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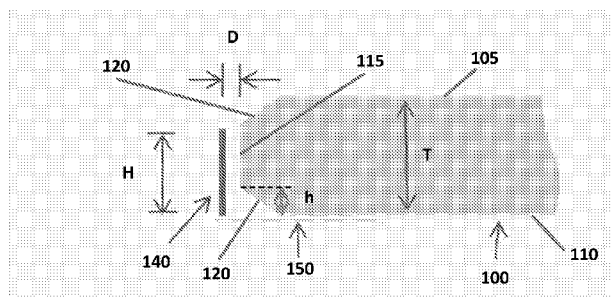


FIG. 1

(57) Abstract: Disclosed herein are glass article, such as light guide plates, comprising a first surface, an opposing second surface, and a thickness extending therebetween; and at least one side edge comprising a laser ablated region having a thickness of less than or equal to about 35% of the thickness of the glass article, or a chamfer having a height of less than or equal to about 15% of the thickness of the glass article. Display devices comprising such glass articles are also disclosed herein as well as methods for producing such glass articles.



GLASS ARTICLES WITH LASER CUT EDGES AND METHODS FOR MAKING 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. 62/162373 filed on May 15, 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 glass articles and display devices comprising such glass articles, and more particularly to glass light guides with at least one laser cut edge and methods for making the same.

BACKGROUND

[0003] Liquid crystal displays (LCDs) are commonly used in various electronics, such as cell phones, laptops, electronic tablets, televisions, and computer monitors. Increased demand for larger, high-resolution flat panel displays drives the need for large high-quality glass substrates for use in the display. For example, glass substrates may be used as light guide plates (LGPs) in LCDs, to which a light source may be coupled. The thinness and/or screen size of an LCD device may be affected by the size and/or properties of the light-emitting and/or light-incident surfaces of the light guide.

[0004] Current light guides are often manufactured from polymethylmethacrylate (PMMA). However, PMMA has a relatively high coefficient of thermal expansion (e.g., approximately one order of magnitude greater than that of glass), which may necessitate a larger space between the light source, e.g., LED, and the light guide when designing an LCD device. This gap can both decrease the efficiency of light coupling from the light source to the light guide and/or require a larger bezel to conceal the edges of the display. Moreover, due to its relatively weak mechanical strength, it can be difficult to make light guides from PMMA that are both sufficiently large and thin to meet current consumer demands. PMMA light guides

can thus limit the light-emitting surface area available to display an image, either due to concealment by a bezel or inability to manufacture sheets large enough for the desired display size.

[0005] Glass light guides have been proposed as alternatives to PMMA due to their low light attenuation, low coefficient of thermal expansion, and high mechanical strength. However, the light-incident surface area of a glass substrate can be affected by the method by which the glass is cut. For instance, glass can be cut by a mechanical scoring technique to provide perforated dashes along which the glass can be broken in a relatively straight line; however, this method may cause significant damage to the edge of the glass such as chipping, cracking, and/or sheet rupture. Defects in the glass edges are often observed at the intersecting regions between the major surfaces and the edges (e.g., around the 90° sharp corners). To improve reliability and reduce defects, the edges of the glass can be finished, often by introduction of chamfers, which may eliminate all or a part of the damaged portion of the glass. For example, in the case of a 0.7 mm thick sheet of glass, about 0.2 mm of the thickness may be ground or polished to produce such a chamfer on each corner of the side edge.

[0006] While this technique may improve glass reliability, it may have adverse effects from an optical standpoint, as the chamfer can reduce the surface area at the edge of the light guide that is available to couple the light from the light source into the light guide. For instance, 0.2 mm chamfers in a 0.7 mm thick glass sheet can result in a decrease of about 14% or more in coupling efficiency as compared to a flat, non-chamfered edge. It would therefore be advantageous to reduce chamfering of the light-incident edge, as this may allow for a thinner light guide and thus a thinner overall LCD device. It would also be advantageous to provide improved methods for finishing the edges of light guide plates to increase the surface area of the light-incident edge available to couple with the light source.

SUMMARY

[0007] The disclosure relates, in various embodiments, to glass articles, such as light guide plates, comprising a first surface, an opposing second surface, and a thickness extending therebetween; and at least one side edge comprising a laser ablated region having a thickness of about 35% or less than the thickness of

the glass article. The disclosure also relates to glass articles comprising a first surface, an opposing second surface, and a thickness extending therebetween; and at least one side edge comprising a chamfer having a height of about 15% or less than the thickness of the glass article. Display devices comprising such glass articles are further disclosed herein.

[0008] In certain embodiments, the side edge can comprise a non-laser ablated or non-chamfered region. According to various embodiments, the scattering parameter of a light-incident surface of the laser ablated region can be less than 0.1, and the scattering parameter of a light-incident surface of the non-laser ablated region can be less than about 0.2. The scattering parameter of a light-incident surface of the chamfered and non-chamfered regions can, in non-limiting embodiments, be less than about 0.1. In a further embodiment, display devices comprising the light guides may further comprise a light source, such as a light-emitting diode (LED), coupled to the at least one side edge. According to various embodiments, the light source can be coupled to the at least one side edge proximate the non-laser ablated region or the non-chamfered region.

[0009] Methods for making such glass articles or light guide plates are also disclosed, the methods comprising providing a glass sheet having a first surface, an opposing second surface, and a thickness extending therebetween; contacting the glass sheet with a laser along a predetermined path on the first surface to form a defect line; and separating the glass sheet into two or more portions along the defect line to form a glass article comprising at least one side edge comprising a laser ablated region having a thickness of less than or equal to about 35% of the thickness of the glass sheet.

[0010] Further disclosed herein are methods for making a glass article, the methods comprising providing a glass sheet having a first surface, an opposing second surface, and a thickness extending therebetween; contacting the glass sheet with a laser along a predetermined path on the first surface to form a groove; and separating the glass sheet into two or more portions along the groove to form a glass article comprising at least one side edge comprising a chamfer having a height of less than or equal to about 15% of the thickness of the glass sheet.

[0011] In various embodiments, the predetermined path can comprise a straight line, which can be perpendicular to an adjacent side edge of the glass sheet.

According to additional embodiments, the defect line can comprise laser ablated holes extending to a depth in the glass sheet of less than or equal to about 35% of the thickness of the glass sheet and/or a plurality of fault lines extending in a substantially perpendicular direction from the first surface to the second surface. In yet further embodiments, separating the glass sheet into two or more portions can comprise applying mechanical or thermal stress on or around the defect line or groove.

[0012] 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.

[0013] 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

[0014] The following detailed description can be further understood when read in conjunction with the following drawings, wherein, when possible, like numerals refer to like components, it being understood that the appended figures are not necessarily drawn to scale.

[0015] **FIG. 1** illustrates a glass article having a side edge comprising two mechanically-formed chamfers;

[0016] **FIG. 2** is a plot of optical coupling efficiency of the glass article of **FIG. 1** as a function of chamfer height;

[0017] **FIG. 3A** illustrates the side edge of an exemplary glass article comprising a laser ablated region;

[0018] **FIG. 3B** is an SEM cross-sectional image of a glass article comprising a laser ablated region according to various embodiments of the disclosure;

[0019] **FIG. 4** illustrates a glass article comprising a laser ablated region according to certain embodiments of the disclosure;

[0020] **FIG. 5** is a plot of optical coupling efficiency of the glass article of **FIG. 4** as a function of the thickness of the laser ablated region;

[0021] **FIGS. 6A-B** illustrate glass articles comprising a laser ablated region according to certain embodiments of the disclosure;

[0022] **FIGS. 7A-B** are plots of optical coupling efficiency of the glass articles of **FIGS. 6A-B** as a function of the thickness of the laser ablated region;

[0023] **FIG. 8** is a plot of optical coupling efficiency as a function of the scattering parameter Sigma;

[0024] **FIGS. 9A-B** illustrate a glass article having a side edge comprising one laser cut chamfer according to various embodiments of the disclosure; and

[0025] **FIGS. 10A-C** illustrate a method for making a glass article according to various embodiments.

DETAILED DESCRIPTION

Glass Articles

[0026] Disclosed herein are glass articles comprising a first surface, an opposing second surface, and a thickness extending therebetween; and at least one side edge comprising a laser ablated region having a thickness of about 35% or less than the thickness of the glass article. Exemplary glass articles can include, but are not limited to, glass light guide plates. The disclosure also relates to glass articles comprising a first surface, an opposing second surface, and a thickness extending therebetween; and at least one side edge comprising a chamfer having a height of about 15% or less than the thickness of the glass article. Display devices comprising such glass articles are further disclosed herein.

