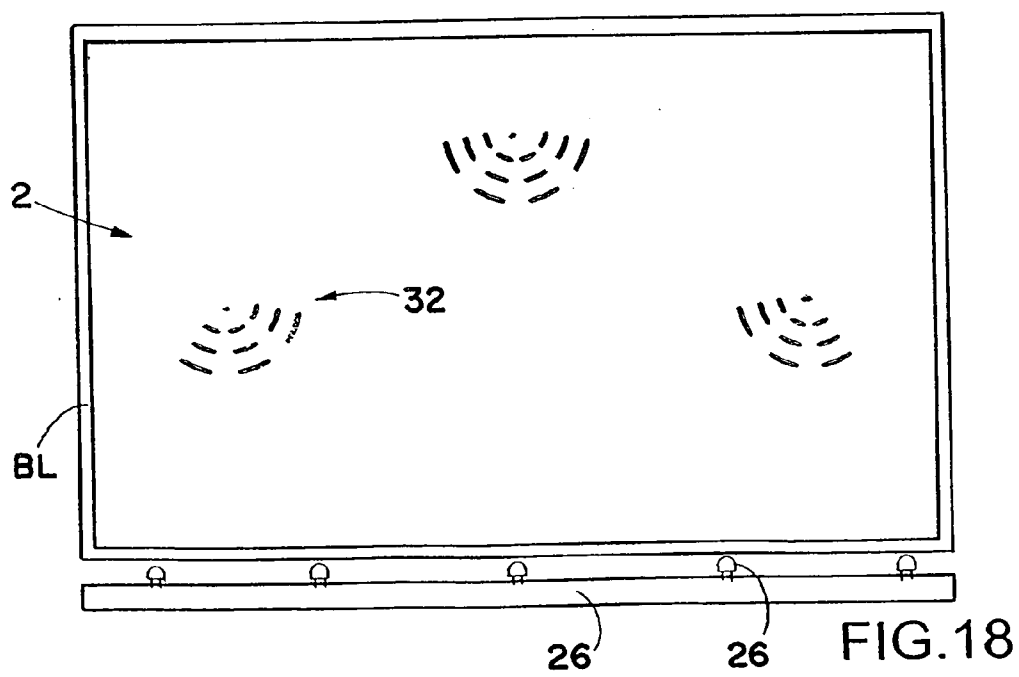
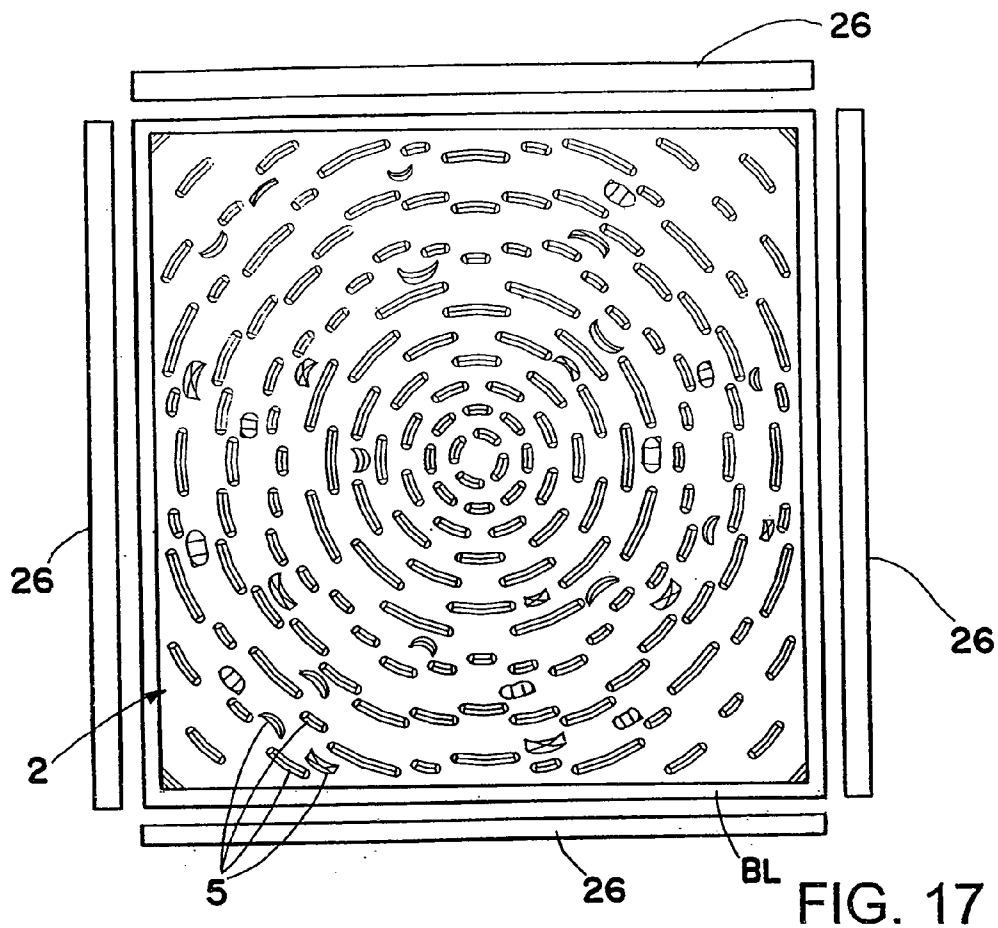
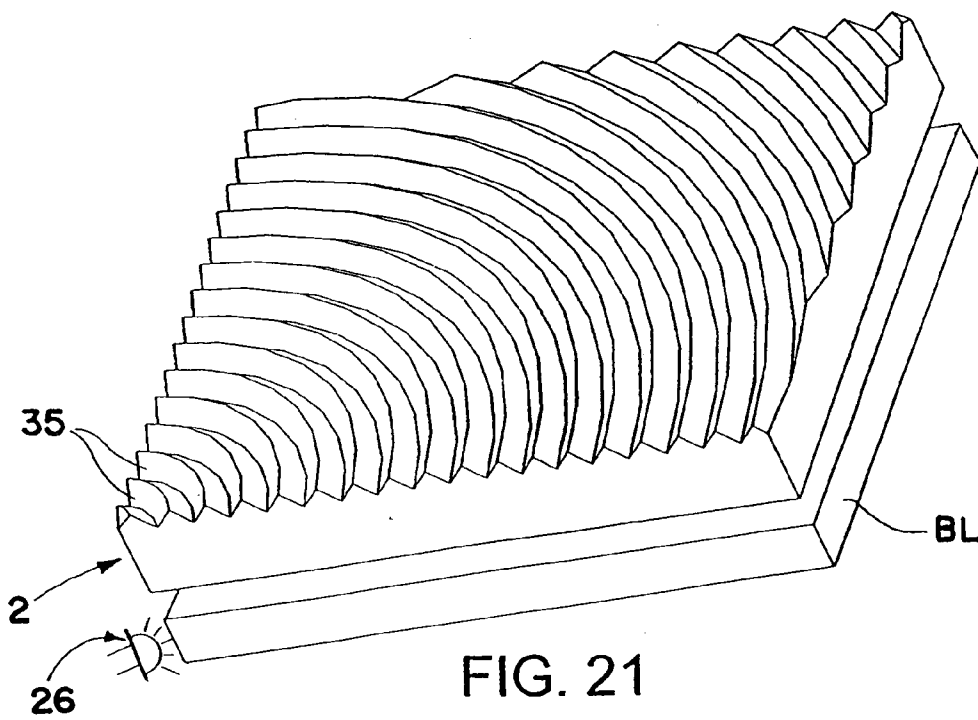
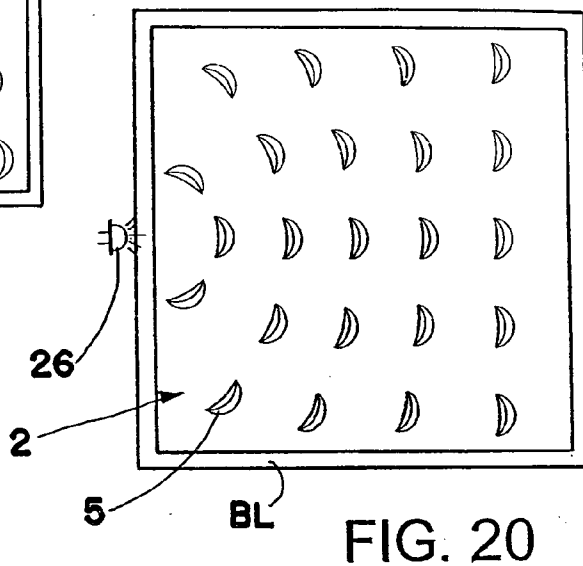
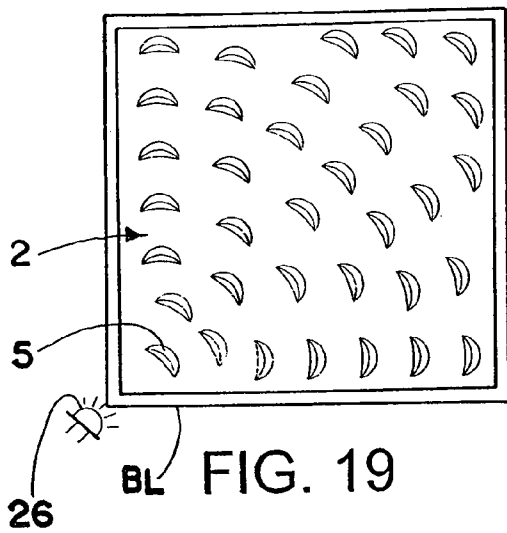
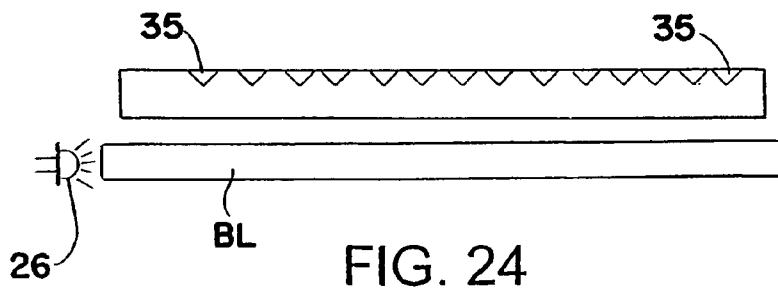
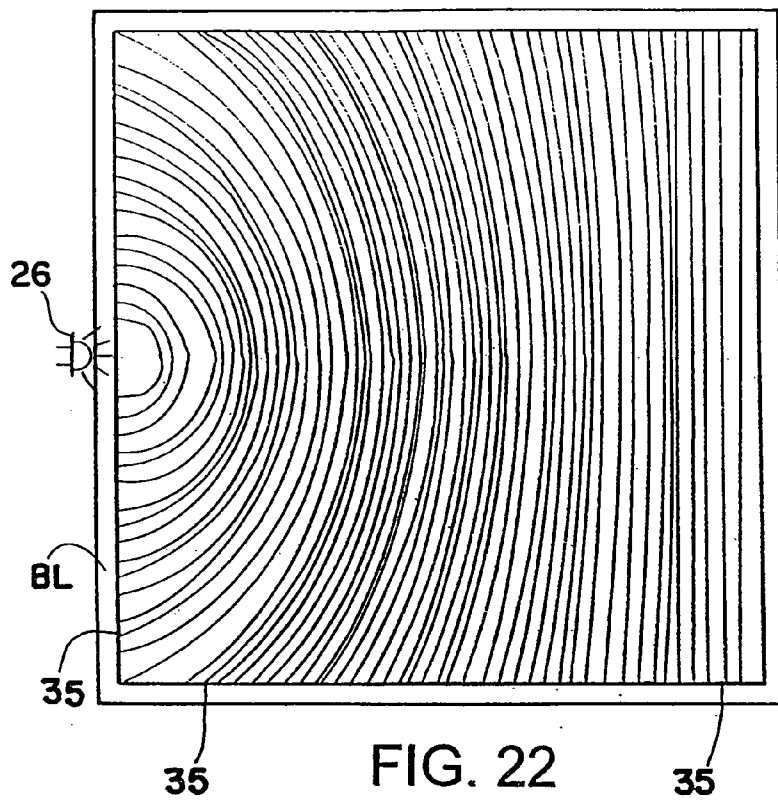
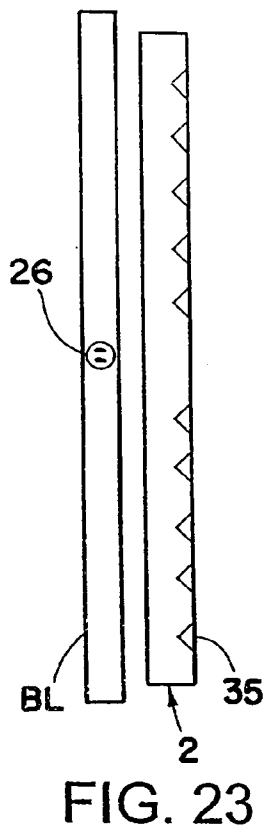


