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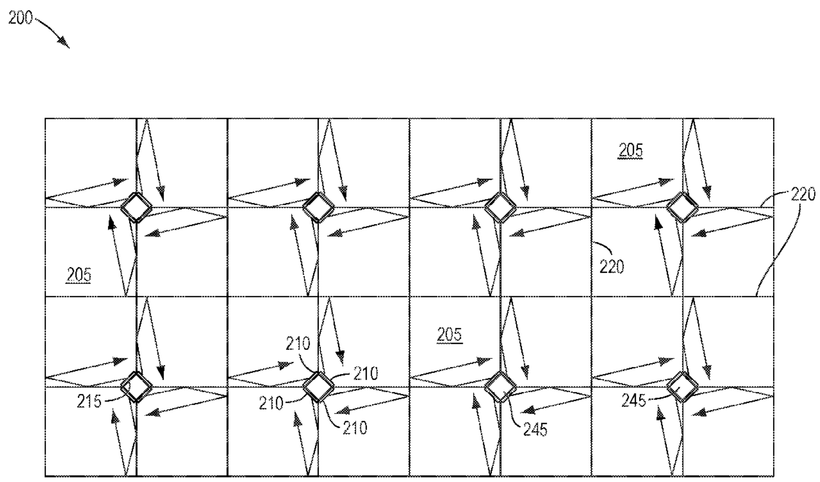


FIG. 2

**(57) Abstract**: Disclosed herein are lighting devices comprising a light guide plate comprising a first edge and a first major surface comprising a plurality of light extraction features; at least one light source coupled to the first edge; and at least one edge reflector disposed along at least a portion of an edge of the light guide plate. Lighting devices comprising a plurality of light guide plates are also disclosed herein. Display devices comprising such lighting devices are further disclosed.

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# LIGHT GUIDE PLATES AND DISPLAY DEVICES COMPRISING THE SAME

## CROSS-REFERENCE TO RELATED APPLICATIONS

**[0001]** This application claims the benefit of priority under 35 U.S.C. § 119 of U.S. Provisional Application Serial No. 62/268173 filed on December 16, 2015, the content of which is relied upon and incorporated herein by reference in its entirety.

## FIELD OF THE DISCLOSURE

**[0002]** The disclosure relates generally to light guide plates and display devices comprising such light guide plates, and more particularly to light guide plates and devices producing a substantially uniform light output intensity.

## BACKGROUND

**[0003]** Liquid crystal displays (LCDs) are commonly used in various electronics, such as cell phones, laptops, electronic tablets, televisions, and computer monitors. However, LCDs can be limited as compared to other display devices in terms of brightness, contrast ratio, efficiency, and viewing angle. For instance, to compete with other display technologies, there is a continuing demand for higher contrast ratio, color gamut, and brightness in conventional LCDs while also balancing power requirements and device size (e.g., thickness).

**[0004]** LCDs can comprise a backlight unit (BLU) for producing light which can then be converted, filtered, and/or polarized to produce the desired image. BLUs may be edge-lit, e.g., comprising a light source coupled to an edge of a light guide plate (LGP), or back-lit, e.g., comprising a two-dimensional array of light sources disposed behind the LCD panel. Direct-lit BLUs may have the advantage of improved contrast as compared to edge-lit BLUs. For example, to produce dark regions of an image, various light sources in the direct-lit BLU can be turned off to provide local dimming. However, to achieve desired light uniformity and/or to avoid hot spots in direct-lit BLUs, the light source may be positioned at a distance from the LGP, thus making the overall display thickness greater than that of an edge-lit BLU

**[0005]** Conventional edge-lit LCDs typically use an LGP to distribute the light behind the LCD array in an even intensity across the entire surface of the panel.

In such displays, the LED light is coupled into the LGP from at least one edge of the LGP (the coupling edge) and light is extracted as it propagates by diffusing structures, typically white paint or surface scattering components, on the LGP. The edge-lit LGP present significant advantages over direct illumination, where a square array of LEDs is used to directly illuminate the panel, because the panel can be made extremely thin. However, one advantage direct illumination has over edge-lit displays is that every single LED of the array can be driven separately so that dimmer areas into images can be illuminated with less light by dimming some of the LED's. This is referred to as "local dimming" which provides savings in energy consumption and also improves image contrast, especially in the black regions of a picture. While local dimming has also been introduced into edge-lit LGPs, the efficiency is relatively low and the improvement in image contrast is less effective since the light emitted by individual LED's rapidly expands into the LGP as light propagates, providing less discrimination between the pixels. Simply put, the current methods of local dimming fail to satisfy the needs of the manufacturers and customers in the display industry.

**[0006]** Accordingly, it would be advantageous to provide backlights for display devices which address one or more of the above drawbacks, e.g., to provide thinner backlights with increased uniformity of light output intensity, improved contrast ratio, and/or local or active dimming. It would also be advantageous to provide backlights for display devices which can have a reduced thickness similar to that of edge-lit BLUs while also providing local dimming capabilities similar to that of back-lit BLUs.

## SUMMARY

**[0007]** The disclosure relates, in various embodiments, to lighting devices comprising a light guide plate comprising a first edge and a first major surface comprising a plurality of light extraction features; at least one light source coupled to the first edge; and at least one edge reflector disposed along at least a portion of an edge of the light guide plate. Display devices comprising such lighting devices are also disclosed herein.

**[0008]** In certain embodiments, the first edge can comprise a recessed portion or chamfer to which the light source is coupled. According to other embodiments, the plurality of light extraction features can be disposed on the first

major surface or in the LGP matrix adjacent (e.g., below) the first major surface. The light extraction features may be produced, for example, by printing or etching a surface of the LGP or by laser damaging at or below the surface of the LGP. In various embodiments, the plurality of light extraction features may be arranged in a pattern to produce substantially uniform light output intensity across the first major surface of the LGP. The pattern of light extraction features may be uniform or non-uniform. According to certain embodiments, at least one edge reflector can be disposed along all edges of the LGP except a portion of the first edge that is coupled to the light source.

**[0009]** The disclosure also relates to lighting devices comprising a plurality of light guide plates, wherein at least a first edge of each light guide plate in the plurality of light guide plates is coupled to at least one light source; and wherein at least one edge reflector is disposed along at least a portion of an edge of each light guide plate. Display devices comprising such lighting devices are also disclosed herein.

**[0010]** According to various embodiments, at least one LGP in the plurality of LGPs can comprises light extraction features disposed on a first major surface of the LGP or within the LGP matrix adjacent (e.g., below) the first major surface. The light extraction features of at least one LGP may be arranged in a pattern to produce substantially uniform light output intensity across the first major surface of the LGP. In additional embodiments, the light extraction features of at least two LGPs can be arranged in a pattern to produce substantially uniform light output intensity across a light-emitting surface of the lighting device. According to certain embodiments, the LGPs can be arranged in a two-dimensional array. The lighting device may also comprise, in additional embodiments, at least one additional LGP positioned in overlying registration with at least one light source. The additional LGP can comprise supplemental light extraction features on a major surface facing the at least one light source. In some embodiments, the lighting device can further comprise an apparatus for splitting a light source output of the at least one light source.

**[0011]** Additional features and advantages of the disclosure will be set forth in the detailed description which follows, and in part will be readily apparent to those skilled in the art from that description or recognized by practicing the methods as described herein, including the detailed description which follows, the claims, as well as the appended drawings.

**[0012]** It is to be understood that both the foregoing general description and the following detailed description present various embodiments of the disclosure, and are intended to provide an overview or framework for understanding the nature and character of the claims. The accompanying drawings are included to provide a further understanding of the disclosure, and are incorporated into and constitute a part of this specification. The drawings illustrate various embodiments of the disclosure and together with the description serve to explain the principles and operations of the disclosure.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0013]** The following detailed description can be further understood when read in conjunction with the following drawings.

**[0014]** **FIGS. 1A-D** illustrate a lighting device comprising according to various embodiments of the disclosure;

**[0015]** **FIG. 2** illustrates a lighting device comprising an array of light guide plates according to certain embodiments of the disclosure;

**[0016]** **FIG. 3A** illustrates a lighting device comprising an additional light guide plate according to various embodiments of the disclosure;

**[0017]** **FIG. 3B** illustrates light output intensity for an exemplary lighting device according to certain embodiments of the disclosure; and

**[0018]** **FIG. 4** is a graphical depiction of light output intensity as a function of emission angle for light guide plates having different etched surfaces according to some embodiments of the disclosure.