[0027] The glass article or light guide plate may comprise any material known in the art for use in displays and other similar devices including, but not limited to, aluminosilicate, alkali-aluminosilicate, borosilicate, alkali-borosilicate, aluminoborosilicate, alkali-aluminoborosilicate, and other suitable glasses. In certain

embodiments, the glass article may have a thickness of less than or equal to about 3 mm, for example, ranging from about 0.3 mm to about 2 mm, from about 0.7 mm to about 1.5 mm, or from about 1.5 mm to about 2.5 mm, including all ranges and subranges therebetween. Non-limiting examples of commercially available glasses suitable for use as a light guide plate include, for instance, EAGLE XG[®], Gorilla[®], Iris[™], Lotus[™], and Willow[®] glasses from Corning Incorporated.

[0028] The glass article may comprise a first surface and an opposing second surface. The surfaces may, in certain embodiments, be planar or substantially planar, e.g., substantially flat and/or level. The first and second surfaces may, in various embodiments, be parallel or substantially parallel. The glass article may further comprise at least one side edge, for instance, at least two side edges, at least three side edges, or at least four side edges. By way of a non-limiting example, the glass article may comprise a rectangular or square glass sheet having four edges, although other shapes and configurations are envisioned and are intended to fall within the scope of the disclosure.

[0029] FIG. 1 illustrates a glass article, e.g., glass light guide, comprising chamfers created by a mechanical score-and-break technique followed by polishing. The illustrated glass article **100** can comprise a first surface **105**, a second surface **110**, and a side edge **115**. A thickness **T** of the glass article **100** extends between the first and second surfaces. After mechanical scoring and breaking, edge defects on the side edge **115** can be removed by grinding and/or polishing to produce mechanically formed chamfers **120**. These chamfers **120** can have a height **h**. An exemplary height **h** for the chamfer **120** can be at least about 25% of the overall thickness **T** of the glass article. For example, in the case of a 0.7 mm thick glass sheet, chamfers having a height of about 0.2 mm can be used to correct defects at both corners of the side edge **115**. The chamfers **120** can be cut at any suitable angle, for example, ranging from about 30° to about 60°, such as about 45°.

[0030] A light source **140**, such as an LED, can be coupled to the side edge **115**. The light source can have a height **H**, which can be at least about 50% of the overall thickness **T** of the glass article, such as at least about 60%, at least about 70%, at least about 80%, at least about 90%, or 100% of the thickness **T** of the glass article. Light sources having a height **H** exceeding the thickness **T** of the glass article can also be used in some embodiments. A reflector **150** can be included on a

surface to which the light source **150** is proximate or adjacent (reflector **150** adjacent the second surface **110** illustrated in **FIG. 1**) to cover the gap (gap width = **D**) between the light source **140** and the side edge **115**. According to non-limiting embodiments, the light source can be spaced apart from the side edge of the glass article at a distance **D**, which can range, for example, from about 0.01 mm to about 2 mm, such as from about 0.04 mm to about 1.8 mm, from about 0.5 mm to about 1.5 mm, from about 0.6 mm to about 1.2 mm, or from about 0.8 mm to about 1 mm, including all ranges and subranges therebetween.

[0031] **FIG. 2** is a graphical plot of optical coupling efficiency as a function of chamfer height (with and without a reflector) for the glass article illustrated in **FIG. 1**. The graphical model includes the following assumptions: 0.7 mm glass thickness **T**; 0.5 mm light source (LED) height **H**; 0.04 mm gap width **D**; 45 degree chamfer; glass refractive index (n_d) = 1.497; and reflector having 99% reflection and Lambertian scattering. As illustrated in **FIG. 2**, as chamfer height **h** increases, optical coupling efficiency decreases. For light guides without chamfered side edges (height = 0), optical coupling efficiency can be as high as 91% (with a reflector) or 88% (without a reflector). Chamfering the edge at a height of 0.2 mm is shown to decrease the optical coupling efficiency by 11% (with a reflector) or 14% (without a reflector). Thus, **FIG. 2** illustrates that chamfering to reduce edge defects can result in undesirable optical losses. Alternative edge-finishing methods with reduced optical losses could advantageously provide larger and/or thinner displays with improved display properties.

[0032] According to a first embodiment illustrated in **FIG. 3A**, which depicts a cross-sectional view of a side edge **215** of a glass article **200** comprising a laser ablated region **225**. The laser ablated region **225** can comprise, for example, a plurality of laser ablated holes or damage tracks **230**. The glass in the laser ablated region **225** can be modified by a high energy density laser via nonlinear effects. Scanning a laser along a predetermined line or path can thus create a defect line which can define the perimeter or shape of one or more glass pieces to be separated from the glass sheet. The laser ablated region may, in certain embodiments, not extend through the entire thickness **T** of the glass article **200**. For example, the thickness **t1** of the laser ablated region **225** can be less than about 35% of the thickness **T** of the glass article, such as less than about 30%, less than about 25%,

or less than about 20% of thickness **T**, including all ranges and subranges therebetween. In various embodiments, the thickness **T** of the glass article **200** can be less than or equal to about 3 mm, for example, ranging from about 0.3 mm to about 2 mm, from about 0.7 mm to about 1.5 mm, or from about 1.5 mm to about 2.5 mm, including all ranges and subranges therebetween. Thus, in certain embodiments, the thickness **t1** of the laser ablated region **225** can be less than or equal to about 1 mm, such as ranging from about 0.05 mm to about 0.9 mm, from about 0.1 mm to about 0.8 mm, from about 0.2 mm to about 0.7 mm, from about 0.3 mm to about 0.6 mm, or from about 0.4 mm to about 0.5 mm, including all ranges and subranges therebetween. In some embodiments, the thickness **t1** of the laser ablated region may vary, e.g., linearly, randomly, etc. Thus, the thickness **t2** will also vary accordingly as a function of **t1**.

[0033] The remaining portion of the side edge **215** may comprise a non-laser ablated region **235**, e.g., a region not comprising laser ablated holes and/or nonlinear modifications. This region **235** can have any thickness **t2** such that **t1 + t2 = T**. For instance, the thickness **t2** of the non-laser ablated region **235** can be greater than about 65% of the thickness **T** of the glass article, such as greater than about 70%, greater than about 75%, or greater than about 80% of thickness **T**, including all ranges and subranges therebetween. In some embodiments, the thickness **t2** can be less than about 2 mm, such as ranging from about 0.25 mm to about 1.5 mm, from about 0.5 mm to about 1.2 mm, or from about 0.8 mm to about 1 mm, including all ranges and subranges therebetween. While the laser ablated region **225** is illustrated in **FIG. 3A** adjacent the first surface **205**, and the non-laser ablated region **235** adjacent the second surface **210**, it is to be understood that these orientations and labels can be switched without limitation, the surfaces being referred to herein as “first” and “second” solely for the purposes of discussion.

[0034] **FIG. 3B** is a cross-sectional scanning electron microscope (SEM) image of the side edge of a glass article comprising 0.7 mm thick Corning Iris™ Glass. As discussed above with respect to **FIG. 3A**, the side edge can comprise a laser ablated region **225** and a non-laser ablated region **235**. As evidenced by **FIG. 3B**, the laser ablated region has been modified by intense laser energy via nonlinear effects to a predetermined depth. In the illustrated embodiment, the thickness **t1** of the laser ablated region is 0.24 mm, whereas the overall thickness **T** of the glass

substrate is 0.7 mm. Accordingly, as illustrated, $t1/T = 0.34$, e.g., $t1$ is less than or equal to about 35% of the overall thickness T . The light-incident surface of the laser ablated region **225** can, in certain embodiments, have a scattering parameter (Sigma) of less than about 0.2, such as less than about 0.15, or less than about 0.1. Similarly, the light-incident surface of the non-laser ablated region **235** can have a scattering parameter (Sigma) of less than about 0.1, such as less than about 0.05, or lower. The Sigma scattering parameter can be proportional to a surface roughness of the region and can also indicate the width of Gaussian distribution on the projected plane. In certain embodiments, the non-laser ablated region **235** can have a scattering parameter less than the scattering parameter of the laser ablated region **225** and, thus, a relatively smoother light-incident surface. The relatively smoother surface of the non-laser ablated region **235** can be created when the glass sheet is separated into two (or more) portions by cracking or snapping the glass sheet along the defect line created by the laser.

