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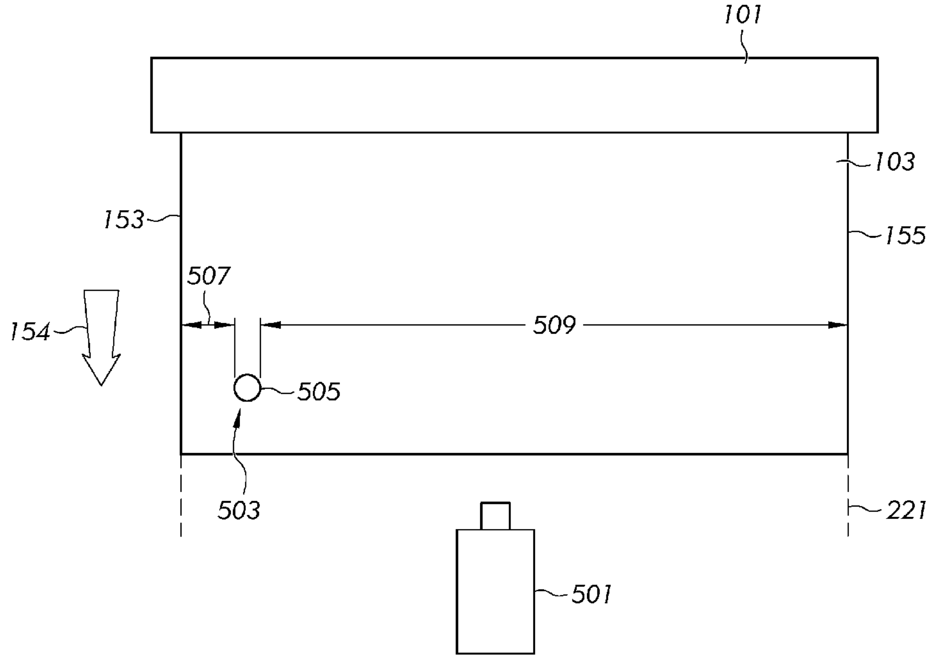
(54) **Title:** METHODS FOR MANUFACTURING A GLASS RIBBON

FIG. 5



(57) **Abstract:** Methods of manufacturing glass include determining a first location of a first region from a sample of a glass ribbon. The first region includes a first stress outside of a predetermined stress range. Methods include determining a second location of a second region from the glass ribbon based on the first location from the sample. The second region includes a second stress outside the predetermined stress range. Methods include heating the second region by irradiating the second region with a laser beam while the glass ribbon travels along a ribbon travel path such that the second region is heated from a first temperature, which is greater than or equal to a transition temperature of the glass ribbon, to a second temperature. Methods include cooling the second region from the second temperature such that the second region comprises a third stress within the predetermined stress range.

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[Continued on next page]

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METHODS FOR MANUFACTURING A GLASS RIBBON

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. 63/432753 filed on December 15, 2022, the content of which is relied upon and incorporated herein by reference in its entirety.

FIELD

[0002] The present disclosure relates generally to apparatus and methods for manufacturing a glass ribbon and, more particularly, to methods for manufacturing a glass ribbon with a laser beam.

BACKGROUND

[0003] It is known to manufacture a glass ribbon with a glass manufacturing device. Conventional forming devices are known to operate to down draw a quantity of molten material from the glass ribbon forming device as the glass ribbon. However, areas of the glass ribbon can experience stress that is outside of a predetermined stress range. Excess stress is undesirable and can reduce the quality of the glass ribbon. Further, treating the entire glass ribbon is not cost effective when only one area of the glass ribbon experiences stress that is outside of the predetermined stress range.

SUMMARY

[0004] The following presents a simplified summary of the disclosure to provide a basic understanding of some aspects described in the detailed description.

