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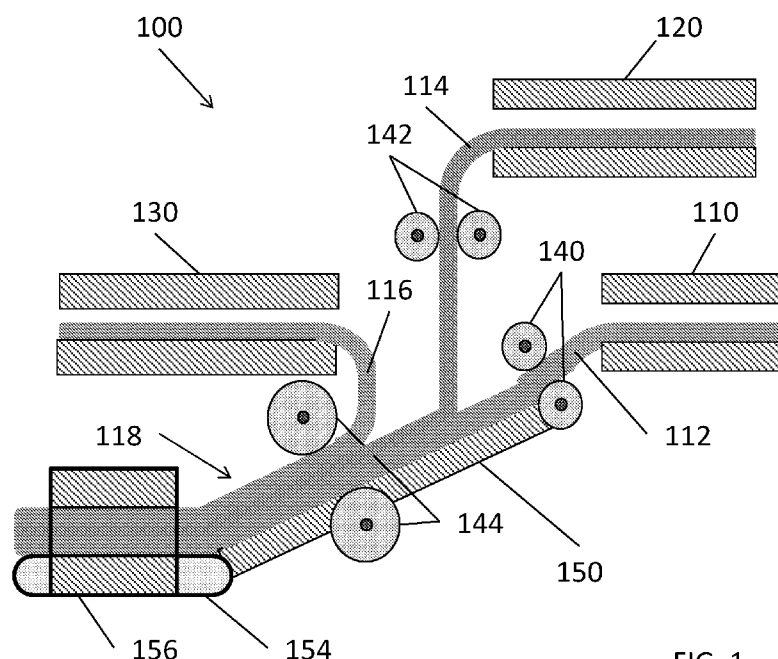


FIG. 1

(57) Abstract: A glass lamination method and system including: a first glass source configured to provide a first ribbon of a glass material; a second glass source configured to provide a second ribbon of a glass material, such that the second ribbon is disposed on the first ribbon; a third glass source configured to provide a third ribbon of a glass material, such that the third ribbon is disposed on the second ribbon, and the second ribbon is layered between the first and third ribbons; and fusion rollers configured to apply pressure to the layered first, second, and third ribbons, such that the first, second, and third ribbons are fused to form a glass laminate. At least two of the first, second, and third ribbons may be provided in a molten state.

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GLASS LAMINATION SYSTEM AND METHOD

BACKGROUND

[0001] This application claims the benefit of priority to U.S. Application No. 62/331761, filed May 4, 2016, the content of which is incorporated herein by reference in its entirety.

Field

[0002] This disclosure relates to glass lamination systems and methods for forming laminated glass articles, and more particularly, to methods of producing continuously-rolled, high-strength, laminate glass articles.

Technical Background

[0003] Currently, strengthened, laminated glass may be produced through a fusion draw process, an ion exchange process, a tempering process, or a combination thereof, to create strong, thin, glass. However, fusion draw processed glass is generally limited to a thickness of 2 mm or less, which may prevent the glass from being used in applications where greater thicknesses are desirable, such as in windows, fire doors, etc. In addition, such fusion draw processes may require costly equipment.

[0004] Non-laminated glasses generally require post processing to increase the strength thereof. In addition, heating may reduce the strength of thermally tempered glasses.

[0005] As such, there remains a need for improved processes for forming high-strength laminated glass articles.

SUMMARY

[0006] Disclosed herein are systems and methods for producing strengthened laminated glass articles.

[0007] According to various embodiments, provided are glass lamination systems comprising: a first glass source configured to provide a first ribbon of a glass material; a

second glass source configured to provide and layer a second ribbon of a glass material on the first ribbon; and a third glass source configured to provide and layer a third ribbon of a glass material on the second ribbon, such that the second ribbon is disposed between the first and third ribbons; and fusion rollers configured to apply pressure to the layered first, second, and third ribbons such that the first, second, and third ribbons are fused to form a glass laminate. At least two of the first, second, and third ribbons may, in various embodiments, be provided in a molten state.

[0008] layering first, second, and third ribbons, such that the second ribbon is disposed between the first and third ribbons, the first, second, and third ribbons each comprising a glass material, at least two of the first, second, and third ribbons having a molten state during the layering; applying pressure to the layered first, second, and third ribbons, such that the first, second, and third ribbons are fused by the pressure to form a glass laminate; annealing the glass laminate; and cutting the cooled glass laminate to form a glass article.

[0009] Additional features and advantages 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 embodiments as described herein, including the detailed description which follows, the claims, as well as the appended drawings.

[0010] It is to be understood that both the foregoing general description and the following detailed description are merely exemplary, and are intended to provide an overview or framework to understanding the nature and character of the claims. The accompanying drawings are included to provide a further understanding, and are incorporated in and constitute a part of this specification. The drawings illustrate one or more embodiment(s), and together with the description serve to explain principles and operation of the various embodiments.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] FIG. 1 is a cross-sectional view of an exemplary system for producing a glass laminate, according to various embodiments of the present disclosure.

[0012] FIG. 2 is a cross-sectional view of an exemplary system for producing a glass laminate, according to various embodiments of the present disclosure.

[0013] FIG. 3 is a cross-sectional view of an exemplary system for producing a glass laminate, according to various embodiments of the present disclosure.

[0014] FIG. 4 is a cross-sectional view of an exemplary system for producing a glass laminate, according to various embodiments of the present disclosure.

[0015] FIG. 5 is a block diagram illustrating an exemplary method of forming a glass laminate, according to various embodiments of the present disclosure.

[0016] FIG. 6 is a sectional view of an exemplary glass laminate according to various embodiments of the present disclosure.

DETAILED DESCRIPTION

[0017] Reference will now be made in detail to exemplary embodiments which are illustrated in the accompanying drawings. Whenever possible, the same reference numerals will be used throughout the drawings to refer to the same or like parts. The components in the drawings are not necessarily to scale, emphasis instead being placed upon illustrating the principles of the exemplary embodiments.

[0018] As used herein, the term “about” means that amounts, sizes, formulations, parameters, and other quantities and characteristics are not and need not be exact, but may be approximate and/or larger or smaller, as desired, reflecting tolerances, conversion factors, rounding off, measurement error and the like, and other factors known to those of skill in the art. In general, an amount, size, formulation, parameter or other quantity or characteristic is “about” or “approximate” whether or not expressly stated to be such.

[0019] The term “or”, as used herein, is inclusive; that is, the phrase “A or B” means “A, B, or both A and B”. In addition, the ranges set forth herein include their endpoints unless expressly stated otherwise. Further, when an amount, concentration, or other value or parameter is given as a range, one or more preferred ranges or a list of upper preferable values and lower preferable values, this is to be understood as specifically disclosing all ranges formed from any pair of any upper range limit or preferred value

and any lower range limit or preferred value, regardless of whether such pairs are separately described. The scope of the invention is not limited to the specific values recited when defining a range.

[0020] Herein, the terms “clad” and “core” are relative.

[0021] In various embodiments, a glass article comprises at least a first layer and a second layer. For example, the first layer comprises a core layer, and the second layer comprises one or more cladding layers adjacent to the core layer. The first layer and/or the second layer are glass layers comprising a glass, a glass-ceramic, or a combination thereof. In some embodiments, the first layer and/or the second layer are transparent glass layers. In some embodiments, the first layer and/or the second layer comprise opal glass that is translucent or opaque. The glass article can comprise a glass sheet or a shaped glass article comprising a suitable 3-dimensional (3D) shape. In some embodiments, an average coefficient of thermal expansion (CTE) of the first layer is greater than an average CTE of the second layer(s). Such a CTE mismatch can aid in strengthening the glass article.

[0022] **FIG. 1** is a sectional view of an exemplary glass lamination system 100, according to various embodiments of the present disclosure. Referring to **FIG. 1**, the system 100 may include multiple glass sources. For example, the system 100 may include at least a first glass source 110, a second glass source 120, and a third glass source 130. The glass sources 110, 120, 130 may be any source configured to produce glass ribbons (e.g., sheets of molten glass). For example, the glass sources 110, 120, 130 may include an overflow distributor or isopipe of a fusion draw apparatus, a slot distributor of a slot draw apparatus, a float bath, a forehearth and/or corresponding glass melting furnaces, and may include heating elements configured to maintain the glass ribbons in a liquid or viscous state. The glass sources 110, 120, 130 may, in certain embodiments, be configured to continuously form glass ribbons, so long as glass source materials are loaded in the corresponding glass melting furnaces. The system 100 may, in various embodiments, also include a support 150, a pair of first rollers 140, a pair of second rollers 142, and a pair of fusion rollers 144.