[0035] An additional schematic of an exemplary glass article **200** is depicted in **FIG. 4**. The glass article can have a thickness T extending between a first surface **205** and a second surface **210**, as well as a side edge **215**. The side edge **215** can comprise a laser ablated region **225** having a thickness $t1$. A light source (e.g., LED) **240** having a height H can be coupled to the side edge **215** and positioned centrally between the first surface **205** and second surface **210**, although any alternative orientation can be used, as discussed in more detail below. A first reflector **245** and/or a second reflector **250** can be positioned adjacent the first surface **205** and/or the second surface **210** to cover the gap (gap width = D) between the light source **240** and the side edge **215**. Suitable reflectors can include broadband reflectors covering the full visible spectrum (~420-700 nm). The first reflector can be referred to herein as a “front” reflector, indicating that the first surface is a light-emitting surface, and the second reflector can be referred to herein as a “back” reflector. However, it is to be understood that these orientations and labels can be switched without limitation, the reflectors being referred to herein as “first”/“front” and “second”/“back” solely for the purposes of discussion.

[0036] **FIG. 5** is a graphical plot of optical coupling efficiency as a function of the thickness of the laser ablated region (with only a back reflector or with a front and back reflector) for the glass article illustrated in **FIG. 4**. The graphical model

includes the following assumptions: 0.7 mm glass thickness **T**; 0.5 mm light source (LED) height **H**; 0.04 mm gap width **D**; central LED alignment along the side edge; glass refractive index (N_d) = 1.497; a Lambertian reflector having 99% reflection; and Gaussian function scattering of the laser ablated region with Sigma = 0.36. As illustrated in **FIG. 5**, as the thickness **t1** of the laser ablated region increases, optical coupling efficiency decreases. For light guides without laser ablated regions (thickness = 0), optical coupling efficiency can be as high as 91.5% (with both a front and back reflector) or 91% (without only a back reflector). Laser ablation of the side edge to a depth of 0.24 mm (see, e.g., **FIG. 3B**) is shown to decrease the optical coupling efficiency by 2.43% (with both a front and back reflector) or 2.38% (without only a back reflector). Thus, **FIG. 5** illustrates that, compared to chamfered regions on the side edge (see, e.g., **FIG. 2**), laser ablated regions can result in at least about an 8.6% improvement in optical coupling efficiency.

[0037] Slightly varied results were obtained when aligning an edge of the light source with the non-laser ablated region **235** (e.g., aligning an edge of the light source **240** with the second surface **250**, as shown in the schematic of **FIG. 6A**), or with the laser-ablated region **225** (e.g., aligning an edge of the light source **240** with the second surface **250**, as shown in the schematic of **FIG. 6B**). Of course, it is to be understood that the laser ablated region can abut either the first surface (**FIG. 6A**) or the second surface (**FIG. 6B**), and the light source can be aligned with either the first surface (not illustrated) or the second surface (as illustrated). Table I shows the experimental results to compare the difference of coupling efficiency when LED light is coupled from these two regions. As shown in Table I below, when the light source is aligned with the non-laser ablated region **235**, optical coupling efficiency losses (as compared to a light guide having a “mirror” side edge, e.g., no laser ablated region) were 2.52% (without front reflector) or 1.71% (with front reflector). These results demonstrate, among other things, that the use of a front reflector can enhance coupling efficiency. Moreover, when the light source is aligned with the laser ablated region (without front reflector), the optical efficiency loss increases to 3.33%, indicating that alignment of the light source with the non-laser ablated (smoother) region can enhance the coupling efficiency.

Table I: Coupling Efficiency Loss of LGP with Laser Ablated Edge

	Coupling Efficiency Loss Compared to LGP with Mirror Edge	
	FIG. 6A (LED aligned with non-laser ablated region)*	FIG. 6B (LED aligned with laser ablated region)*
Back reflector only	2.52%	3.33%
Front and back reflector	1.71%	

*0.7 mm Corning® Iris™ glass with 0.24 mm laser ablated side edge region; 0.5 mm LED light source spaced 0.04 mm away from side edge

[0038] **FIGS. 7A-B** are graphical plots of optical coupling efficiency as a function of the thickness of the laser ablated region, with a back reflector only (**FIG. 7A**) or with both a front and back reflector (**FIG. 7B**). Both graphs plot a comparison between alignment of the light source with the laser ablated region or the non-laser ablated region of the side edge of the light guide plate. The graphical models includes the following assumptions: 0.7 mm glass thickness **T**; 0.5 mm light source (LED) height **H**; 0.04 mm gap width **D**; glass refractive index (n_d) = 1.497; a Lambertian reflector having 99% reflection; and Gaussian function scattering of the laser ablated region with Sigma = 0.36. For both **FIGS. 7A-B** it is observed that the location of the light source can impact the coupling efficiency. For example, at a laser ablated region thickness of 0.24 mm, the coupling efficiency improvement obtained when a light source is aligned with the non-laser ablated region as compared to a light source aligned with the laser ablated region is 3.1% (back reflector only; **FIG. 7A**) and 2.8% (back and front reflector; **FIG. 7B**).

[0039] The results illustrated in **FIGS. 7A-B** suggest that the surface properties (e.g., smoothness or roughness) of the side edge can meaningfully impact coupling efficiency. **FIG. 8** is a graphical plot illustrating optical coupling efficiency as a function of the scattering parameter (Sigma), which is proportional to the roughness of the glass surface. The graphical model includes the following assumptions: 2 mm glass thickness **T**; 1.5 mm light source (LED) height **H**; and 1.4 mm gap width **D**. As shown in **FIG. 8**, as Sigma (or surface roughness) increases, optical coupling efficiency generally decreases. However, in the region of $0 < \text{Sigma} < 0.2$, the coupling efficiency loss is not quite as dramatic as observed in the

remainder of the curve. Accordingly, it can be advantageous to employ a Sigma scattering parameter of less than 0.2 along the side edge surface. In some embodiments, the scattering parameter for the laser ablated region may be less than about 0.2, such as less than about 0.15, or less than about 0.1. Similarly, the scattering parameter of the non-laser ablated region may be less than about 0.1 or even less than about 0.05.

[0040] Laser cutting techniques can also be used to provide glass articles with chamfers, as shown in **FIGS. 9A-B**. Methods for producing such glass articles, e.g., light guide plates, are discussed in more detail below. Similar to the glass articles of **FIGS. 4** and **6A-B**, the glass article **300** can comprise a first surface **305**, a second surface **310**, and a thickness **T** extending therebetween, as well as a side edge **315**. A portion of the side edge **315** may comprise a chamfer **360**, which can be adjacent the first surface or second surface (chamfer **360** adjacent the first surface **305** illustrated). The chamfer **360** can have a width **w2** and a height **h2**. In some embodiments, the width **w2** of the chamfer **360** can correspond to or be proportional to the width of the predetermined path created by the laser. For example, in some embodiments, the width **w2** can be less than about 10 microns, such as less than about 8 microns, or less than about 5 microns (e.g., less than about 5, 4, 3, 2, or 1 microns). The width **w2** can, in various embodiments, be equal to approximately half of the width of the defect line created by the laser. In additional embodiments, the width **w2** can be at least about 10% of the total thickness **T** of the glass article, e.g., at least about 15%, at least about 20%, at least about 25% or at least about 30% of the thickness **T**, including all ranges and subranges therebetween. In some embodiments, the height **h2** of the chamfer **360** can correspond to or be proportional to the depth of the predetermined path created by the laser. The height **h2** of the chamfer can, for example, be less than about 30% of the thickness **T** of the glass article, such as less than about 25%, less than about 20%, less than about 15%, less than about 10%, or less than about 5% of the thickness **T**, including all ranges and subranges therebetween. For example, the height **h2** of the chamfer can be less than about 1 mm, such as ranging from about 0.05 mm to about 0.9 mm, from about 0.1 mm to about 0.8 mm, from about 0.2 mm to about 0.7 mm, from about 0.3 mm to about 0.6 mm, or from about 0.4 mm to about 0.5 mm, including all ranges and subranges therebetween.

[0041] Table II below illustrates optical coupling efficiency for the glass article illustrated in **FIGS. 9A-B** when coupled to a light source (LED). The light source was aligned with the non-chamfered region of the side edge (e.g., in the embodiment depicted in **FIG. 9A**, an edge of the light source was aligned with the second surface **310**). Of course, it is to be understood that the chamfered region can abut either the first surface (as illustrated) or the second surface (not illustrated). As shown in Table II below, when the light source is aligned with the non-chamfered region, optical coupling efficiency losses (as compared to a light guide having a “mirror” side edge, e.g., no laser ablated region) were 6.93% (without front reflector) or 5.32% (with front reflector). Thus, as with the laser ablated light guide plates, the use of a front reflector can also enhance coupling efficiency and laser cut chamfers can decrease optical losses as compared to mechanically formed chamfers (see, e.g., **FIG. 2**).

