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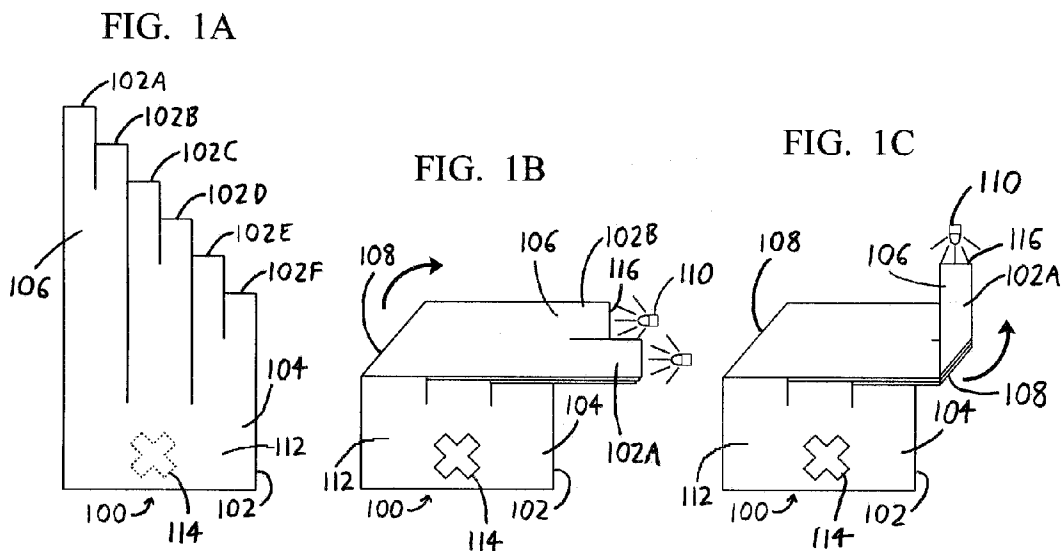
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(54) Title: LIGHT COUPLING INTO ILLUMINATED FILMS



(57) Abstract: A flexible translucent sheet is folded to have portions of its bounding edge closely situated in overlapping relationship, and these overlapping portions are illuminated by a light source. The illumination is transmitted through the interior of the sheet to any adjacent unfolded area of the sheet, which may bear emission areas which are treated so that the light emits from the sheet at these areas. Preferred versions of the invention have a series of legs cut into one edge of the sheet, and the legs are then bundled in stacked relationship, with a light source providing light input into the bundle.

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# LIGHT COUPLING INTO ILLUMINATED FILMS

## Cross-Reference to Related Applications

This application claims priority under 35 USC §119(e) to United States  
5 Provisional Patent Application 60/978,755 filed October 9, 2007, the entirety of which  
is incorporated by reference herein.

## Field of the Invention

This document concerns an invention relating generally to lightguides such as  
10 fiberoptic cable and edge-lit films, and more specifically to devices and methods for  
providing edge-lighting for films with high efficiency.

## Background of the Invention

There are numerous forms of lightguides, with perhaps the most common being  
15 the optical fiber, which is typically formed as a clear glass or plastic cylinder with a  
diameter of 1 micrometer to 5 mm. A light source is coupled to an end of the optical  
fiber, and is transmitted through its length, typically with the intent of delivering as much  
of the light as possible to the opposite end of the optical fiber. Some of the light is lost  
20 along the length of the optical fiber owing to light absorption and light scattering (i.e.,  
light escaping through the surface of the fiber). However, with the choice of appropriate  
materials and manufacturing processes, absorption and scattering losses can be  
minimized. For example, whereas an optical fiber formed of plastic (e.g., polymethyl  
methacrylate or PMMA) typically has an attenuation of less than 0.2 dB per meter, an  
optical fiber formed of high-grade fused silica typically has an attenuation of less than  
25 0.01 dB per meter. Plastic lightguides tend to have greater losses, and thus tend to be  
used only in circumstances where light only needs to be transmitted short distances.  
Scattering can also be reduced by forming an optical fiber with a core having a higher  
refractive index, and an outer layer having a lower refractive index, so that light received  
by the core experiences internal reflection (i.e., it reflects from the boundary between the

5 core and the outer layer and continues to travel along the fiber, rather than being transmitted from the core to the outer layer and its surroundings). Efficient light transfer is also enhanced if the light source is coupled to the end of the optical fiber with high efficiency so that the greatest possible amount of light from the light source is transmitted into the fiber. Good coupling efficiency can be achieved by (for example) treating the end of the optical fiber to be as smooth and transparent as possible, thereby better allowing the light to be transferred into the end of the fiber rather than being reflected therefrom, and by transmitting the light from the light source to the fiber using an optical coupling gel matched to the refractive index of the fiber.