[0005] There are set forth methods of manufacturing glass with a laser beam. For example, a glass ribbon can travel along a ribbon travel path in a ribbon travel direction. One or more areas of the glass ribbon can comprise a stress that is outside of a desired predetermined stress range. Rather than treat the entire glass ribbon to alter the stress, a laser beam can be used to locally heat the area of the glass ribbon comprising the stress that is outside of the desired predetermined stress range. Further, the laser beam can impinge upon the glass ribbon at a time when the glass ribbon is within a fusion machine and at an elevated temperature. As such, the amount of power needed to heat the area of the glass ribbon with the laser beam is limited, and the stress within the glass ribbon can be locally adjusted.

[0006] In aspects, methods of manufacturing glass can comprise determining a first location of a first region from a sample of a glass ribbon. The first region can comprise a first stress outside of a predetermined stress range. Methods can comprise determining a second location of a second region from the glass ribbon based on the first location from the sample. The second region can comprise a second stress outside of the predetermined stress range. Methods can comprise heating the second region of the glass ribbon by irradiating the second region with a laser beam while the glass ribbon travels along a ribbon travel path in a ribbon travel direction such that the second region can be heated from a first temperature, which is greater than or equal to a transition temperature of the glass ribbon, to a second temperature. Methods can comprise cooling the second region from the second temperature such that the second region can comprise a third stress within the predetermined stress range.

[0007] In aspects, the second region can comprise a first viscosity prior to heating with the laser beam and a second viscosity after heating with the laser beam, and a difference between the first viscosity and the second viscosity can be less than about 1×10^{12} poise.

[0008] In aspects, a difference between the first temperature and the second temperature can be less than about 10° C.

[0009] In aspects, the second region can comprise a first fictive temperature prior to heating with the laser beam and a second fictive temperature after heating with the laser beam. The second fictive temperature can be different than the first fictive temperature.

[0010] In aspects, determining the first location can comprise measuring one or more of a first distance between the first region and a first edge of the sample or a second distance between the first region and an opposing second edge of the sample.

[0011] In aspects, determining the second location can comprise locating one or more of the first distance from a first edge of the glass ribbon or the second distance from an opposing second edge of the glass ribbon.

[0012] In aspects, heating the second region can comprise setting a wavelength of the laser beam irradiating the second region based on a difference between the second stress and the third stress.

[0013] In aspects, heating the second region can comprise setting a power of the laser beam irradiating the second region based on a difference between the second stress and the third stress.

[0014] In aspects, methods can comprise moving the laser beam relative to the glass ribbon in a first laser travel direction along the ribbon travel path in the ribbon travel direction.

[0015] In aspects, methods can comprise moving the laser beam relative to the glass ribbon in a second laser travel direction across the ribbon travel path perpendicular to the ribbon travel direction.

[0016] In aspects, methods of manufacturing glass can comprise heating a region of a glass ribbon comprising a first stress outside of a predetermined stress range by irradiating the region with a laser beam as the glass ribbon moves along a ribbon travel path in a ribbon travel direction such that the region is heated from a first temperature greater than or equal to a transition temperature of the glass ribbon to a second temperature. The region can comprise a first viscosity prior to heating with the laser beam and a second viscosity after heating with the laser beam such that a difference between the first viscosity and the second viscosity is less than about 1×10^{12} poise and a difference between the first temperature and the second temperature is less than about 10° C. Methods can comprise cooling the region from the second temperature such that the region comprises a second stress within the predetermined stress range.

[0017] In aspects, the region can comprise a first fictive temperature prior to heating with the laser beam and a second fictive temperature after heating with the laser beam. The second fictive temperature can be different than the first fictive temperature.

[0018] In aspects, heating the region can comprise setting a wavelength of the laser beam irradiating the region based on a difference between the first stress and the second stress.

[0019] In aspects, heating the region can comprise setting a power of the laser beam irradiating the region based on a difference between the first stress and the second stress.

[0020] In aspects, methods can comprise moving the laser beam relative to the glass ribbon in a first laser travel direction along the ribbon travel path in the ribbon travel direction.