[0042] Notably, compared the optical coupling efficiency loss for a mechanically chamfered glass light guide (11% with a back reflector or 14% without a back reflector), optical coupling efficiency losses for laser cut chamfered glass light guides are decreased by nearly half. Without wishing to be bound by theory, it is believed that this improvement may be due to (a) the presence of only one laser cut chamfer in certain embodiments, as opposed to two mechanically formed chamfers, and/or (b) negligible defects and/or surface damage during laser cutting, as opposed to mechanical scoring, breaking, and polishing techniques. Thus, in some embodiments, the glass light guide plate disclosed herein can comprise only one chamfer, either adjacent the first surface or the second surface, thereby minimizing coupling efficiency losses that might otherwise be caused by the presence of a second chamfer.

[0043] Moreover, as compared to a laser ablated light guide plate (LED aligned with non-laser ablated region), the optical efficiency loss is greater by a factor of more than 2. Without wishing to be bound by theory, it is believed that the additional optical losses may be due to (a) the chamfered region **360** and/or (b) the twist hackles **365** that may be formed in the light guide depending on the method used to separate (e.g., break) the glass sheet. Twist hackles may be formed, for example, when mechanical force is used to break a glass sheet following laser scribing, as discussed in more detail below.

Table II: Coupling Efficiency Loss of LGP with Laser Cut Chamfered Edge

	Coupling Efficiency Loss Compared to LGP with Mirror Edge	
	LED aligned with non-chamfered region*	LED aligned with non-laser ablated region (FIG. 6A)**
Back reflector only	6.93%	2.52%
Front and back reflector	5.32%	1.71%

*0.7 mm Corning® Iris™ glass with laser cut chamfer 0.165 mm thick and 0.085 mm wide; 0.5 mm LED light source spaced 0.04 mm away from side edge

**0.7 mm Corning® Iris™ glass with 0.24 mm laser ablated side edge region; 0.5 mm LED light source spaced 0.04 mm away from side edge

Methods

[0044] Also disclosed herein are methods for making glass articles or light guide plates, the methods comprising providing a glass sheet having a first surface, an opposing second surface, and a thickness extending therebetween; contacting the glass sheet with a laser along a predetermined path on the first surface to form a defect line; and separating the glass sheet into two or more portions along the defect line to form a glass article comprising at least one side edge comprising a laser ablated region having a thickness of less than or equal to about 35% of the thickness of the glass sheet.

[0045] Further disclosed herein are methods for making a glass article or light guide plate, the methods comprising providing a glass sheet having a first surface, an opposing second surface, and a thickness extending therebetween; contacting the glass sheet with a laser along a predetermined path on the first surface to form a groove; and separating the glass sheet into two or more portions along the groove to form a glass article comprising at least one side edge comprising a chamfer having a height of less than or equal to about 15% of the thickness of the glass sheet.

[0046] Methods for making the glass articles of **FIGS. 4** and **6A-B** will now be discussed with reference to **FIGS. 10A-C**. A glass sheet **400** can be provided

having a first surface, an opposing second surface, and a thickness extending therebetween, and at least one side edge. The first or second surface of the glass sheet can be contacted with a laser, for example, by moving a laser along a predetermined path **470** (dashed line) on the surface of a stationary glass sheet. Alternatively, the laser may be stationary and the glass sheet can be moved along the predetermined path. As illustrated, the predetermined path **470** can be a straight line that is substantially perpendicular to at least one adjacent side edge **475**; however, other predetermined paths, including non-linear paths are envisioned. Moreover, more than one predetermined path can be traced on the surface to form a more complex shape and/or to separate the glass sheet **400** into more than two portions. Contact with the laser, e.g., an ultra-short pulsed laser, can comprise single laser pulses along the predetermined path, or multiple pulses can be used to increase the depth and/or width of the laser ablated region. The pulses can have, for example, a duration of less than a second, such as less than a nanosecond, or less than a picosecond. Non-limiting exemplary methods and lasers suitable for laser ablating and cutting glass are disclosed, for instance, in U.S. Application Nos. 14/145,525; 14/530,457; 14/535,800; 14/535,754; 14/530,379; 14/529,801; 14/529,520; 14/529,697; 14/536,009; 14/530,410; and 14/530,244; and International Application Nos. PCT/EP14/055364; PCT/US15/130019; and PCT/US15/13026; all of which are incorporated herein by reference in their entireties.

[0047] Irradiation of the glass sheet **400** with the laser along the predetermined path **470** can create a laser ablated region that is modified via nonlinear effects by the high energy density laser. Scanning over the predetermined path can create a narrow defect line **480** (width = **W**) defining the shape to be separated in a subsequent step. As shown in **FIG. 10A**, the defect line **480** can have any width **W** suitable to achieve the desired optical properties and/or separation or breakage profile. In some embodiments, the width **W** can range from about 1 micron to about 10 microns, such as from about 2 microns to about 9 microns, from about 3 microns to about 8 microns, from about 4 microns to about 7 microns, or from about 5 microns to about 6 microns, including all ranges and subranges therebetween. With reference to **FIG. 10C**, the laser can modify the glass sheet along the predetermined path to any desired depth to create a laser ablated region having a thickness **t1**. Furthermore, the laser can create a plurality of fault lines extending in

a substantially perpendicular direction from the first surface to the second surface along the predetermined path **470**. The predetermined path and/or defect line may thus delineate the desired shape and the vertical fault lines along the defect line can establish a path of least resistance for separation by crack propagation or any other mechanical or thermal separation technique. According to some embodiments, the laser does not or does not substantially alter the overall thickness **T** of the glass sheet at the side edge.

[0048] Once the defect line **480** is created, separation can occur by applying manual and/or thermal stress on or around the defect line. Manual or mechanical stress or pressure can be applied, for example, in an amount sufficient to create tension on the vertical fault lines thus resulting in a break along the defect line. Thermal stress can be applied using any suitable heat source to create a stress zone on or around the defect line, thereby placing tension on the vertical fault lines and inducing partial or total self-separation of the glass sheet. The methods used to separate the glass sheet can be carried out alone or in combinations and the parameters for the separation methods (e.g., force, temperature, etc.) can vary depending on various process parameters revolving around the laser (e.g., laser scan speed, laser power, pulse width, repetition rate, pulse time, etc.).

[0049] The glass sheet **400** can thus be separated into two or more portions (two portions illustrated in **FIG. 10B: 485, 490**). Referring to portion **485**, the glass portion can have a length **L** and a side edge **415**. The side edge **415** can comprise a laser ablated region **425** having a width **w1**. The width **w1** of the laser ablated region may vary depending, e.g., on the defect line width **W** and/or on the method of separation. In some embodiments (not illustrated), $w1 \approx W$, e.g., if substantially all of the defect line is incorporated into the side edge **415** as the laser ablated region **425**. In additional embodiments, $w1 < W$, e.g., if a portion of the defect line makes up the laser ablated region **425** of side edge **415**. In yet further embodiments (as illustrated), $2 \cdot w1 \approx W$, e.g., in the case of a break substantially along the middle of the defect line.

[0050] A perspective view of a portion of the resulting glass article **500** (**485**) is illustrated in **FIG. 10C**, having a side edge **515** with a laser ablated region **525** as described above with respect to **FIG. 4**. The laser ablated region **525** has a thickness **t1** extending partially along the overall thickness **T** of the glass article, as

well as a width **w1** extending partially along the overall length **L** of the glass article (full length not illustrated). In some embodiments, the described method can be used to create two glass articles having substantially identical side edges **515**.

[0051] Methods for forming the glass article of **FIG. 9A** are also disclosed herein, although not illustrated in the figures. A glass article of **FIG. 9A** can be prepared for example, following the procedure outlined above with respect to **FIGS. 10A-B**. However, in contrast to the laser ablation method, which does not substantially alter the thickness **T** of the glass article at the side edge, methods for forming the glass article of **FIG. 9A** include creating a chamfer **360** in the side edge **315** of the glass article. Accordingly, contacting a surface of the glass sheet with a laser along the predetermined path can result in the formation of a vent or groove along the predetermined path. Similar to the defect line of **FIG. 10A**, the groove can have a width and can penetrate to a depth sufficient to form a chamfer having a width **w2** and a height **h2** (referring to **FIG. 9A**).

[0052] Suitable lasers for laser cutting a vent or groove into the glass sheet can include, for example, CO₂ lasers, UV lasers, and infrared lasers operating at wavelengths greater than about 3 microns. Such lasers are described, for example, in U.S. Patent Application Nos. 14/145,525; 14/530,457; 14/535,800; 14/535,754; 14/530,379; 14/529,801; 14/529,520; 14/529,697; 14/536,009; 14/530,410; and 14/530,244; and International Application Nos. PCT/EP14/055364; PCT/US15/130019; and PCT/US15/13026; which are all incorporated herein by reference in their entireties. A suitable cutting technique can include, for example, a CO₂ laser scribing technique, which utilizes a CO₂ laser to quickly heat the glass to a temperature at, near, or above the glass strain point. Rapid laser heating can be followed by a rapid quenching process using, e.g., a solid water or water mist jet. The rapid heating and quenching process can produce a tensile stress (σ) in the glass sheet that can be estimated by the following formula:

$$\sigma = \frac{1}{2} \alpha \cdot E \cdot \Delta T$$

wherein α is the coefficient of thermal expansion, E is the Young's modulus, and ΔT is the temperature drop from the laser beam and cooling jet quenching cycle.