10 Another form of lightguide is a transparent plate which has a light source coupled to one edge. This arrangement is often referred to as "edge-lighting," and it typically requires plates with thicknesses greater than 2 mm to achieve effective coupling from typical light sources such as light emitting diodes (LEDs) and halogen, incandescent, metal halide or xenon lamps. The surface of a plate may be treated at certain areas, as by surface roughening, etching, or the addition of a material that promotes light scattering (e.g., white paint), to reduce or defeat internal reflection at these areas to cause light emission from the plate at these or adjacent areas. As a result, the treated areas appear to glow. Because the plates typically do not efficiently receive or transmit light, and have higher losses along their lengths, the treated areas must often be functionally graded (i.e., they must generate lesser scattering near the light source and greater scattering farther from the light source) if the treated areas are to appear to have uniform illumination.

15 The plates are typically rigid, having very limited flexibility, though in some cases flexible plastic films are used (typically having a thickness of 0.5 mm or so). However, these are rarely used because it is difficult to efficiently couple light into such films at low cost. Most light sources have dimensions greater than millimeters, with the films having much smaller thicknesses for receiving the input light, so it is difficult to efficiently and inexpensively channel the majority of the light source's light output into the edge of the film. One solution to this problem is presented in U.S. Patent 7,237,396, wherein a light source is coupled to the first ends of a bunched bundle of optical fibers, and the second

20

25

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ends are spread along an edge of the film to effectively provide an array of input light sources. The drawback of this approach is that it can be time-consuming and difficult to achieve: for efficient coupling, the second ends of the fibers must be precisely aligned with the edge of the film; treatment of the fiber ends and film edge to reduce scattering is time-consuming; and similarly the assembly demands of the system (which preferably uses optical coupling gel at the various optical interfaces) are high. There are also losses at the interface between the light source and the bundle, since the spaces between the fibers in the bundle create a loss. It would therefore be advantageous to have devices and methods available for high-efficiency coupling of light sources to films and plates with lower cost and ease of manufacture and assembly.

### Summary of the Invention

The invention, which is defined by the claims set forth at the end of this document, is directed to devices and methods which at least partially alleviate the aforementioned problems. A basic understanding of some of the features of preferred versions of the invention can be attained from a review of the following brief summary of the invention, with more details being provided elsewhere in this document. To assist in the reader's understanding, the following review makes reference to the accompanying drawings (which are briefly reviewed in the "Brief Description of the Drawings" section following this Summary section of this document).

Referring to **FIGS. 1A-1C** for a schematic view of an exemplary version of the invention, a flexible sheet **100** of at least partially translucent material is surrounded by a bounding edge **102** (see particularly **FIG. 1A**). The sheet **100** is folded upon itself – here twice, once in **FIG. 1B** and once in **FIG. 1C** – such that portions **102A**, **102B**, **102C**, **102D**, **102E**, **102F** of the bounding edge **102** overlap, and an unfolded portion **104** (a "body") is left where the sheet **100** is not folded upon itself. In this example, the sheet **100** is formed with a number of discrete legs **106** extending from the unfolded portion / body **104**, and the legs **106** each terminate at the portions **102A**, **102B**, **102C**, **102D**, **102E**, **102F** of the bounding edge **102** which are to overlap. The legs **106** are

folded between their bounding edges **102A**, **102B**, **102C**, **102D**, **102E**, **102F** and the  
body **104** at folds **108** (as seen in **FIG. 1B**, as well as in **FIG. 1C**) such that at least some  
of the legs **106** are bent into stacked relationship, with their bounding edges **102A**, **102B**,  
**102C**, **102D**, **102E**, **102F** preferably being at least substantially aligned, and also being  
5 prepared to define an at least substantially smooth and continuous surface (e.g., by  
polishing). One or more light sources **110** can then be situated to illuminate the  
adjacently situated bounding edges **102A**, **102B**, **102C**, **102D**, **102E**, **102F** of the  
stacked legs **106**. The light is received by the overlapping edges **102A**, **102B**, **102C**,  
**102D**, **102E**, **102F**, which inherently provide an area greater than the thickness of the  
10 sheet **100** so that the sheet **100** (the stacked edges **102A**, **102B**, **102C**, **102D**, **102E**,  
**102F**) more efficiently receive a greater amount of light from the light source **110**. The  
received light is transmitted through the sheet **100** via internal reflection such that the  
unfolded portion/body **104** is internally illuminated. To enhance such internal reflection,  
the sheet **100** preferably bears a layer of reflective material, and/or of a material with a  
15 lower refractive index, on its non-illuminated bounding edges **102** and on one or more  
of its faces **112**. Areas **114** on the face(s) **112** of the sheet **100** can then be made to emit  
light by disrupting internal reflection at these areas **114**, as by roughening their surfaces,  
removing any reflective layers, adding colorants or other less-reflective material, or  
otherwise preparing these areas **114** such that the light within the sheet **100** tends to emit  
20 at these areas **114** to a greater extent than at surrounding areas. Alternatively or  
additionally, areas **114** of the sheet **100** can be treated to fluoresce in response to some  
or all of the wavelengths of light provided to the sheet **100**, such that these areas **114** will  
appear to be illuminated.