[0021] In aspects, methods can comprise moving the laser beam relative to the glass ribbon in a second laser travel direction across the ribbon travel path perpendicular to the ribbon travel direction.

[0022] In aspects, methods can comprise determining a first location of a first region from a sample of the glass ribbon. The first region can comprise a first stress outside of the predetermined stress range. Determining the first location can comprise measuring one or more of a first distance between the first region and a first edge of the sample or a second distance between the first region and an opposing second edge of the sample.

[0023] In aspects, prior to heating the region, methods can comprise determining a location of the region based on the first location from the sample.

[0024] Additional features and advantages of the aspects disclosed herein will be set forth in the detailed description that follows, and in part will be clear to those skilled in the art from that description or recognized by practicing the aspects described herein, including the detailed description which follows, the claims, as well as the appended drawings. It is to be understood that both the foregoing general description and the following detailed description present aspects intended to provide an overview or framework for understanding the nature and character of the aspects disclosed herein. The accompanying drawings are included to provide further understanding and are incorporated into and constitute a part of this specification. The drawings illustrate various aspects of the disclosure, and together with the description explain the principles and operations thereof.

BRIEF DESCRIPTION OF THE DRAWINGS

[0025] These and other features, aspects and advantages are better understood when the following detailed description is read with reference to the accompanying drawings, in which:

[0026] **FIG. 1** schematically illustrates example aspects of a glass manufacturing apparatus in accordance with aspects of the disclosure;

[0027] **FIG. 2** illustrates a perspective cross-sectional view of the glass manufacturing apparatus along lines **2-2** of **FIG. 1** in accordance with aspects of the disclosure;

[0028] FIG. 3 illustrates a perspective view of a sample of a glass ribbon comprising a first region with a first stress outside of a predetermined stress range in accordance with aspects of the disclosure;

[0029] FIG. 4 illustrates a perspective view of a sample of a glass ribbon comprising a first region with a first stress outside of a predetermined stress range in accordance with aspects of the disclosure;

[0030] FIG. 5 illustrates a perspective view of the glass ribbon comprising a second region with a second stress outside of a predetermined stress range in accordance with aspects of the disclosure; and

[0031] FIG. 6 illustrates a perspective view of a laser irradiating the second region of the glass ribbon in accordance with aspects of the disclosure.

DETAILED DESCRIPTION

[0032] Aspects will now be described more fully hereinafter with reference to the accompanying drawings in which example aspects are shown. Whenever possible, the same reference numerals are used throughout the drawings to refer to the same or like parts. However, this disclosure may be embodied in many different forms and should not be construed as limited to the aspects set forth herein.

[0033] 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.

[0034] Ranges can be expressed herein as from "about" one value, and/or to "about" another value. When such a range is expressed, aspects include from the one value to the other value. Similarly, when values are expressed as approximations by use of the antecedent "about," it will be understood that the 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.

[0035] Directional terms as used herein - for example up, down, right, left, front, back, top, bottom, upper, lower, etc. - are made only with reference to the figures as drawn and are not intended to imply absolute orientation.

[0036] Unless otherwise expressly stated, it is in no way intended that any methods set forth herein be construed as requiring that its steps be performed in a specific order, nor that with any apparatus, specific orientations be required. Accordingly, where a method claim does not actually recite an order to be followed by its steps, or that any apparatus claim does not actually recite an order or orientation to individual components, or it is not otherwise specifically stated in the claims or description that the steps are to be limited to a specific order, or that a specific order or orientation to components of an apparatus is not recited, it is in no way intended that an order or orientation be inferred in any respect. This holds for any possible non-express basis for interpretation, including matters of logic relative to arrangement of steps, operational flow, order of components, or orientation of components; plain meaning derived from grammatical organization or punctuation, and; the number or type of aspects described in the specification.

[0037] As used herein, the singular forms "a," "an" and "the" include plural references unless the context clearly dictates otherwise. Thus, for example, reference to “a” component includes aspects having two or more such components, unless the context clearly indicates otherwise.