[0023] The support 150 may be any type of support configured to support glass ribbons disposed thereon, such as, for example a support plate or chute. In some

embodiments, the support 150 may include one or more rollers, and air bearing, or another suitable support mechanism to support the glass ribbon moving over the support. Optionally, in various embodiments, one of the first rollers 140 and/or one of the fusion rollers 144 may be disposed in corresponding openings formed in the support 150. The support 150 may optionally be disposed at an angle as shown to facilitate movement of the glass ribbons. However, in other embodiments, the support 150 may be oriented substantially horizontally or vertically.

[0024] The first glass source 110 may be configured to form a first ribbon 112 of glass using a molten glass material received from a glass melting furnace (not shown). In particular, the first ribbon 112 may be provided from the first glass source 110 in a molten state (e.g., at a temperature above the softening temperature of the glass material). In some embodiments, the first ribbon 112 may be used to form a cladding layer, as discussed below.

[0025] The first rollers 140 may be configured to guide or pull the first ribbon 112 onto the support 150 and towards the fusion rollers 144. The first rollers 140 may operate as nip rollers configured to control the size of the first ribbon 112, by applying a particular amount of pressure to opposing sides thereof.

[0026] The second glass source 120 may be configured to form a second ribbon 114 of glass using a molten second glass material received from a glass melting furnace (not shown). In particular, the second ribbon 114 may be provided from the second glass source 120 in a molten state. In some embodiments, the second ribbon 114 may be used to form a core layer, as discussed below.

[0027] The second rollers 142 may be configured to guide or pull the second ribbon 114, such that the second ribbon 114 is disposed on the first ribbon 112. The second rollers 142 may operate as nip rollers configured to control the size of the second ribbon 114, by applying a particular amount of pressure to opposing sides thereof.

[0028] The third glass source 130 may be configured to form a third ribbon 116 of glass using a third molten glass material received from a glass melting furnace (not shown). In various embodiments, the third ribbon 116 may be provided from the third glass source 130 in a molten state. In some embodiments, the third ribbon 116 may be used to form a cladding layer, as discussed below.

[0029] The first and third glass materials may, in various embodiments, be the same type of glass material, and may optionally be produced in the same glass melting furnace. For example, the first and third glass sources 110, 130 may be forehearths of the same glass melting furnace. In other embodiments, the first and third glass materials may be different types of glass material, and may be received from different glass melting furnaces. In certain embodiments, the first and third glass sources 110, 130 may be forehearths of different glass melting furnaces.

[0030] The fusion rollers 144 may be configured to guide or pull the third ribbon 116, such that the third ribbon 116 is disposed on the second ribbon 114. The fusion rollers 144 may operate as nip rollers to apply pressure to, and thereby fuse together, the first, second, and third ribbons 112, 114, 116 to form a glass laminate 118. The fusion rollers 144 may also operate to guide or pull the glass laminate 118 along the support 150.

[0031] The system 100 may also include a conveyor 154 and a Lehr 156. In particular, the conveyor 154 may be configured to receive the glass laminate 118 from the support 150 and convey the glass laminate 118 to the Lehr 156. The conveyor 154 may be configured to move the glass laminate 118 into and/or through the Lehr 156.

[0032] The Lehr 156 may be configured to anneal the glass laminate 118. In certain embodiments, the Lehr 156 may be configured to anneal the glass laminate 118 by slowly cooling the glass laminate 118, to prevent or reduce cracking thereof. The anneal cooling rate may be set according to the thickness of the glass laminate 118. For example, the cooling rate can range from several tens of °C per hour for thin ribbons, to a fraction of a °C per hour for thick ribbons.

[0033] After annealing, the glass laminate 118 may exit the Lehr 156, optionally to be cut and finished. For example, the glass laminate 118 can be cut using any suitable technique such as, for example, scoring, bending, thermally shocking, and/or laser cutting. However, according to some embodiments, the glass laminate 118 may be cut into sections before being annealed.

[0034] **FIG. 2** is a sectional view of an exemplary glass lamination system 200, according to various embodiments of the present disclosure. The system 200 is similar to the system 100, so only the differences therebetween will be discussed in detail. Referring to **FIG. 2**, the system 200 includes a spool 122 around which a non-molten

flexible glass web may be wrapped or “spooled.” In various embodiments, the flexible glass web may be a core glass that is wrapped around the spool 122. The flexible glass web may be unspooled to provide the second ribbon 114.

[0035] For example, the flexible glass web may be a commercially available borosilicate glass, such as Corning® Willow® glass or the like. According to various exemplary embodiments, the second ribbon may have a thickness of less than about 300 μm , for example ranging from about 25 μm to about 300 μm , such as from about 150 μm to about 250 μm . The second ribbon 114 may be guided onto the first ribbon 112 by the second rollers 142, such that the second ribbon 114 is disposed on or between the first and/or third ribbons 112, 116.

[0036] In at least certain exemplary embodiments, the use of a non-molten flexible glass web may provide for improved dimensional control of the glass laminate 118. In particular, such a flexible glass web may have a consistent thickness, width, and/or length. In addition, the second rollers 142 may operate as guide rollers, since the second ribbon 114 formed from the spooled glass material may not require thickness control. The heat from the first and third ribbons 112, 116, in conjunction with the relatively small thickness of the spooled glass, may be sufficient to heat the second ribbon 114 to a temperature at which the ribbons 112, 114, 116 fuse and form the glass laminate 118. However, in some embodiments, the system 200 may optionally include an additional heat source 147 to pre-heat the second ribbon 114 before the second ribbon 114 is disposed on or between the first and/or third ribbons 112, 116.

[0037] **FIG. 3** is a sectional view of an exemplary glass lamination system 300, according to various embodiments of the present disclosure. The system 300 is similar to the system 100, so only the differences therebetween will be discussed in detail. Referring to **FIG. 3**, the system 300 includes a pair of third rollers 146 configured to guide or pull the third ribbon 116 from the third glass source 130. In particular, the third rollers 146 may operate as nip rollers configured to control the thickness of the third ribbon 116 by applying pressure thereto.

[0038] Accordingly, the system 300 may be configured to independently control the thickness of each of the ribbons 112, 114, 116, by controlling an amount of pressure applied by thereto by the corresponding rollers 140, 142, 146. In addition, the system

300 may also control the thickness of the glass laminate 118, by controlling the amount of pressure applied thereto by the fusion rollers 144.

[0039] According to various embodiments of the disclosure, the third rollers 146 may be applied to any of the systems described herein. For example, the systems 100 and 200 may also optionally include the third rollers 146.

[0040] **FIG. 4** is a sectional view of an exemplary glass lamination system 400, according to various embodiments of the present disclosure. The system 400 is similar to the system 200, so only the differences therebetween will be discussed in detail. Referring to **FIG. 4**, the system 400 includes a pair of fourth rollers 148 disposed between the fusion rollers 144 and the conveyor 154. The fourth rollers 148 may be configured to pattern one or both sides of the glass laminate 118. For example, either or both of the fourth rollers 148 may be an embossed roller configured to pattern a surface of the glass laminate 118. For example, an embossed roller may have a patterned or textured surface, such as a sand-blasted, ridged, or knurled surface, that is configured to impart corresponding features to all or a portion of a surface of the glass laminate 118, when rolled against the glass laminate 118. In some embodiments, one embossed fourth roller 148 may be used alone or in conjunction with a flat roller, in order to pattern one side of the glass laminate 118. For example, one fourth roller 148 may be configured to press the glass laminate 118 against the support 150.

[0041] However, according to other exemplary embodiments, one or more of the fusion rollers 144 may be embossed in order to pattern the glass laminate 118. As such, the glass laminate 118 may be patterned without the use of the optional fourth rollers 148.