FIG. 16









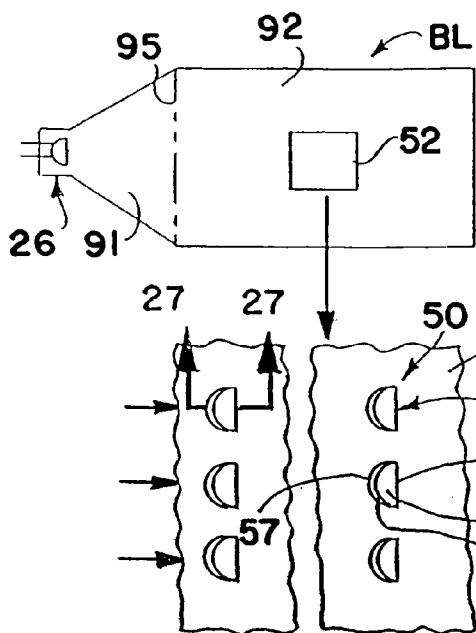


FIG. 25

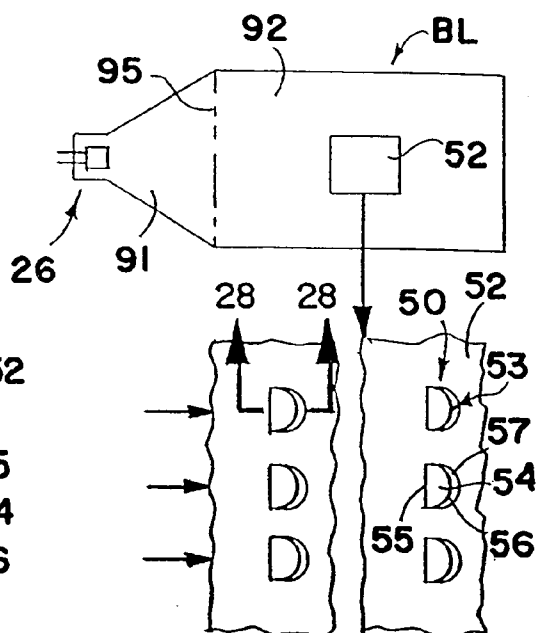


FIG. 26

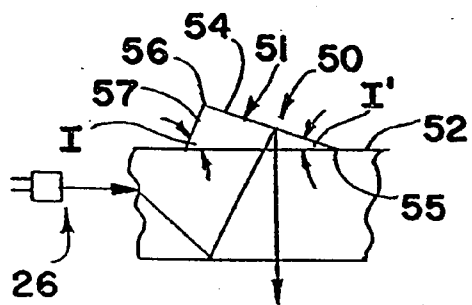


FIG. 27

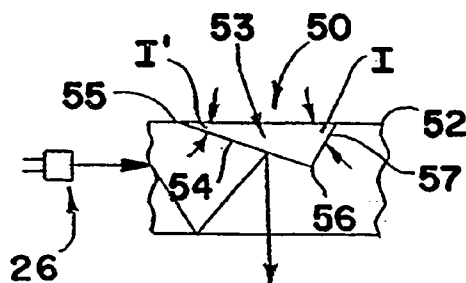


FIG. 28

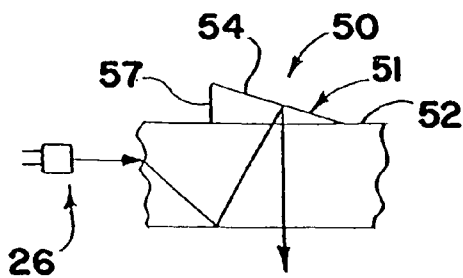


FIG. 29

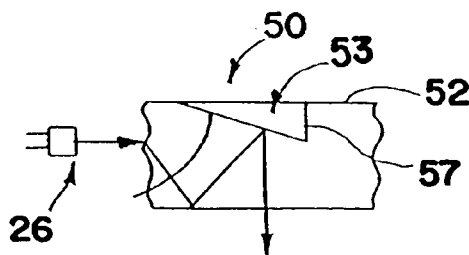


FIG. 30

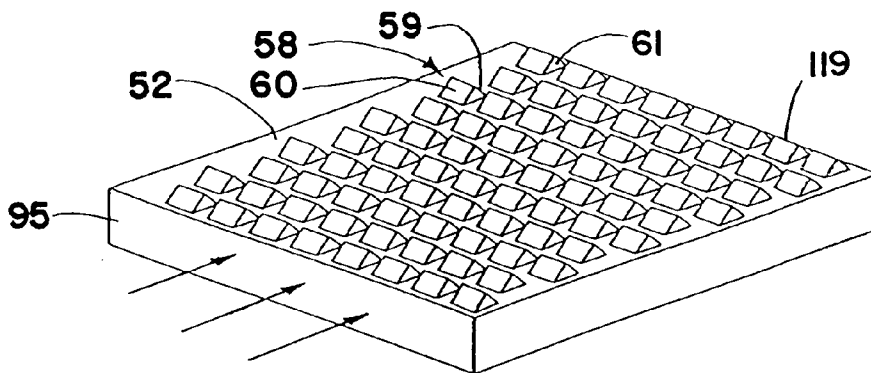


FIG. 31

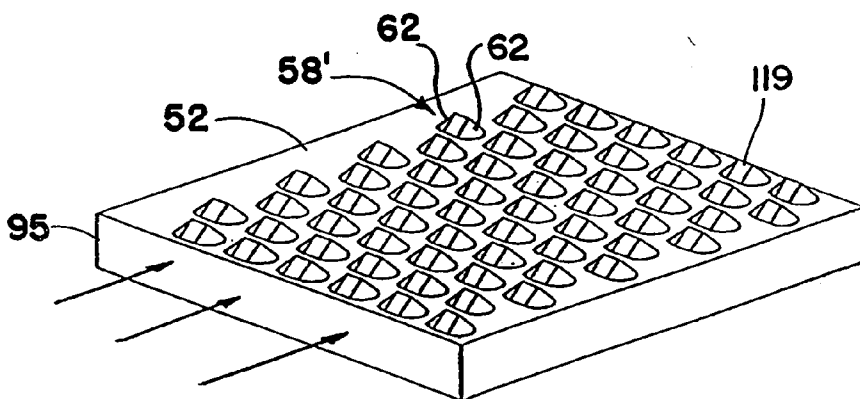


FIG. 32

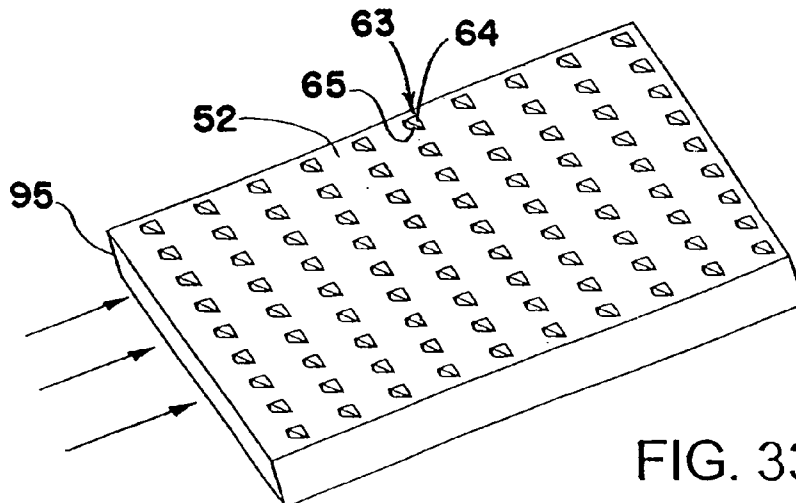
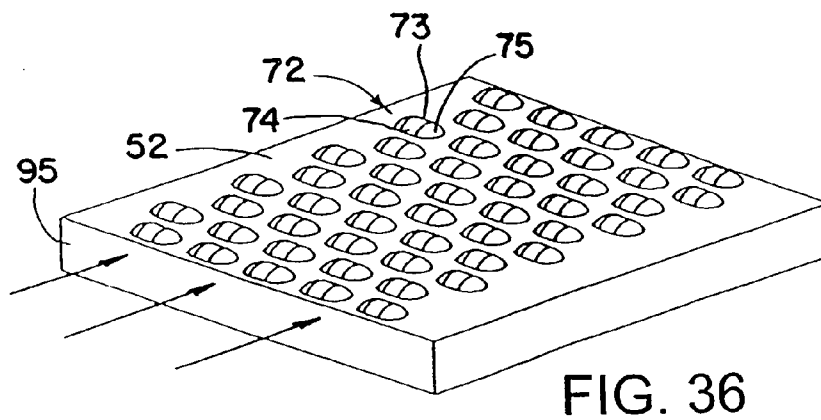
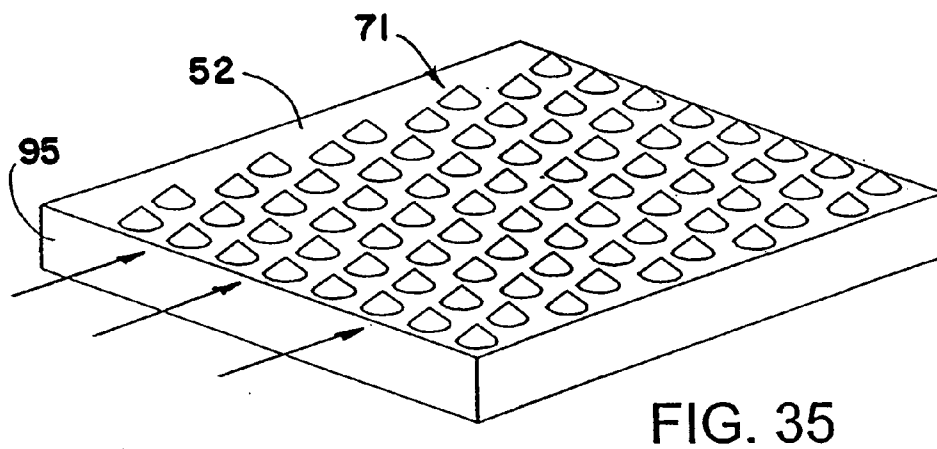
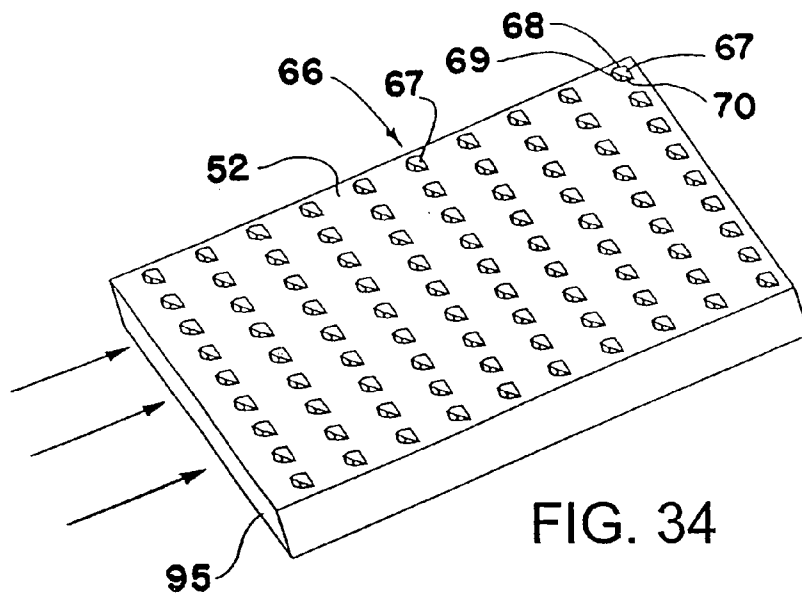
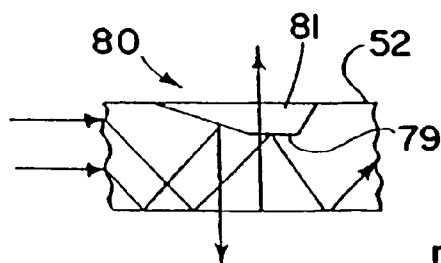
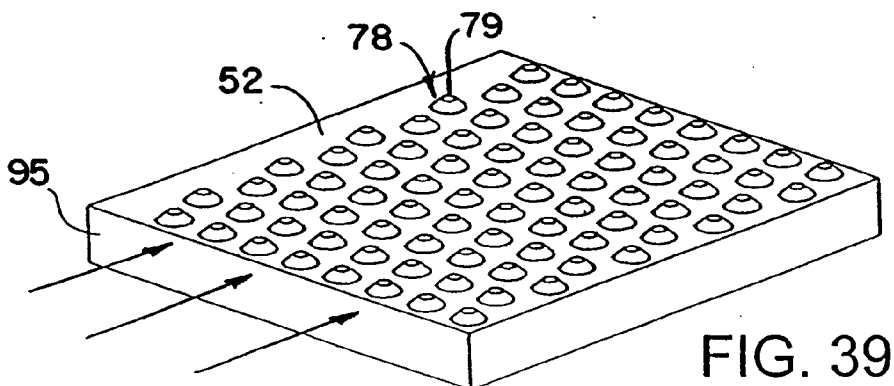
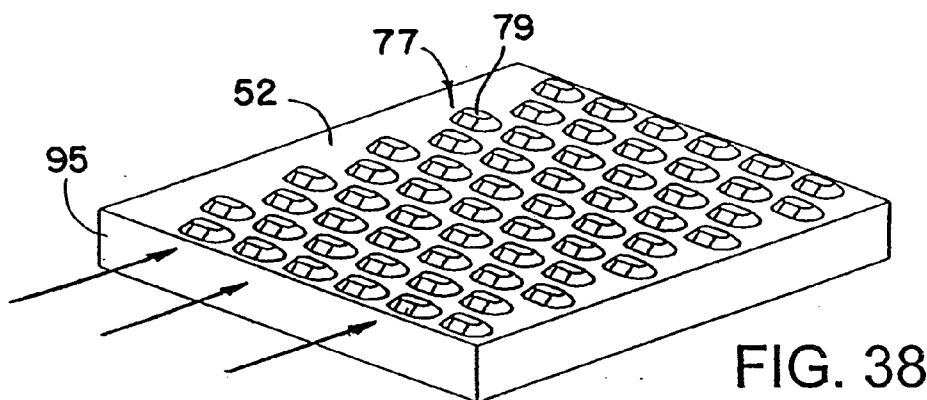
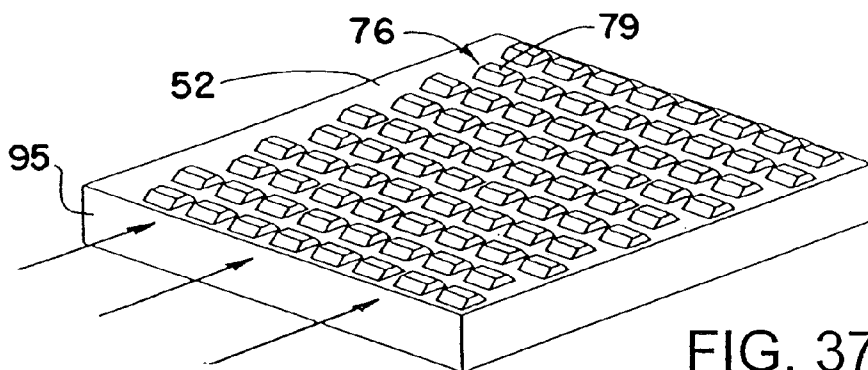
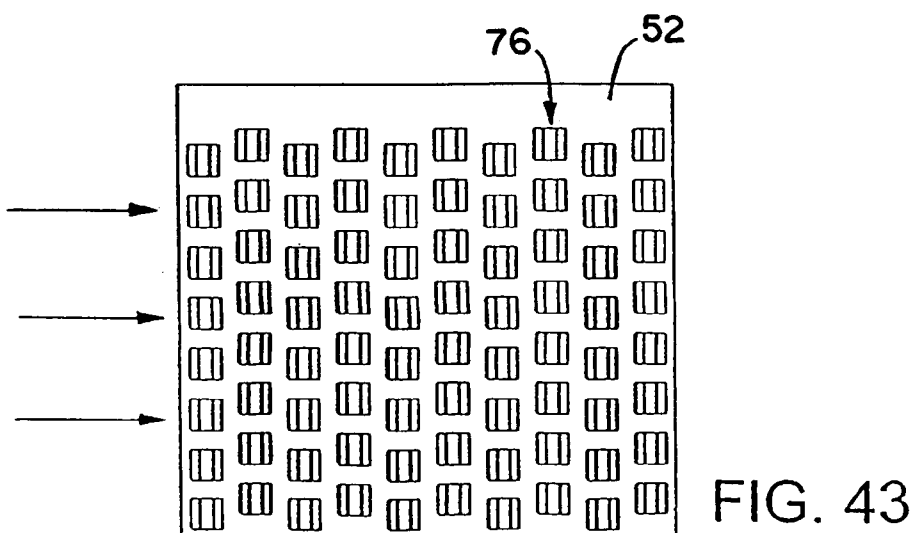
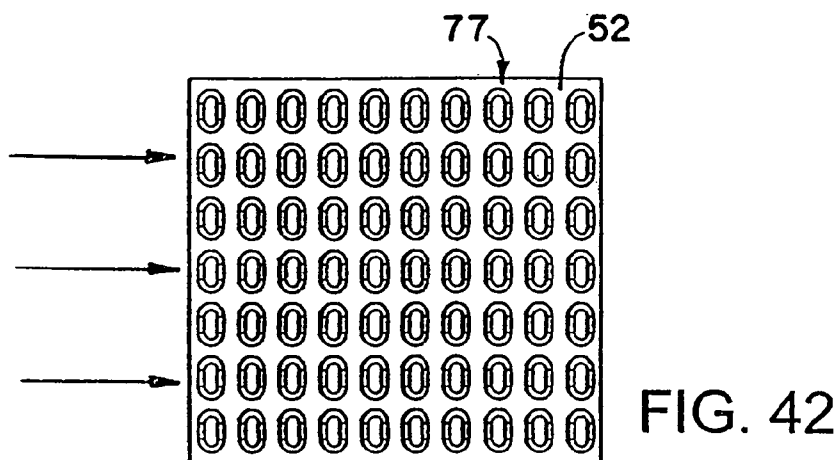
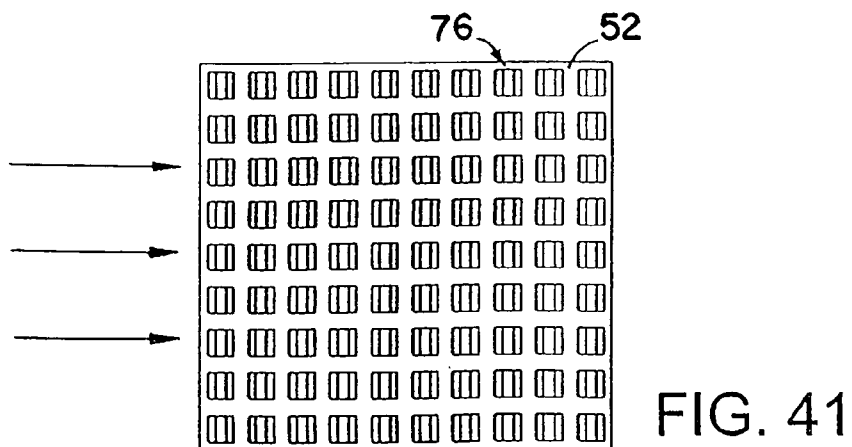