## DETAILED DESCRIPTION

**[0019]** Disclosed herein are lighting devices comprising a light guide plate comprising a first edge and a first major surface comprising a plurality of light extraction features; at least one light source coupled to the first edge; and at least one edge reflector disposed along at least a portion of an edge of the light guide plate. Various devices comprising such lighting devices are also disclosed herein, such as display and illuminating devices, e.g., televisions, computers, phones, tablets, and other display panels, luminaires, solid-state lighting, billboards, and other architectural elements, to name a few. The devices and apparatuses described herein can be used to provide thinner backlights with increased uniformity of light output intensity, improved contrast ratio, and/or local or active dimming.

**[0020]** **FIGS. 1A-C** illustrate various embodiments of a lighting device **100** or “tile” comprising a light guide plate (LGP) **105** and at least one light source **110**, e.g., at least one light-emitting diode (LED) that can be used for local or active dimming and for an increased uniformity of light output intensity and improved contrast ratio. In **FIG. 1A**, the light source **110** can be coupled to a first edge **115** of the LGP **105**, e.g., positioned adjacent to the first edge **115**. At least one edge reflector **120** may be disposed along at least a portion of an edge of the LGP **105**. For example, as illustrated, an edge reflector **120** may be disposed along the second, third, and fourth edges **125**, **130**, **135** of the LGP **105**. The edge reflector **120** can, in some embodiments, also extend along at least a portion of the first edge **115**, e.g., a portion of the edge that is not coupled to the light source **110**. In some embodiments, substantially the entire perimeter of the LGP **105** is covered by the at least one edge reflector **120** (except for the edge portion coupled to the light source). Of course, any edge reflector arrangement is possible and can be configured to achieve a desired light output effect. In some embodiments, the edge reflector **120** can reflect substantially all of the light impinging thereon. In other embodiments, the edge reflector **120** or portions thereof can reflect a certain percentage of light and allow some light to leak into adjacent LGPs (see FIG. 2). Exemplary percentages of reflection can include greater than 50%, between 50 to 95%, less than or equal to 100%, between 60 and 90%, and all subranges therebetween.

**[0021]** As used herein, the term “coupled” is intended to denote that a light source is positioned at an edge of the LGP so as to introduce light into the LGP. When light is injected into the LGP, according to certain embodiments, the light may be trapped and bounce within the LGP due to total internal reflection (TIR) until it hits a light extraction feature in, on, or at a surface of the LGP and exits the LGP. Exemplary and non-limiting light paths within the LGPs are depicted in the figures by arrows. According to various embodiments, by incorporating one or more edge reflectors in the lighting device, recycling of light through the light guide may be enhanced, which can result in improved homogeneity of light intensity and/or color. In some embodiments, the edge reflectors can provide either increased specular or increased diffuse reflectance of light within the LGP such that the light may bounce multiple times within the LGP before being extracted. Suitable materials for use as edge reflectors can include, for example, reflective tapes such as diffuse reflector films or enhanced specular reflector (ESR) films commercially available from WhiteOptics (e.g., White98™) and 3M (e.g., Vikuiti™), or metallic films, such as aluminum, gold, silver, copper, platinum, and the like.

**[0022]** As illustrated in **FIG. 1B**, the light source **110** may also be coupled to a first edge **115**, which can comprise a chamfer **117** adjoining two side edges, e.g., third and fifth edges **130**, **140**, or any other two adjacent side edges. While the chamfer **117** of the first edge **115** in **FIG. 1B** is illustrated as being substantially symmetrical (e.g., forming 45° angles with the adjoining side edges), it is also possible for the first edge to comprise an asymmetrical chamfer, if so desired. Moreover, while the length of the chamfer **117** of the first edge **115** is illustrated as corresponding roughly to the length of light source **110**, it is also possible for the chamfer length to be larger than that of the light source, according to any desired configuration. In some non-limiting embodiments, the configuration depicted in **FIG. 1B** may have improved light recycling within the LGP because light emitted at steeper angles may remain trapped within the LGP longer. Referring to **FIG. 1C**, it is also possible for the first edge **115** to comprise at least one recess **145** and for the light source **110** to be positioned adjacent said recess. For instance, the light source **110** may be positioned such that it is substantially flush with the remainder of the first edge **115** (as illustrated).

**[0023]** As depicted in **FIG. 1D**, which is a side view of the LGP of **FIG. 1A**, the LGP **105** may comprise a first major surface **155** and an opposing second major surface **160**. The major surfaces may, in certain embodiments, be planar or substantially planar, e.g., substantially flat and/or level. The first and second major surfaces may, in various embodiments, be parallel or substantially parallel. The LGP **105** may comprise four edges as illustrated in **FIGS. 1A** and **1C**, or may comprise more than four edges, as illustrated in **FIG. 1B**, e.g. a multi-sided polygon. In other embodiments, the LGP **105** may comprise less than four edges, e.g., a triangle. By way of non-limiting examples, the light guide may comprise a rectangular, square, or rhomboid sheet having a plurality of edges, or a rectangular, square, or rhomboid sheet comprising a chamfer on at least one corner, although other shapes and configurations are intended to fall within the scope of the disclosure including those having circular shapes or having other curvilinear portions or edges on one or more edges thereof.

**[0024]** In some embodiments, the LGP may have a square shape with any desired dimensions, such as 1 mm x 1mm, 5 mm x 5mm, 10 mm x 10 mm, 50 mm x 50 mm, 100 mm x 100 mm, 200 mm x 200 mm, 300 mm x 300 mm, 400 mm x 400 mm, 500 mm x 500 mm, 600 mm x 600 mm, 700 mm x 700 mm, 800 mm x 800 mm, 900 mm x 900 mm, 1 m x 1 m, 2 m x 2 m, 3 m x 3 m, 4 m x 4 m, 5 m x 5 m, 6 m x 6 m, 7 m x 7 m, 8 m x 8 m, 9 m x 9 m, 10 m x 10 m, and so on. Of course the LGP may also have any other shape (e.g., rectangular, rhomboid, triangular, circular, etc.) and the dimensions above may correspond to one or more dimensions of these shapes (e.g., width, length, height, diameter, etc.). In some embodiments, the LGP may have at least one dimension ranging from 1 mm to about 1 m.

**[0025]** According to various embodiments, referring again to **FIG. 1D**, a first major surface **155** or a second major surface **160** of the LGP **105** may be patterned with a plurality of light extraction features **150**. As used herein, the term "patterned" is intended to denote that the plurality of light extraction features are present on or in the surface of the light guide in any given pattern or design, which may, for example, be random or arranged, repetitive or non-repetitive, uniform or non-uniform. In other embodiments, the light extraction features may be located within the matrix of the LGP adjacent the surface, e.g., below the surface. For instance, the light extraction features may be distributed across the surface, e.g. as textural features making up a roughened or raised surface, or may be distributed within and throughout the LGP or portions thereof, e.g., as laser-damaged features. Suitable methods for creating such light extraction features can include printing, such as inkjet printing, screen printing, microprinting, and the like, texturing, mechanical roughening, etching, injection molding, coating, laser damaging, or any combination thereof. Non-limiting examples of such methods include, for instance, acid etching a surface, coating a surface with $TiO_2$, and laser damaging the LGP by focusing a laser on a surface or within the matrix of the LGP.

**[0026]** Also disclosed herein are lighting devices comprising a plurality of light guide plates, wherein at least a first edge of each light guide plate in the plurality of light guide plates is coupled to at least one light source; and wherein at least one edge reflector is disposed along at least a portion of an edge of each light guide plate in the plurality of light guide plates. Display devices comprising such lighting devices are also disclosed herein.

**[0027]** **FIG. 2** depicts a lighting device **200** comprising a plurality of LGPs **205** or tiles depicted in **FIGS. 1A-1D** that can be used to provide thinner backlights with increased uniformity of light output intensity, improved contrast ratio, and/or local or active dimming. As illustrated, a first edge **115** of each LGP **205** may be coupled to at least one light source **210**. Moreover, at least one edge of each LGP **205** can comprise an edge reflector **220**, such as a second, third, and/or fourth edge or, in some embodiments, a portion of the first edge. According to various embodiments, the plurality of LGPs can define one or more recesses **245**, and the light sources **210** may be positioned in said recesses. For example, as depicted in **FIG. 2**, the first edge **215** can comprise a chamfer (see, e.g., **FIG. 1B**), and the plurality of LGPs can be arranged such that the individual chamfers form a four-sided, e.g., square, recess **245** in which one or more light sources **210** can be positioned. Of course the recesses and chamfers can have any other suitable size and/or shape, without limitation, such as triangular, rectangular, rhomboid, polygonal, or any other shape including those with one or more curvilinear portions or edges. In other embodiments (not illustrated), the first edge **215** can comprise a recess similar to that depicted in **FIG. 1C**, and the plurality of LGPs can be arranged in any desired pattern, with the recesses all facing the same direction or facing different directions. It is also possible to form a lighting device comprising a plurality of LGPs having the configuration illustrated in **FIG. 1A**.