[0042] **FIG. 5** is a block diagram illustrating an exemplary method of producing a glass article, which may be performed using one of the above systems, according to various embodiments of the present disclosure. Referring to **FIGS. 1-5**, in step 500, the method may include forming or providing ribbons of at least two different glass materials. In various embodiments, the ribbons may be formed by flowing molten glass materials from corresponding glass material sources, such that molten ribbons are formed from at least two different glass materials. For example, three molten ribbons may be formed from three different molten glass materials. In the alternative, first and third ribbons may be formed from a first molten glass material, and a second ribbon may be formed from a

different second molten glass material. If the ribbons are in a molten state, the ribbons may be supplied continuously as long as glass materials for forming the ribbons are replenished in corresponding glass melting furnaces.

[0043] In the alternative, first and third ribbons may be formed from the same or from different molten glass materials, and a second ribbon formed of a second non-molten, thin, flexible glass web (e.g., a previously formed ribbon) may be provided. For example, such a second ribbon may be unrolled from a spool containing the same.

[0044] Step 500 may also include adjusting the thickness of one or more of the ribbons. By way of non-limiting example, any or each of the molten ribbons may be fed through rollers configured to control the thicknesses thereof, by applying pressure thereto.

[0045] In step 502 of the exemplary method, the method may include layering the second ribbon on the first ribbon, and, if a third glass ribbon is present, layering the third ribbon on the second ribbon. In other words, in embodiments with three layered glass ribbons, the ribbons are layered such that the second ribbon is disposed between the first and third ribbons.

[0046] In step 504 of the exemplary method, the layered ribbons are fed through fusion rollers. The fusion rollers are configured to apply a pressure that is sufficient to fuse the ribbons to one another. As noted above, the ribbons may each be in a molten state when layered on one another. In other embodiments, at least one of the ribbons, such as the second ribbon, may be in a non-molten state when layered, and heat from the first and/or third ribbons may heat at least a portion of the second ribbon, such that the ribbons may be fused together. In certain embodiments diffusion layers may be formed at one or more interfaces of the ribbons, where glass compositions of the ribbons at least partially mix during fusion.

[0047] For example, the temperature of the ribbons during fusion may be set according to the viscosity of the glass compositions thereof. In some embodiments, the temperature of the ribbons may range between the working points and the softening points of the ribbons being fused. In various embodiments, ribbons heated to such temperatures ranging between the working point and the softening point may have a viscosity ranging from about 10^4 poise (the working point viscosity) to about $10^{7.6}$ poise (the softening point viscosity).

[0048] Step 504 of the exemplary method may further include patterning one or more surfaces of the glass laminate. For example, the glass laminate may be fed through one or more embossed rollers configured to pattern at least one surface of the glass laminate. In some embodiments, one or more of the fusion rollers may be embossed to pattern the glass laminate.

[0049] In step 506 of the exemplary method, the glass laminate is cooled. For example, the glass laminate may be disposed on a conveyor configured to move the glass laminate through alehr. As the glass laminate passes through the lehr, the glass laminate may be gradually cooled to anneal the glass laminate. Alternatively, as the glass laminate passes through the lehr, the glass laminate may be rapidly cooled to temper the glass laminate. In various embodiments, the cooling rate may be chosen based on the thickness of the glass laminate. Following the cooling process, the glass laminate (or portion thereof downstream of the cooling process) may be referred to as a cooled glass laminate.

[0050] In step 508 of the exemplary method, the cooled glass laminate may be cut or shaped to form a glass article. Any suitable cutting or shaping method may be used. For example, scoring, bending, thermally shocking, and/or laser cutting may be used to cut the glass laminate. Step 508 may also include one or more additional finishing processes. For example, the glass article may be cleaned, molded, bent, subjected to an ion exchange process, etc.

[0051] According to various embodiments steps 500-508 may occur continuously and/or simultaneously or substantially simultaneously, such that multiple glass articles may be sequentially formed from the cooled glass laminate. For example, the providing, layering, and fusion of the ribbons to form the glass laminate may continue, while a portion of the glass laminate is cooled, and while a cooled portion of the glass laminate is periodically cut to form glass articles. In other words, the method may include continuously forming glass articles and/or a glass laminate, so long as the glass material sources are provided with corresponding glass batch materials. For example, the method may include forming glass articles continuously for a time period ranging from 1 hour to several days.

[0052] It is to be understood that the method described with respect to **FIG. 5** is exemplary only. The skilled artisan will appreciate that the order of one or more steps may change, and/or one or more steps may be added or omitted.

[0053] **FIG. 6** is a cross-sectional view an exemplary laminated glass article 10 produced according to various embodiments of the present disclosure. Referring to **FIGS. 1-4** and **6** the glass article 10 may be cut from the glass laminate 118 formed by one of the presently disclosed systems and/or methods. The glass article 10 may be planar or substantially planar as shown in **FIG. 6**, or may be non-planar. In other embodiments, the glass article 10 may be a shaped glass article. For example, the glass article 10 may be molded into a particular shape.

[0054] The glass article 10 may comprise a first cladding layer 12 formed from the first ribbon 112, a core layer 14 formed from the second ribbon 114, and a second cladding layer 16 formed from the third ribbon 116. The core layer 14 may be disposed between first cladding layer 12 and second cladding layer 16. In some embodiments, the first cladding layer 12 and the second cladding layer 16 are exterior layers, as shown in **FIG. 6**. In other embodiments, the first cladding layer 12 and/or the second cladding layer 16 may be intermediate layers disposed between the core layer 14 and one or more exterior layers.

[0055] The core layer 14 comprises a first major surface and a second major surface opposite the first major surface. In some embodiments, the first cladding layer 12 is fused to the first major surface of the core layer 14. Additionally, or alternatively, the second cladding layer 16 is fused to the second major surface of core layer 14. In such embodiments, the interfaces between the first cladding layer 12 and the core layer 14 and/or between the second cladding layer 16 and the core layer 14 may be free of any bonding material such as, for example, a polymer interlayer, an adhesive, a coating layer, or any non-glass material added or configured to adhere the respective cladding layers to the core layer. Thus, the first cladding layer 12 and/or second cladding layer 16 are fused directly to the core layer 14, and/or are directly adjacent to the core layer 14.

[0056] In some embodiments, the glass article 10 comprises one or more intermediate layers disposed between the core layer and the first cladding layer and/or between the

core layer and the second cladding layer. For example, the intermediate layers may comprise intermediate glass layers and/or diffusion layers formed at the interface of the core layer and the cladding layer. The diffusion layer can comprise a blended region comprising components of each layer adjacent to the diffusion layer. Thus, two directly adjacent glass layers are fused at the diffusion layer. In some embodiments, glass article 10 comprises a glass-glass laminate (e.g., an in situ fused multilayer glass-glass laminate) in which the interfaces between directly adjacent glass layers are glass-glass interfaces.

[0057] As described above, in at least some embodiments, the core layer 14 comprises a first glass composition, and the first and/or second cladding layers 12 and 16 comprise a second glass composition that is different than the first glass composition. In this case, the first and third glass sources 110, 130 may include the same glass material or may be connected to the same glass supply. For example, the first and third glass sources 110, 130 may be forehearth of the same glass melting forge, and the second glass source 120 may be a forehearth of a separate glass melting forge.

[0058] In other embodiments, the first cladding layer 12 comprises the second glass composition, and the second cladding layer 16 comprises a third glass composition that is different than the first glass composition and/or the second glass composition. In this case, the first, second, and third glass sources 110, 120, 130 may be forehearths of different glass melting forges.

[0059] Although glass article 10 is shown to comprise three layers, other embodiments are included in this disclosure. In other embodiments, a glass article can have a determined number of layers, such as two, four, or more layers. For example, a glass article comprising two layers can be formed by omitting one of the ribbons 112, 114, 116. In further exemplary embodiments, a glass article comprising four or more layers can be formed using additional glass sources and corresponding ribbons.

[0060] In some embodiments, glass article 10 and/or the glass laminate 118 may have a thickness ranging from about 1 mm to about 80 mm, such as from about 2 mm to about 80 mm, from about 2.5 mm to about 80 mm, from about 3 mm to about 78 mm, or from about 3.2 mm to about 76.2 mm. According to at least certain embodiments, the present systems and methods may be capable of producing glass articles having a

thickness of greater than about 2 mm, which is the upper thickness limit of some conventional fusion draw processes.