Tensile stresses that can be generated using this process for display glasses can range up to about 100 MPa in some instances.

[0053] The laser scribing process can be followed by a mechanical separation (break) or a subsequent laser separation, such as a CO₂ laser separation step. In some embodiments, a scribe-and-break technique can be employed. Because the breaking stress can be directly correlated with crack depth, in some embodiments, the groove cut into the glass surface can have a depth of at least about 10% of the glass thickness, such as greater than about 15% or greater than about 20% of the glass thickness, e.g. greater than about 25% or greater than about 30% of the glass thickness. However, when laser cutting the glass sheet, competing considerations should be balanced between ease of breaking the glass sheet and minimizing the chamfer height in the resulting glass article. Another consideration during the mechanical separation of the glass sheet is minimizing the creation of twist hackles, which can be produced by tensile stress applied to the vent or groove. Twist hackles can significantly impact the coupling efficiency of the light guide plate (as shown in Table II above). Thus, according to various embodiments, the glass light guide disclosed herein may comprise twist hackles or may be substantially free of twist hackles.

[0054] According to various embodiments, the first and/or second surface of the glass article may be patterned with a plurality of light extraction features. As used herein, the term “patterned” is intended to denote that the plurality of elements and/or features are present on the surface of the glass article in any given pattern or design, which may, for example, be random or arranged, repetitive or non-repetitive. For instance, in the case of light extraction features, such features may be distributed across the second surface, e.g. as textural features making up a roughened surface.

[0055] In various embodiments, the light extraction features present on the first and/or second surface of the glass article may comprise light scattering sites. For example, the first surface of the glass article may be textured, etched, coated, damaged and/or roughened to produce the light extraction features. Non-limiting examples of such methods include, for instance, laser damaging the surface, acid etching the surface, and coating the surface with TiO₂. In certain embodiments, a laser can be used both to cut holes into the glass sheet and to damage the first and/or second surface to create light extraction features. According to various embodiments, the extraction features may be patterned in a suitable density so as to

produce a substantially uniform illumination. The light extraction features may produce surface scattering and/or volumetric scattering of light, depending on the depth of the features in the glass surface. The optical characteristics of these features can be controlled, e.g., by the processing parameters used when producing the extraction features.

[0056] The glass article 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 No. PCT/US2013/063622, incorporated herein by reference in its entirety. For example, a glass sheet may be ground and/or polished to achieve the desired thickness and/or surface quality. The glass may then be optionally cleaned and/or the surface of the glass to be etched may be subjected to a process for removing contamination, such as exposing the surface to ozone.

[0057] The glass sheet may also be 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.

[0058] 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.

[0059] 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.

[0060] As used herein, the term “optically coupled” is intended to denote that a light source is positioned at an edge of the glass article so as to introduce light into the guide. When light is injected into the glass article, e.g. glass light guide plate, according to certain embodiments, the light is trapped and bounces within the light guide due to total internal reflection (TIR) until it hits a light extraction feature on the first or second surface. As used herein, the term “light-emitting surface” is intended to denote a surface from which light is emitted from the light guide plate toward a viewer. For instance, the first or second surface can be a light-emitting surface. Similarly, the term “light-incident surface” is intended to denote a surface that is coupled to a light source, e.g., an LED, such that light enters the light guide. For example, the side edge of the light guide plate can be a light-incident surface.

[0061] The glass articles and light guide plates disclosed herein may be used in various display devices including, but not limited to LCDs or other displays used in the television, advertising, automotive, and other industries. Traditional backlight units used in LCDs can comprise various components. One or more light sources may be used, for example light-emitting diodes (LEDs) or cold cathode fluorescent lamps (CCFLs). Conventional LCDs may employ LEDs or CCFLs packaged with color converting phosphors to produce white light. According to various aspects of the disclosure, display devices employing the disclosed glass articles may comprise at least one light source emitting blue light (UV light, approximately 100-400 nm), such as near-UV light (approximately 300-400nm). The light guide plates and devices disclosed herein may also be used in any suitable lighting applications such as, but not limited to, luminaires or the like.

[0062] 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.

[0063] 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” is intended to denote “more than one.” As such, a “plurality of fault lines” includes two or more such fault lines, such as three or more such fault lines, etc.

[0064] 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.

[0065] 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.

[0066] 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.

[0067] 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 method that comprises A+B+C include embodiments where a method consists of A+B+C and embodiments where a method consists essentially of A+B+C.

[0068] 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 glass article comprising:
a first surface, an opposing second surface, and a thickness extending therebetween; and
at least one side edge comprising a laser ablated region having a thickness less than or equal to about 35% of the thickness of the glass article.
2. The glass article of claim 1, wherein the thickness of the laser ablated region is about 20% or less of the thickness of the article.
3. The glass article of any of claims 1-2, wherein the scattering parameter of a light-incident surface of the laser ablated region is less than about 0.2.
4. The glass article of any of claims 1-3, further comprising a non-laser ablated region comprising a light-incident surface having a scattering parameter of less than about 0.1.
5. The glass article any of claims 1-4, wherein the thickness of the glass article ranges from about 0.3 mm to about 3 mm.
6. The glass article any of claims 1-5, wherein the glass article is a light guide plate.
7. A display device comprising the glass article of any of claims 1-6.
8. The display device of claim 7, further comprising a light source optically coupled to the at least one side edge of the glass article.
9. The display device of claim 8, wherein the light source is a light-emitting diode.

10. The display device of claim 8, wherein the light source is positioned between the first and second surfaces, or wherein an edge of the light source is aligned with the first or second surface.
11. The display device of claim 8, wherein the light source is coupled to the at least one side edge of the glass article in a position proximate a non-laser ablated region.
12. The display device of claim 7, further comprising at least one reflector positioned on the first surface of the glass article, on the second surface of the glass article, or on both the first and second surfaces of the glass article.
13. A glass article comprising:
 - a first surface, an opposing second surface, and a thickness extending therebetween; and
 - at least one side edge comprising a chamfer adjacent the first or second surface, the chamfer having a height less than or equal to about 15% of the thickness of the glass article.
14. The glass article of claim 13, wherein the chamfer is a laser cut chamfer.
15. The glass article of any of claims 13-14, wherein the at least one side edge comprises only one chamfer.
16. The glass article of any of claims 13-15, wherein the scattering parameter of a light-incident surface of the chamfer is less than about 0.1.
17. The glass article of any of claims 13-16, further comprising a non-chamfered region comprising a light-incident surface having a scattering parameter of less than about 0.1.

18. The glass article of claim 17, wherein the non-chamfered region comprises a twisted hackle pattern extending across at least a portion of the thickness of the glass article.
19. The glass article of claim 17, wherein the non-chamfered region does not comprise a twisted hackle pattern.
20. The glass article of any of claims 13-16, wherein the thickness of the glass article ranges from about 0.3 mm to about 3 mm.
21. The glass article of any of claims 13-16, wherein the glass article is a light guide plate.
22. A display device comprising the glass article of any of claims 13-21.
23. The display device of claim 22, further comprising a light source optically coupled to the at least one side edge of the glass article.
24. The display device of claim 23, wherein the light source is a light-emitting diode.
25. The display device of claim 23, wherein the laser cut chamfer is adjacent the first surface, and wherein an edge of the light source is aligned with the second surface.
26. The display device of claim 22, further comprising at least one reflector positioned on the first surface of the glass article, on the second surface of the glass article, or on both the first and second surfaces of the glass article.
27. A method for manufacturing a glass article comprising:
providing a glass sheet having a first surface, an opposing second surface, and a thickness extending therebetween;

contacting the glass sheet with a laser along a predetermined path on the first surface to form a defect line; and

separating the glass sheet into two or more portions along the defect line to form a glass article comprising at least one side edge comprising a laser ablated region having a thickness of less than or equal to about 35% of the thickness of the glass sheet.

28. The method of claim 27, wherein the laser is chosen from ultra-short pulsed lasers.

29. The method of any of claims 27-28, wherein forming the defect line comprises producing laser ablated holes in the glass sheet to a depth of less than or equal to about 35% of the thickness of the glass sheet, and optionally forming fault lines extending in a substantially perpendicular direction from the first surface to the second surface of the glass sheet.