**[0028]** According to various embodiments, the plurality of LGPs (having any configuration) can be arranged or tiled together to form a two-dimensional array. A BLU utilizing such an array of edge-lit LGPs can, in some embodiments, provide improved local dimming and/or contrast as compared to a BLU utilizing a single edge-lit LGP due to the ability to individual address multiple light sources in the array. For example, it can be possible to shut off specified light sources corresponding to a dark region of a displayed image. Such a direct-lit BLU may also provide improved thinness as compared to a traditional back-lit BLU because the light sources are in plane with the LGPs rather than positioned at a distance away from the LGPs. Additionally, the ability to tile multiple LGPs together can provide greater flexibility in preparing lighting devices for multiple applications with different size specifications, for instance, for small lighting applications (e.g., from 1-10 mm), mobile and handheld applications (e.g., from 10 mm – 20 cm), display applications (e.g., from 10 cm – 200 cm), and billboards (e.g., from 1-10 m). In certain embodiments, an array of LGPs can have at least one dimension (e.g., length, width, height, diameter, etc.) ranging from about 50 mm to about 10 m.

**[0029]** Referring now to **FIG. 3A**, it may be desirable in some embodiments to include at least one additional LGP **365** in the lighting device **300**. For instance, the use of multiple edge-lit LGPs in a direct-lit BLU may present challenges in terms of avoiding reduced light intensity in the regions corresponding to the light sources **310** or other associated electronics. In various embodiments, at least one additional LGP **365** can be positioned in overlying registration with at least one of the light sources **310**, thereby masking any reduced light intensity in the region of edge-lighting. For instance, as illustrated in **FIG. 3A**, the additional LGP **365** can partially overlap or bridge ("piggyback") two or more LGPs **305** such that the additional LGP **365** is in overlying registration with one or more light sources **310**. In some embodiments, the additional LGP **365** may be provided with supplemental light extraction features **370** on a surface facing the light source(s) **310**, e.g., the underside.

**[0030]** Additionally, the LGPs **305** may be patterned with light extraction features **350** such that there is a greater density of features proximate the light source(s) **310**. For instance, region **350a** may have a higher density of features as compared to region **350b**. Using such a configuration, it may be possible to engineer the underlying LGPs **305** to more strongly scatter light proximate the additional LGP **365** to provide a substantially uniform light intensity across the entire device (see **FIG. 3B**). As discussed above, each individual LGP **305** in the plurality or array of LGPs may or may not exhibit uniform light intensity distribution; however, the individual LGPs having non-uniform distributions can be arranged and engineered such that an overall substantially uniform light output intensity can be achieved across a light-emitting surface of the overall device. It should also be noted that while the light extraction features **350** are generally depicted as discrete, evenly spaced-apart features in **FIGS. 3A-B**, they can be arranged in in a myriad of different configurations without departing from the spirit and scope of the disclosure.

**[0031]** For example, **FIG. 4** depicts light intensity as a function of emission angle for two LGPs having different exemplary etched surfaces. As can be appreciated from the graph, the different ranges in angular behavior may permit design of LGP tiles such that an emission angle near the light source and/or near an edge reflector may be steeper than an emission angle at a more central point of the

LGP (see circled regions in **FIG. 3B**). Using this behavior, it may be possible to engineer the light extraction features of the LGPs to reduce or even eliminate any dark or shadowed regions between adjacent LGPs in an array (e.g., corresponding to the positions of the light sources and/or electronics).

**[0032]** Referring again to **FIG. 3A**, in various embodiments, a thickness of the additional LGP **365** may be less than a thickness of the LGP(s) **305**. For example, the thickness of the additional LGP **365** may range, in certain embodiments, from about 0.1 mm to about 2 mm, from about 0.3 mm to about 1.5 mm, or from about 0.5 mm to about 1 mm, including all ranges and subranges therebetween. The additional LGP **365** may be constructed from the same material as the LGP(s) **305**, such as plastics, glasses, and micro-structured materials, to name a few. In some embodiments, if the additional LGP **365** comprises a material different than the LGP(s) **305**, the refractive indexes of these materials may be substantially similar. According to additional embodiments, an adhesive material **375**, such as a polymer or other conformable material, may be employed to secure the additional LGP **365** to the underlying LGP(s) **305**. In such embodiments, the refractive index of the adhesive material **375** may be substantially similar to that of the LGP(s) **305** and the additional LGP **365.**

**[0033]** While **FIG. 3A** illustrates one additional LGP **365** bridging two underlying LGPs **305**, it is also possible for more than one additional LGP **365** to bridge multiple pairs of LGPs **305**, or for one additional LGP **365** to bridge more than two LGPs **305**, or for more than one additional LGP **365** to bridge more than two LGPs **305**, and so on. In some embodiments, the additional LGP **365** may be a unitary component covering substantially all of the surface area of the device, e.g., bridging all of the LGPs **305** in the array making up the lighting device **300**.

**[0034]** According to various embodiments, the lighting device may also include an apparatus (not illustrated) for splitting the output of one or more light sources. For example, an optical component, such as a prism or mirror, may be used to redirect some light output from a light source **310** from the LGP **305** (in-plane) to the additional LGP **365** (piggybacked).

**[0035]** In the various embodiments described above and with reference to **FIGS. 1-4**, the light extraction features optionally present on the first or second surface of the LGP may comprise light scattering sites. According to various embodiments, the extraction features may be patterned in a suitable density so as to produce substantially uniform light output intensity across a major surface of the LGP. In other embodiments, the light extraction features may be patterned to produce non-uniform light output intensity across a major surface of the LGP. For instance, in the case of a device comprising a plurality of LGPs, as discussed in more detail below, one or more LGPs in the plurality may have a non-uniform distribution of light output intensity across its individual surface, but an overall distribution of light output intensity across a light-emitting surface of the overall device may be uniform. In certain embodiments, a density of the light extraction features proximate the light source may be greater than a density of the light extraction features at a point further removed from the light source, or vice versa, such as a gradient from one end to another, as appropriate to create the desired light output distribution across the LGP or overall device.

**[0036]** The light extraction features on or near a surface of the LGP may vary along its length such that the extraction efficiency per unit length, $\epsilon(x) = \frac{\eta}{L - x\eta}$, where $\eta \equiv \frac{Power(x=0) - Power(x=L)}{Power(x=0)}$, L is the length of the light guide, and x is the position along the LGP. The extraction efficiency per unit length may be used to engineer the light extraction feature density across the LGP, and the functional form of the extraction per unit length can be modified to accommodate multiple passes of light through the LGP. The density of the light extraction features at any given location along the LGP may thus be controlled so as to produce a substantially spatially, spectrally, and/or angularly uniform light emission, in which the emission brightness may be substantially constant across the light-emitting surface. In some embodiments, to produce a more uniform light distribution across the LGP, the light extraction feature density may vary inversely with the distance from the injection point, e.g., higher density at locations further away from the light source. Of course, the density may also be varied to produce a non-uniform distribution as discussed in more detail herein.

**[0037]** The light extraction features may produce surface scattering and/or volumetric scattering of light, depending on the depth of the features in the LGP surface. The sizes of the light extraction features may also affect the light scattering properties of the LGP. Without wishing to be bound by theory, it is believed that small features may scatter light backwards as well as forwards, whereas larger features tend to scatter light predominantly forward. Thus, for example, according to various embodiments, the light extraction features may have a correlation length less than about 100 nm, such as 70 nm, or less than about 50 nm. Furthermore, larger extraction features may, in some embodiments, provide a forward light scatter but at a small angular spread. Accordingly, in various embodiments, the light extraction features may range in correlation length from about 20 nm to about 500 nm, such as from about 50 nm to about 100 nm, from about 150 nm to about 200 nm, or from about 250 to about 350 nm, including all ranges and subranges therebetween as well as combinations of ranges to form hierarchical features. The optical characteristics of the light extraction features can be controlled, e.g., by the processing parameters used when producing the extraction features.