[0061] In some embodiments, a ratio of a thickness of core layer 14 to a thickness of glass article 10 is at least about 0.7, at least about 0.8, at least about 0.85, at least about 0.9, or at least about 0.95. In some embodiments, a thickness of the second layer (e.g., each of first cladding layer 12 and second cladding layer 16) is from about 0.01 mm to about 0.3 mm.

[0062] In some embodiments, one or both of the first cladding layer 12 and the second cladding layer 16 may be thinner than the core layer 14. In some of such embodiments, the first cladding layer 12 and/or the second cladding layer 16 may comprise a tinting agent such that the respective cladding layer comprises the tinted layer.

[0063] In some embodiments, glass article 10 is configured as a strengthened glass article. For example, in some embodiments, the glass composition of the first and/or second cladding layers 12 and 16 comprises a different average coefficient of thermal expansion (CTE) than the glass composition of core layer 14. For example, first and second cladding layers 12 and 16 may be formed from a glass composition having a lower average CTE than core layer 14. The CTE mismatch (i.e., the difference between the average CTE of first and second cladding layers 12 and 16 and the average CTE of core layer 14) may result in formation of compressive stress in the cladding layers and tensile stress in the core layer upon cooling of glass article 10. Such strengthening can be achieved without subjecting the glass article to a thermal strengthening (e.g., tempering) or chemical strengthening (e.g., ion exchange) process. Thus, strengthening the glass article 10 by CTE mismatch as described herein can enable the use of tinting agents that are incompatible with thermal strengthening and/or chemical strengthening processes. In various embodiments, each of the first and second cladding layers, independently, can have a higher average CTE, a lower average CTE, or substantially the same average CTE as the core layer.

[0064] In some embodiments, the average CTE of core layer 14 and the average CTE of first and/or second cladding layers 12 and 16 differ by at least about $5 \times 10^{-7} \text{ } ^\circ\text{C}^{-1}$, at least about $15 \times 10^{-7} \text{ } ^\circ\text{C}^{-1}$, at least about $25 \times 10^{-7} \text{ } ^\circ\text{C}^{-1}$, or at least about $30 \times 10^{-7} \text{ } ^\circ\text{C}^{-1}$. Additionally, or alternatively, the average CTE of core layer 14 and the average CTE of

first and/or second cladding layers 12 and 16 differ by at most about $100 \times 10^{-7} \text{ }^{\circ}\text{C}^{-1}$, at most about $75 \times 10^{-7} \text{ }^{\circ}\text{C}^{-1}$, at most about $50 \times 10^{-7} \text{ }^{\circ}\text{C}^{-1}$, at most about $40 \times 10^{-7} \text{ }^{\circ}\text{C}^{-1}$, at most about $30 \times 10^{-7} \text{ }^{\circ}\text{C}^{-1}$, at most about $20 \times 10^{-7} \text{ }^{\circ}\text{C}^{-1}$, or at most about $10 \times 10^{-7} \text{ }^{\circ}\text{C}^{-1}$. In some embodiments, the glass composition of first and/or second cladding layers 12, 16 comprises an average CTE of at most about $66 \times 10^{-7} \text{ }^{\circ}\text{C}^{-1}$, at most about $55 \times 10^{-7} \text{ }^{\circ}\text{C}^{-1}$, at most about $50 \times 10^{-7} \text{ }^{\circ}\text{C}^{-1}$, at most about $40 \times 10^{-7} \text{ }^{\circ}\text{C}^{-1}$, or at most about $35 \times 10^{-7} \text{ }^{\circ}\text{C}^{-1}$.

[0065] Additionally, or alternatively, the glass composition of first and/or second cladding layers 12 and 16 comprises an average CTE of at least about $25 \times 10^{-7} \text{ }^{\circ}\text{C}^{-1}$, or at least about $30 \times 10^{-7} \text{ }^{\circ}\text{C}^{-1}$. Additionally, or alternatively, the glass composition of core layer 14 comprises an average CTE of at least about $40 \times 10^{-7} \text{ }^{\circ}\text{C}^{-1}$, at least about $50 \times 10^{-7} \text{ }^{\circ}\text{C}^{-1}$, at least about $55 \times 10^{-7} \text{ }^{\circ}\text{C}^{-1}$, at least about $65 \times 10^{-7} \text{ }^{\circ}\text{C}^{-1}$, at least about $70 \times 10^{-7} \text{ }^{\circ}\text{C}^{-1}$, at least about $80 \times 10^{-7} \text{ }^{\circ}\text{C}^{-1}$, or at least about $90 \times 10^{-7} \text{ }^{\circ}\text{C}^{-1}$. Additionally, or alternatively, the glass composition of core layer 14 comprises an average CTE of at most about $110 \times 10^{-7} \text{ }^{\circ}\text{C}^{-1}$, at most about $100 \times 10^{-7} \text{ }^{\circ}\text{C}^{-1}$, at most about $90 \times 10^{-7} \text{ }^{\circ}\text{C}^{-1}$, at most about $75 \times 10^{-7} \text{ }^{\circ}\text{C}^{-1}$, or at most about $70 \times 10^{-7} \text{ }^{\circ}\text{C}^{-1}$.

[0066] In some embodiments, one or more layers of the glass article 10 comprise an ion exchangeable glass composition. For example, first cladding layer 12 and/or second cladding layer 16 may comprise an ion exchangeable glass composition such that the glass article can be further strengthened (e.g., to achieve a surface compressive stress greater than that achieved by CTE mismatch) after formation thereof. Exemplary ion exchangeable glass compositions suitable for use in the cladding layers include, but are not limited to, those described in U.S. Patent Application Pub. No. 2015/0030827, which is incorporated herein by reference in its entirety.

[0067] For example, in some embodiments, the first cladding layer 12 and/or the second cladding layer 16 may comprise an alkali metal. The core layer 14 can comprise an alkali metal or can be substantially free (e.g., comprise less than about 0.1 mol %) or free of alkali metal. Additionally, or alternatively, core layer 14 comprises an ion exchangeable glass composition such that the glass article can be further strengthened (e.g., to achieve an increased compressive stress at the core/clad interface by ion exchange between adjacent layers of the glass article and/or to achieve a surface compressive stress at an exposed portion of the core layer along an edge of the glass

article) after formation thereof. Exemplary commercially available ion exchangeable glass compositions suitable for use in the core layer include, but are not limited to, Corning® Gorilla® Glass compositions. For example, in some embodiments, the core layer comprises an alkali metal. The cladding layer can comprise an alkali metal or can be substantially free (e.g., comprise less than about 0.1 mol %) or free of alkali metal.

[0068] In various embodiments, the relative thicknesses of the glass layers can be selected to achieve a glass article having desired strength properties. For example, in some embodiments, the glass composition of core layer 14 and a glass composition of first and/or second cladding layers 12 and 16 may be selected to achieve a desired CTE mismatch, and the relative thicknesses of the glass layers may be selected, in combination with the desired CTE mismatch, to achieve a desired compressive stress in the cladding layers and tensile stress in the core layer.

[0069] Without wishing to be bound by any theory, it is believed that the strength profile of the glass article can be determined predominantly by the relative thicknesses of the glass layers and the compressive stress in the cladding layers, and that the breakage pattern of the glass article can be determined predominantly by the relative thicknesses of the glass layers and the tensile stress in the core layer. Thus, the glass compositions and relative thicknesses of the glass layers can be selected to achieve a glass article having a desired strength profile and/or breakage pattern. The glass article can have the desired strength profile and/or breakage pattern in an as-formed condition without additional processing (e.g., thermal tempering or ion-exchange treatment). For example, the as-formed glass sheet or shaped glass article can have an improved strength profile as compared to thermally tempered or ion-exchanged glass articles as described herein.

[0070] In some embodiments, the compressive stress of the cladding layers 12, 16 is at most about 800 MPa, at most about 500 MPa, at most about 350 MPa, or at most about 150 MPa. Additionally, or alternatively, the compressive stress of the cladding layers 12, 16 is at least about 10 MPa, at least about 20 MPa, at least about 30 MPa, at least about 50 MPa, or at least about 250 MPa. Additionally, or alternatively, the tensile stress of the core layer 14 is at most about 150 MPa, or at most about 100 MPa.