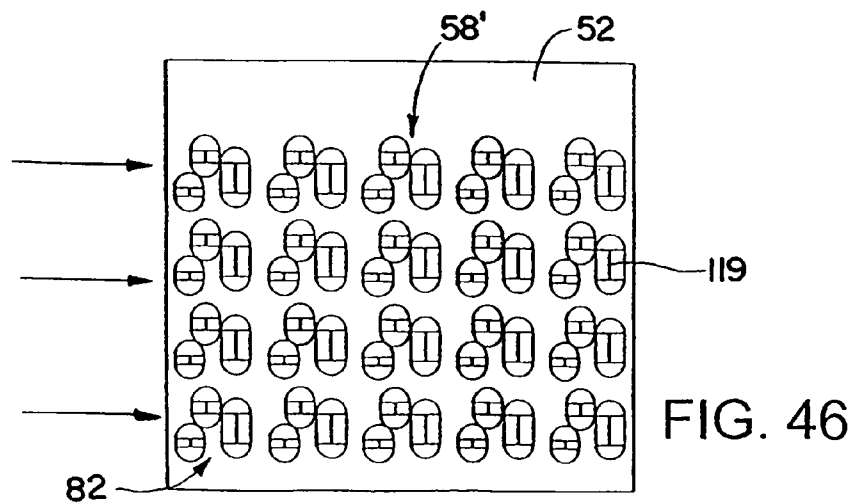
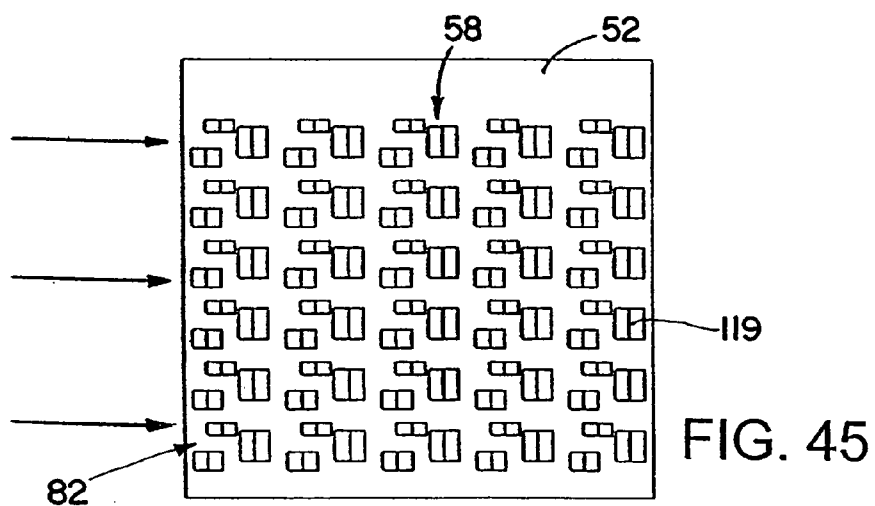
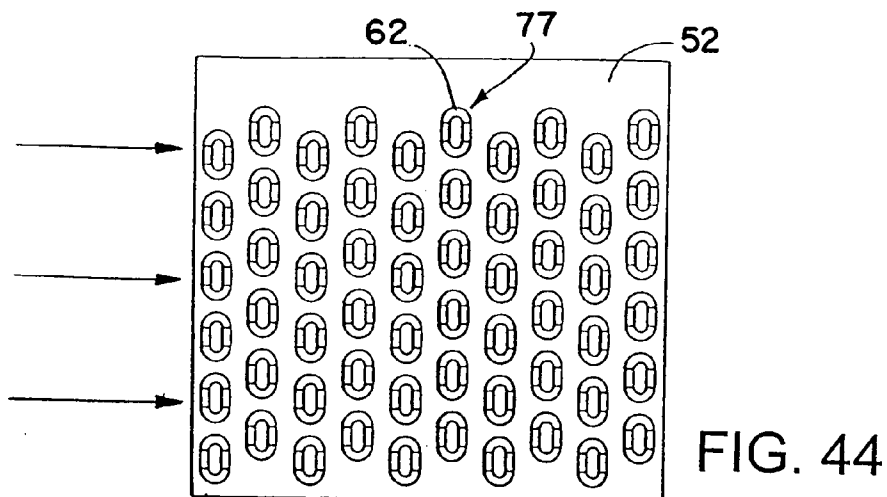
FIG. 33

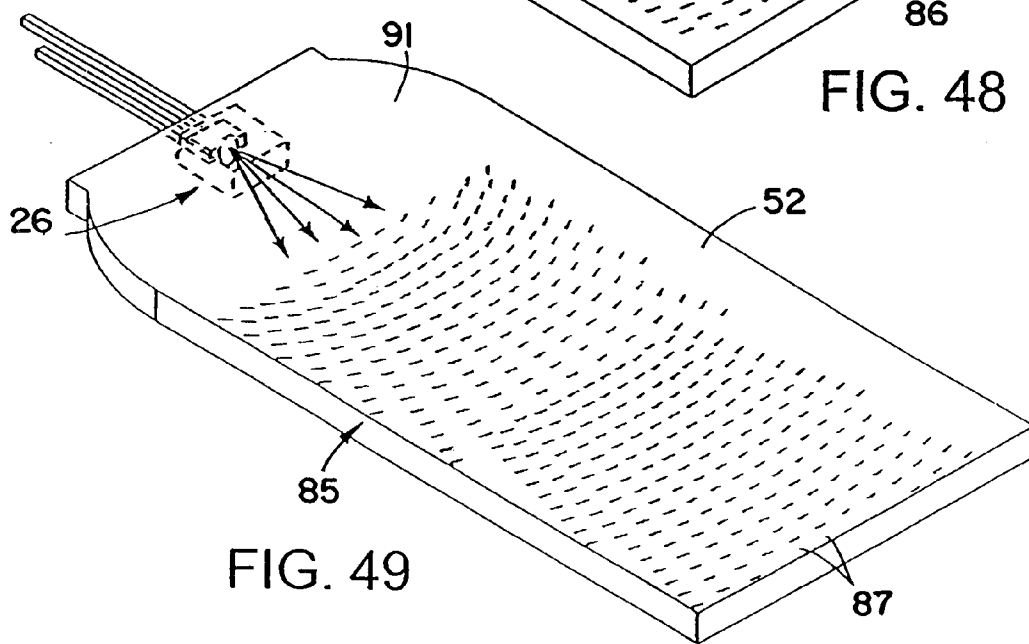
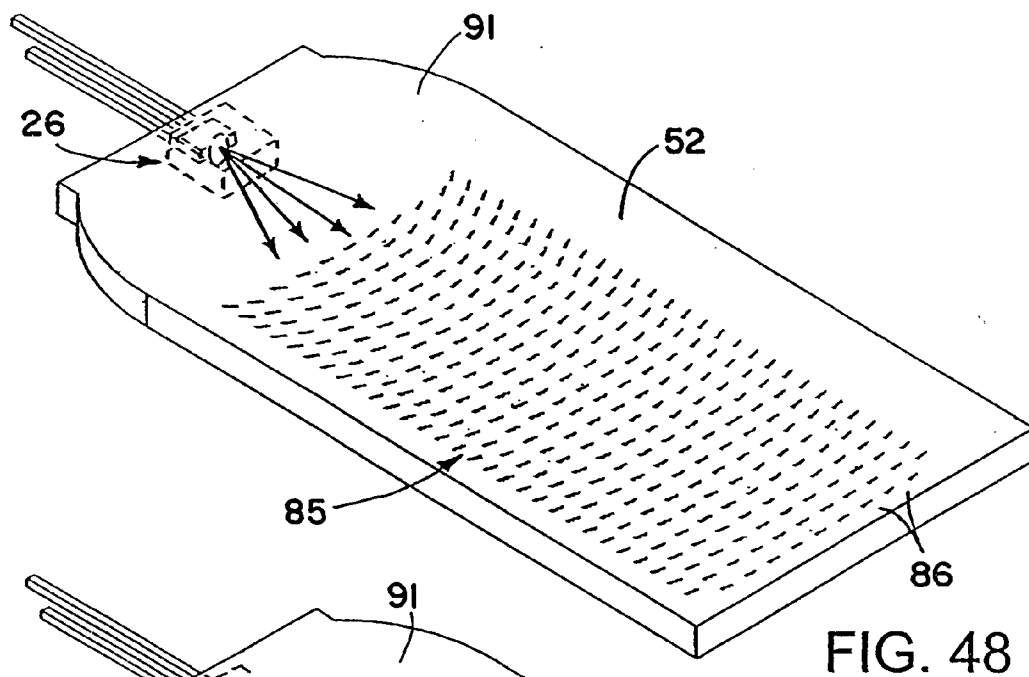
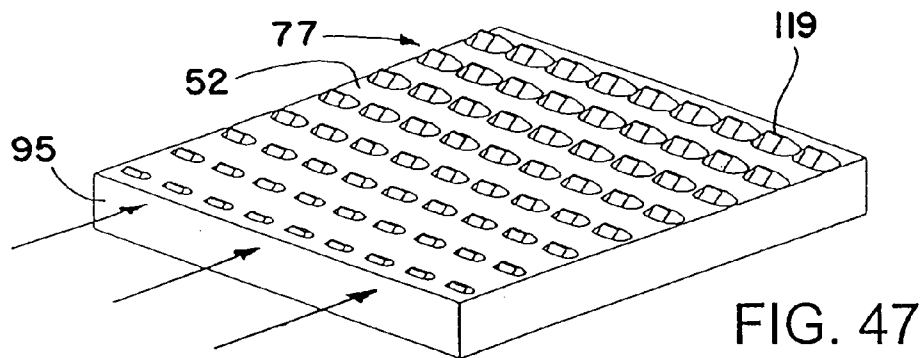