30. The method of any of claims 27-29, wherein separating the glass sheet into two or more portions comprises applying mechanical or thermal stress on or around the defect line.

31. A method for manufacturing a glass article comprising:

providing a glass sheet having a first surface, an opposing second surface, and a thickness extending therebetween;

contacting the glass sheet with a laser along a predetermined path on the first surface to form a groove; and

separating the glass sheet into two or more portions along the groove to form a glass article comprising at least one side edge comprising a chamfer having a height of less than or equal to about 15% of the thickness of the glass sheet.

32. The method of claim 31, wherein the laser is chosen from CO₂ lasers, UV lasers, and infrared lasers operating at a wavelength greater than about 3 microns.

33. The method of claim 31, wherein separating the glass sheet into two or more portions comprises applying mechanical or thermal stress on or around the groove.

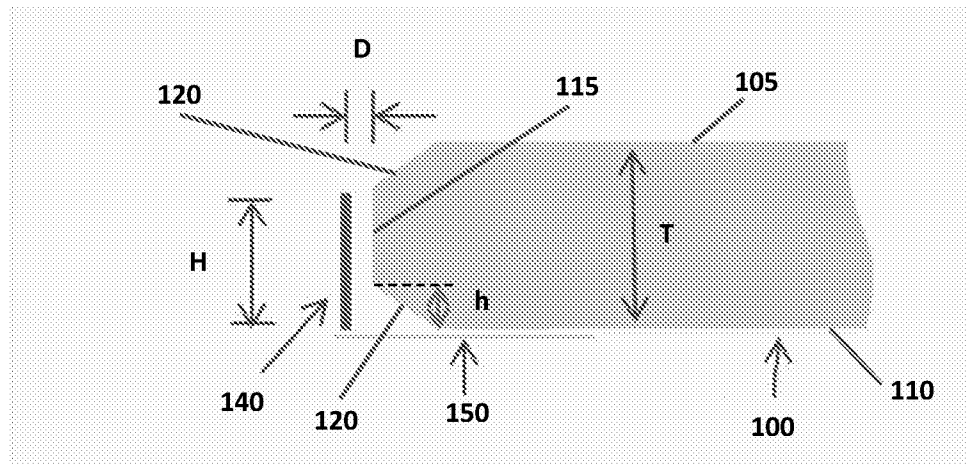


FIG. 1

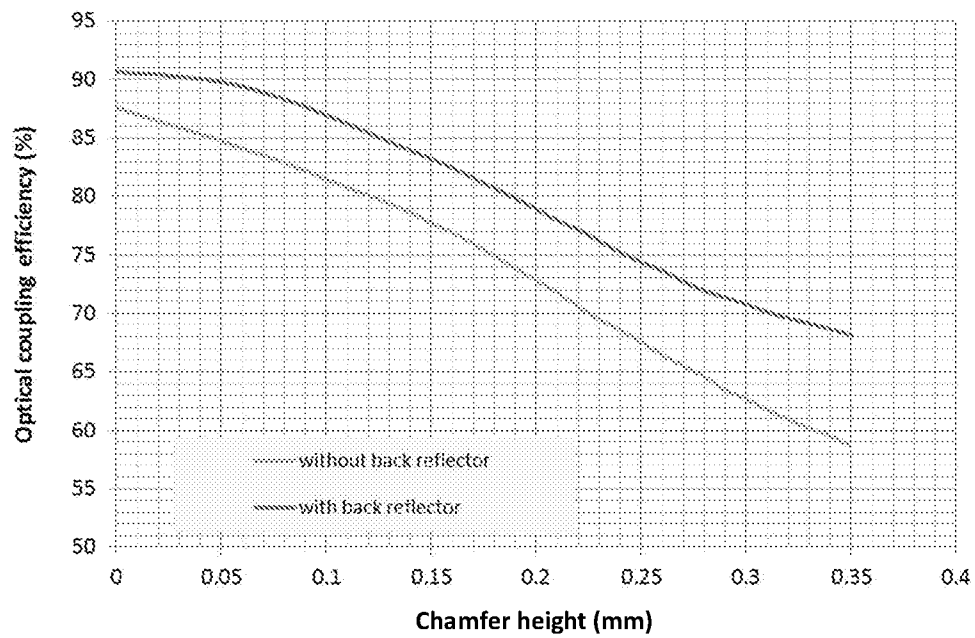


FIG. 2

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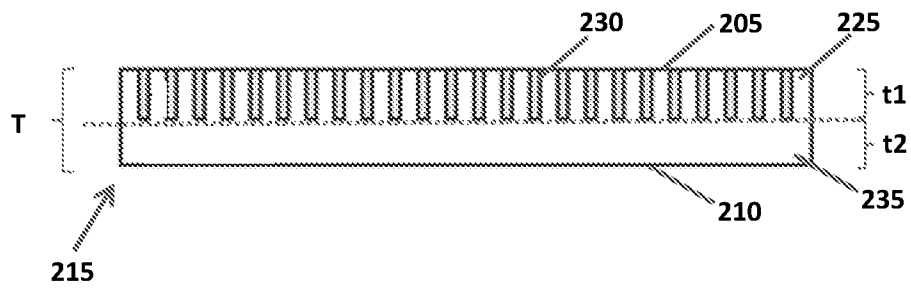


FIG. 3A

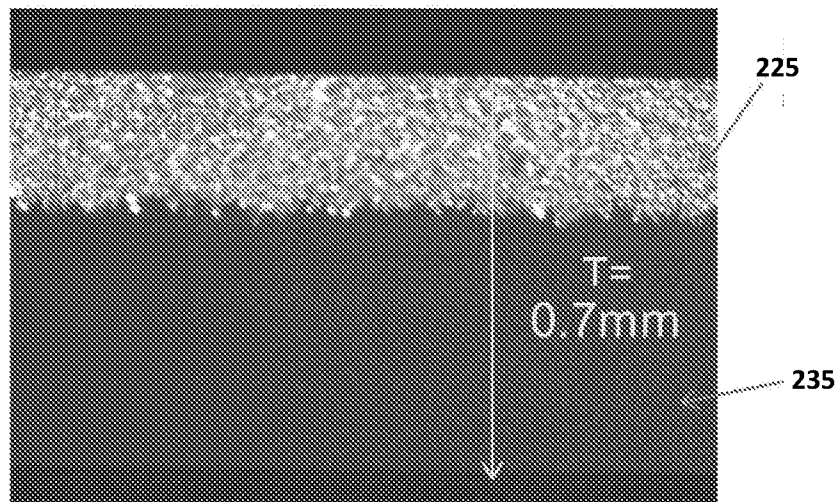


FIG. 3B

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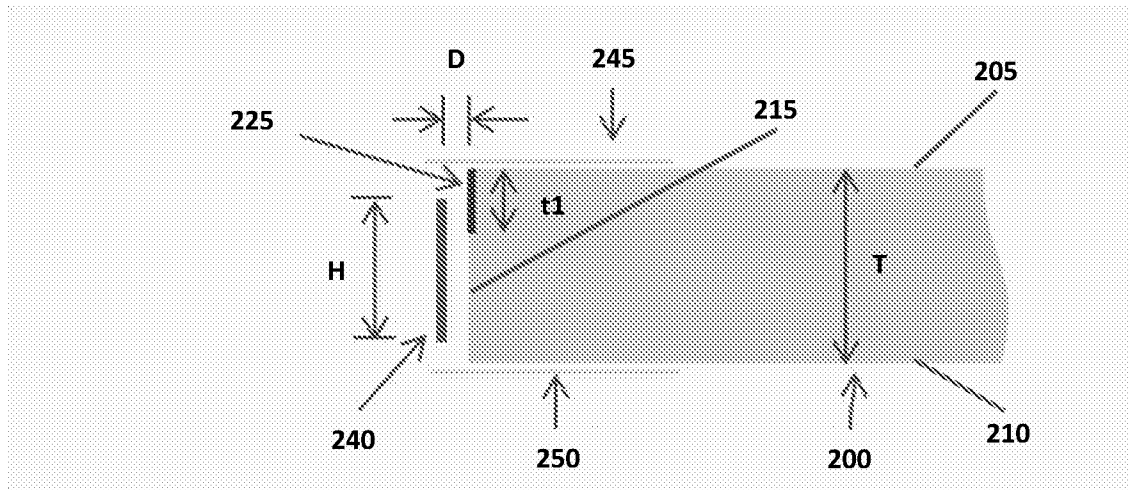