Additionally, or alternatively, the tensile stress of the core layer 14 is at least about 5 MPa, at least about 10 MPa, at least about 25 MPa, or at least about 50 MPa.

[0071] In some embodiments, glass article 10 may be configured as a durable glass article. For example, glass article 10 may be resistant to degradation in response to exposure to a reagent. In various embodiments, the reagent comprises an acid, a base, or a combination thereof. In some embodiments, one or both of the glass compositions of the first and/or second cladding layers 12 and 16 comprises a durable glass composition that is resistant to degradation in response to exposure to the reagent.

[0072] In some embodiments, the glass article comprises a core enveloped within a cladding. For example, core layer 14 may be enveloped within a cladding comprising first cladding layer 12 and second cladding layer 16 as shown in **FIG. 6**. In some of such embodiments, the glass composition of core layer 14 comprises a non-durable glass composition that is non-resistant to degradation in response to exposure to the reagent. The durable cladding can aid in protecting the core from exposure to the reagent. In other embodiments, the glass composition of core layer 14 comprises a durable glass composition that is resistant to degradation in response to exposure to the reagent. Thus, because the core is enveloped within the cladding, the glass composition of the core layer of the durable glass article can comprise a durable or non-durable glass composition.

[0073] In various embodiments, a glass article can be used in applications in which strength and/or chemical durability are beneficial. For example, chemical durability can be beneficial for applications in which the glass will be used outdoors (e.g., automotive glass or architectural glass) or for other applications in which the glass article is likely to come into contact with potentially corrosive reagents such as acids or bases (e.g., laboratory bench tops). Strength can be beneficial in these same applications to avoid breakage of the glass article.

[0074] The glass composition of core layer 14 and the glass composition of first and/or second cladding layers 12 and 16 can comprise suitable glass compositions capable of forming a glass article with desired properties as described herein. Exemplary glass compositions and selected properties of the exemplary glass compositions can include

those described in International Patent Application Pub. No. 2015171883, which is incorporated by reference herein in its entirety.

[0075] In various embodiments, a glass article comprises a first layer (e.g., a core layer) comprising one of the exemplary glass compositions and a second layer (e.g., one or more cladding layers) comprising another of the exemplary glass compositions. The glass composition of the first layer and/or the second layer is selected such that the glass article comprises strength and/or chemical durability properties as described herein. For example, the glass compositions of the first layer and the second layer are selected such that the glass article comprises a desired CTE mismatch. Additionally, or alternatively, the glass composition of the first layer and/or the second layer is selected such that the glass article comprises a desired chemical durability.

[0076] In some embodiments, the glass article described herein can be used as a first pane or ply in a glass-polymer laminate. For example, an exemplary glass-polymer laminate comprises at least a first pane and a second pane laminated to each other with a polymeric interlayer disposed therebetween. In some embodiments, the second pane comprises a second glass article as described herein. The first pane can have the same or a different configuration than the second pane. In exemplary embodiments of the glass-polymer laminate, the first pane may comprise a single-layer glass sheet (e.g., an annealed glass sheet, a thermally strengthened glass sheet, or a chemically strengthened glass sheet) or a polymeric sheet (e.g., a polycarbonate sheet). The interlayer of the glass-polymer laminate may comprise poly vinyl butyral (PVB) or another suitable polymeric material between the first and second panes.

[0077] The glass articles described herein can be used for a variety of applications including, for example, for cover glass or glass backplane applications in consumer or commercial electronic devices including, for example, LCD, LED, microLED, OLED, and quantum dot displays, computer monitors, and automated teller machines (ATMs); for touch screen or touch sensor applications, for portable electronic devices including, for example, mobile telephones, personal media players, and tablet computers; for integrated circuit applications including, for example, semiconductor wafers; for photovoltaic applications; for architectural glass applications; for automotive or vehicular glass applications including, for example, glazing and displays; for commercial or

household appliance applications; for lighting or signage (e.g., static or dynamic signage) applications; or for transportation applications including, for example, rail and aerospace applications.

[0078] According to various embodiments, the present systems and methods provide substantial advantages over conventional systems and methods of forming strengthened glasses, such as fusion draw, lamination, and/or tempering processes. For example, the present systems and methods may have lower capital costs and may not require post process tempering. Further, the present systems and methods may provide glass articles having thicknesses greater than 2 mm, and that are more resistant to heat degradation than tempered articles. In addition, glass articles may be cut from a glass laminate that is provided continuously, thereby improving production efficiency.

[0079] It will be apparent to those skilled in the art that various modifications and variations can be made without departing from the spirit or scope of the invention. Accordingly, the invention is not to be restricted except in light of the attached claims and their equivalents.

What is claimed is:

1. A system comprising:
 - a first glass source configured to provide a first ribbon of a glass material;
 - a second glass source configured to provide a second ribbon of a glass material to be layered on the first ribbon;
 - a third glass source configured to provide a third ribbon of a glass material to be layered on the second ribbon such that the second ribbon is disposed between the first ribbon and the third ribbon; and
 - first and second fusion rollers configured to apply pressure to the layered first, second, and third ribbons, such that the first, second, and third ribbons are fused to form a glass laminate,
 - wherein at least two of the first, second, or third ribbons are provided by the respective first, second, or third glass sources in a molten state.
2. The system of claim 1, further comprising:
 - first rollers configured to pull the first ribbon from the first glass source toward the first and second fusion rollers;
 - second rollers configured to pull the second ribbon from the second glass source toward the first ribbon; and
 - third rollers configured to pull the third ribbon from the third glass source toward the second ribbon.
3. The system of claim 2, wherein the first, second, and third rollers are configured to control respective thicknesses of the first, second, and third ribbons.
4. The system of any of claims 1 to 3, further comprising a support configured to support the first, second, and third ribbons.
5. The system of claim 4, wherein at least one of the first or second fusion rollers is disposed in an opening formed in the support.

6. The system of any of claims 1 to 5, further comprising one or more embossed rollers configured to pattern one or more surfaces of the glass laminate.

7. The system of any of claims 1 to 6, wherein:

the first and third glass sources comprise forehearth of a first glass melting furnace configured to deliver a first glass material used to form the first and third ribbons; and

the second glass source comprises a forehearth of a second glass melting furnace configured to deliver a different second glass material used to form the second ribbon.

8. The system of any of claims 1 to 6, wherein:

the first glass source comprises a forehearth of a first glass melting furnace configured to deliver a first glass material used to form the first ribbon;

the second glass source comprises a forehearth of a second glass melting furnace configured to deliver a second glass material used to form the second ribbon;

the third glass source comprises a forehearth of a third glass melting furnace configured to deliver a third glass material used to form the third ribbon; and

the first, second, and third glass materials have different compositions from one another.

9. The system of any of claims 1 to 8, further comprising:

a Lehr configured to cool the glass laminate; and

a conveyor configured to move the glass laminate through the Lehr.

10. The system of claim 9, further comprising a support configured to support the first, second, and third ribbons, and guide the glass laminate toward the conveyor.

11. The system of any of claims 1 to 10, wherein:

the first and third glass sources are respectively configured to provide the first and third ribbons in a molten state; and

the second glass source is configured to provide the second ribbon in a non-molten state.

12. The system of claim 11, wherein:

the second ribbon comprises a flexible glass web; and

the second glass source comprises a spool around which the flexible glass web is wound in a non-molten state.

13. The system of any of claims 1 to 12, wherein the glass laminate comprises:

a first cladding layer formed from the first ribbon;

a second cladding layer formed from the third ribbon; and

a core layer formed from the second ribbon and disposed between the first and second cladding layers.

14. The system of any of claims 1 to 13, wherein the first and second fusion rollers are configured to fuse the first and third ribbons directly to opposing surfaces of the second ribbon.

15. A method of forming a glass article, the method comprising:

layering first, second, and third ribbons, such that the second ribbon is disposed between the first and third ribbons, the first, second, and third ribbons each comprising a glass material, at least two of the first, second, or third ribbons in a molten state during the layering;

applying pressure to the layered first, second, and third ribbons such that the first, second, and third ribbons are fused together to form a glass laminate;

cooling the glass laminate; and

cutting the cooled glass laminate to form the glass article.

16. The method of claim 15, wherein each of the first, second, and third ribbons is in a molten state during the layering.