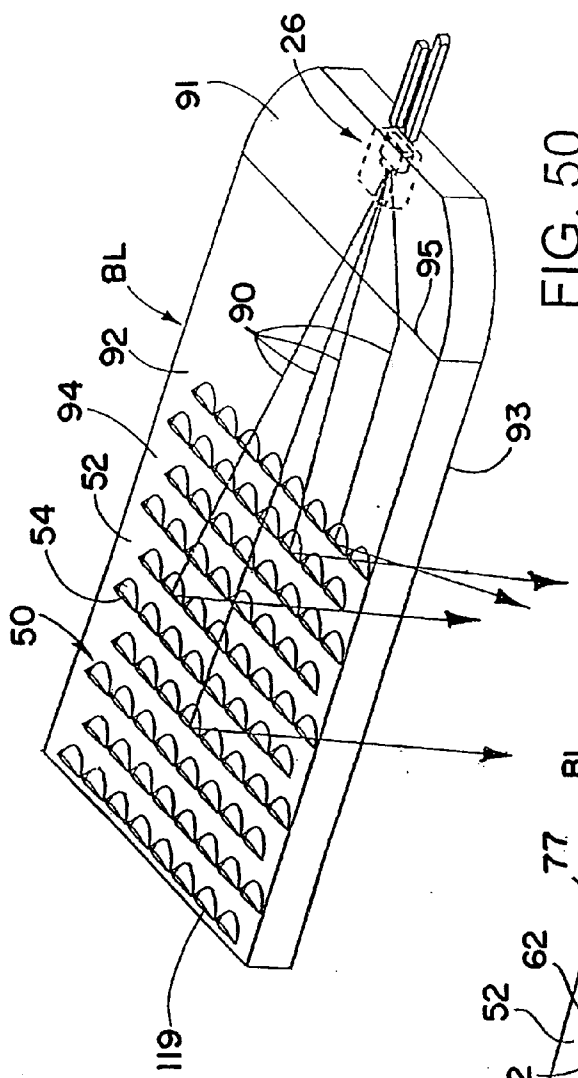


FIG. 50

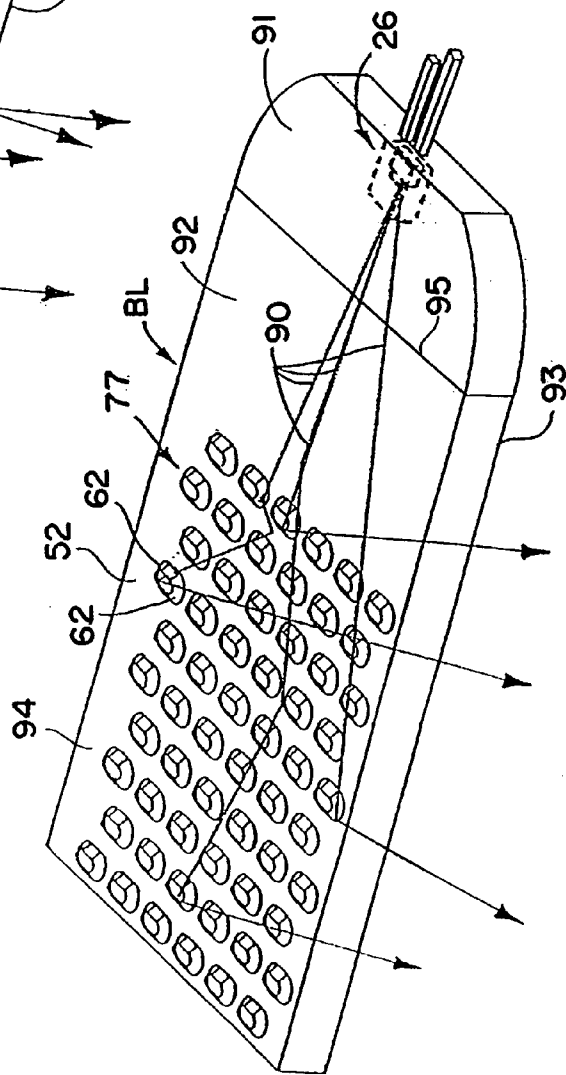


FIG. 51

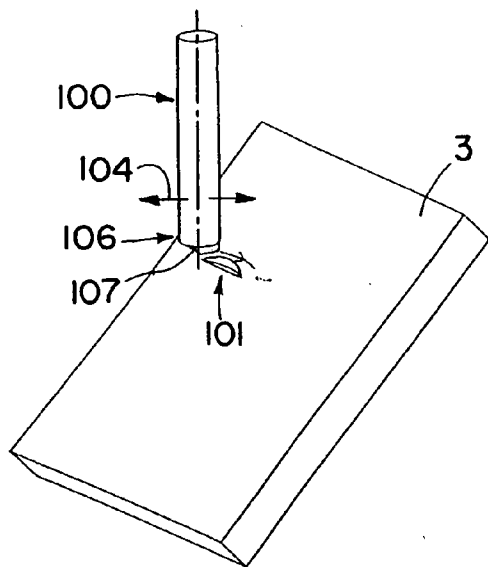


FIG. 52

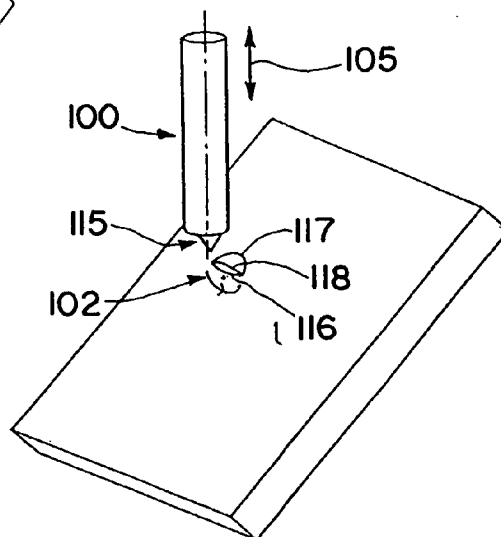


FIG. 53

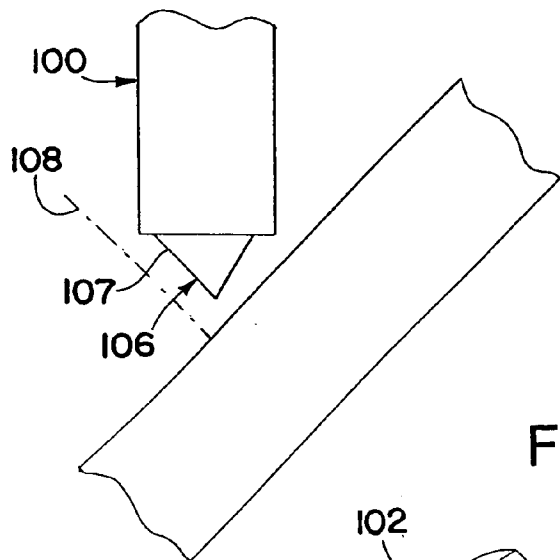


FIG. 54

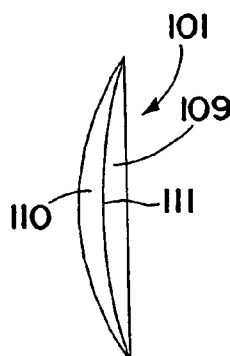


FIG. 55a

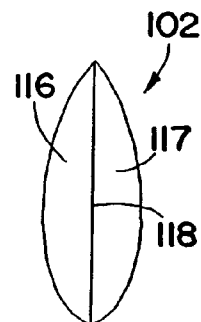


FIG. 55b

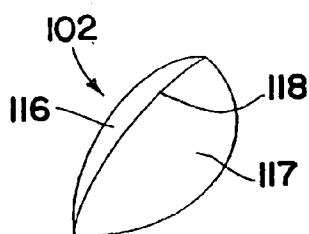


FIG. 55c

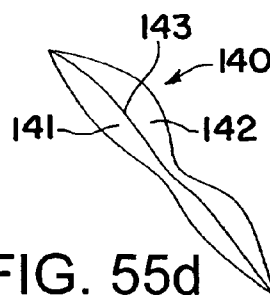


FIG. 55d

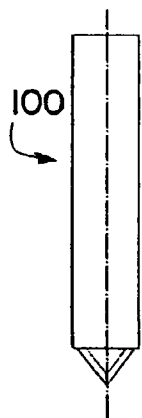


FIG. 56a

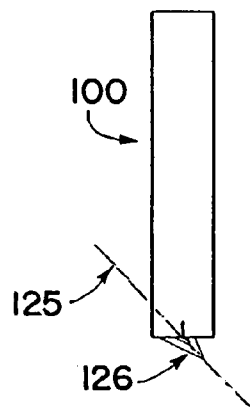


FIG. 56b

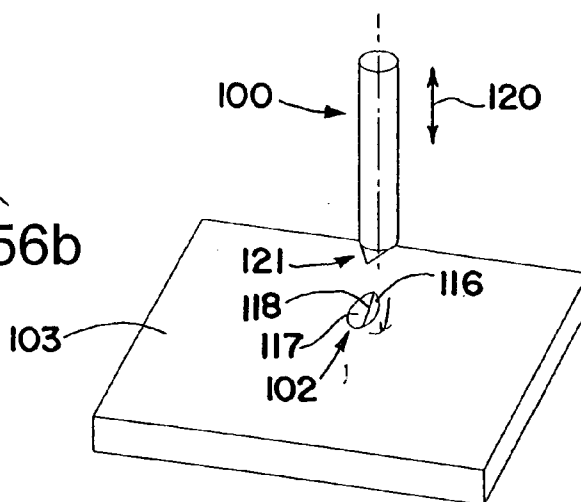


FIG. 57

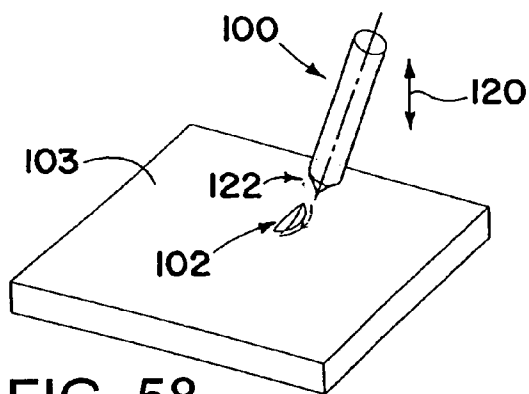


FIG. 58

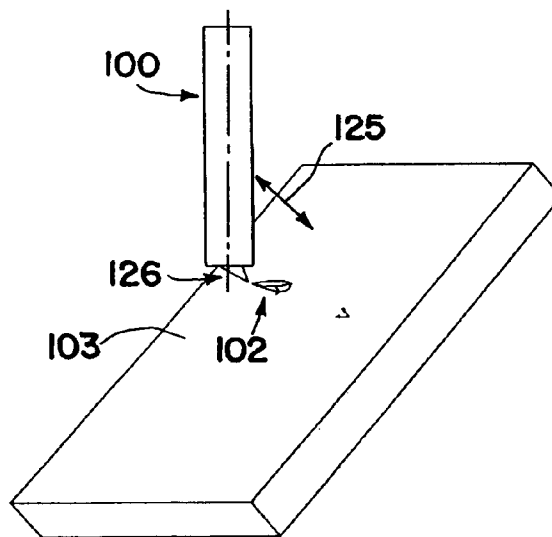


FIG. 60

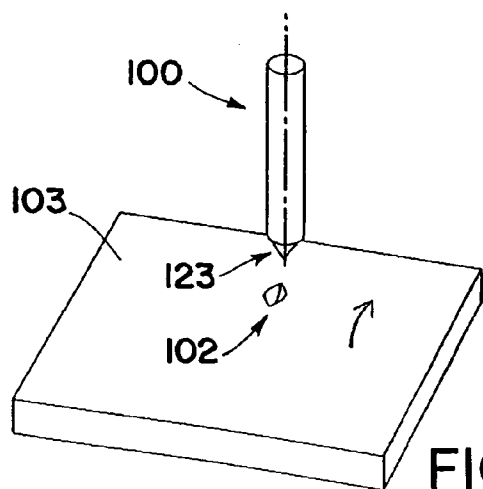
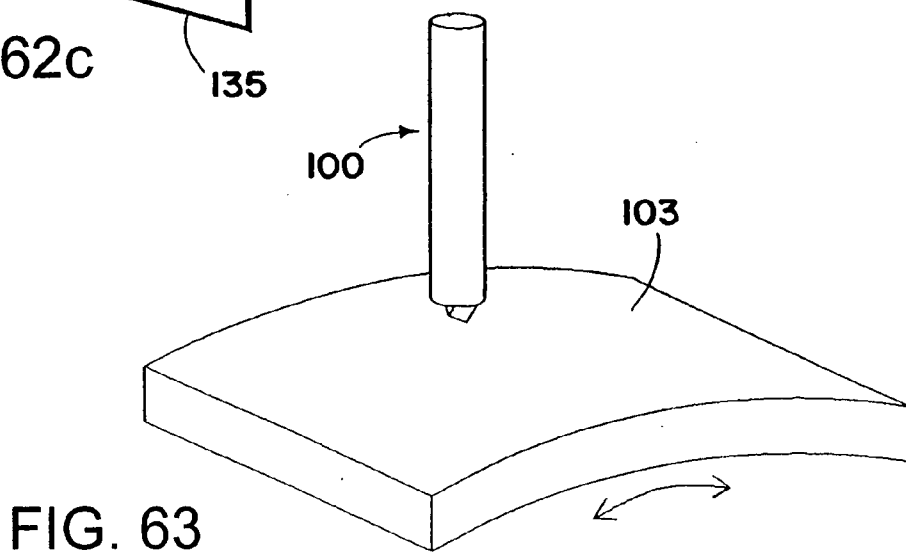
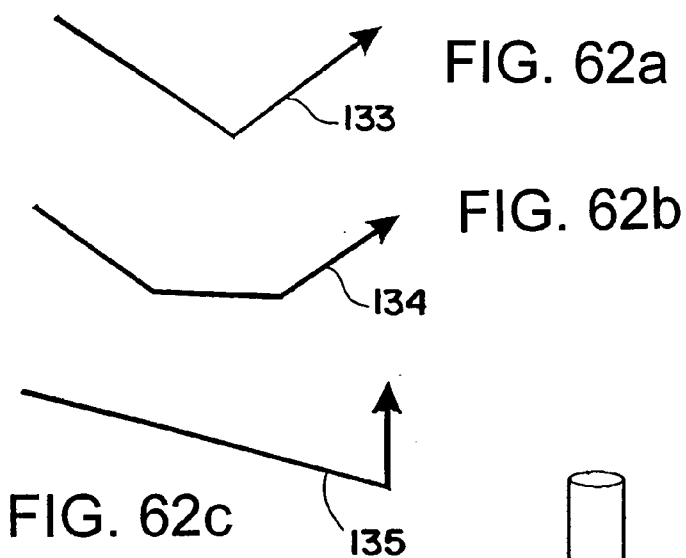
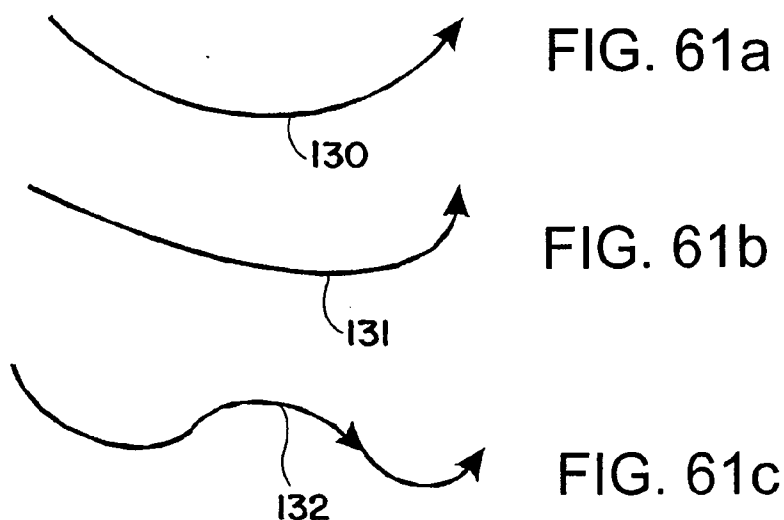
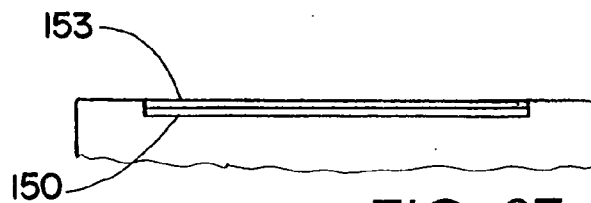
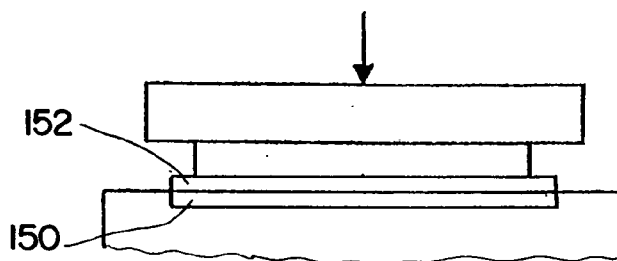
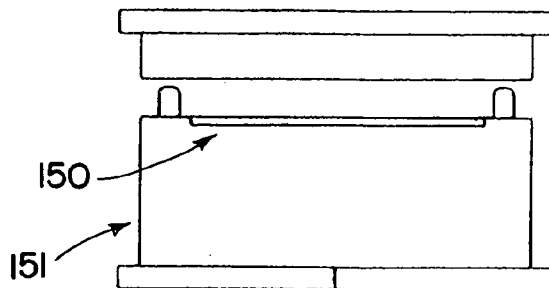
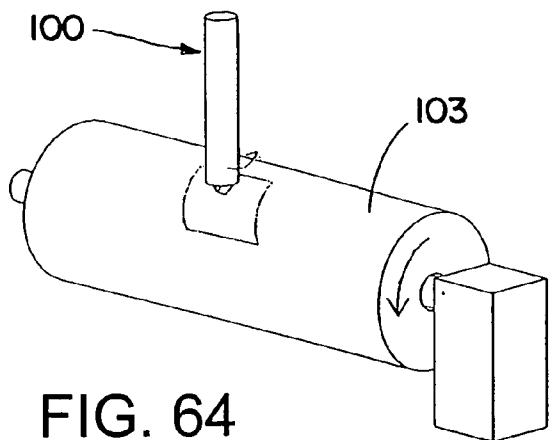


FIG. 59





## METHODS OF CUTTING OR FORMING CAVITIES IN A SUBSTRATE FOR USE IN MAKING OPTICAL FILMS, COMPONENTS OR WAVE GUIDES

### CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is a continuation-in-part of U.S. patent application Ser. No. 10/729,113, filed Dec. 5, 2003, which is a division of U.S. patent application Ser. No. 09/909,318, filed Jul. 19, 2001, now U.S. Pat. No. 6,752,505, dated Jun. 22, 2004, which is a continuation-in-part of U.S. patent application Ser. No. 09/256,275, filed Feb. 23, 1999, now U.S. Pat. No. 6,712,481, dated Mar. 30, 2004, the entire disclosures of which are incorporated herein by reference.

### FIELD OF THE INVENTION

[0002] This invention relates to methods of cutting or forming one or more patterns of optical element shaped cavities in a substrate for use in forming corresponding patterns of optical elements on or in optical substrates including films, components or wave guides and the like.

### BACKGROUND OF THE INVENTION

[0003] It is generally known to provide multiple optical elements on or in one or more surfaces of optical substrates including films, components or wave guides for directing light passing through the optical substrates. At least some of the optical elements may have at least two surfaces that come together to form a ridge and are quite small relative to the length and width of the optical substrates.

[0004] It is generally known to cut or form a predetermined pattern of cavities of such optical element shapes in a flat sheet or plate using a milling or laser cutter and using the cut optical element shapes in the sheet or plate to form a corresponding pattern of optical elements on or in optical substrates. A drawback to this method is the difficulty and expense of cutting or forming cavities of certain types of optical element shapes including particularly those having at least two surfaces that come together to form a ridge and are quite small relative to the length and width of the optical substrates. Also the spinning tools needed to make these geometric shapes are quite expensive and difficult to make, and have a relatively short useful life because of breakage or the like, which further adds to the cost of making cavities having these geometric shapes.

### SUMMARY OF THE INVENTION

[0005] The difficulty and cost of making optical substrates including one or more patterns of optical elements having at least two surfaces that come together to form a ridge and are quite small relative to the length and width of the optical substrates are substantially reduced by using a tool to cut or form cavities of such patterns of optical element shapes in a substrate without rotating the tool or substrate during the cutting or forming process, and thereafter using the substrate to form the optical substrates having the optical elements on or in at least one surface of the optical substrates corresponding to the cavities in the substrate.

[0006] The tool that is used to cut or form the optical element shaped cavities in a substrate may either be perpendicular or nonperpendicular to the path of the tool during

the cutting or forming process. Also the tool may either have a symmetrical or nonsymmetrical cutting or forming tip or have a symmetrical or nonsymmetrical profile on either side of the plane of the cutting or forming path (cut move) of the tool. If the tool has a symmetrical profile on either side of the plane of the cut move of the tool, at least the two surfaces of the cavities that come together to form a ridge during the cutting or forming process are symmetrical surfaces, whereas if the tool has a nonsymmetrical profile on either side of the plane of the tool cutting or forming path, at least the two surfaces of the cavities that come together to form a ridge during the cutting or forming process are nonsymmetrical surfaces. Moreover at least some of the cavities may have one flat surface and one curved surface or two curved surfaces. Also at least some of the cavities may only have two surfaces, one of which may be flat and the other curved. Alternatively, both surfaces may be curved.

[0007] During the cutting or forming process, one or both the tool and substrate may move relative to each other without rotating relative to each other. The substrate or tool is positioned to produce a specific placement for each cavity prior to each cutting or forming process. Also the substrate or tool may be rotated relative to each other prior to cutting or forming at least some of the cavities to produce a different orientation for these cavities. Other cavities that have the same orientation may be cut or formed consecutively so that the substrate or tool need only be rotated between the cutting or forming of some of the cavities.

[0008] The tool may have a cutting or forming edge that lies in a plane parallel to a vector normal to the surface of the substrate or parallel to the path of the tool during the cutting or forming process. Also the tool may move into the substrate along either a nonlinear path, which may be a curve, or a linear path, which may change directions at discrete points during the cutting or forming process.

[0009] The surface of the substrate in which the cavities are cut or formed may either be flat, curved, conical or cylindrical. Also at least some of the cavities may vary in size, shape, angle, rotation, orientation, density, depth, height, type or placement, and may overlap, intersect or interlock with other cavities. Further, at least some of the cavities may vary randomly in the substrate, and at least some of the ridges may generally be in the same direction, and may be curved, segmented or hybrid in shape.

[0010] Either the substrate itself or a deposition or mirror copy of the substrate may be used to form such optical substrates either by molding, thermoforming, hot stamping, embossing, extrusion, or radiation curing or the like. The optical substrates that are formed using the substrate (or a deposition or mirror copy of the substrate) formed in accordance with the present invention may have a light entrance surface and an opposite light exit surface with at least some of the optical elements being formed on at least one of the surfaces having a ridge angle of between 60 and 80 degrees or between 85 and 95 degrees. Moreover, the optical elements may substantially cover at least 90% of at least one surface of the optical substrates.