Further advantages, features, and objects of the invention will be apparent from  
25 the remainder of this document in conjunction with the associated drawings.

## Brief Description of the Drawings

5 **FIGS. 1A-1C** present schematic views of a flexible translucent sheet **100** having legs **106** (in **FIG. 1A**) which are folded into stacked / overlapping sets (in **FIG. 1B**, and also in **FIG. 1C**) to define input areas **116** at which light may be input from one or more light sources **110** to cause emitting areas **114** to emit light.

**FIG. 2** is a schematic view of a flexible translucent sheet **200** showing an arrangement similar to that of **FIGS. 1B-1C**, wherein the legs **206** of sheet **200** are folded at bends **208** to define an input area **216** for a light source **210**.

## Detailed Description of Preferred Versions of the Invention

10 Expanding on the discussion given in the foregoing Summary, the sheets used in the invention may have any appropriate form. The sheets preferably have at least substantially uniform thickness (with thickness often being between 0.025 mm to 0.5 mm thick), and preferably bear the aforementioned layers of reflective and/or lower refractive index material on one or more of their surfaces (most preferably on at least their  
15 opposing major faces). If legs are formed in a sheet, the legs are preferably cut using a method which leaves cut edges which are as optically smooth as possible to promote efficient internal reflection at these edges. Stamping or cutting with very sharp and/or heated blades, or using laser cutting or another form of thermal cutting, can promote  
20 smoothness. Other forms of cutting, e.g., water jet cutting, can also provide acceptable results. Polishing can occur after cutting to further promote smoothness, and such polishing can be performed mechanically (e.g., with abrasives), thermally (e.g., by surface melting), and/or chemically (e.g., by application of caustics).

25 The invention can be generated without forming legs in the sheet, as by pleating/folding one end of a sheet to form a stacked light input area, and leaving the other end of the sheet unfolded to define the body to be illuminated. However, such an arrangement can be bulky in comparison to the arrangements shown in the drawings. One can choose among arrangements with or without legs, or may combine features of these arrangements, to achieve an arrangement which best fits the space requirements for

the application at hand. Any pleated areas, stacked legs, or similar arrangements can be mechanically urged together, melted together, and/or adhered together (preferably with an adhesive having the same index of refraction as the sheet, or a lower one so as to serve as a reflective layer) for ease of handling, and potentially for better coupling efficiency at the light input area.

It is notable that where sheets are folded/bent, the folds/bends are preferably such that they do not generate an immediate 180 degree change in direction of a sheet, but rather they have some radius of curvature. This helps to promote more efficient internal reflection, and additionally some films can "craze" (i.e., whiten or otherwise introduce a scattering haze) if overly stressed by a sharp bend. Preferably, the radius of curvature of a bend/fold will be at least ten times the thickness of the film., with greater radii of curvature helping to reduce the possibility of light loss. Radii of curvature of 75 times the thickness of the film or less are useful for providing acceptable light losses versus the space required for accommodating the gradual folds/bends. However, if space or other considerations make sharp bends/folds preferable, light loss can be reduced by applying reflective and/or low refractive index cladding layers at the folds/bends, and/or by treating sheets to reduce stress when they are being folded/bent (as by heating sheets to become more plastic). Any folds/bends that are made in the sheets need not redirect legs into directions perpendicular to their axes, as shown in the examples of **FIGS. 1** and **2**, and folds can instead (or additionally) be made at different angles (e.g., to redirect legs along angles oriented 45 degrees to their original unfolded states).

The use of flexible sheets as lightguides provides many advantages over the use of rigid sheets. The invention's improvement in light-coupling efficiency and cost is particularly pronounced at sheet thicknesses below 0.25 mm, which is approximately the size of average LED and laser diode chips suitable for use in edge lighting applications.