17. The method of claim 15 or claim 16, further comprising feeding at least two of the first, second, or third ribbons through rollers configured to adjust the thicknesses thereof, prior to the layering.

18. The method of any of claims 15 to 17, wherein the layering comprises:
layering the second ribbon on the first ribbon while the first ribbon is in a molten state and the second ribbon is in a non-molten state; and
layering the third ribbon on the second ribbon while the third ribbon is in a molten state and the second ribbon is in the non-molten state.

19. The method of any of claims 15 to 18, wherein the glass article comprises:
a first cladding layer formed from the first ribbon;
a second cladding layer formed from the third ribbon; and
a core layer formed from the second ribbon and disposed between the first and second cladding layers.

20. The method of any of claims 15 to 19, wherein the layering, applying pressure, cooling, and cutting occur substantially simultaneously.

21. The method of any of claims 15 to 19, wherein the layering, applying pressure, cooling, and cutting occur continuously such that multiple glass articles are sequentially formed from the cooled glass laminate.

22. A glass article formed by the method of any of claims 15 to 21, wherein the glass article has a thickness of greater than 2 mm.

23. A glass article comprising:
a first cladding layer formed from a first glass ribbon;
a second cladding layer formed from a third glass ribbon; and
a core layer disposed between the first cladding layer and the second cladding layer and formed from a second glass ribbon;

wherein each of the first cladding layer and the second cladding layer is fused to the core layer by applying pressure to outer surfaces of the first glass ribbon and the third glass ribbon with fusion rollers while each of the first glass ribbon and the second glass ribbon is in a molten state.