[0011] To the accomplishment of the foregoing and related ends, the invention, then, comprises the features hereinafter more fully described and particularly pointed out in the claims, the following description and annexed drawings setting forth in detail certain illustrative embodiments of the



invention, these being indicative, however, of but several of the various ways in which the principles of the invention may be employed.

#### BRIEF DESCRIPTION OF THE DRAWINGS

[0012] In the annexed drawings:

[0013] **FIG. 1** is a schematic side elevation view of one form of light redirecting film system in accordance with the present invention;

[0014] **FIG. 2** is an enlarged fragmentary side elevation view of a portion of the backlight and light redirecting film system of **FIG. 1**;

[0015] **FIGS. 3 and 4** are schematic side elevation views of other forms of light redirecting film systems of the present invention;

[0016] **FIGS. 5-20** are schematic perspective or plan views showing different patterns of individual optical elements on light redirecting films of the present invention;

[0017] **FIGS. 5a-5n** are schematic perspective views of different geometric shapes that the individual optical elements on the light redirecting films may take;

[0018] **FIG. 21** is a schematic perspective view of a light redirecting film having optical grooves extending across the film in a curved pattern facing a corner of the film;

[0019] **FIG. 22** is a top plan view of a light redirecting film having a pattern of optical grooves extending across the film facing a midpoint on one edge of the film that decreases in curvature as the distance from the one edge increases;

[0020] **FIG. 23** is an end elevation view of the light redirecting film of **FIG. 22** as seen from the left end thereof;

[0021] **FIG. 24** is a side elevation view of the light redirecting film of **FIG. 22**;

[0022] **FIGS. 25 and 26** are enlarged schematic fragmentary plan views of a surface area of a backlight/light emitting panel assembly showing various forms of optical deformities formed on or in a surface of the backlight;

[0023] **FIGS. 27 and 28** are enlarged longitudinal sections through one of the optical deformities of **FIGS. 25 and 26**, respectively;

[0024] **FIGS. 29 and 30** are enlarged schematic longitudinal sections through other forms of optical deformities formed on or in a surface of a backlight;

[0025] **FIGS. 31-39** are enlarged schematic perspective views of backlight surface areas containing various patterns of individual optical deformities of other well defined shapes;

[0026] **FIG. 40** is an enlarged schematic longitudinal section through another form of optical deformity formed on or in a surface of a backlight;

[0027] **FIGS. 41 and 42** are enlarged schematic top plan views of backlight surface areas containing optical deformities similar in shape to those shown in **FIGS. 37 and 38** arranged in a plurality of straight rows along the length and width of the surface areas;

[0028] **FIGS. 43 and 44** are enlarged schematic top plan views of backlight surface areas containing optical de-

formities also similar in shape to those shown in **FIGS. 37 and 38** arranged in staggered rows along the length of the surface areas;

[0029] **FIGS. 45 and 46** are enlarged schematic top plan views of backlight surface areas containing a random or variable pattern of different sized optical deformities on the surface areas;

[0030] **FIG. 47** is an enlarged schematic perspective view of a backlight surface area showing optical deformities increasing in size as the distance of the deformities from the light input surface increases or intensity of the light increases along the length of the surface area;

[0031] **FIGS. 48 and 49** are schematic perspective views showing different angular orientations of the optical deformities along the length and width of a backlight surface area;

[0032] **FIGS. 50 and 51** are enlarged perspective views schematically showing how exemplary light rays emitted from a focused light source are reflected or refracted by different individual optical deformities of well defined shapes of a backlight surface area;

[0033] **FIGS. 52, 53, 57-60, 63 and 64** are schematic perspective views showing tools used to cut or form optical element shaped cavities of the desired size, shape, angle, rotation, orientation, density, depth, height, type and placement in flat, curved or cylindrical substrates wherein the cavities have at least two surfaces that come together to form a ridge;

[0034] **FIG. 54** is an enlarged schematic fragmentary elevation view showing a tool tip having at least one cutting or forming edge that is parallel to the tool cross path to form at least one flat surface in a cavity during the cutting or forming process;

[0035] **FIGS. 55a-55d** are enlarged schematic perspective views of different representative geometric shapes of the individual cavities that may be cut or formed in the substrates;

[0036] **FIG. 56a** is a schematic front elevation view of a tool having a cutting or forming tip that is symmetrical about both the tool axis and the tool cut path;

[0037] **FIG. 56b** is a schematic front elevation view of a tool having a cutting or forming tip that is not symmetrical about the tool axis but is symmetrical about the tool cut path;

[0038] **FIGS. 61a-61c** are schematic illustrations of representative non-linear tool cross paths;

[0039] **FIGS. 62a-62c** are schematic illustrations of representative linear tool cross paths; and

[0040] **FIGS. 65-67** are schematic elevation views showing production tooling made from the substrates containing the cavities or a deposition or mirror copy of the substrates used to form optical substrates by molding, thermoforming, hot stamping, embossing, extrusion and/or radiation curing and the like.

#### DETAILED DESCRIPTION OF THE INVENTION

[0041] **FIGS. 1 and 2** schematically show one form of light redirecting film system 1 in accordance with this invention including a light redirecting film 2 that redistrib-

utes more of the light emitted by a backlight BL or other light source toward a direction more normal to the surface of the film. Film 2 may be used to redistribute light within a desired viewing angle from almost any light source for lighting, for example, a display D such as a liquid crystal display, used in laptop computers, word processors, avionic displays, cell phones, PDAs and the like, to make the displays brighter. The liquid crystal display can be any type including a transmissive liquid crystal display as schematically shown in FIGS. 1 and 2, a reflective liquid crystal display as schematically shown in FIG. 3 and a transreflective liquid crystal display as schematically shown in FIG. 4.