Thus, below 0.25 mm sheet thicknesses, it becomes particularly difficult and/or expensive to generate arrangements for efficiently coupling light into the sheet edge from a chip because of etendue and manufacturing tolerance limitations. Further, since the sheets of the invention are flexible, the sheets can shape to surfaces (e.g., a window surface) without appreciably changing in a surface's shape, thickness and/or appearance,

and they can deform as needed (including during use, e.g., an illuminated sheet may wave in the air, and/or during storage, e.g., a sheet can be rolled or folded when not in use). Such flexible sheets are also typically less expensive, thinner and lighter, and easier to store and machine than rigid sheets, assisting in reduction of material, fabrication, storage and shipping costs. Rolls of appropriate sheet material are readily available with widths up to 20 feet (6 meters), and with lengths of thousands of feet/meters, allowing the production of very large sheets where desired (e.g., for billboards or other large signage). Since flexible films are used in many industries, many providers of sheet treatment services (e.g., cutting and coating/laminating services) are available. Additionally, many film manufacturers can accommodate coextrusion of films bearing from two to hundreds of layers, and/or coating of films, so it is relatively easy and inexpensive to generate sheets having different layers which decrease light loss and/or otherwise promote internal reflection.

The light source may be any suitable light source noted in this document, and may take any other suitable form as well. Such light sources may be directly coupled to the light input area (i.e., the overlapping edges of the sheet), or may be coupled via an intermediate lightguide, such as an optical fiber (or bundle) which provides the light from the light source to the light input area. The light sources need not emit visible light, and they might interact with the light-emitting areas of the sheet to emit visible light at these areas. More than one light input area can be provided on a sheet (and multiple light sources can be used); for example, two or more sets of the legs shown in **FIGS. 1-2** might be provided on opposing or different bounding edges of a sheet, and each might be supplied with light from a different light source (or from the same light source, if the stacked legs from each edge are bent/folded to route to the same light source). In similar respects, multiple sheets can be provided with light from the same light source, as by having the same light source illuminate the stacked legs of more than one sheet. If desired, the legs from the separate sheets can be stacked together, perhaps in interleaved fashion. Legs need not be folded and stacked in an orderly manner, and multiple legs could simply extend outwardly, and then be gathered in a disorganized bundle to have their bounding edges stacked in random order. Stacking need not have all edges situated



in a linear array, and legs could, for example, be stacked side-by-side in addition to being stacked top-to-bottom, such that the input area presents a two-dimensional array of leg ends.

To illustrate an exemplary construction of the invention in greater detail, a 0.01 inch (0.25 mm) thick and 48 inch (122 cm) wide roll of BPA (bisphenol A) polycarbonate film was used to construct illuminated sheets. The sheet had a yellowness index of less than 0.54 measured using the ASTM D1925 standard. (The yellowness index is related to the light absorption within the sheet, and is preferably minimized to reduce absorption losses and/or color shifting.) Similarly, the haze of the sheet was less than 0.5% as measured using the ASTM D1003 standard. (Haze is a value related to light scattering caused from imperfections on the sheet surface and the existence of particles, air bubbles, or other imperfections within the sheet's volume, and haze, like the yellowness index, is also preferably minimized in the invention where greater light transmission is desired.) In testing, this material was found to allow high-quality light transfer, without any significant degradation or color shifting, for approximately 8 feet (2.4 m) within the sheet, without significant color shifting, when a broad band xenon illumination source was input at the edge. At greater than 8 feet, color began to shift from white to red due to uneven absorption of longer and shorter wavelengths, but otherwise light intensity was substantially maintained for approximately 20 feet (6 m) along the sheet with minimal light leakage from haze.

The sheet was cut down into a 20 inch by 8 inch (51 cm by 20 cm) sheet using a #11 scalpel blade. Eleven legs having 10 inch (25 cm) length and approximately 0.73 inch (1.8 cm) width were cut using #11 scalpel blades mounted in spaced relation on a bar between two guiderails, such that the bar could be translated to have the blades thereon cut the sheet beneath. After cutting the slots, surface roughening and colorants were added to portions of the roughly 10 inch by 10 inch (25 cm by 25 cm) body to frustrate internal reflection at these areas. Different methods for adding the areas were used, such as sandblasting, surface scratching, and inkjet printing of a light-scattering pigment. The legs were then folded and stacked in a manner similar to that illustrated in **FIG. 2**. After stacking, the ends of the legs were cut using a heated scalpel blade so

that they better defined a smooth and continuous light input area. The bounding edges of the legs partially melted together during such cutting, enhancing smoothness and continuity.

5 A green solid-state light source, more specifically a PhlatLight PT120 offered from Luminus Devices, Inc. (Billerica, MA, USA), was then coupled to the light input area. The light traveled down the legs into the unfolded body area, and scattered at the treated areas, causing them to glow/illuminate. Some light loss/scattering also occurred at the edges of the legs and unfolded body area owing to the surface roughness of the cut edges. This was reduced by polishing the surfaces of the sheet edges using methylene chloride vapor polishing so that more optically smooth edges were generated. Illumination also improved with better coupling of the light source at the input areas, as by placing the light source within a reflective shroud so concentrate the emitted light onto the input area, and with polishing of the input area (with flame polishing being used).