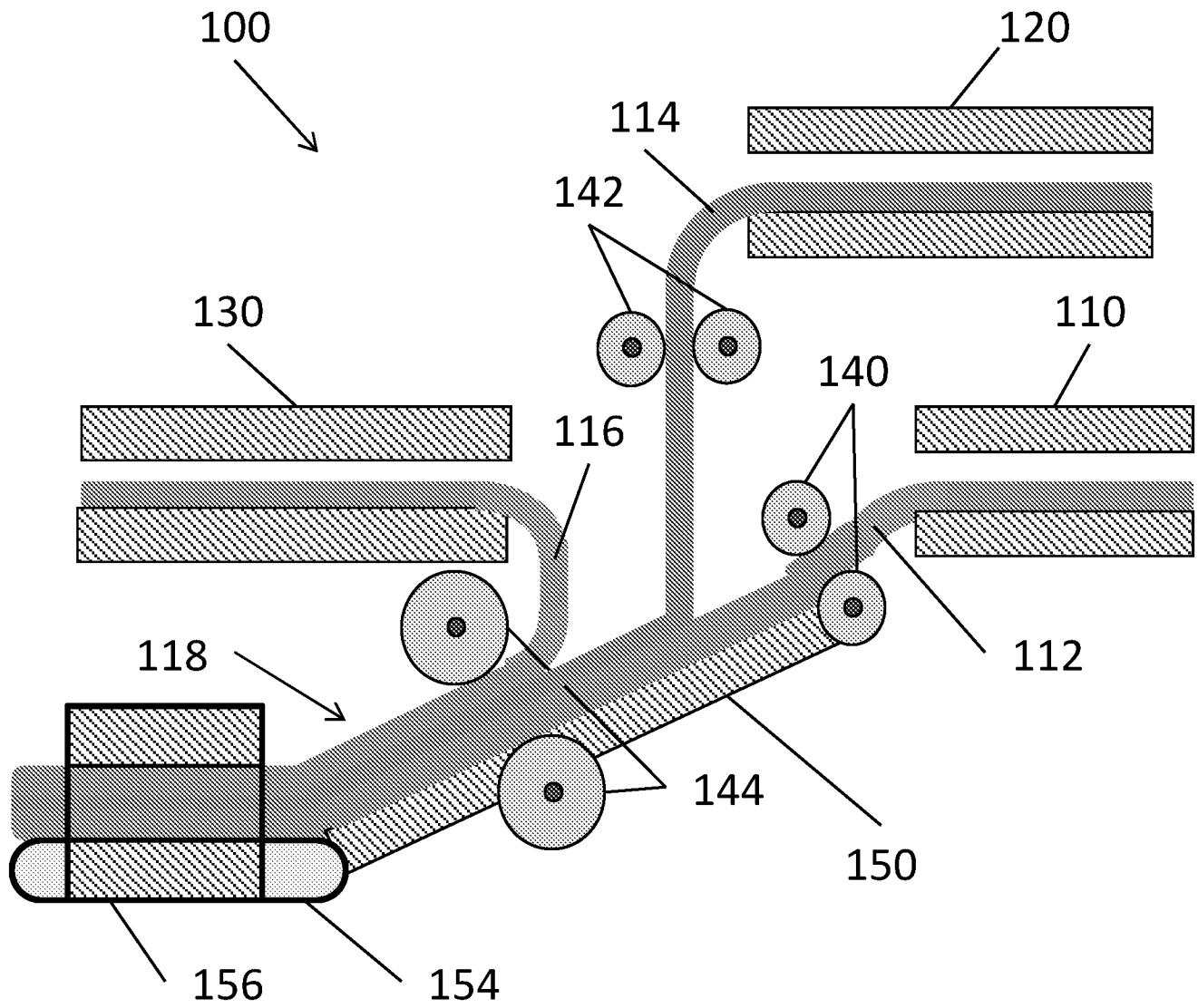


FIG. 1

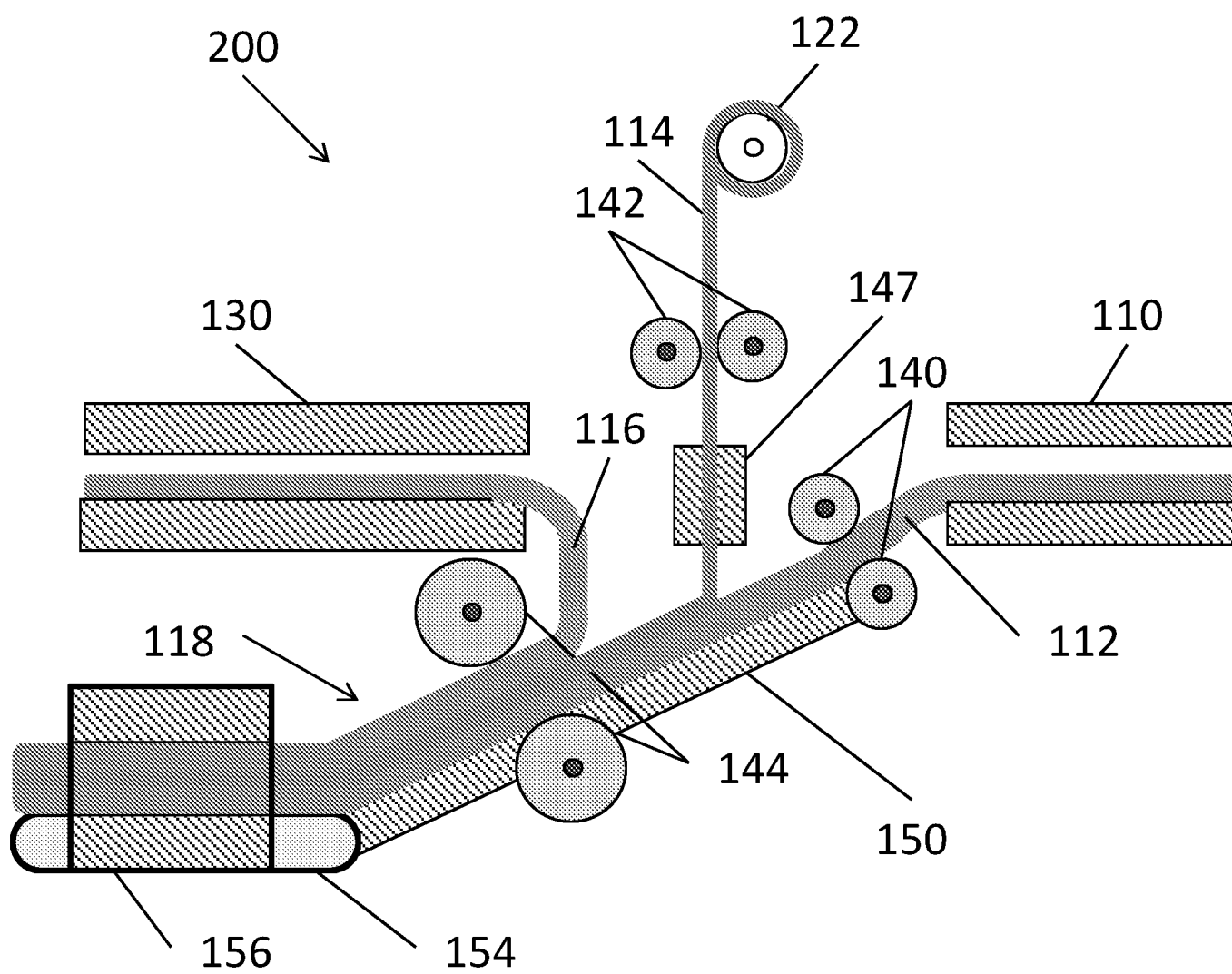


FIG. 2

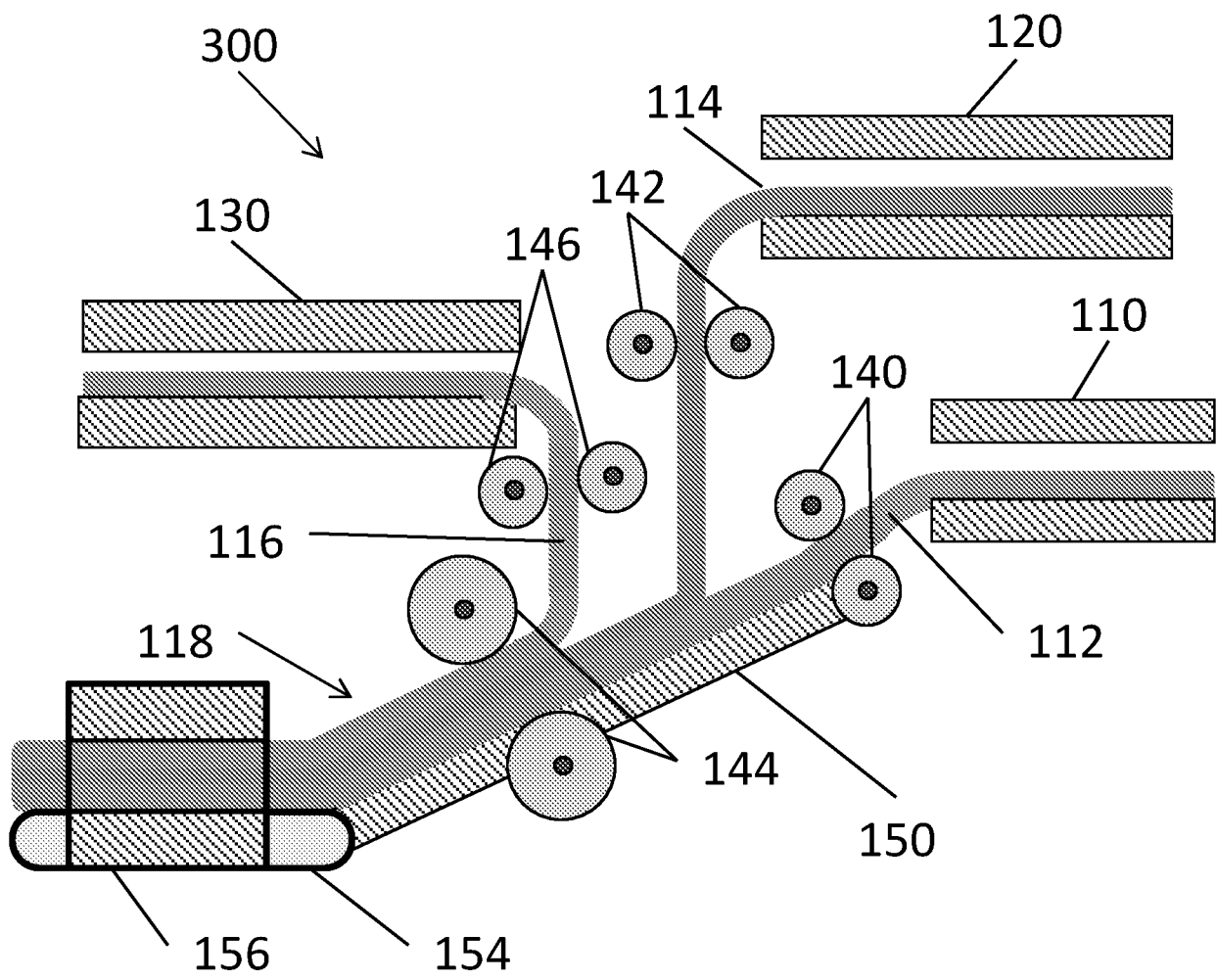


FIG. 3

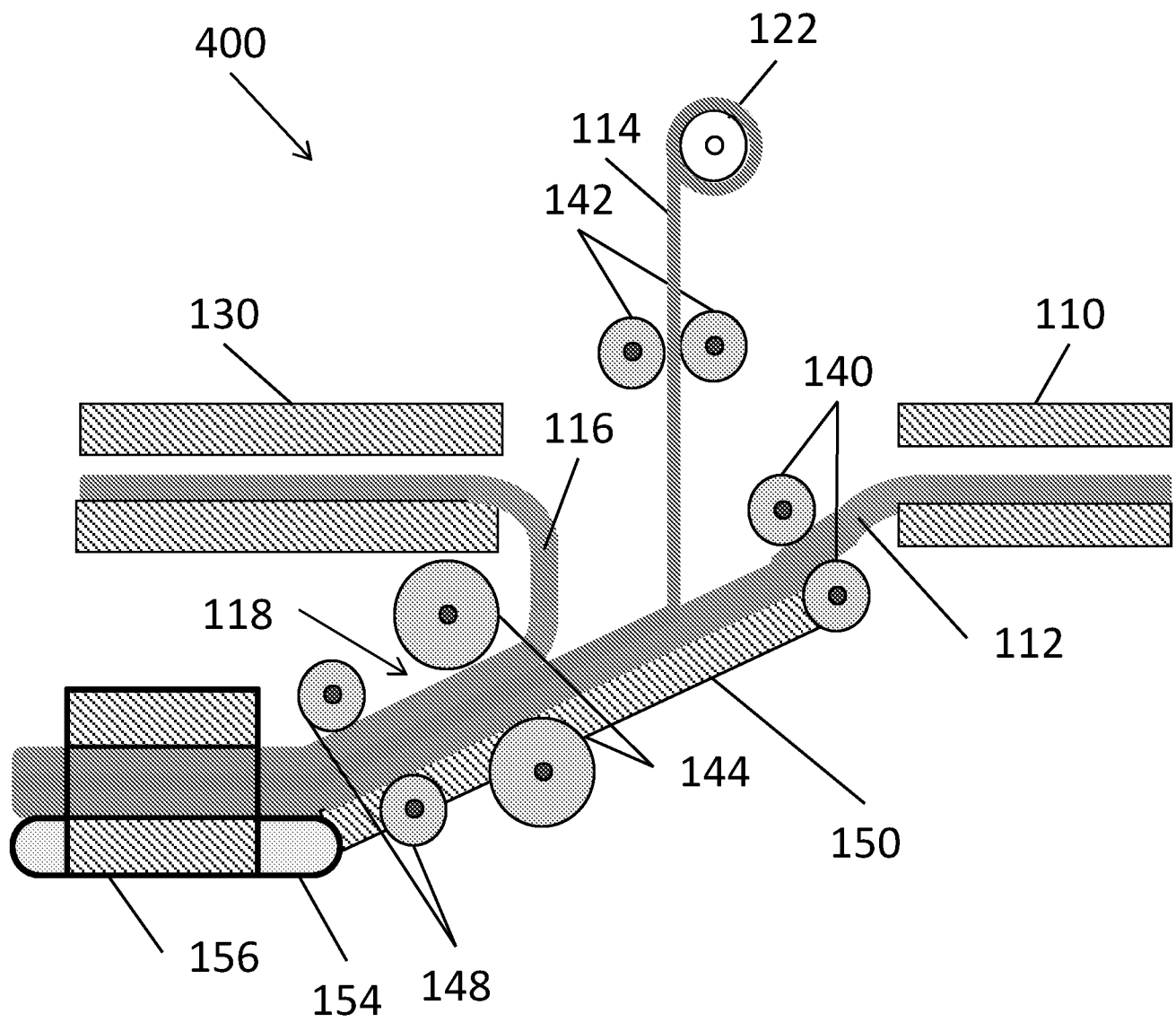


FIG. 4

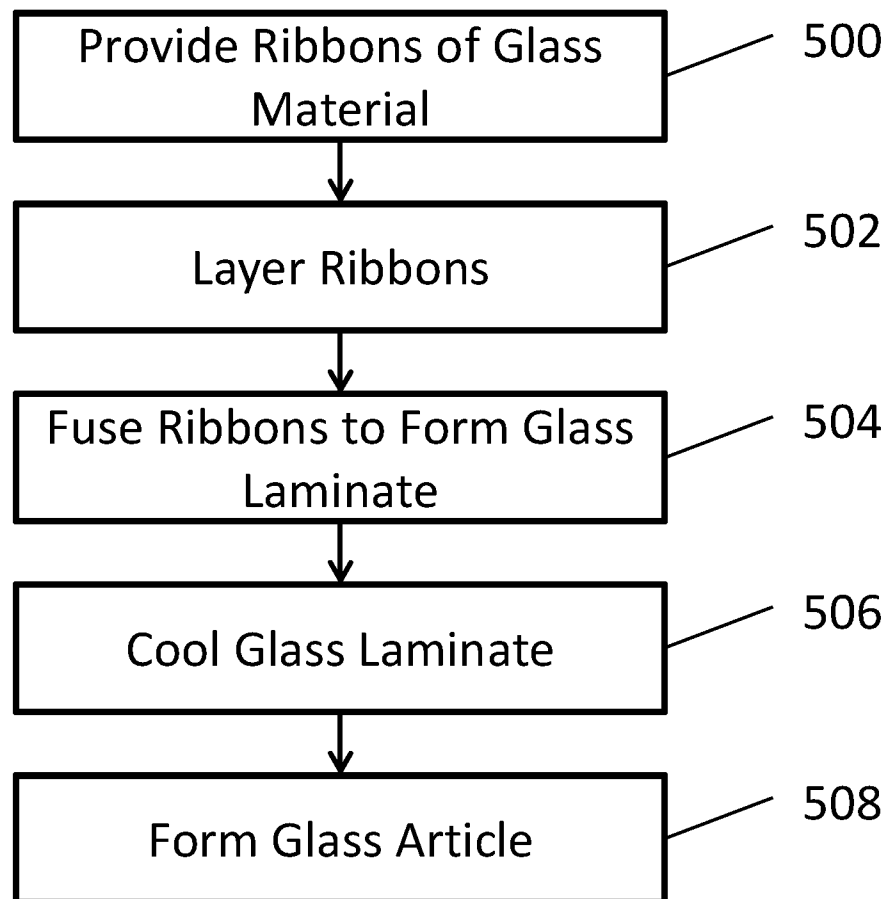


FIG. 5

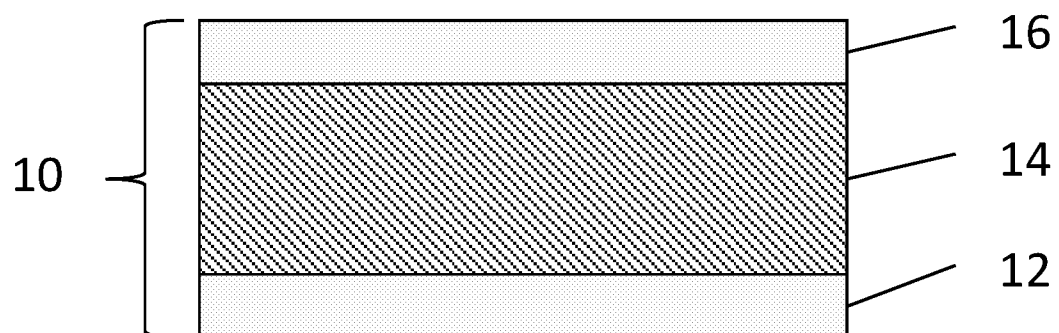


FIG. 6

INTERNATIONAL SEARCH REPORT

International application No

PCT/US2017/030959

A. CLASSIFICATION OF SUBJECT MATTER

INV. C03B17/02 C03B17/06
ADD.

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

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, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2004/197575 A1 (BOCKO PETER L [US] ET AL) 7 October 2004 (2004-10-07)	1,6,9, 10,15, 16, 18-21,23
Y	70b,170,164a,164,70,140,256,258,250; paragraphs [0088], [0083], [0061] - [0063]; figures 11,20,9A,3,5 -----	7,11,12
X	US 2006/127679 A1 (GULATI SURESH T [US] ET AL) 15 June 2006 (2006-06-15) paragraphs [0079], [0080], [0074], [0058]; claim 10; figures 5-6 -----	1,7,8, 22,23
Y	US 1 748 587 A (SMEDLEY ANDERSON B) 25 February 1930 (1930-02-25) figure 3 ----- -/-	11,12



Further documents are listed in the continuation of Box C.



See patent family annex.

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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

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"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

18 August 2017

Date of mailing of the international search report

25/08/2017

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Gkerou, Elisavet

INTERNATIONAL SEARCH REPORT

International application No

PCT/US2017/030959

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 1 563 584 A (O'SHAUGHNESSY THOMAS A) 1 December 1925 (1925-12-01) figure 1 -----	1,11, 13-15, 17-19