FIG. 4

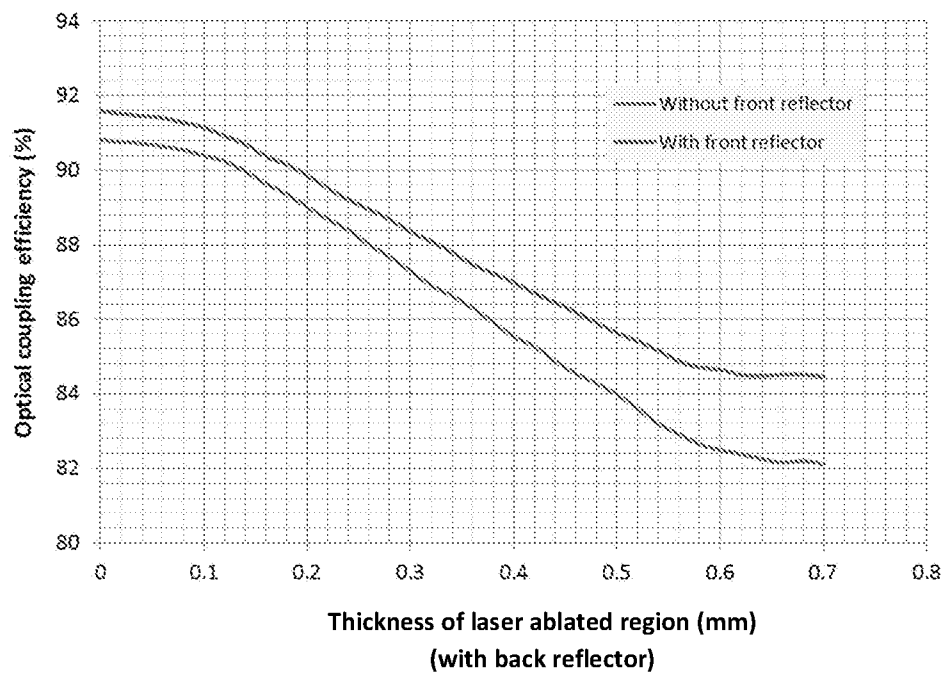


FIG. 5

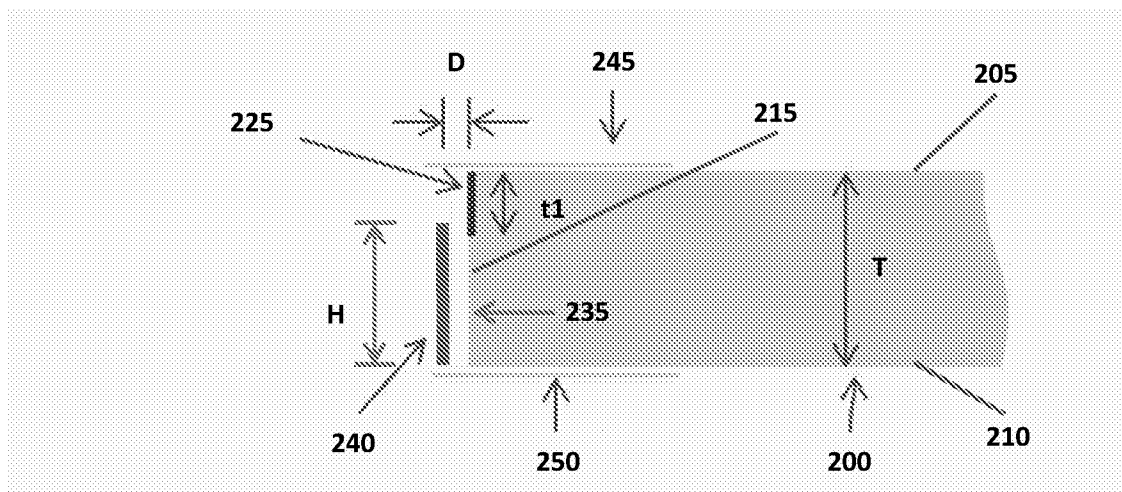


FIG. 6A

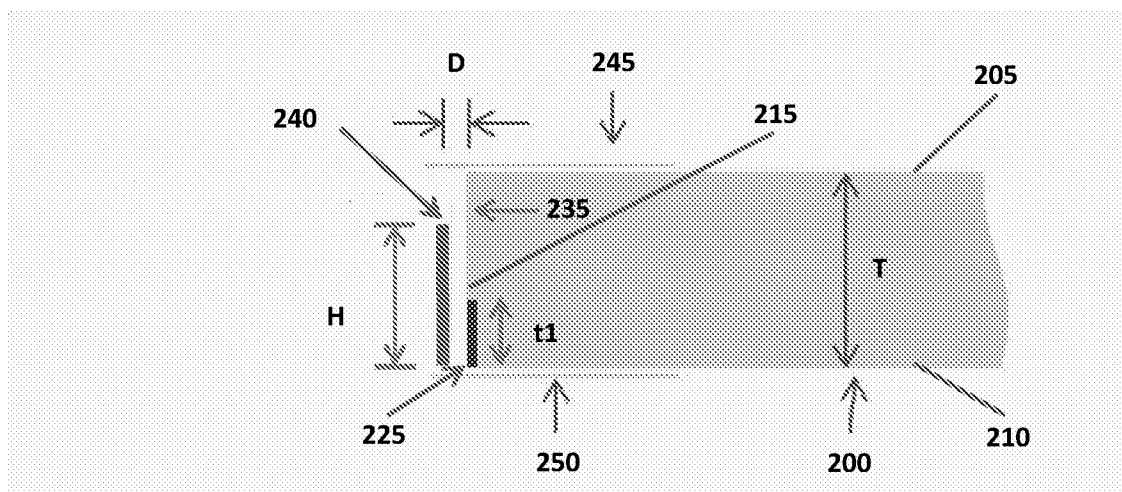


FIG. 6B

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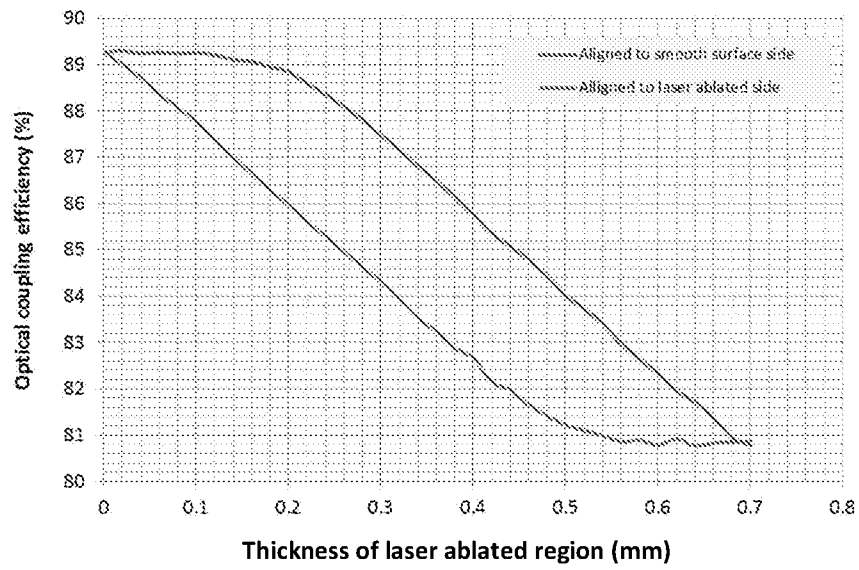