**[0038]** In certain embodiments, the first or second major surface of the LGP may have a texture produced, for instance, by etching, damaging, coating, and/or roughening, such that the surface has an average roughness $R_a$ ranging from about 10 nm to about 150 nm, such as less than about 100 nm, less than about 80 nm, less than about 60 nm, less than about 50 nm, or less than about 25 nm, including all ranges and subranges therebetween. For example, the first or second surface of the LGP may have a surface roughness $R_a$ of about 50 nm or, in other embodiments, about 100 nm, or about 20 nm. According to various embodiments, the first or second surface may be substantially planar, even when textured to produce a plurality of light extraction features.

**[0039]** The LGP may be treated to create light extraction features according to any method known in the art, e.g., the methods disclosed in co-pending and co-owned International Patent Application Nos. PCT/US2013/063622 and PCT/US2014/070771, each incorporated herein by reference in their entirety. For example, a surface of the LGP may be ground and/or polished to achieve the desired thickness and/or surface quality. The surface may then be optionally cleaned and/or the surface to be etched may be subjected to a process for removing contamination, such as exposing the surface to ozone. The surface to be etched may, by way of a non-limiting embodiment, be exposed to an acid bath, e.g., a mixture of glacial acetic acid (GAA) and ammonium fluoride ($NH_4F$) in a ratio, e.g., ranging from about 1:1 to about 9:1. The etching time may range, for example, from about 30 seconds to about 15 minutes, and the etching may take place at room temperature or at elevated temperature. Process parameters such as acid concentration/ratio, temperature, and/or time may affect the size, shape, and distribution of the resulting extraction features. It is within the ability of one skilled in the art to vary these parameters to achieve the desired surface extraction features.

**[0040]** In a first step of an exemplary etching process, the glass substrate to be etched can be cleaned using a detergent to remove all inorganic contamination, then rinsed sufficiently to remove detergent residue. A level of cleanliness sufficient to obtain a water contact angle of less than about 20°C may be attained. Contact angle can be evaluated using, for example, a DSA100 drop shape analyzer manufactured by Kriiss GmbH and employing a sessile drop method, although other suitable methods may also be used. In an optional second step, one side of the glass substrate can be laminated with a suitable adhesive polymer film (or other acid barrier), if only a single side of the glass substrate is to be etched. The polymer film can be removed from the glass substrate after the etching process is completed. It should be noted that a similar process can be used if the opposite (back side) of the substrate is to be etched, wherein the polymer film is added to the front surface of the substrate.

**[0041]** In a third step, the glass substrate can be contacted with an etchant for a time sufficient to create the desired texture (typically in a range from about 0.5 minutes to 6 minutes). For immersion, fast insertion and suitable environmental controls, for example an ambient air flow of at least a 2.83 cubic meter per minute in the enclosure in which the etching occurs may be used to limit exposure of the glass substrate to acid vapor prior to and/or during insertion. The glass substrate may be inserted into the acid bath using a smooth motion to prevent defects forming in the etched surface. The glass substrate may be dried prior to contact with the etchant.

**[0042]** In a fourth step, the glass substrate can be removed from the etchant and allowed to drain, then rinsed one or more times with water, for example deionized water, or alternatively with a solution in which the precipitant is dissolvable. Agitation of either the glass substrate or the rinse liquid sufficient to ensure uniform diffusion of fluoride-containing acid clinging to the glass substrate may be performed. Rinse steps can employ agitation to prevent defects. Small oscillations of approximately 300 oscillations per minute are sufficient, for example between about 250 and 350 oscillations per minute. The etchant bath may in some instances be recirculated to prevent stratifications and depletion.

**[0043]** In a fifth step of the example process any etchant-blocking film previously applied to the back side of the glass substrate can be removed, such as by peeling. In a sixth step of the example process, the glass substrate can be dried using forced clean (filtered) air to prevent water spots, or spots from other rinsing solutions, from forming on the glass substrate.

**[0044]** A non-limiting exemplary etchant may comprise acetic acid, for example glacial acetic acid, in an amount from about 92% to about 98% by weight, ammonium fluoride in an amount from about 0.5% to about 5.5% by weight, and less than 6% by weight water. While not wishing to be bound by any particular theory, it is believed that for some embodiments the lower the water content, the lower the ammonium fluoride dissociation rate, which leads to a reduced release of HF. A reduced concentration of HF can also lead to a reduction in the removal of glass from the glass substrate, which in turn results in shallower pits in the etched surface thereof, which can in turn result in low haze (e.g., greater transparency). Additionally, reduced water content can provide for a reduction in the solubility of the precipitated crystal mask in the etchant. This means the mask can stay on the glass substrate surface longer. When the nucleated crystals stay undissolved on the glass surface, the etch rate for the etchant is lower and the crystal lateral dimension remains unchanged, thus leading to a low correlation length.

**[0045]** In certain embodiments, the etchant may be adjusted depending on the glass substrate and/or desired result. For example, in some embodiments the etchant can comprise acetic acid ($HC_2H3O_2$) in a range from about 10% by weight to about 90%> by weight, for example in a range from about 10%> to about 80%> by weight, in a range from about 20%> to about 70% by weight, in a range from about 20% by weight to about 30% by weight or in a range from about 40%) by weight to about 60%> by weight. The etchant may further include $NH_4F$ in a range from about 1%> to about 50%> by weight, for example in a range from about 5% to about 40%) by weight, in a range from about 10%> by weight to about 30%> by weight. In certain embodiments polyethylene glycol or other organic solvents can be substituted for the acetic acid. Depending on the desired texture, etching times can be in a range from about thirty seconds to two minutes, and in some cases up to four minutes. When the etching is complete, the glass substrate can be soaked in 1 M $H_2SO_4$ for up to 1 minute to remove precipitated crystal residue on the surface of the glass substrate. However, in some embodiments other mineral acids may be substituted for $H_2SO_4$, for example HC1 or HNO3. In some cases hot water may be sufficient. A low pH value and/or a high temperature can increase the solubility of the crystals. Finally, the glass substrate may be rinsed with water (e.g. deionized water) and dried. To avoid increased production costs associated with high temperature etching, the etching process can be performed at room temperature, with the understanding that higher temperature etching can be carried out if so desired.

**[0046]** In certain embodiments, a single LGP or tile or a plurality of LGPs or tiles may have a thickness of less than or equal to about 3 mm, for example, ranging from about 0.1 mm to about 2.5 mm, from about 0.3 mm to about 2 mm, from about 0.5 mm to about 1.5 mm, or from about 0.7 mm to about 1 mm, including all ranges and subranges therebetween. The LGP can have any desired size and/or shape as appropriate to produce a desired light distribution. In some embodiments, the LGP may have at least one dimension (e.g. length and/or width) ranging from about 10 mm to about 50 mm, such as from about 20 mm to about 40 mm, or from about 25 mm to about 30 mm, including all ranges and subranges therebetween.

**[0047]** The LGP can comprise any material known in the art for use in display devices. For example, the LGP can comprise plastics, such as polymethylmethacrylate (PMMA), micros-structured (MS) materials, or glasses, to name a few. Exemplary glasses can include, but are not limited to, aluminosilicate, alkali-aluminosilicate, borosilicate, alkali-borosilicate, aluminoborosilicate, alkali-aluminoborosilicate, soda lime, and other suitable glasses. Non-limiting examples of commercially available glasses suitable for use as a glass light guide include, for instance, EAGLE XG®, Lotus™, Willow®, Iris™, and Gorilla® glasses from Corning Incorporated. Some non-limiting glass compositions can include between about 50 mol % to about 90 mol% $SiO_2$, between 0 mol% to about 20 mol% $Al_2O_3$, between 0 mol% to about 20 mol% $B_2O_3$, and between 0 mol% to about 25 mol% $R_xO$, wherein R is any one or more of Li, Na, K, Rb, Cs and x is 2, or Zn, Mg, Ca, Sr or Ba and x is 1, and wherein the glass produces less than or equal to 2 dB/500mm absorption. In some embodiments, $R_xO - Al_2O_3 > 0$; $0 < R_xO - Al_2O_3 < 15$; $x = 2$ and $R_2O - Al_2O_3 < 15$; $R_2O - Al_2O_3 < 2$; $x=2$ and $R_2O - Al_2O_3 - MgO > -15$; $0 < (R_xO - Al_2O_3) < 25$, $-11 < (R_2O - Al_2O_3) < 11$, and $-15 < (R_2O - Al_2O_3 - MgO) < 11$; and/or $-1 < (R_2O - Al_2O_3) < 2$ and $-6 < (R_2O - Al_2O_3 - MgO) < 1$. In some embodiments, the glass comprises less than 1 ppm each of Co, Ni, and Cr. In some embodiments, the concentration of Fe is < about 50 ppm, < about 20 ppm, or < about 10 ppm. In other embodiments, Fe + 30Cr + 35Ni < about 60 ppm, Fe + 30Cr + 35Ni < about 40 ppm, Fe + 30Cr + 35Ni < about 20 ppm, or Fe + 30Cr + 35Ni < about 10 ppm. In other embodiments, the composition sheet comprises between about 60 mol % to about 80 mol% $SiO_2$, between about 0.1 mol% to about 15 mol% $Al_2O_3$, 0 mol% to about 12 mol% $B_2O_3$, and about 0.1 mol% to about 15 mol% $R_2O$ and about 0.1 mol% to about 15 mol% RO, wherein R is any one or more of Li, Na, K, Rb, Cs and x is 2, or Zn, Mg, Ca, Sr or Ba and x is 1, and wherein the glass produces less than or equal to 2 dB/500mm absorption.