Y	WO 2015/048726 A1 (CORNING INC [US]) 2 April 2015 (2015-04-02) figure 1A -----	7
X	US 972 433 A (BLACKMORE LAWRENCE R [US]) 11 October 1910 (1910-10-11) figure 2 -----	1-5
X	WO 97/09278 A1 (CORNING INC [US]; PRASSAS MICHEL [FR]; KERDONCUFF ALAIN [FR]; GILLE CL) 13 March 1997 (1997-03-13) FIGURES -----	1
A	US 1 108 205 A (MEYERCORD GEORGE R [US]) 25 August 1914 (1914-08-25) FIGURES -----	1-23

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2017/030959

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2004197575	A1	07-10-2004	CN 1780797 A 31-05-2006
			EP 1618075 A2 25-01-2006
			JP 4750692 B2 17-08-2011
			JP 5670791 B2 18-02-2015
			JP 5911543 B2 27-04-2016
			JP 2006525150 A 09-11-2006
			JP 2011136902 A 14-07-2011
			JP 2015024956 A 05-02-2015
			KR 20060016748 A 22-02-2006
			TW I324263 B 01-05-2010
			US 2004197575 A1 07-10-2004
			US 2009162545 A1 25-06-2009
			US 2012234050 A1 20-09-2012
			WO 2004094321 A2 04-11-2004
US 2006127679	A1	15-06-2006	CN 101076447 A 21-11-2007
			EP 1836274 A2 26-09-2007
			EP 2444246 A1 25-04-2012
			JP 5649267 B2 07-01-2015
			JP 5820039 B2 24-11-2015
			JP 2008522950 A 03-07-2008
			JP 2015078115 A 23-04-2015
			KR 20070087650 A 28-08-2007
			TW I284091 B 21-07-2007
			US 2006127679 A1 15-06-2006
			WO 2006065657 A2 22-06-2006
US 1748587	A	25-02-1930	NONE
US 1563584	A	01-12-1925	NONE
WO 2015048726	A1	02-04-2015	CN 105593176 A 18-05-2016
			JP 2016536238 A 24-11-2016
			KR 20160063355 A 03-06-2016
			TW 201518080 A 16-05-2015
			US 2016229729 A1 11-08-2016
			WO 2015048726 A1 02-04-2015
US 972433	A	11-10-1910	NONE
WO 9709278	A1	13-03-1997	DE 69619682 D1 11-04-2002
			DE 69619682 T2 31-10-2002
			EP 0848688 A1 24-06-1998
			JP H11512374 A 26-10-1999
			US 6138479 A 31-10-2000
			WO 9709278 A1 13-03-1997
US 1108205	A	25-08-1914	NONE