10 To illustrate another exemplary construction of the invention, a roll of BPA (bisphenol A) polycarbonate film having 0.01 inch (0.25 mm) thickness was coated with a 2-10 micrometer thick cladding layer of material having a lower refractive index using a sheet coater. The chosen cladding material was the TC106 coating from Sun Process Corporation (Mt. Prospect, IL, USA). The cladded film was then stamped into smaller sheets with predefined legs. A stack of sheets was placed in a methylene chloride vapor etching chamber to simultaneously polish their edges. Areas of the sheets were scraped to remove their cladding so that these areas would later illuminate when light is supplied to the sheets. The legs of each sheet were then folded so that their bounding edges were aligned in stacked relationship to provide a light input area. When a light input area of a sheet was illuminated in the manner discussed above, the treated areas lit up brightly, and when the illumination was removed, the treated areas were barely visible.

15 The illuminated sheets provided by the invention have numerous applications. Following are several examples.

20 Initially, there are numerous general illumination and backlighting applications. General home and office lighting could be provided by applying sheets to ceilings or

walls, and the flexibility of the sheets can usefully allow them to be applied to non-planar surfaces. Since the sheets can accept high-intensity point sources of light and disperse the light over a wide area, the sheets offer a useful means for adapting LED lights – which are often too intense for general home/office illumination, and which require diffusion for comfortable viewing – for use in general illumination.

The sheets are also highly useful for use in illuminated signs, graphics, and other displays. Since a sheet can be installed on a wall or window without significantly changing its appearance, with the light-emitting area(s) becoming visible when the light source(s) are activated, the invention allows displays to be located at areas where typical displays would be aesthetically unacceptable (e.g., on windows). The sheets may also be used in situations where space considerations are paramount, e.g., when lighting is desired within the ice of skating rinks (as discussed in US Patent 7,237,396, which also describes other features and applications that could be utilized with the invention). The flexibility of the sheets allows them to be used in lieu of the curtains sometimes used for climate containment, e.g., in the film curtains that are sometimes used at the fronts of grocery store freezers to better maintain their internal temperatures. The flexibility of the sheets also allows their use in displays that move, e.g., in flags that may move in the breeze.

The sheets can be used for backlighting or frontlighting purposes in passive displays, e.g., as a backlight for an illuminated advertising poster, as well as for active (changing) displays such as LCD displays. Such applications generally require compact, low-cost white-light illumination of consistent brightness and color across the illuminated area. It is cost-effective and energy-efficient to mix the light from red, blue, and green LEDs for this purpose, but color mixing is often problematic. However, with the invention, red, blue, and green light sources can all be input into each stack of legs/input areas, and by the time the light reaches the sheet, it will be sufficiently mixed that it appears as white light. The light sources can be geometrically situated, and adjusted in intensity, to better provide uniform intensities and colors across the body. A similar arrangement can be attained by providing stacked sheets (more specifically stacked sheet bodies) wherein the colors in the sheets combine to provide white light. Since some

displays are provided on flexible substrates – for example, “E-ink” thin-film displays on printed pages – the sheets provide a means for allowing backlighting while maintaining the flexibility of the display’s media.

5 It is also notable that the invention has utility when operated “in reverse” – that is, the light-emitting face(s) of a sheet could be used as a light collector, with the sheet collecting light and transmitting it through the legs to a photosensitive element. As an example, sheets in accordance with the invention could collect incoming light and internally reflect it to direct it to a photovoltaic device for solar energy collection purposes. Such an arrangement can also be useful for environmental monitoring /  
10 sensing purposes, in that the sheet can detect and collect light across a broad area, and the detector(s) at the legs will then provide a measurement representative of the entire area. A sheet could perform light collection of this nature in addition to light emission. For example, in lighting applications, a sheet might monitor ambient light, and then might be activated to emit light once twilight or darkness is detected. Usefully, since it is  
15 known that LEDs can also be “run in reverse” – that is, they can provide output current/voltage when exposed to light – if LEDs are used as an illumination source when a sheet is used for light emission, they can also be used as detectors when a sheet is used for light collection.

20 The invention is not limited to the preferred versions of the invention described above, but rather is intended to be limited only by the claims set out below. Thus, the invention encompasses all different versions that fall literally or equivalently within the scope of these claims.