[0042] The reflective liquid crystal display D shown in FIG. 3 includes a back reflector 40 adjacent the back side for reflecting ambient light entering the display back out the display to increase the brightness of the display. The light redirecting film 2 of the present invention is placed adjacent the top of the reflective liquid crystal display to redirect ambient light (or light from a front light) into the display toward a direction more normal to the plane of the film for reflection back out by the back reflector within a desired viewing angle to increase the brightness of the display. Light redirecting film 2 may be attached to, laminated to or otherwise held in place against the top of the liquid crystal display.

[0043] The transreflective liquid crystal display D shown in FIG. 4 includes a transreflector T placed between the display and a backlight BL for reflecting ambient light entering the front of the display back out the display to increase the brightness of the display in a lighted environment, and for transmitting light from the backlight through the transreflector and out the display to illuminate the display in a dark environment. In this embodiment the light redirecting film 2 may either be placed adjacent the top of the display or adjacent the bottom of the display or both as schematically shown in FIG. 4 for redirecting or redistributing ambient light and/or light from the backlight more normal to the plane of the film to make the light ray output distribution more acceptable to travel through the display to increase the brightness of the display.

[0044] Light redirecting film 2 comprises a thin transparent film or substrate 8 having a pattern of discrete individual optical elements 5 of well defined shape on the light exit surface 6 of the film for refracting the incident light distribution such that the distribution of the light exiting the film is in a direction more normal to the surface of the film.

[0045] Each of the individual optical elements 5 has a width and length many times smaller than the width and length of the film, and may be formed by depressions in or projections on the exit surface of the film. These individual optical elements 5 include at least one sloping surface for refracting the incident light toward the direction normal to the light exit surface. FIG. 5 shows one pattern of individual optical elements 5 on a film 2. These optical elements may take many different shapes. For example, FIG. 5a shows a non-prismatic optical element 5 having a total of two surfaces 10, 12, both of which are sloping. One of the surfaces 10 shown in FIG. 5a is planar or flat whereas the other surface 12 is curved. Moreover, both surfaces 10, 12 intersect each other and also intersect the surface of the film. Alternatively, both surfaces 10, 12 of the individual optical elements may be curved as schematically shown in FIG. 5b.

[0046] Alternatively, the optical elements 5 may each have only one surface that is curved and sloping and intersects the film. FIG. 5c shows one such optical element 5 in the shape of a cone 13, whereas FIG. 5d shows another such optical element having a semispherical or dome shape 14. Also, such optical elements may have more than one sloping surface intersecting the film.

[0047] FIG. 5e shows an optical element 5 having a total of three surfaces, all of which intersect the film and intersect each other. Two of the surfaces 15 and 16 are curved, whereas the third surface 17 is planar.

[0048] FIG. 5f shows an optical element 5 in the shape of a pyramid 18 with four triangular shaped sides 19 that intersect each other and intersect the film. The sides 19 of the pyramid 18 may all be of the same size and shape as shown in FIG. 5f, or the sides 19 of the pyramids 18 may be stretched so the sides have different perimeter shapes as shown in FIG. 5g. Also, the optical elements 5 may have any number of planar sloping sides. FIG. 5h shows an optical element 5 with four planar sloping sides 20, whereas FIG. 5i shows an optical element 5 with eight planar sloping sides 20.

[0049] The individual optical elements 5 may also have more than one curved and more than one planar sloping surface, all intersecting the film. FIG. 5j shows an optical element 5 having a pair of intersecting oppositely sloping planar sides 22 and oppositely rounded or curved ends or sides 23. Further, the sloping planar sides 22 and curved ends or sides 23 may have different angled slopes as shown in FIGS. 5k and 5l. Moreover, the optical elements 5 may have at least one curved surface that does not intersect the film. One such optical element 5 is shown in FIG. 5m which includes a pair of oppositely sloping planar sides 22 and oppositely rounded or curved ends or sides 23 and a rounded or curved top 24 intersecting the oppositely sloping sides and oppositely rounded ends. Further, the optical elements 5 may be curved along their length as shown in FIG. 5n.

[0050] Providing the individual optical elements 5 with a combination of planar and curved surfaces redirects or redistributes a larger viewing area than is possible with a grooved film. Also, the curvature of the surfaces, or the ratio of the curved area to the planar area of the individual optical elements may be varied to tailor the light output distribution of the film to customize the viewing area of a display device used in conjunction with the film.

[0051] The light entrance surface 7 of the film 2 may have an optical coating 25 (see FIG. 2) such as an antireflective coating, a reflective polarizer, a retardation coating or a polarizer. Also, a matte or diffuse texture may be provided on the light entrance surface 7 depending on the visual appearance desired. A matte finish produces a softer image but is not as bright. The combination of planar and curved surfaces of the individual optical elements 5 of the present invention may be configured to redirect some of the light rays impinging thereon in different directions to produce a softer image without the need for an additional diffuser or matte finish on the entrance surface of the film.

[0052] The individual optical elements 5 of the light redirecting film 2 also desirably overlap each other in a staggered, interlocked and/or intersecting configuration, creating an optical structure with excellent surface area cover-

age. **FIGS. 6, 7, 13** and **15**, for example, show optical elements **5** staggered with respect to each other; **FIGS. 8-10** show the optical elements **5** intersecting each other; and **FIGS. 11** and **12** show the optical elements **5** intersecting each other.

[0053] Moreover, the slope angle, density, position, orientation, height or depth, shape, and/or size of the optical elements **5** of the light redirecting film **2** may be matched or tuned to the particular light output distribution of a backlight BL or other light source to account for variations in the distribution of light emitted by the backlight in order to redistribute more of the light emitted by the backlight within a desired viewing angle. For example, the angle that the sloping surfaces (e.g., surfaces **10, 12**) of the optical elements **5** make with the surface of the light redirecting film **2** may be varied as the distance from the backlight BL from a light source **26** increases to account for the way the backlight emits light rays R at different angles as the distance from the light source increases as schematically shown in **FIG. 2**. Also, the backlight BL itself may be designed to emit more of the light rays at lower angles to increase the amount of light emitted by the backlight and rely on the light redirecting film **2** to redistribute more of the emitted light within a desired viewing angle. In this way the individual optical elements **5** of the light redirecting film **2** may be selected to work in conjunction with the optical deformations of the backlight to produce an optimized output light ray angle distribution from the system.

[0054] **FIGS. 2, 5** and **9** show different patterns of individual optical elements **5** all of the same height or depth, whereas **FIGS. 7, 8, 10, 13** and **14** show different patterns of individual optical elements **5** of different shapes, sizes and height or depth.

[0055] The individual optical elements **5** may also be randomized on the film **2** as schematically shown in **FIGS. 16** and **17** in such a way as to eliminate any interference with the pixel spacing of a liquid crystal display. This eliminates the need for optical diffuser layers **30** shown in **FIGS. 1** and **2** to defeat moiré and similar effects. Moreover, at least some of the individual optical elements **5** may be arranged in groupings **32** across the film, with at least some of the optical elements **5** in each grouping having a different size or shape characteristic that collectively produce an average size or shape characteristic for each of the groupings that varies across the film as schematically shown in **FIGS. 7, 13** and **15** to obtain characteristic values beyond machining tolerances to defeat moiré and interference effects with the liquid crystal display pixel spacing. For example, at least some of the optical elements **5** in each grouping **32** may have a different depth or height that collectively produce an average depth or height characteristic for each grouping that varies across the film. Also, at least some of the optical elements in each grouping may have a different slope angle that collectively produce an average slope angle for each grouping that varies across the film. Further, at least one sloping surface of the individual optical elements in each grouping may have a different width or length that collectively produce an average width or length characteristic in each grouping that varies across the film.

[0056] Where the individual optical elements **5** include a combination of planar and curved surfaces **10, 12**, the curvature of the curved surfaces **12**, or the ratio of the curved

area to the planar area of the individual optical elements as well as the perimeter shapes of the curved and planar surfaces may be varied to tailor the light output distribution of the film. In addition, the curvature of the curved surfaces, or the ratio of the curved area to the planar area of the individual optical elements may be varied to redirect more or less light that is traveling in a plane that would be parallel to the grooves of a prismatic or lenticular grooved film, partially or completely replacing the need for a second layer of light redirecting film. Also, at least some of the individual optical elements may be oriented at different angles relative to each other as schematically shown in **FIGS. 13** and **16** to redistribute more of the light emitted by a light source along two different axes in a direction more normal to the surface of the film, partially or completely replacing the need for a second layer of light redirecting film. However, it will be appreciated that two layers of such light redirecting film each having the same or different patterns of individual optical elements **5** thereon may be placed between a light source and viewing area with the layers rotated 90 degrees (or other angles greater than 0 degrees and less than 90 degrees) with respect to each other so that the individual optical elements on the respective film layers redistribute more of the light emitted by a light source traveling in different planar directions in a direction more normal to the surface of the respective films.

[0057] Also, the light redirecting film **2** may have a pattern of optical elements **5** that varies at different locations on the film as schematically shown in **FIG. 15** to redistribute the light ray output distribution from different locations of a backlight or other light source to redistribute the light ray output distribution from the different locations toward a direction normal to the film.

[0058] Further, the properties and pattern of the optical elements of the light redirecting film may be customized to optimize the light redirecting film for different types of light sources which emit different light distributions, for example, one pattern for single bulb laptops, another pattern for double bulb flat panel displays, and so on.

[0059] **FIG. 17** shows the optical elements **5** arranged in a radial pattern from the outside edges of the film **2** toward the center to redistribute the light ray output distribution of a backlight BL that receives light from cold cathode fluorescent lamps **26** along all four side edges of the backlight.

[0060] **FIG. 18** shows the optical elements **5** arranged in a pattern of angled groupings **32** across the film **2** that are tailored to redistribute the light ray output distribution of a backlight BL that receives light from one cold cathode fluorescent lamp **26** or a plurality of light emitting diodes **26** along one input edge of the backlight.

[0061] **FIG. 19** shows the optical elements **5** arranged in a radial type pattern facing a corner of the film **2** to redistribute the light ray output distribution of a backlight BL that is corner lit by a light emitting diode **26**. **FIG. 20** shows the optical elements **5** arranged in a radial type pattern facing a midpoint on one input edge of the film **2** to redistribute the light ray output distribution of a backlight BL that is lighted at a midpoint of one input edge of the backlight by a single light emitting diode **26**.

[0062] **FIG. 21** shows a light redirecting film **2** having optical grooves **35** extending across the film in a curved

pattern facing a corner of the film to redistribute the light ray output distribution of a backlight BL that is corner lit by a light emitting diode 26, whereas FIGS. 22-24 show a light redirecting film 2 having a pattern of optical grooves 35 extending across the film facing a midpoint along one edge of the film that decreases in curvature as the distance from the one edge increases to redistribute the light ray output distribution of a backlight BL that is edge lit by a light emitting diode 26 at a midpoint of one input edge of the backlight.

[0063] Where the light redirecting film 2 has a pattern 40 of optical elements 5 thereon that varies along the length of the film, a roll 41 of the film 2 may be provided having a repeating pattern of optical elements thereon as schematically shown in FIG. 15 to permit a selected area of the pattern that best suits a particular application to be die cut from the roll of film.

[0064] The backlight BL may be substantially flat, or curved, or may be a single layer or multi-layers, and may have different thicknesses and shapes as desired. Moreover, the backlight may be flexible or rigid, and be made of a variety of compounds. Further, the backlight may be hollow, filled with liquid, air, or be solid, and may have holes or ridges.

[0065] Also, the light source 26 may be of any suitable type including, for example, an arc lamp, an incandescent bulb which may also be colored, filtered or painted, a lens end bulb, a line light, a halogen lamp, a light emitting diode (LED), a chip from an LED, a neon bulb, a cold cathode fluorescent lamp, a fiber optic light pipe transmitting from a remote source, a laser or laser diode, or any other suitable light source. Additionally, the light source 26 may be a multiple colored LED, or a combination of multiple colored radiation sources in order to provide a desired colored or white light output distribution. For example, a plurality of colored lights such as LEDs of different colors (e.g., red, blue, green) or a single LED with multiple color chips may be employed to create white light or any other colored light output distribution by varying the intensities of each individual colored light.

[0066] A pattern of optical deformities may be provided on one or both sides of the backlight BL or on one or more selected areas on one or both sides of the backlight as desired. As used herein, the term optical deformities means any change in the shape or geometry of a surface and/or coating or surface treatment that causes a portion of the light to be emitted from the backlight. These deformities can be produced in a variety of manners, for example, by providing a painted pattern, an etched pattern, machined pattern, a printed pattern, a hot stamp pattern, or a molded pattern or the like on selected areas of the backlight. An ink or print pattern may be applied for example by pad printing, silk printing, inkjet, heat transfer film process or the like. The deformities may also be printed on a sheet or film which is used to apply the deformities to the backlight. This sheet or film may become a permanent part of the backlight for example by attaching or otherwise positioning the sheet or film against one or both sides of the backlight in order to produce a desired effect.

[0067] By varying the density, opaqueness or translucence, shape, depth, color, area, index of refraction or type of deformities on or in an area or areas of the backlight, the

light output of the backlight can be controlled. The deformities may be used to control the percent of light output from a light emitting area of the backlight. For example, less and/or smaller size deformities may be placed on surface areas where less light output is wanted. Conversely, a greater percentage of and/or larger deformities may be placed on surface areas of the backlight where greater light output is desired.

[0068] Varying the percentages and/or size of deformities in different areas of the backlight is necessary in order to provide a substantially uniform light output distribution. For example, the amount of light traveling through the backlight will ordinarily be greater in areas closer to the light source than in other areas further removed from the light source. A pattern of deformities may be used to adjust for the light variances within the backlight, for example, by providing a denser concentration of deformities with increased distance from the light source thereby resulting in a more uniform light output distribution from the backlight.

[0069] The deformities may also be used to control the output ray angle distribution from the backlight to suit a particular application. For example, if the backlight is used to backlight a liquid crystal display, the light output will be more efficient if the deformities (or a light redirecting film 2 is used in combination with the backlight) direct the light rays emitted by the backlight at predetermined ray angles such that they will pass through the liquid crystal display with low loss. Additionally, the pattern of optical deformities may be used to adjust for light output variances attributed to light extractions of the backlight. The pattern of optical deformities may be printed on the backlight surface areas utilizing a wide spectrum of paints, inks, coatings, epoxies or the like, ranging from glossy to opaque or both, and may employ half-tone separation techniques to vary the deformity coverage. Moreover, the pattern of optical deformities may be multiple layers or vary in index of refraction.