[0038] The word “exemplary,” “example,” or various forms thereof are used herein to mean serving as an example, instance, or illustration. Any aspect or design described herein as “exemplary” or as an “example” should not be construed as preferred or advantageous over other aspects or designs. Furthermore, examples are provided solely for purposes of clarity and understanding and are not meant to limit or restrict the disclosed subject matter or relevant portions of this disclosure in any manner. It can be appreciated that a myriad of additional or alternate examples of varying scope could have been presented but have been omitted for purposes of brevity.

[0039] As used herein, the terms “comprising” and “including”, and variations thereof, shall be construed as synonymous and open-ended, unless otherwise indicated. A list of elements following the transitional phrases comprising or including is a non-exclusive list, such that elements in addition to those specifically recited in the list may also be present.

[0040] The terms “substantial,” “substantially,” and variations thereof as used herein are intended to represent that a described feature is equal or approximately equal to a value or description. For example, a “substantially planar” surface is intended to denote a surface that is planar or approximately planar. Moreover, "substantially" is intended to denote that two values are equal or approximately equal. The term "substantially" may denote values within about 10% of each other, for example, within about 5% of each other, or within about 2% of each other.

[0041] Modifications may be made to the instant disclosure without departing from the scope or spirit of the claimed subject matter. Unless specified otherwise, "first," "second," or the like are not intended to imply a temporal aspect, a spatial aspect, an ordering, etc. Rather, such terms are merely used as identifiers, names, etc. for features, elements, items, etc. For example, a first end and a second end generally correspond to end A and end B or two different ends.

[0042] The present disclosure relates to a glass manufacturing apparatus and methods for producing a glass ribbon. For purposes of this application, "ribbon" may be considered one or more of a glass ribbon in a viscous state, a glass ribbon in an elastic state (e.g., at room temperature) and/or a glass ribbon in a viscoelastic state between the viscous state and the elastic state. The glass ribbon may comprise a glass ribbon of an indeterminate length or one or more separated glass articles (e.g., separated ribbons, separated sheets, etc.) that comprise multiple, e.g., four, discrete edges. Methods and apparatus for manufacturing a glass ribbon will now be described by way of example aspects. As schematically illustrated in **FIG. 1**, an exemplary glass manufacturing apparatus **100** can comprise a glass melting and delivery apparatus **102** and a forming device **101** designed to produce a glass ribbon **103** from a quantity of molten material **121**. The glass ribbon **103** can comprise a central portion **152** positioned between opposite edge portions (e.g., edge beads) formed along a first edge **153** and a second edge **155** of the glass ribbon **103**, wherein a thickness of the edge portions can be greater than a thickness of the central portion. Additionally, a separated glass ribbon **104** can be separated from the glass ribbon **103** along a separation path **151** by a glass separator **149** (e.g., scribe, score wheel, diamond tip, laser, etc.).

[0043] In aspects, the glass melting and delivery apparatus **102** can comprise a melting vessel **105** oriented to receive batch material **107** from a storage bin **109**. The batch material **107** can be introduced by a batch delivery device **111** powered by a motor **113**. An optional controller **115** can be operated to activate the motor **113** to introduce a desired amount of batch material **107** into the melting vessel **105**, as indicated by arrow **117**. The melting vessel **105** can heat the batch material **107** to provide molten material **121**. A melt probe **119** can be employed to measure a level of molten material **121** within a standpipe **123** and communicate the measured information to the controller **115** by way of a communication line **125**.

[0044] Additionally, in aspects, the glass melting and delivery apparatus **102** can comprise a first conditioning station comprising a fining vessel **127** located downstream from the melting vessel **105** and coupled to the melting vessel **105** by way of a first connecting conduit **129**. For example, molten material **121** can be gravity fed from the melting vessel **105** to the fining vessel **127** by way of an interior pathway of the first connecting conduit **129**. Additionally, bubbles can be removed from the molten material **121** within the fining vessel **127** by various techniques.