FIG. 7A

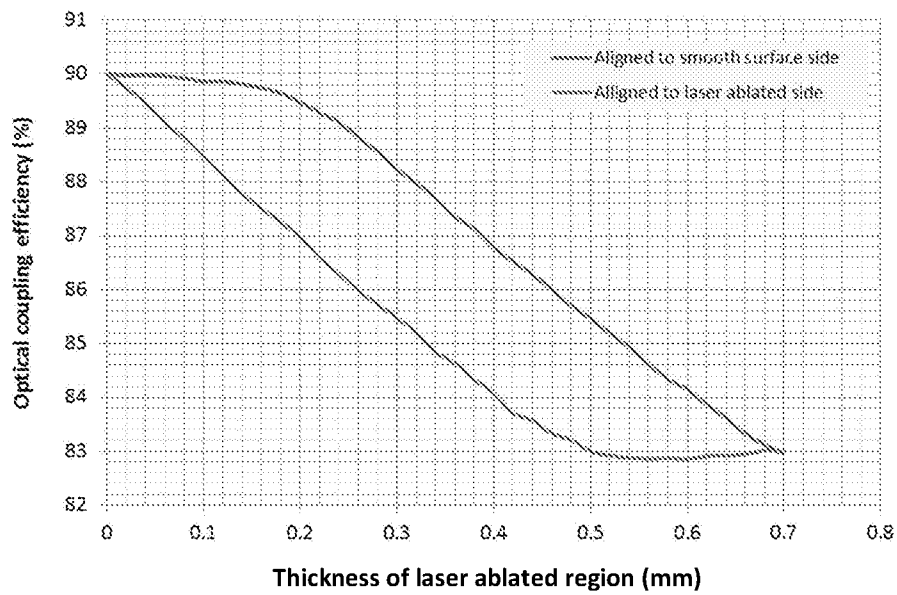


FIG. 7B

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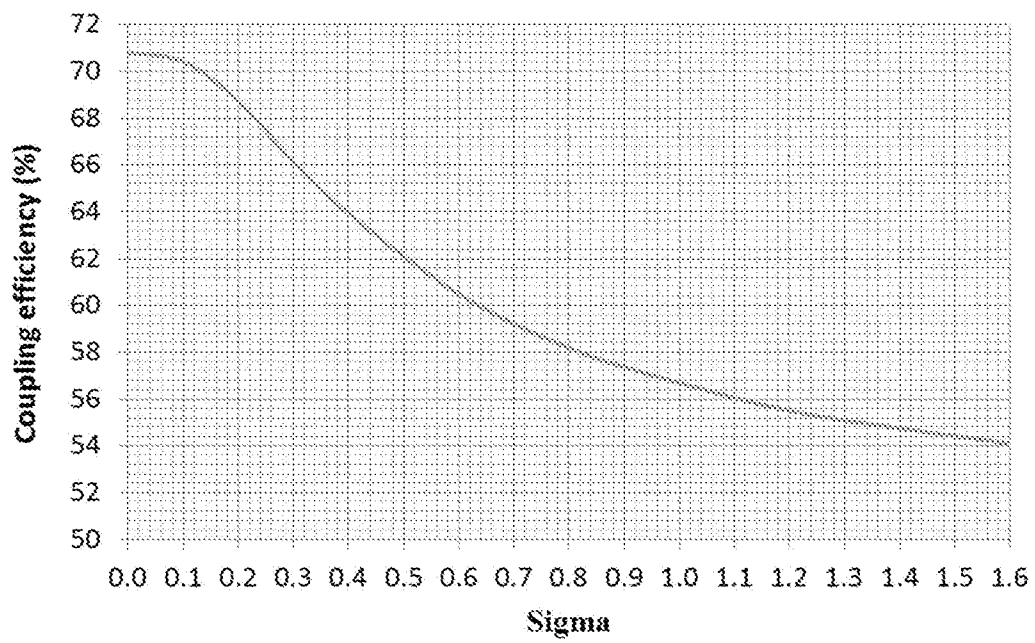


FIG. 8

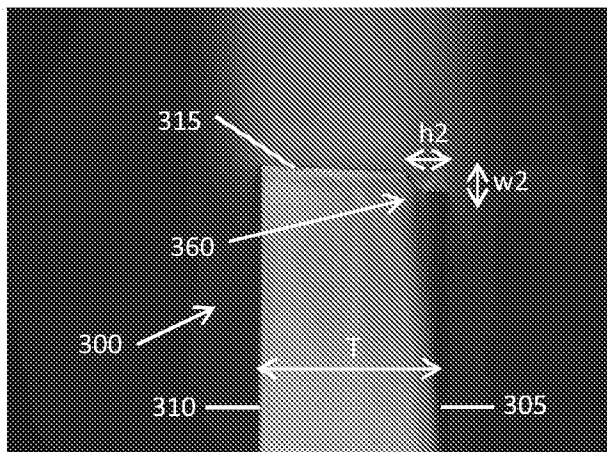


FIG. 9A

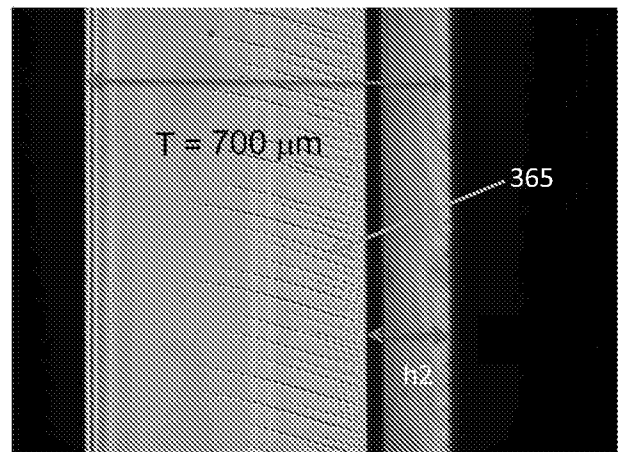


FIG. 9B

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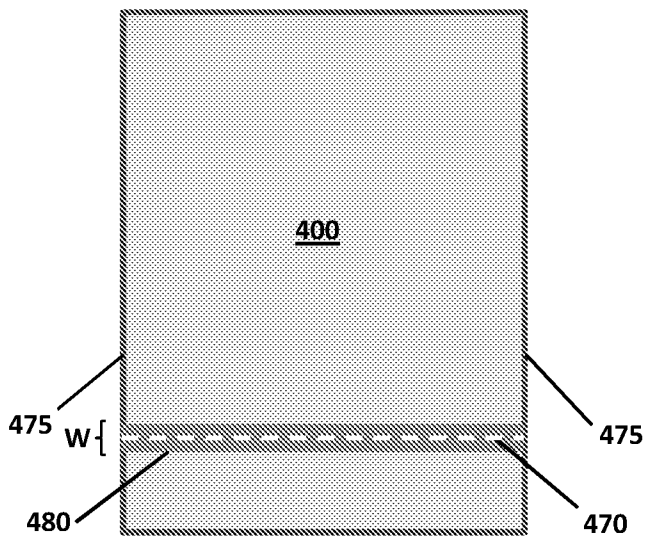


FIG. 10A

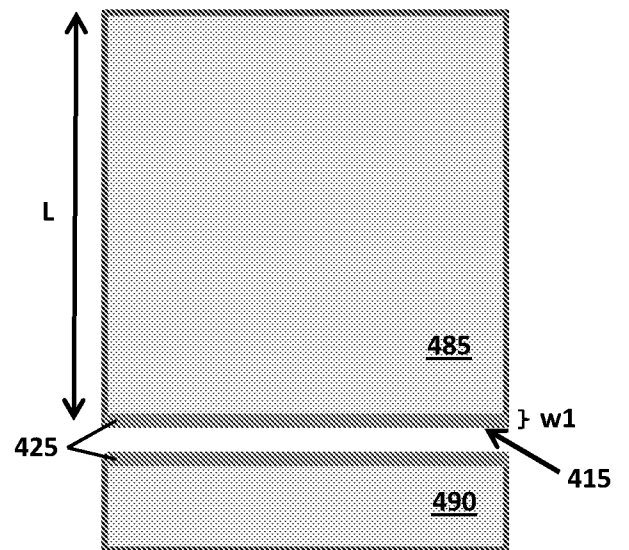


FIG. 10B

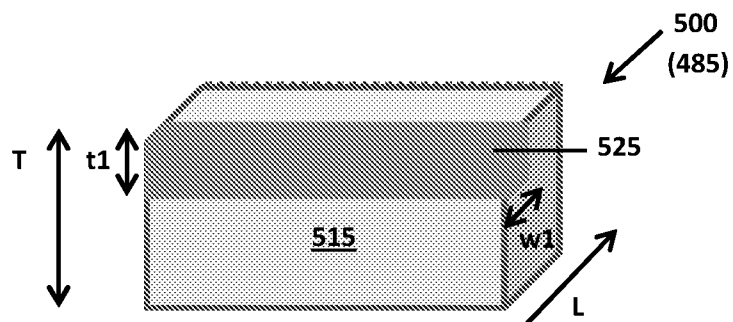


FIG. 10C

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2016/031961

A. CLASSIFICATION OF SUBJECT MATTER
INV. C03B33/02 B23K26/00 C03B33/09 B23K26/53 B23K26/0622
ADD. B23K103/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
C03B B23K

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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X	US 2007/090100 A1 (YONAI TOSHIFUMI [JP] ET AL) 26 April 2007 (2007-04-26) figures 1,2,8 -----	1-33
X	US 2013/068736 A1 (MIELKE MICHAEL [US] ET AL) 21 March 2013 (2013-03-21) paragraph [0036] - paragraph [0040]; figures 3,4A,5 -----	1-33
X	US 2013/192305 A1 (BLACK MATTHEW L [US] ET AL) 1 August 2013 (2013-08-01) figures 9A,9B ----- -/-	1-33



Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

23 August 2016

Date of mailing of the international search report

30/08/2016

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Marrec, Patrick

INTERNATIONAL SEARCH REPORT

International application No

PCT/US2016/031961

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
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