## Claims

What is claimed is:

1. A film illumination system including:
  - a. a flexible sheet of at least partially translucent material, the sheet having:
    - (1) a bounding edge;
    - (2) a folded portion wherein the sheet is folded upon itself such that portions of the bounding edge overlap; and
    - (3) an unfolded portion wherein the sheet is not folded upon itself;
  - b. a light source adjacent the overlapping portions of the bounding edge.
2. The film illumination system of claim 1 wherein the sheet is sufficiently flexible that it can be rolled upon itself with a radius of curvature of less than 50 times the thickness of the sheet.
3. The film illumination system of claim 1 wherein the sheet is sufficiently flexible that it can be rolled upon itself with a radius of curvature of less than 25 times the thickness of the sheet.
4. The film illumination system of claim 1 wherein the sheet bears a layer of at least one of:
  - a. reflective material, and
  - b. material having a lower refractive index.
5. The film illumination system of claim 1 wherein an area on the surface of the sheet is:
  - a. roughened, and/or
  - b. rendered less translucent or reflective,to reduce internal reflection of light within the sheet at or adjacent the area.

- 5
6. The film illumination system of claim 1 wherein:
- a. at least a portion of the sheet fluoresces when exposed to light at an activating wavelength;
  - b. the light source emits light at the activating wavelength.
7. The film illumination system of claim 1 wherein the overlapping portions of the bounding edge are at least substantially aligned to define an at least substantially smooth and continuous surface.
- 10
8. The film illumination system of claim 1 wherein:
- a. the flexible sheet has discrete legs defined therein, wherein each portion of the bounding edge situated adjacent an overlapping portion is provided on one of the discrete legs, and
  - b. at least some of the legs are folded to have the portions of the bounding edge overlap.
- 15
9. A film illumination system including:
- a. a flexible sheet of at least partially translucent material wherein:
    - (1) the sheet has several discrete legs extending therefrom, each leg terminating at a bounding edge;
    - (2) the legs are stacked, with their bounding edges being at least substantially aligned;
  - b. a light source adjacent the bounding edges of the stacked legs.
- 20
- 25
10. The film illumination system of claim 9 wherein at least some of the legs are folded between their bounding edges and the sheet.
- 30
11. The film illumination system of claim 9 wherein the sheet is sufficiently flexible that it can be rolled upon itself with a radius of curvature of less than 75 times the thickness of the sheet.

12. The film illumination system of claim 9 wherein the sheet is sufficiently flexible that it can be rolled upon itself with a radius of curvature of less than 35 times the thickness of the sheet.
- 5 13. The film illumination system of claim 9 wherein the sheet bears, upon at least one of its opposing faces, a layer of at least one of:
- a. reflective material, and
  - b. material having a lower refractive index.
- 10 14. The film illumination system of claim 9 wherein:
- a. the sheet has one or more areas which are:
    - (1) roughened, and/or
    - (2) rendered less translucent or reflective,to reduce internal reflection of light within the sheet at or adjacent the

15 area, and

    - b. the areas are collectively at least 1% of the area of the sheet, exclusive of the legs.

20 15. The film illumination system of claim 9 wherein:

    - a. at least a portion of the sheet fluoresces when exposed to light at an activating wavelength;
    - b. the light source emits light at the activating wavelength.

- 5
16. A film illumination system including:
- a. a flexible sheet of at least partially translucent material including:
    - (1) a body;
    - (2) several legs joined to the body, the legs each having a bounding edge from which the leg extends to join the body, wherein at least some of the legs are bent so that their bounding edges are adjacently situated;
  - b. a light source oriented to illuminate the adjacently situated bounding edges of the stacked legs.
- 10
17. The film illumination system of claim 16 wherein the sheet is sufficiently flexible that a leg can be rolled upon itself from its bounding edge with a radius of curvature of less than 60 times the thickness of the sheet.
- 15
18. The film illumination system of claim 16 wherein the sheet bears, upon at least one of its opposing faces, a layer of material which promotes internal reflection within the film.
- 20
19. The film illumination system of claim 16 wherein:
- a. the sheet has one or more discrete areas which have enhanced emission of light in comparison to their surrounding areas within the sheet, and
  - b. the areas having enhanced emission of light each have a minor dimension which is at least three times greater than the thickness of the sheet.
- 25
20. The film illumination system of claim 16 wherein:
- a. at least a portion of the sheet fluoresces when exposed to light at an activating wavelength, and
  - b. the light source emits light at the activating wavelength.