**[0048]** In other embodiments, the glass composition can comprise between about 65.79 mol % to about 78.17 mol% $SiO_2$, between about 2.94 mol% to about 12.12 mol% $Al_2O_3$, between about 0 mol% to about 11.16 mol% $B_2O_3$, between about 0 mol% to about 2.06 mol% $Li_2O$, between about 3.52 mol% to about 13.25 mol% $Na_2O$, between about 0 mol% to about 4.83 mol% $K_2O$, between about 0 mol% to about 3.01 mol% ZnO, between about 0 mol% to about 8.72 mol% MgO, between about 0 mol% to about 4.24 mol% CaO, between about 0 mol% to about 6.17 mol% SrO, between about 0 mol% to about 4.3 mol% BaO, and between about 0.07 mol% to about 0.11 mol% $SnO_2$. In some embodiments, the glass substrate can comprise a color shift < 0.015. In some embodiments, the glass subsrate can comprise a color shift < 0.008.

**[0049]** In additional embodiments, the glass substrate can comprises an $R_xO/Al_2O_3$ ratio between 0.95 and 3.23, wherein R is any one or more of Li, Na, K, Rb, Cs and x is 2. In further embodiments, the glass substrate may comprise an $R_xO/Al_2O_3$ ratio between 1.18 and 5.68, wherein R is any one or more of Li, Na, K, Rb, Cs and x is 2, or Zn, Mg, Ca, Sr or Ba and x is 1. In yet further embodiments, the glass substrate can comprise an $R_xO - Al_2O_3 - MgO$ between -4.25 and 4.0, wherein R is any one or more of Li, Na, K, Rb, Cs and x is 2. In still further embodiments, the glass substrate may comprise between about 66 mol % to about 78 mol% $SiO_2$, between about 4 mol% to about 11 mol% $Al_2O_3$, between about 4 mol% to about 11 mol% $B_2O_3$, between about 0 mol% to about 2 mol% $Li_2O$, between about 4 mol% to about 12 mol% $Na_2O$, between about 0 mol% to about 2 mol% $K_2O$, between about 0 mol% to about 2 mol% ZnO, between about 0 mol% to about 5 mol% MgO, between about 0 mol% to about 2 mol% CaO, between about 0 mol% to about 5 mol% SrO, between about 0 mol% to about 2 mol% BaO, and between about 0 mol% to about 2 mol% $SnO_2$.

**[0050]** In additional embodiments, the glass article can comprise between about 72 mol % to about 80 mol% $SiO_2$, between about 3 mol% to about 7 mol%

$Al_2O_3$, between about 0 mol% to about 2 mol% $B_2O_3$, between about 0 mol% to about 2 mol% $Li_2O$, between about 6 mol% to about 15 mol% $Na_2O$, between about 0 mol% to about 2 mol% $K_2O$, between about 0 mol% to about 2 mol% ZnO, between about 2 mol% to about 10 mol% MgO, between about 0 mol% to about 2 mol% CaO, between about 0 mol% to about 2 mol% SrO, between about 0 mol% to about 2 mol% BaO, and between about 0 mol% to about 2 mol% $SnO_2$. In certain embodiments, the glass substrate can comprise between about 60 mol % to about 80 mol% $SiO_2$, between about 0 mol% to about 15 mol% $Al_2O_3$, between about 0 mol% to about 15 mol% $B_2O_3$, and about 2 mol% to about 50 mol% $R_xO$, wherein R is any one or more of Li, Na, K, Rb, Cs and x is 2, or Zn, Mg, Ca, Sr or Ba and x is 1, and wherein Fe + 30Cr + 35Ni < about 60 ppm.

**[0051]** The LGP may comprise a glass that has been chemically strengthened, e.g., by ion exchange. During the ion exchange process, ions within a glass sheet at or near the surface of the glass sheet may be exchanged for larger metal ions, for example, from a salt bath. The incorporation of the larger ions into the glass can strengthen the sheet by creating a compressive stress in a near surface region. A corresponding tensile stress can be induced within a central region of the glass sheet to balance the compressive stress.

**[0052]** Ion exchange may be carried out, for example, by immersing the glass in a molten salt bath for a predetermined period of time. Exemplary salt baths include, but are not limited to, $KNO_3$, $LiNO_3$, $NaNO_3$, $RbNO_3$, and combinations thereof. The temperature of the molten salt bath and treatment time period can vary. It is within the ability of one skilled in the art to determine the time and temperature according to the desired application. By way of a non-limiting example, the temperature of the molten salt bath may range from about 400°C to about 800°C, such as from about 400°C to about 500°C, and the predetermined time period may range from about 4 to about 24 hours, such as from about 4 hours to about 10 hours, although other temperature and time combinations are envisioned. By way of a non-limiting example, the glass can be submerged in a $KNO_3$ bath, for example, at about 450°C for about 6 hours to obtain a K-enriched layer which imparts a surface compressive stress.

**[0053]** The LGP can, in certain embodiments be transparent or substantially transparent. As used herein, the term “transparent” is intended to denote that the LGP, at a thickness of approximately 1mm, has a transmission of greater than about 85% in the visible region of the spectrum (400-700nm). For instance, an exemplary transparent LGP may have greater than about 85% transmittance in the visible light range, such as greater than about 90%, greater than about 95%, or greater than about 99% transmittance, including all ranges and subranges therebetween. According to various embodiments, the LGP may have a transmittance of less than about 50% in the visible region, such as less than about 45%, less than about 40%, less than about 35%, less than about 30%, less than about 25%, or less than about 20%, including all ranges and subranges therebetween. In certain embodiments, an exemplary LGP may have a transmittance of greater than about 50% in the ultraviolet (UV) region (100-400nm), such as greater than about 55%, greater than about 60%, greater than about 65%, greater than about 70%, greater than about 75%, greater than about 80%, greater than about 85%, greater than about 90%, greater than about 95%, or greater than about 99% transmittance, including all ranges and subranges therebetween.

**[0054]** In some embodiments, an exemplary transparent LGP can comprise less than 1 ppm each of Co, Ni, and Cr. In some embodiments, the concentration of Fe is < about 50 ppm, < about 20 ppm, or < about 10 ppm. In other embodiments, Fe + 30Cr + 35Ni < about 60 ppm, Fe + 30Cr + 35Ni < about 40 ppm, Fe + 30Cr + 35Ni < about 20 ppm, or Fe + 30Cr + 35Ni < about 10 ppm. According to additional embodiments, an exemplary transparent LGP can comprise a color shift < 0.015 or, in some embodiments, a color shift < 0.008.

**[0055]** The optical light scattering characteristics of the LGP may also be affected by the refractive index of the LGP material. According to various embodiments, the LGP may have a refractive index ranging from about 1.3 to about 1.8, such as from about 1.35 to about 1.7, from about 1.4 to about 1.65, from about 1.45 to about 1.6, or from about 1.5 to about 1.55, including all ranges and subranges therebetween. In some embodiments, a surface of the LGP comprising a plurality of light extraction features may be coated with an organic or inorganic material having a substantially similar index of refraction as the LGP. As used herein, the term “substantially similar” is intended to denote that two values are approximately equal, e.g., within about 10% of each other, such as within about 5% of each other, or within about 2% of each other in some cases. For example, in the case of a refractive index of 1.5, a substantially similar refractive index may range from about 1.35 to about 1.65. In some embodiments, the roughened surface may be coated with a resin, such as Accuglass T-11 from Honeywell Corp. According to non-limiting embodiments, the coating may include an appropriate thickness to reduce the roughness of the respective light extraction features. For example, in some embodiments the coating (formed by any suitable means of deposition) can conform to the roughness of a respective surface such that the thickness of the coating is substantially equal to the root mean square (RMS) roughness of that surface.