[0070] Print patterns of optical deformities may vary in shapes such as dots, squares, diamonds, ellipses, stars, random shapes, and the like. Also, print patterns of sixty lines per inch or finer are desirably employed. This makes the deformities or shapes in the print patterns nearly invisible to the human eye in a particular application, thereby eliminating the detection of gradient or banding lines that are common to light extracting patterns utilizing larger elements. Additionally, the deformities may vary in shape and/or size along the length and/or width of the backlight. Also, a random placement pattern of the deformities may be utilized throughout the length and/or width of the backlight. The deformities may have shapes or a pattern with no specific angles to reduce moiré or other interference effects. Examples of methods to create these random patterns are printing a pattern of shapes using stochastic print pattern techniques, frequency modulated half tone patterns, or random dot half tones. Moreover, the deformities may be colored in order to effect color correction in the backlight. The color of the deformities may also vary throughout the backlight, for example, to provide different colors for the same or different light output areas.

[0071] In addition to or in lieu of the patterns of optical deformities, other optical deformities including prismatic or lenticular grooves or cross grooves, or depressions or raised surfaces of various shapes using more complex shapes in a

mold pattern may be molded, etched, stamped, thermoformed, hot stamped or the like into or on one or more surface areas of the backlight. The prismatic or lenticular surfaces, depressions or raised surfaces will cause a portion of the light rays contacted thereby to be emitted from the backlight. Also, the angles of the prisms, depressions or other surfaces may be varied to direct the light in different directions to produce a desired light output distribution or effect. Moreover, the reflective or refractive surfaces may have shapes or a pattern with no specific angles to reduce moiré or other interference effects.

[0072] A back reflector 40 may be attached or positioned against one side of the backlight BL as schematically shown in FIGS. 1 and 2 in order to improve light output efficiency of the backlight by reflecting the light emitted from that side back through the backlight for emission through the opposite side. Additionally, a pattern of optical deformities 50 may be provided on one or both sides of the backlight as schematically shown in FIGS. 1 and 2 in order to change the path of the light so that the internal critical angle is exceeded and a portion of the light is emitted from one or both sides of the backlight.

[0073] FIGS. 25-28 show optical deformities 50 which may either be individual projections 51 on the respective backlight surface areas 52 or individual depressions 53 in such surface areas. In either case, each of these optical deformities 50 has a well defined shape including a reflective or refractive surface 54 that intersects the respective backlight surface area 52 at one edge 55 and has a uniform slope throughout its length for more precisely controlling the emission of light by each of the deformities. Along a peripheral edge portion 56 of each reflective/refractive surface 54 is an end wall 57 of each deformity 50 that intersects the respective panel surface area 52 at a greater included angle I than the included angle I' between the reflective/refractive surfaces 54 and the panel surface area 52 (see FIGS. 27 and 28) to minimize the projected surface area of the end walls on the panel surface area. This allows more deformities 50 to be placed on or in the panel surface areas than would otherwise be possible if the projected surface areas of the end walls 57 were substantially the same as or greater than the projected surface areas of the reflective/refractive surfaces 54.

[0074] In FIGS. 25 and 26 the peripheral edge portions 56 of the reflective/refractive surfaces 54 and associated end walls 57 are curved in the transverse direction. Also in FIGS. 27 and 28 the end walls 57 of the deformities 50 are shown extending substantially perpendicular to the reflective/refractive surfaces 54 of the deformities. Alternatively, such end walls 57 may extend substantially perpendicular to the panel surface areas 52 as schematically shown in FIGS. 29 and 30. This virtually eliminates any projected surface area of the end walls 57 on the panel surface areas 52 whereby the density of the deformities on the panel surface areas may be even further increased.

[0075] The optical deformities may also be of other well defined shapes to obtain a desired light output distribution from a panel surface area. FIG. 31 shows individual light extracting deformities 58 on a panel surface area 52 each including a generally planar, rectangular reflective/refractive surface 59 and associated end wall 60 of a uniform slope throughout their length and width and generally planar side

walls 61. Alternatively, the deformities 58' may have rounded or curved side walls 62 as schematically shown in FIG. 32.

[0076] FIG. 33 shows individual light extracting deformities 63 on a panel surface area 52 each including a planar, sloping triangular shaped reflective/refractive surface 64 and associated planar, generally triangularly shaped side walls or end walls 65. FIG. 34 shows individual light extracting deformities 66 each including a planar sloping reflective/refractive surface 67 having angled peripheral edge portions 68 and associated angled end and side walls 69 and 70.

[0077] FIG. 35 shows individual light extracting deformities 71 which are generally conically shaped, whereas FIG. 36 shows individual light extracting deformities 72 each including a rounded reflective/refractive surface 73 and rounded end walls 74 and rounded or curved side walls 75 all blended together. These additional surfaces will reflect or refract other light rays impinging thereon in different directions to spread light across the backlight/panel member BL to provide a more uniform distribution of light emitted from the panel member.

[0078] Regardless of the particular shape of the reflective/refractive surfaces and end and side walls of the individual deformities, such deformities may also include planar surfaces intersecting the reflective/refractive surfaces and end and/or side walls in parallel spaced relation to the panel surface areas 52. FIGS. 37-39 show deformities 76, 77 and 78 in the form of individual projections on a panel surface area having representative shapes similar to those shown in FIGS. 31, 32 and 35, respectively, except that each deformity is intersected by a planar surface 79 in parallel spaced relation to the panel surface area 52. In like manner, FIG. 40 shows one of a multitude of deformities 80 in the form of individual depressions 81 in a panel surface area 52 each intersected by a planar surface 79 in parallel spaced relation to the general planar surface of the panel surface area 52. Any light rays that impinge on such planar surfaces 79 at internal angles less than the critical angle for emission of light from the panel surface area 52 will be internally reflected by the planar surfaces 79, whereas any light rays impinging on such planar surfaces 79 at internal angles greater than the critical angle will be emitted by the planar surfaces with minimal optical discontinuities, as schematically shown in FIG. 40.

[0079] Where the deformities are projections on the panel surface area 52, the reflective/refractive surfaces extend at an angle away from the panel in a direction generally opposite to that in which the light rays from the light source 26 travel through the panel as schematically shown in FIGS. 27 and 29. Where the deformities are depressions in the panel surface area, the reflective/refractive surfaces extend at an angle into the panel in the same general direction in which the light rays from the light source 26 travel through the panel member as schematically shown in FIGS. 28 and 30.

[0080] Regardless of whether the deformities are projections or depressions on or in the panel surface areas 52, the slopes of the light reflective/refractive surfaces of the deformities may be varied to cause the light rays impinging thereon to be either refracted out of the light emitting panel or reflected back through the panel and emitted out the opposite side of the panel which may be etched to diffuse the

light emitted therefrom or covered by a light redirecting film 2 to produce a desired effect. Also, the pattern of optical deformities on the panel surface area may be uniform or variable as desired to obtain a desired light output distribution from the panel surface areas. FIGS. 41 and 42 show deformities 76 and 77 similar in shape to those shown in FIGS. 37 and 38 arranged in a plurality of generally straight uniformly spaced apart rows along the length and width of a panel surface area 52, whereas FIGS. 43 and 44 show such deformities 76 and 77 arranged in staggered rows that overlap each other along the length of a panel surface area.

[0081] Also, the size, including the width, length and depth or height as well as the angular orientation and position of the optical deformities may vary along the length and/or width of any given panel surface area to obtain a desired light output distribution from the panel surface area. FIGS. 45 and 46 show a random or variable pattern of different size deformities 58 and 58' similar in shape to those shown in FIGS. 31 and 32, respectively, arranged in staggered rows on a panel surface area 52, whereas FIG. 47 shows deformities 77 similar in shape to those shown in FIG. 38 increasing in size as the distance of the deformities from the light source increases or intensity of the light decreases along the length and/or width of the panel surface area. The deformities 58 and 58' are shown in FIGS. 45 and 46 arranged in clusters 82 across the panel surface, with at least some of the deformities in each cluster having a different size or shape characteristic that collectively produce an average size or shape characteristic for each of the clusters that varies across the panel surface. For example, at least some of the deformities in each of the clusters may have a different depth or height or different slope or orientation that collectively produce an average depth or height characteristic or average slope or orientation of the sloping surface that varies across the panel surface. Likewise at least some of the deformities in each of the clusters may have a different width or length that collectively produce an average width or length characteristic that varies across the panel surface. This allows one to obtain a desired size or shape characteristic beyond machinery tolerances, and also defeats moiré and interference effects.

[0082] FIGS. 48 and 49 schematically show different angular orientations of optical deformities 85 of any desired shape along the length and width of a panel surface area 52. In FIG. 48 the deformities are arranged in straight rows 86 along the length of the panel surface area but the deformities in each of the rows are oriented to face the light source 26 so that all of the deformities are substantially in line with the light rays being emitted from the light source. In FIG. 49 the deformities 85 are also oriented to face the light source 26 similar to FIG. 48. In addition, the rows 87 of deformities in FIG. 49 are in substantial radial alignment with the light source 26.

[0083] FIGS. 50 and 51 schematically show how exemplary light rays 90 emitted from a focused light source 26 insert molded or cast within a light transition area 91 of a light emitting panel assembly BL in accordance with this invention are reflected during their travel through the light emitting panel member 92 until they impinge upon individual light extracting deformities 50, 77 of well defined shapes on or in a panel surface area 52 causing more of the light rays to be reflected or refracted out of one side 93 of the panel member than the other side 94. In FIG. 50 the

exemplary light rays 90 are shown being reflected by the reflective/refractive surfaces 54 of the deformities 50 in the same general direction out through the same side 93 of the panel member, whereas in FIG. 51 the light rays 90 are shown being scattered in different directions within the panel member 92 by the rounded side walls 62 of the deformities 77 before the light rays are reflected/refracted out of the same side 93 of the panel member. Such a pattern of individual light extracting deformities of well defined shapes in accordance with the present invention can cause 60 to 70% or more of the light received through the input edge 95 of the panel member to be emitted from the same side of the panel member.

[0084] From the foregoing, it will be apparent that the light redirecting films of the present invention redistribute more of the light emitted by a backlight or other light source toward a direction more normal to the plane of the films. Also, the light redirecting films and backlights of the present invention may be tailored or tuned to each other to provide a system in which the individual optical elements of the light redirecting films work in conjunction with the optical deformities of the backlights to produce an optimized output light ray angle distribution from the system.

[0085] Predetermined patterns of individual optical elements (including optical deformities) of well defined shape may be formed on or in films, components or wave guides (hereafter optical substrates) using known manufacturing methods. One such known manufacturing method involves cutting or forming a pattern of cavities of such optical element shapes in a flat sheet or plate using a milling or laser cutter and using the cut or formed optical element shapes in the sheet or plate to form a corresponding pattern of optical elements on or in the optical substrates. A drawback to this method is the difficulty and expense of cutting or forming cavities of certain types of optical element shapes including particularly those having at least two surfaces that come together to form a ridge and are quite small relative to the length and width of the optical substrates in which the optical elements are subsequently formed. Also the spinning tools needed to make these geometric shapes are quite expensive and difficult to make, and have a relatively short useful life because of breakage or the like, which further adds to the cost of making cavities having these geometric shapes.

[0086] The difficulty and cost of making cavities having these geometric shapes may be substantially reduced in accordance with the present invention by using a tool to cut or form such patterns of optical element shaped cavities in a substrate without rotating the tool or substrate during the cutting or forming process.

[0087] FIGS. 52 and 53 show one such tool 100 for cutting or forming such cavities 101 and 102, respectively, in a substrate 103 that is not perpendicular to the cutting or forming path (cut move) of the tool. One or both the tool 100 and substrate 103 may be moved either in a linear or nonlinear cross path during the cut move. In the case of FIG. 52 the cut move 104 is perpendicular to the axis of the tool, whereas in the case of FIG. 53 the cut move 105 is parallel to the tool axis. Also in FIG. 52 (as well as in FIG. 54) the tool tip 106 (which may be a diamond tip or a tip made of some other suitable cutting or forming material) has at least one cutting or forming edge 107 that is parallel to the tool

cross path (shown in phantom lines **108** in **FIG. 54**) in order to cut/form a cavity **101** such as shown in **FIG. 52** (and also in **FIG. 55a**) having at least one flat surface **109** and at least one curved surface **110** that come together to form a ridge **111** and are quite small relative to the length and width of the optical substrates in which the optical elements are subsequently formed. In **FIG. 53**, on the other hand, the tool **100** is provided with a different shaped tip **115** that is shaped to form a cavity **102** having at least two curved surfaces **116**, **117** that come together to form a ridge **118** and that may either be symmetrical to one another as shown in **FIG. 55b** or nonsymmetrical to one another as shown in **FIG. 55c** depending on whether or not the tool tip has a symmetrical profile on either side of the plane of the cut move **105** of the tool.

[**0088**] The substrate **103** or tool **100** or both is positioned to produce a specific placement for each cavity prior to each cutting or forming process. For example, the substrate or tool (or both) may be positioned so that at least some of the ridges of at least some of the cavities are generally in the same direction for producing optical elements having ridges **119** generally in the same direction as shown, for example, in **FIGS. 5, 8-11, 31, 32, 45-47** and **50**. Also the substrate or tool may be positioned so that at least some of the cavities overlap, intersect or interlock with other cavities so that the correspondingly shaped optical elements produced thereby also overlap, intersect or interlock with other optical elements as shown, for example, in **FIGS. 5, 6-11** and **13**. Moreover, the optical elements may cover at least 90% of at least one surface of the optical substrates.

[**0089**] The optical substrates that are formed using the substrates made in accordance with the present invention may have a light entrance surface and a light exit surface with at least some of the optical elements formed on at least one of the surfaces having a ridge angle RA (see **FIG. 2**) of between 60 degrees and 80 degrees or between 85 degrees and 95 degrees.

[**0090**] The cavities that are cut or formed in the substrate during the cutting or forming process may also vary in size, shape, angle, rotation, orientation, depth, height, type and/or placement to form optical elements on or in the optical substrates that correspondingly vary. Likewise, at least some of the cavities may be cut or formed randomly in the substrate to produce at least some optical elements on or in the optical substrates that also vary randomly.