FIG. 1A

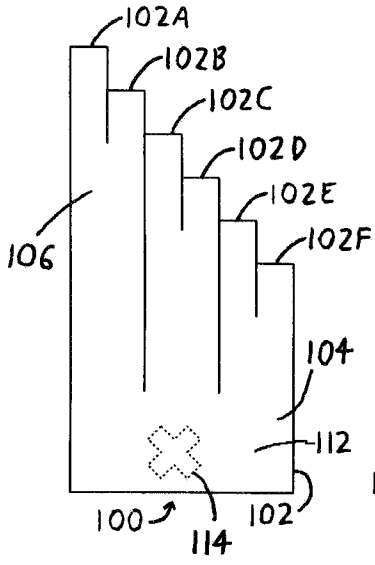


FIG. 1B

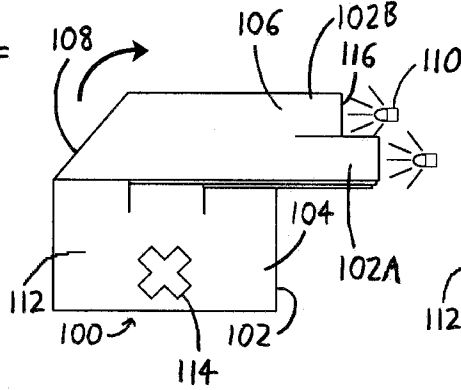


FIG. 1C

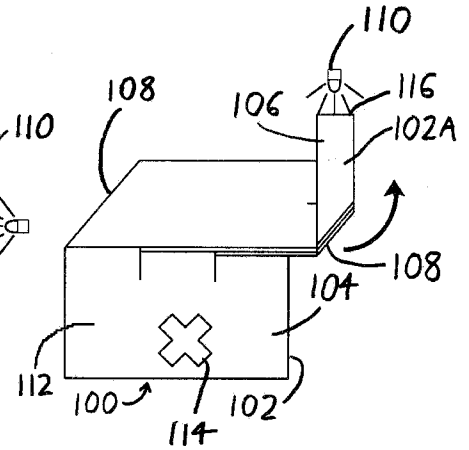
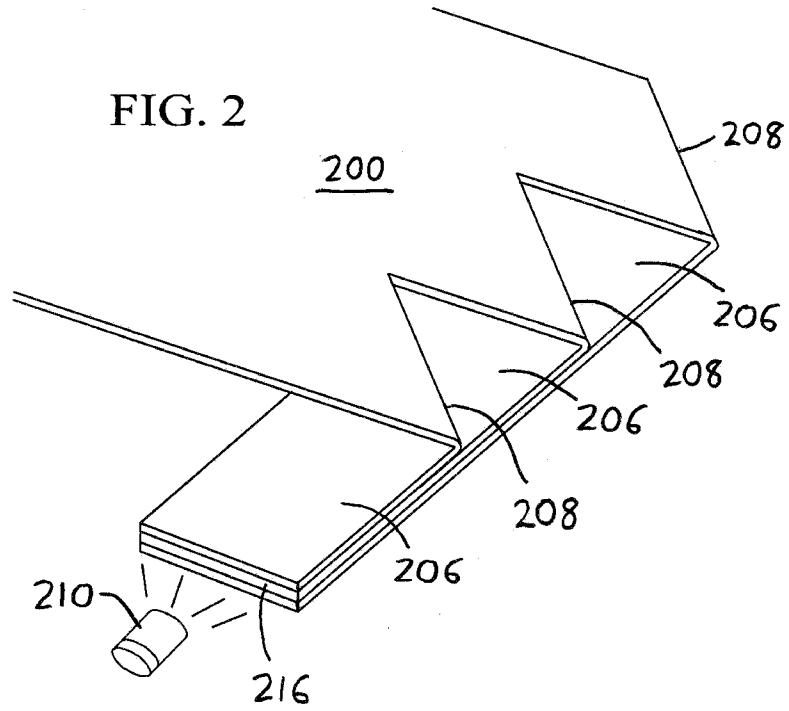