**[0056]** The LGPs disclosed herein may be used in various display devices including, but not limited to LCDs. According to various aspects of the disclosure, display devices can comprise at least one of the disclosed LGPs coupled to at least one light source, which may emit blue light such as UV light (approximately 100-400 nm) or near-UV light (approximately 300-400nm). In some embodiments, the light source may be an LED light source. The optical components of an exemplary LCD may further comprise a reflector, a diffuser, one or more prism films, one or more linear or reflecting polarizers, a thin film transistor (TFT) array, a liquid crystal layer, and one or more color filters, to name a few components.

**[0057]** According to one exemplary embodiment, light from at least one LED can be optically coupled to an edge of the LGP and may be extracted with substantially uniform intensity across the light-emitting surface. An optional reflecting polarizer may reflect light oriented at undesirable polarizations back towards a reflector for recycling back through the LGP, which may serve to concentrate light into a single polarization. Light passing through the optional reflecting polarizer may pass through a first prism film which can reflect light at high angles back towards the reflecting polarizer for recycling and may thus concentrate light in a forward direction toward the user. A second prism film may be positioned orthogonal to the first prism film and may function in the same manner but along the orthogonal axis. A first linear polarizer may be employed to permit passage of only light with a single polarization. A TFT array may comprise active switching elements that permit voltage addressing of each sub-pixel of the display. A liquid crystal layer may comprise an electrooptic material, the structure of which rotates upon application of an electric field, causing a polarization rotation of any light passing through it. The light may then pass through a color filter comprising an array of red, green, and blue filters to produce the desired display color. Finally, a second linear polarizer may be used to filter any non-rotated light.

**[0058]** It will be appreciated that the various disclosed embodiments may involve particular features, elements or steps that are described in connection with that particular embodiment. It will also be appreciated that a particular feature, element or step, although described in relation to one particular embodiment, may be interchanged or combined with alternate embodiments in various non-illustrated combinations or permutations.

**[0059]** It is also to be understood that, as used herein the terms “the,” “a,” or “an,” mean “at least one,” and should not be limited to “only one” unless explicitly indicated to the contrary. Thus, for example, reference to “a light source” includes examples having two or more such light sources unless the context clearly indicates otherwise. Likewise, a “plurality” or an “array” is intended to denote “more than one.” As such, a “plurality of light extraction features” includes two or more such features, such as three or more such features, etc., and an “array of light guide plates” includes two or more such LGPs, such as three or more such LGPs, and so on.

**[0060]** Ranges can be expressed herein as from “about” one particular value, and/or to “about” another particular value. When such a range is expressed, examples include from the one particular value and/or to the other particular value. Similarly, when values are expressed as approximations, by use of the antecedent “about,” it will be understood that the particular value forms another aspect. It will be further understood that the endpoints of each of the ranges are significant both in relation to the other endpoint, and independently of the other endpoint.

**[0061]** The terms “substantial,” “substantially,” and variations thereof as used herein are intended to note that a described feature is equal or approximately equal to a value or description. For example, a “substantially planar” surface is intended to denote a surface that is planar or approximately planar. Moreover, as defined above, “substantially similar” is intended to denote that two values are equal or approximately equal. In some embodiments, “substantially similar” may denote values within about 10% of each other, such as within about 5% of each other, or within about 2% of each other.

**[0062]** Unless otherwise expressly stated, it is in no way intended that any method set forth herein be construed as requiring that its steps be performed in a specific order. Accordingly, where a method claim does not actually recite an order to be followed by its steps or it is not otherwise specifically stated in the claims or descriptions that the steps are to be limited to a specific order, it is no way intended that any particular order be inferred.

**[0063]** While various features, elements or steps of particular embodiments may be disclosed using the transitional phrase “comprising,” it is to be understood that alternative embodiments, including those that may be described using the transitional phrases “consisting” or “consisting essentially of,” are implied. Thus, for example, implied alternative embodiments to a device that comprises A+B+C include embodiments where a device consists of A+B+C and embodiments where a device consists essentially of A+B+C.

**[0064]** It will be apparent to those skilled in the art that various modifications and variations can be made to the present disclosure without departing from the spirit and scope of the disclosure. Since modifications combinations, sub-combinations and variations of the disclosed embodiments incorporating the spirit and substance of the disclosure may occur to persons skilled in the art, the disclosure should be construed to include everything within the scope of the appended claims and their equivalents.

**WHAT IS CLAIMED IS:**

1. A lighting device comprising a plurality of light guide plates, wherein:
   (a) at least a first edge of each light guide plate in the plurality of light guide plates is coupled to at least one light source;
   (b) at least one edge reflector is disposed along at least a portion of an edge of each light guide plate in the plurality of light guide plates.

2. The lighting device of claim 1, wherein the first edge of at least one light guide plate in the plurality of light guide plates comprises a recessed portion and the at least one light source is coupled to the recessed portion.

3. The lighting device of claim 1, wherein the first edge of at least one light guide plate in the plurality of light guide plates comprises a chamfer adjoining two side edges and the at least one light source coupled to the chamfer.

4. The lighting device of claim 1, wherein at least one light guide plate in the plurality of light guide plates comprises light extraction features disposed on a first major surface of the light guide plate or within the light guide plate adjacent the first major surface.

5. The lighting device of claim 4, wherein the light extraction features comprise etched, laser-damaged, or printed light extraction features.

6. The lighting device of claim 4, wherein the light extraction features are arranged in a pattern to produce a substantially uniform light output intensity across the first major surface of the at least one light guide plate.

7. The lighting device of claim 4, wherein the light extraction features of two or more light guide plates in the plurality of light guide plates are arranged in a pattern to produce a substantially uniform light output intensity across a light-emitting surface of the lighting device.

8. The lighting device of claim 1, wherein at least one light guide plate in the plurality of light guide plates comprises glass, polymethylmethacrylate, or a micro-structured material.

9. The lighting device of claim 1, wherein at least one light guide plate in the plurality of light guide plates comprises a glass including between about 50 mol % to about 90 mol% $SiO_2$, between about 0 mol% to about 20 mol% $Al_2O_3$, between 0 mol% to about 20 mol% $B_2O_3$, and between 0 mol% to about 25 mol% $R_xO$, wherein x is 2 and R is chosen from Li, Na, K, Rb, Cs, and combinations thereof, or wherein x is 1 and R is chosen from Zn, Mg, Ca, Sr, Ba, and combinations thereof.

10. The lighting device of claim 1, wherein at least one light guide plate in the plurality of light guide plates comprises a glass including less than about 1 ppm each of Co, Ni, and Cr.

11. The lighting device of claim 1, wherein at least one light guide plate in the plurality of light guide plates comprises a glass including a color shift of less than about 0.015.

12. The lighting device of claim 1, further comprising at least one additional light guide plate positioned in overlying registration with the at least one light source.

13. The lighting device of claim 12, wherein the at least one additional light guide plate is positioned in overlying registration with two or more light guide plates in the plurality of light guide plates.

14. The lighting device of claim 12, wherein the at least one additional light guide plate is positioned in overlying registration with substantially all of the light guide plates in the plurality of light guide plates.

15. The lighting device of claim 12, wherein the at least one additional light guide plate comprises supplemental light extraction features on a major surface facing the at least one light source.

16. The lighting device of claim 12, wherein a refractive index of the at least one additional light guide plate is substantially equal to a refractive index of the plurality of light guide plates.

17. The lighting device of claim 12, wherein a light output intensity of a first light source in registration with the at least one additional light guide plate is greater than a light output intensity of a second light source not in registration with the at least one additional light guide plate.

18. The lighting device of claim 12, wherein at least one light guide plate in the plurality of light guide plates comprises light extraction features arranged in a pattern to produce increased light output in a region of the light guide plate adjacent the at least one light source.

19. The lighting device of claim 1, further comprising an apparatus for splitting a light source output of the at least one light source.

20. The lighting device of claim 1, wherein the plurality of light guide plates is arranged in a two-dimensional array.

21. The lighting device of claim 16, wherein the two-dimensional array has at least one dimension ranging from about 50 mm to about 10 m.

22. A display device comprising the lighting device of claim 1.

23. A lighting device comprising:
   (a) a light guide plate comprising a first edge and a first major surface comprising a plurality of light extraction features,
   (b) at least one light source coupled to the first edge, and
   (c) at least one edge reflector disposed along at least a portion of an edge of the light guide plate.

24. The lighting device of claim 23, wherein the first edge comprises a recessed portion and the at least one light source is coupled with the recessed portion.

25. The lighting device of claim 23, wherein the first edge comprises a chamfer adjoining two side edges and the at least one light source is coupled to the chamfer.