[**0091**] In order to produce a different orientation for at least some of the cavities (to produce for example optical substrates having optical elements with the different orientations shown in **FIGS. 13, 16, 17-20, 48** and **49**), the substrate or tool is rotated prior to cutting or forming these cavities. However, where at least some of the optical elements also have the same orientation as shown in these figures, the cavities for forming these optical elements may be cut or formed consecutively so that the substrate or tool need only be positioned between the cutting or forming of at least some of the cavities.

[**0092**] In **FIGS. 57** and **58** the cut move **120** of the tool **100** is in a plane perpendicular to the substrate **103**. Also in **FIG. 57** the cut move is parallel to the tool axis (because the tool axis is perpendicular to the substrate) whereas in **FIG. 58** the cut move is at an angle to the tool axis (because the tool axis is at an angle relative to the substrate).

[**0093**] In **FIG. 57** the tool **100** has a cutting or forming tip **121** that is nonsymmetrical about the tool axis which produces nonsymmetrical cavities **102** in the substrate having at least one curved surface **117** on one side of the cavity that is larger than at least one other curved surface **116** on the other side of the cavity, similar to the cavity shown in **FIG. 55(c)**.

[**0094**] In **FIG. 58** the tool tip **122** is symmetrical with respect to the tool axis. However, because the tool axis is at an angle to the substrate and the cut move **120** is in a plane perpendicular to the substrate, the tool tip of **FIG. 58** also produces nonsymmetrical cavities having at least two curved surfaces **116** and **117**, one of which is larger than the other.

[**0095**] **FIG. 59** shows a tool **100** similar to that shown in **FIG. 57** except that the tool tip **123** is symmetrical about the tool axis. Also **FIG. 59** shows that the tool **100** may be fixed and the substrate **103** may move in a direction parallel to the tool axis and in the tool cross path direction during the cutting or forming process. Likewise, the substrate may be positioned to produce a specific placement for each cavity **102** prior to each cutting or forming process, and may also be rotated to produce a different orientation for at least some of the cavities prior to cutting or forming at least some of the cavities.

[**0096**] **FIG. 60** shows a tool **100** that is not perpendicular to the substrate **103**. However, the cut move **125** is perpendicular to the substrate. Also in **FIG. 60** the tool tip **126** is not symmetrical to the tool axis. However, the plane of the cut move **125** bisects the tool tip so the tool tip **126** is symmetrical to the cut move as schematically shown in **FIG. 56b** to form cavities **102** having symmetrical shapes as shown, for example, in **FIG. 55b**.

[**0097**] **FIGS. 61a-c** show different non-linear tool cross paths **130, 131** and **132** for forming different cavity geometries, whereas **FIGS. 62a-c** show different linear tool cross paths **133, 134** and **135** for forming different cavity geometries which may approximate various non-linear tool cross paths by increasing the number of linear segments during tool movement through such tool cross paths. For example, the linear tool cross paths **133** and **134** shown in **FIGS. 62a** and **b** may be an approximation of the non-linear tool cross paths **130** and **131** shown in **FIGS. 61a** and **b**. **FIG. 62c**, on the other hand, show a cross tool path **135** that progresses monotonically into the substrate and then pulls out when the cutting or forming process is completed. Also the tools may be moved through different tool cross paths to form at least some cavities having ridges that are curved, segmented or hybrid in shape. Likewise, the tools may be moved through different cross paths to form at least some of the cavities **140** with at least two irregularly shaped curves **141** and **142** and at least one wavy ridge **143** as shown, for example, in **FIG. 55d**.

[**0098**] The various surfaces of the substrates in which the cavities are cut or formed may either be substantially flat as shown in **FIGS. 52-54** and **57-60**. Alternatively the surfaces of the substrates **103** in which the cavities are cut or formed may be curved (including conical) as shown in **FIG. 63** or cylindrical as shown in **FIG. 64**. **FIG. 63** also shows the curved substrate **103** moving in an arc, whereas **FIG. 64** shows the tool **100** moving in a tool cross path during the cut move. Also in **FIG. 64** both the tool and cylindrical substrate may be positioned to produce a specific placement for each

cavity in the substrate prior to each cutting or forming process, and the tool may be rotated to produce a different orientation for at least some of the cavities prior to cutting or forming at least some of the cavities. However, it is to be understood that either the tool or substrate or both may move during and/or prior to the cutting or forming process. Also the cavities may be cut or formed directly in the surface of the cylindrical substrate or in a sleeve or segment of a sleeve that may be removed from the cylinder.

[0099] After the desired number of patterns of optical element shaped cavities are cut or formed in the substrates, the substrates containing the desired pattern or patterns of optical element shaped cavities or deposition or mirror copies or inverse copies thereof may be used in production tooling or as a master for making production tooling. The production tooling may be used to form corresponding patterns of optical elements on or in optical substrates by molding, thermofforming, hot stamping, embossing, extrusion, or radiation curing and the like. For example, **FIG. 65** shows tooling **150** placed in an injection mold **151** for molding optical elements on or in optical substrates; **FIG. 66** shows forming the optical elements on or in optical substrates by applying heat and pressing the optical substrate **152** against the optical element shaped cavities in the tooling **150**; and **FIG. 67** shows forming the optical elements on or in the optical substrate formed by applying a flowable optical substrate material **153** over the optical element shaped cavities in the tooling **150** and having the flowable optical substrate material cure or solidify before removing the cured or solidified optical substrate material from the tooling. The flowable optical substrate material may, for example, be a self-curing material or an ultraviolet or other radiation curing material.

[0100] Where the cavities are formed in a cylindrical substrate, the cylinder itself may be used as the production tooling to form a corresponding pattern of optical elements on a roll of the optical substrate by an embossing or extrusion process or the like.

[0101] Although the invention has been shown and described with respect to certain embodiments, it is obvious that equivalent alterations and modifications will occur to others skilled in the art upon the reading and understanding of the specification. In particular, with regard to the various functions performed by the above described components, the terms (including any reference to a "means") used to describe such components are intended to correspond, unless otherwise indicated, to any component which performs the specified function of the described component (e.g., that is functionally equivalent), even though not structurally equivalent to the disclosed component which performs the function in the herein illustrated exemplary embodiments of the invention. In addition, while a particular feature of the invention may have been disclosed with respect to only one embodiment, such feature may be combined with one or more other features of other embodiments as may be desired and advantageous for any given or particular application.

What is claimed is:

1. A method of making an optical film, component or wave guide that has multiple optical elements on at least one surface, and at least some of the optical elements have at least two surfaces that come together to form a ridge and are

quite small relative to the length and width of the optical film, component or wave guide, comprising using a tool to cut or form multiple optical element shaped cavities in a surface of a substrate that is not perpendicular to the path of the tool during the cutting or forming process, wherein neither the tool nor the substrate is rotated about the axis of the tool during the cutting or forming process, and at least some of the cavities are cut or formed to have at least two surfaces that come together to form a ridge and that are quite small relative to the length and width of the substrate, and using the substrate to form the optical film, component or wave guide having the multiple optical elements on at least one surface corresponding to the cavities in the substrate.

2. The method of claim 1 wherein the substrate or tool is positioned to produce a specific placement for each cavity prior to each cutting or forming process.

3. The method of claim 2 wherein the substrate or tool is rotated to produce a different orientation for at least some of the cavities prior to cutting or forming at least some of the cavities.

4. The method of claim 3 wherein other of the cavities have the same orientation and are cut or formed consecutively so that the substrate or tool is only rotated between the cutting or forming of some of the cavities.

5. The method of claim 1 wherein the tool has a cutting or forming edge that lies in a plane parallel to a vector normal to the surface of the substrate.

6. The method of claim 1 wherein the tool has a cutting or forming edge that lies in a plane parallel to the path of the tool during the cutting or forming process.

7. The method of claim 1 wherein the tool moves into the substrate along a nonlinear path.

8. The method of claim 7 wherein the nonlinear path is a curve.

9. The method of claim 1 wherein the tool moves into the substrate along a linear path.

10. The method of claim 9 wherein the linear path changes directions at discrete points during the cutting or forming process.

11. The method of claim 1 wherein the tool has a nonsymmetrical profile on either side of the plane of the cutting or forming path of the tool.

12. The method of claim 1 wherein the tool has a symmetrical profile on either side of the plane of the cutting or forming path of the tool.

13. The method of claim 1 wherein at least some of the cavities are asymmetrical.

14. The method of claim 13 wherein at least some of the cavities have one flat surface and one curved surface.

15. The method of claim 1 wherein at least some of the cavities are symmetrical.

16. The method of claim 1 wherein at least some of the cavities only have two surfaces, one of the surfaces being flat and the other of the surfaces being curved.

17. The method of claim 1 wherein at least some of the cavities have two curved surfaces.

18. The method of claim 1 wherein during the cutting or forming process, one or both of the tool and the substrate are moved relative to each other.

19. The method of claim 1 wherein the surface of the substrate has one of the following shapes: flat, curved, conical, cylindrical.

20. The method of claim 1 wherein at least some of the cavities overlap, intersect or interlock with other cavities.



21. The method of claim 1 wherein the optical elements that are formed on the one surface of the optical film, component or wave guide substantially cover at least 90% of the one surface.

22. The method of claim 1 wherein the film has a light entrance surface and an opposite light exit surface with at least some of the optical elements being located on the light entrance surface and having a ridge angle of between 60 and 80 degrees.

23. The method of claim 1 wherein the film has a light entrance surface and an opposite light exit surface with at least some of said optical elements being located on the light exit surface and having a ridge angle or between 85 and 95 degrees.

24. The method of claim 1 wherein at least some of the cavities vary in at least one of the following: size, shape, angle, rotation, orientation, density, depth, height, type and placement.

25. The method of claim 24 wherein at least some of the cavities vary randomly in the substrate.

26. The method of claim 1 wherein a deposition or mirror copy of the substrate is used to form the optical film, component or wave guide.

27. The method of claim 1 wherein at least some of the ridges are curved, segmented or hybrid in shape.

28. The method of claim 1 wherein at least some of the ridges are generally in the same direction.

29. The method of claim 1 wherein the substrate is used to form the optical film, component or wave guide by at least one of the following: molding, thermoforming, hot stamping, embossing, extrusion, and radiation curing.

30. A method of making an optical film, component or wave guide that has multiple optical elements on at least one surface, and at least some of the optical elements have at least two surfaces that come together to form a ridge and are quite small relative to the length and width of the optical film, component or wave guide, comprising using a tool to cut or form multiple optical element shaped cavities in a surface of a substrate that is perpendicular to the path of the tool during the cutting or forming process, wherein neither the tool nor the substrate is rotated about the axis of the tool during the cutting or forming process, and at least some of the cavities are cut or formed to have at least two surfaces that come together to form a ridge and that are quite small relative to the length and width of the substrate, and using the substrate to form the optical film, component or wave guide having the multiple optical elements on at least one surface corresponding to the cavities in the substrate.

31. The method of claim 30 wherein the tool has an asymmetrical cutting or forming tip.

32. The method of claim 30 wherein the tool has a symmetrical cutting or forming tip, and at least the two surfaces that come together to form the ridge of at least some of the cavities are symmetrical surfaces.

33. The method of claim 30 wherein the substrate or tool is positioned to produce a specific placement for each cavity prior to each cutting or forming process.

34. The method of claim 33 wherein the substrate or tool is rotated to produce a different orientation for at least some of the cavities prior to cutting or forming at least some of the cavities.

35. The method of claim 34 wherein other of the cavities have the same orientation and are cut or formed consecu-

tively so that the substrate or tool is only rotated between the cutting or forming of some of the cavities.

36. The method of claim 30 wherein the tool has a cutting or forming edge that lies in a plane parallel to a vector normal to the surface of the substrate.

37. The method of claim 30 wherein the tool has a cutting or forming edge that lies in a plane parallel to the path of the tool during the cutting or forming process.

38. The method of claim 30 wherein the tool moves into the substrate along a nonlinear path.

39. The method of claim 38 wherein the nonlinear path is a curve.

40. The method of claim 30 wherein the tool moves into the substrate along a linear path.

41. The method of claim 40 wherein the linear path changes directions at discrete points during the cutting or forming process.

42. The method of claim 26 wherein the tool has a nonsymmetrical profile on either side of the plane of the cutting or forming path of the tool.

43. The method of claim 30 wherein the tool has a symmetrical profile on either side of the plane of the cutting or forming path of the tool.

44. The method of claim 30 wherein at least some of the cavities are asymmetrical.

45. The method of claim 44 wherein at least some of the cavities have one flat surface and one curved surface.

46. The method of claim 30 wherein at least some of the cavities are symmetrical.

47. The method of claim 30 wherein at least some of the cavities only have two surfaces, one of the surfaces being flat and the other of the surfaces being curved.

48. The method of claim 30 wherein at least some of the cavities have two curved surfaces.

49. The method of claim 30 wherein during the cutting or forming process, one or both of the tool and the substrate are moved relative to each other.

50. The method of claim 30 wherein the surface of the substrate has one of the following shapes: flat, curved, conical, cylindrical.

51. The method of claim 30 wherein at least some of the cavities overlap, intersect or interlock with other cavities.

52. The method of claim 30 wherein the optical elements that are formed on the one surface of the optical film, component or wave guide substantially cover at least 90% of the one surface.

53. The method of claim 30 wherein the film has a light entrance surface and an opposite light exit surface with at least some of the optical elements being located on the light entrance surface and having a ridge angle of between 60 and 80 degrees.

54. The method of claim 30 wherein the film has a light entrance surface and an opposite light exit surface with at least some of the optical elements being located on the light exit surface and having a ridge angle of between 85 and 95 degrees.

55. The method of claim 30 wherein at least some of the cavities vary in at least one of the following: size, shape, angle, rotation, orientation, density, depth, height, type and placement.

**56.** The method of claim 55 wherein at least some of the cavities vary randomly in the substrate.

**57.** The method of claim 30 wherein a deposition or mirror copy of the substrate is used to form the optical film, component or wave guide.

**58.** The method of claim 30 wherein at least some of the ridges are curved, segmented or hybrid in shape.

**59.** The method of claim 30 wherein at least some of the ridges are generally in the same direction.

**60.** The method of claim 30 wherein the substrate is used to form the optical film, component or wave guide by at least one of the following: molding, thermoforming, hot stamping, embossing, extrusion, and radiation curing.

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