FIG. 2



INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 08/79041

<p><b>A. CLASSIFICATION OF SUBJECT MATTER</b>                  IPC(8) - B29C 45/14; B29D 11/00; F21V 8/00 (2008.04)                  USPC - 385/146; 264/1.24                  According to International Patent Classification (IPC) or to both national classification and IPC</p>																							
<p><b>B. FIELDS SEARCHED</b></p> <p>Minimum documentation searched (classification system followed by classification symbols)                  IPC(8) B29C 45/14; B29D 11/00; F21V 8/00 (2008.04)                  USPC 385/146; 264/1.24</p> <p>Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched                  IPC(8) B29C 45/14; B29D 11/00; F21V 8/00 (2008.04)                  USPC 385/146; 264/1.24 (text search)</p> <p>Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)                  PubWest (PGPB,USPT,EPAB,JPAB), USPTO, Espacenet, Google, DialogWeb (Inspec, PASCAL), Search terms used: activating wavelength bent bend bisphenol craze crack crease cut edgelighting film fluoresc fold haze lightguid\$ waveguid\$ methacrylate methylmethacrylate pmma polycarbonate sheet slit radius of curvature whitening</p>																							
<p><b>C. DOCUMENTS CONSIDERED TO BE RELEVANT</b></p> <table border="1"> <thead> <tr> <th>Category*</th> <th>Citation of document, with indication, where appropriate, of the relevant passages</th> <th>Relevant to claim No.</th> </tr> </thead> <tbody> <tr> <td>X — Y</td> <td>US 4,151,582 A (Grunberger) 24 April 1979 (24.04.1979), Abstract, Figs 10, 11, 13, 14; Claim 2, and col 1, ln 64-65, col 2, ln 1-2, col 2, ln 64-66</td> <td>9, 13, 16, 18 <hr/>1-8, 10-12, 14, 15, 17, 19, 20</td> </tr> <tr> <td>Y</td> <td>US 2007/0002578 (Furusawa et al.) 04 January 2007 (04.01.2007), Abstract, Fig. 5, para [0014]</td> <td>1-8, 10</td> </tr> <tr> <td>Y</td> <td>US 7,237,396 B1 (Nichol) 03 July 2007 (03.07.2007), Abstract, col 3, ln 6-10, col 3, ln 3-4</td> <td>5, 14, 19</td> </tr> <tr> <td>Y</td> <td>US 2006/0105149 A1 (Donahue) 18 May 2006 (18.05.2006), Abstract, para [0031], [0032]</td> <td>6, 15, 20</td> </tr> <tr> <td>Y</td> <td>Rizzo et al., "The recovery after bending of polycarbonate sheets." Rheol. Acta 20, 133-138 (1981), ISSN 0035-4511, p 138, ln 1-2</td> <td>2, 3, 11, 12, 17</td> </tr> <tr> <td>Y</td> <td>US 4,228,267 A (Higashizume et al.) 14 October 1980 (14.10.1980), Abstract, col 1, ln 11-18</td> <td>2, 3, 11, 12, 17</td> </tr> </tbody> </table>			Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.	X — Y	US 4,151,582 A (Grunberger) 24 April 1979 (24.04.1979), Abstract, Figs 10, 11, 13, 14; Claim 2, and col 1, ln 64-65, col 2, ln 1-2, col 2, ln 64-66	9, 13, 16, 18 <hr/> 1-8, 10-12, 14, 15, 17, 19, 20	Y	US 2007/0002578 (Furusawa et al.) 04 January 2007 (04.01.2007), Abstract, Fig. 5, para [0014]	1-8, 10	Y	US 7,237,396 B1 (Nichol) 03 July 2007 (03.07.2007), Abstract, col 3, ln 6-10, col 3, ln 3-4	5, 14, 19	Y	US 2006/0105149 A1 (Donahue) 18 May 2006 (18.05.2006), Abstract, para [0031], [0032]	6, 15, 20	Y	Rizzo et al., "The recovery after bending of polycarbonate sheets." Rheol. Acta 20, 133-138 (1981), ISSN 0035-4511, p 138, ln 1-2	2, 3, 11, 12, 17	Y	US 4,228,267 A (Higashizume et al.) 14 October 1980 (14.10.1980), Abstract, col 1, ln 11-18	2, 3, 11, 12, 17
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<p><input type="checkbox"/> Further documents are listed in the continuation of Box C. <input type="checkbox"/></p>																							
<p>* Special categories of cited documents:</p> <table border="0"> <tr> <td>"A" document defining the general state of the art which is not considered to be of particular relevance</td> <td>"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</td> </tr> <tr> <td>"E" earlier application or patent but published on or after the international filing date</td> <td>"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone</td> </tr> <tr> <td>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</td> <td>"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art</td> </tr> <tr> <td>"O" document referring to an oral disclosure, use, exhibition or other means</td> <td>"&amp;" document member of the same patent family</td> </tr> <tr> <td>"P" document published prior to the international filing date but later than the priority date claimed</td> <td></td> </tr> </table>			"A" document defining the general state of the art which is not considered to be of particular relevance	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention	"E" earlier application or patent but published on or after the international filing date	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone	"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art	"O" document referring to an oral disclosure, use, exhibition or other means	"&" document member of the same patent family	"P" document published prior to the international filing date but later than the priority date claimed												
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<p>Date of the actual completion of the international search 05 December 2008 (05.12.2008)</p>		<p>Date of mailing of the international search report <b>08 JAN 2009</b></p>																					
<p>Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-3201</p>		<p>Authorized officer: Lee W. Young  PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774</p>																					