26. The lighting device of claim 23, wherein the plurality of light extraction features is disposed on the first major surface of the light guide plate or within the light guide plate adjacent the first major surface.

27. The lighting device of claim 23, wherein the light extraction features comprise etched, laser-damaged, or printed light extraction features, or combinations thereof.

28. The lighting device of claim 23, wherein the plurality of light extraction features is arranged in a pattern to produce substantially uniform light output intensity across the first major surface of the light guide plate.

29. The lighting device of claim 28, wherein the plurality of light extraction features is arranged in a non-uniform pattern.

30. The lighting device of claim 23, wherein the light guide plate comprises glass, polymethylmethacrylate, or a micro-structured material.

31. The lighting device of claim 23, wherein the light guide plate comprises a glass including between about 50 mol % to about 90 mol% $SiO_2$, between about 0 mol% to about 20 mol% $Al_2O_3$, between 0 mol% to about 20 mol% $B_2O_3$, and between 0 mol% to about 25 mol% $R_xO$, wherein x is 2 and R is chosen from Li, Na, K, Rb, Cs, and combinations thereof, or wherein x is 1 and R is chosen from Zn, Mg, Ca, Sr, Ba, and combinations thereof.

32. The lighting device of claim 23, wherein the light guide plate comprises a glass including less than about 1 ppm each of Co, Ni, and Cr.

33. The lighting device of claim 23, wherein the light guide plate comprises a glass including a color shift of less than about 0.015.

34. The lighting device of claim 23, wherein the at least one edge reflector is disposed along all edges of the light guide plate except a portion of the first edge coupled to the at least one light source.

35. The lighting device of claim 23, wherein the light guide plate has at least one dimension ranging from about 1 mm to about 1 m.

36. A display device comprising the lighting device of claim 23.

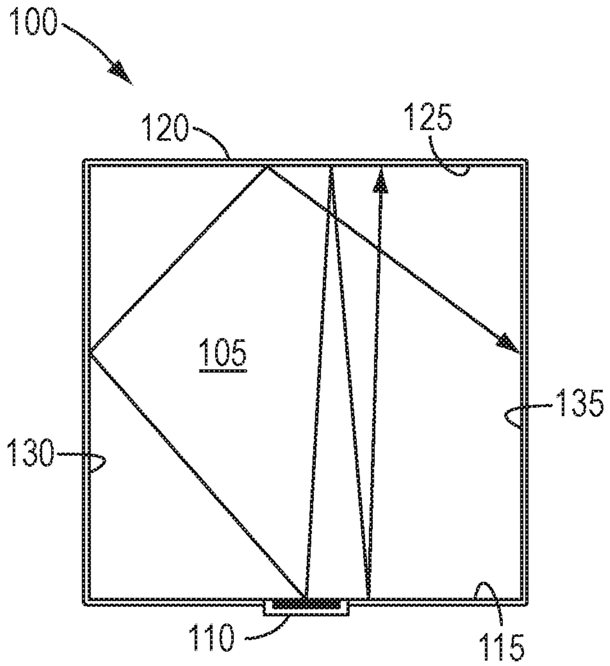


FIG. 1A

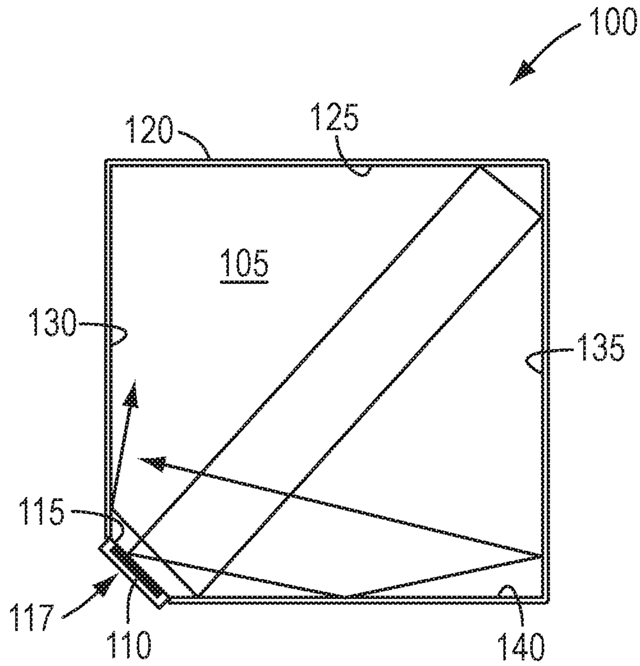


FIG. 1B

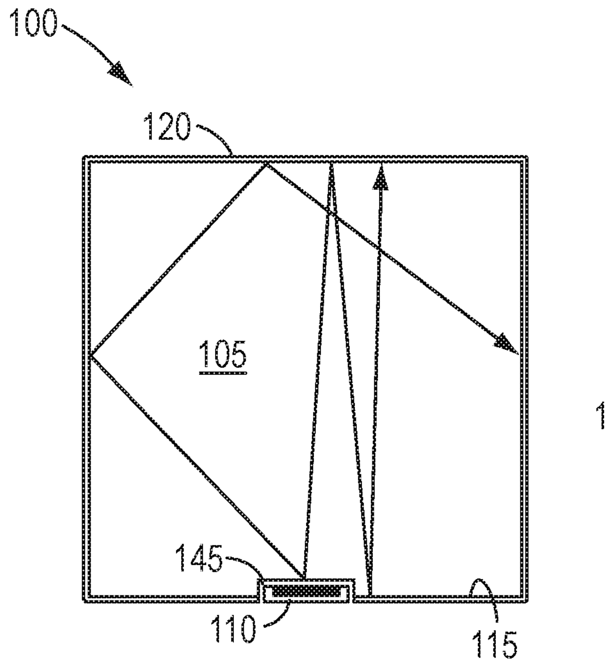


FIG. 1C

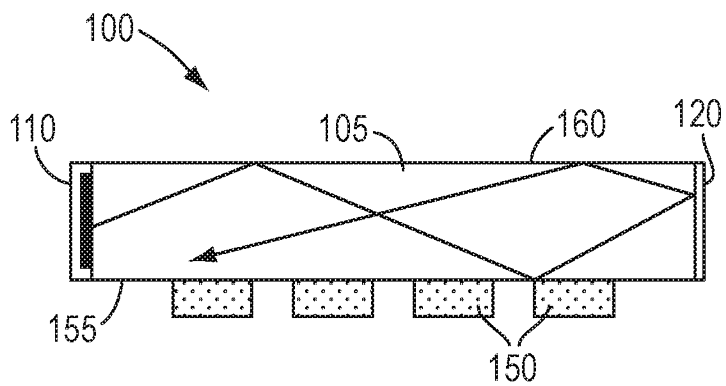


FIG. 1D

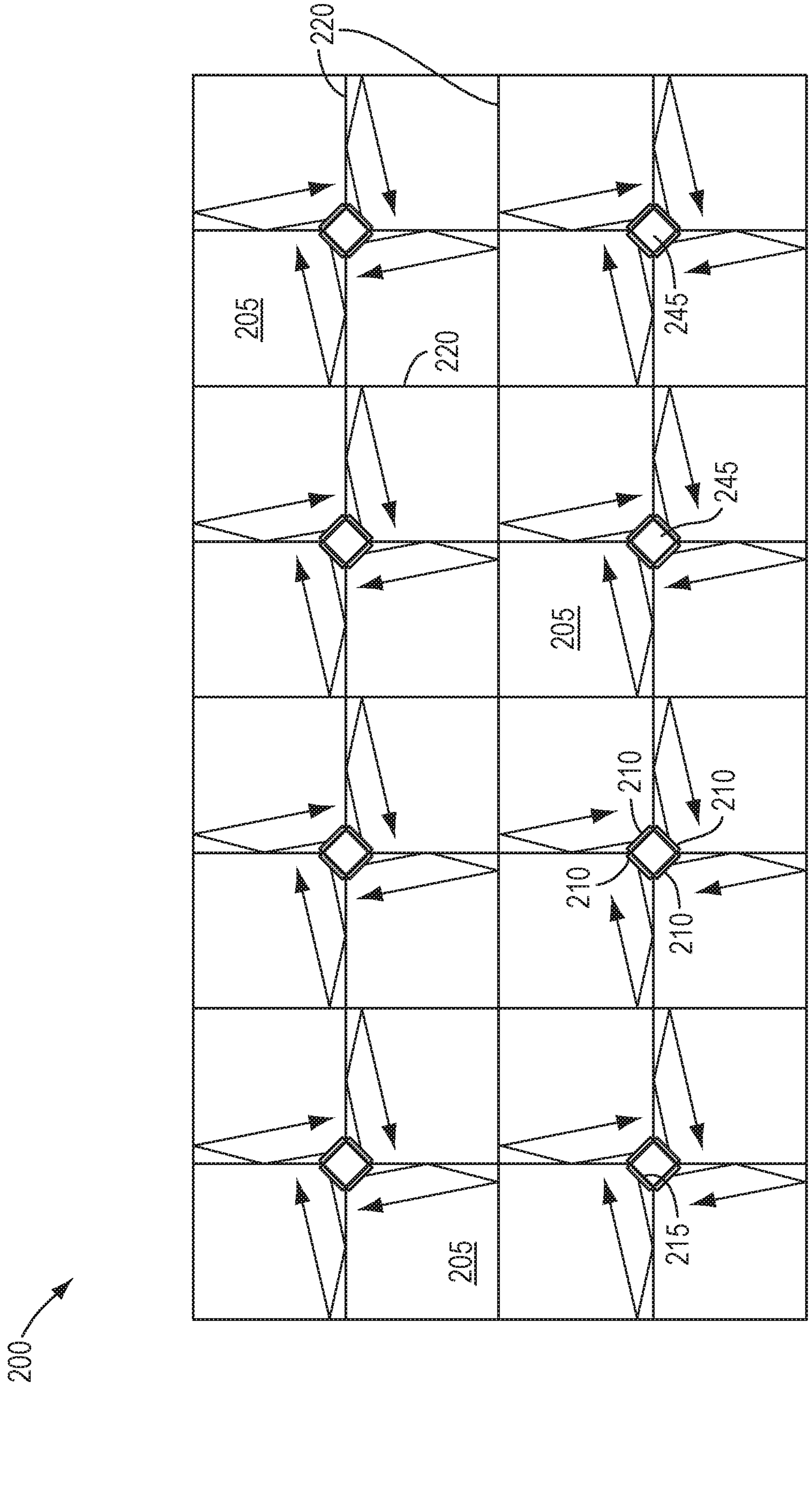


FIG. 2

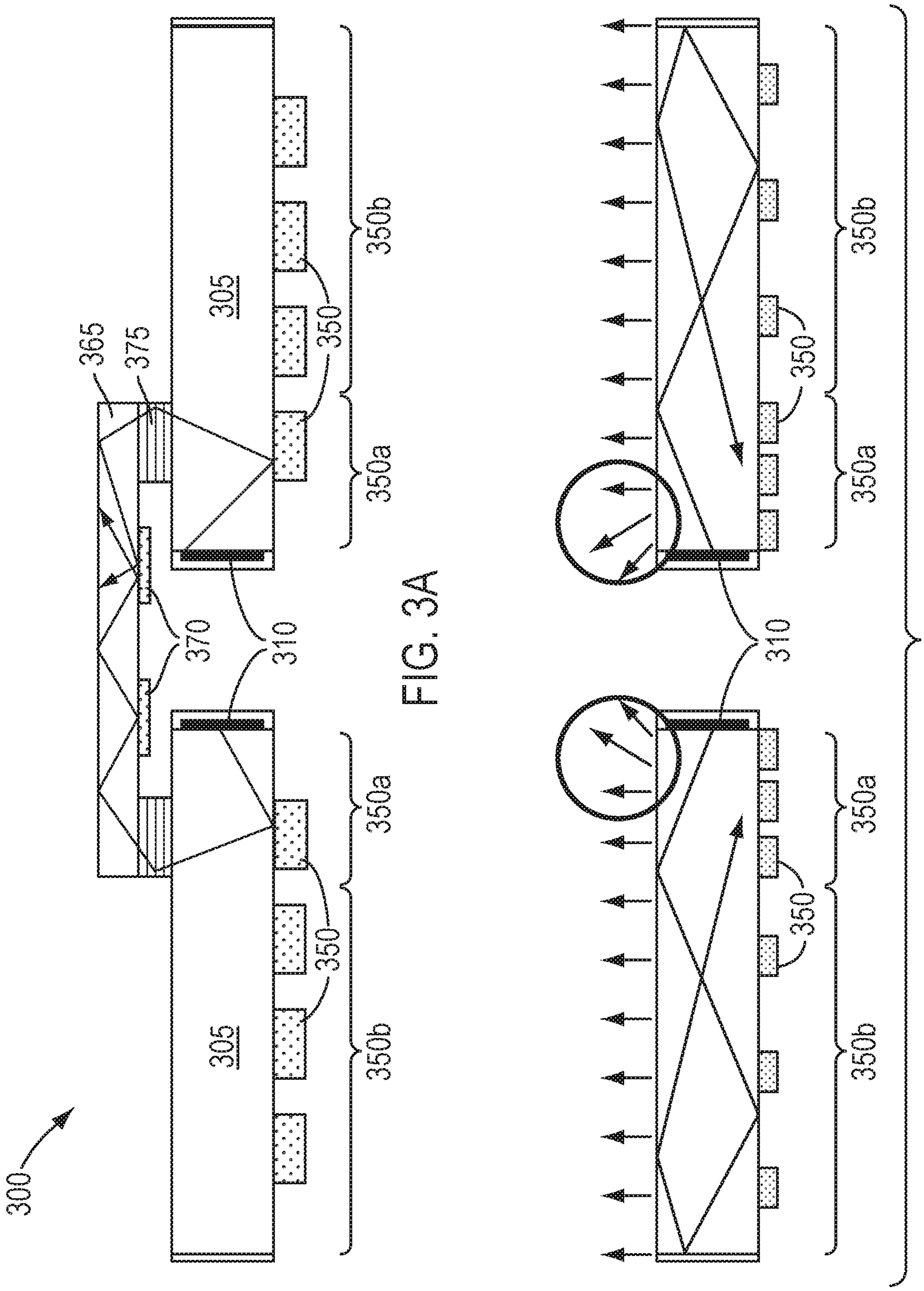
300
305
305
310
310
350
350
350a
350a
350b
350b
365
370
375
310
350
350
350a
350a
350b
350b

FIG. 3A

FIG. 3B

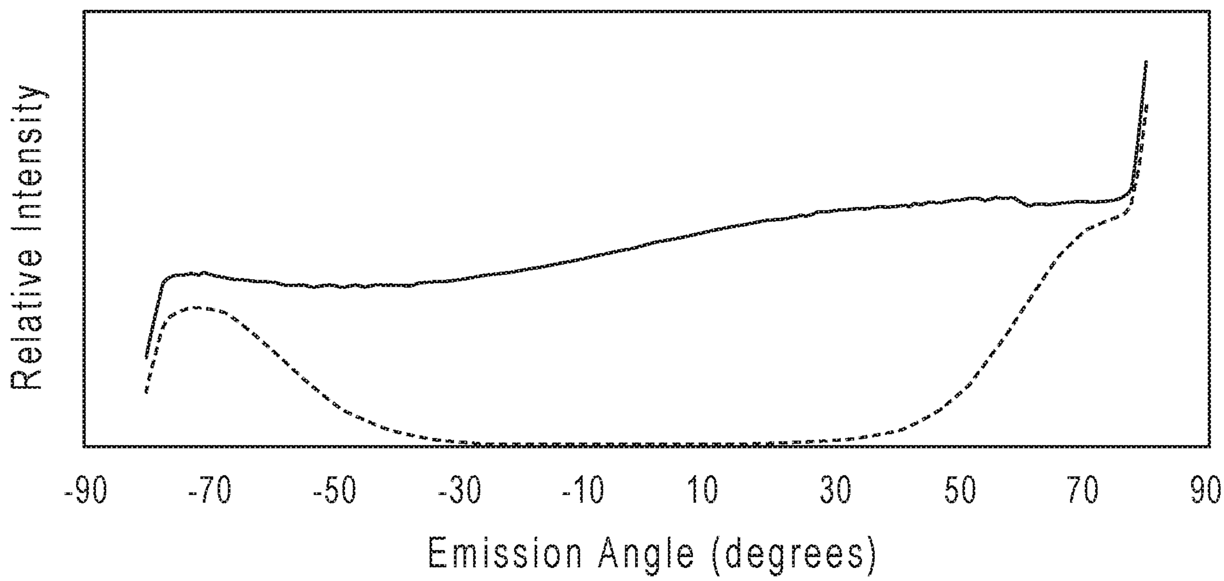
Relative Intensity
-90
-70
-50
-30
-10
10
30
50
70
90
Emission Angle (degrees)

FIG. 4