[0045] In aspects, the glass melting and delivery apparatus **102** can further comprise a second conditioning station comprising a mixing chamber **131** that can be located downstream from the fining vessel **127**. The mixing chamber **131** can be employed to provide a homogenous composition of molten material **121**, thereby reducing or eliminating inhomogeneity that may otherwise exist within the molten material **121** exiting the fining vessel **127**. As shown, the fining vessel **127** can be coupled to the mixing chamber **131** by way of a second connecting conduit **135**. For example, molten material **121** can be gravity fed from the fining vessel **127** to the mixing chamber **131** by way of an interior pathway of the second connecting conduit **135**.

[0046] Additionally, in aspects, the glass melting and delivery apparatus **102** can comprise a third conditioning station comprising a delivery chamber **133** that can be located downstream from the mixing chamber **131**. The delivery chamber **133** can condition the molten material **121** to be fed into an inlet conduit **141**. For example, the delivery chamber **133** can function as an accumulator and/or flow controller to adjust and provide a consistent flow of molten material **121** to the inlet conduit **141**. As shown, the mixing chamber **131** can be coupled to the delivery chamber **133** by way of a third connecting conduit **137**. For example, molten material **121** can be gravity fed from the mixing chamber **131** to the delivery chamber **133** by way of an interior pathway of the third connecting conduit **137**. As further illustrated, a delivery pipe **139** can be positioned to deliver molten material **121** to forming device **101**, for example the inlet conduit **141** of the forming device **101**. The forming device **101** can comprise a trough (e.g., trough **201** illustrated in **FIG. 2**) extending along a trough axis **140**

between an inlet end **142** and an opposing end **143** of the forming device **101** opposite the inlet end **142**. The inlet end **142** is the end of the trough **201** in proximity to the inlet conduit **141** through which the molten material **121** is received. The opposing end **143** is the end farthest from the inlet conduit **141**.

[0047] By way of illustration, the forming device **101** shown and disclosed below can be provided to fusion draw molten material **121** off a bottom edge, defined as a root **145**, of a forming wedge **209** to produce the glass ribbon **103**. For example, the molten material **121** can be delivered from the inlet conduit **141** to the forming device **101**. The molten material **121** can then be formed into the glass ribbon **103** based, in part, on the structure of the forming device **101**. For example, as shown, the molten material **121** can be drawn off the bottom edge (e.g., root **145)** of the forming device **101** along a draw path extending in a ribbon travel direction **154** of the glass manufacturing apparatus **100**. In aspects, edge directors **163**, **164** can direct the molten material **121** off the forming device **101** and define, in part, a width **108** of the glass ribbon **103**. The width **108** of the glass ribbon **103** extends between the first edge **153** of the glass ribbon **103** and the second edge **155** of the glass ribbon **103**.

[0048] In aspects, the width **108** of the glass ribbon **103**, which extends between the first edge **153** of the glass ribbon **103** and the second edge **155** of the glass ribbon **103**, can be greater than or equal to about 20 millimeters (mm), for example, greater than or equal to about 50 mm, for example, greater than or equal to about 100 mm, for example, greater than or equal to about 500 mm, for example, greater than or equal to about 1000 mm, for example, greater than or equal to about 2000 mm, for example, greater than or equal to about 3000 mm, for example, greater than or equal to about 4000 mm, although other widths less than or greater than the widths mentioned above can be provided in aspects. For example, the width **108** can be within a range from about 20 mm to about 4000 mm, for example, within a range from about 50 mm to about 4000 mm, for example, within a range from about 100 mm to about 4000 mm, for example, within a range from about 500 mm to about 4000 mm, for example, within a range from about 1000 mm to about 4000 mm, for example, within a range from about 2000 mm to about 4000 mm, for example, within a range from about 3000 mm to about 4000 mm, for example, within a range from about 20 mm to about 3000 mm, for example, within a range from about 50 mm to about 3000 mm, for example, within a range from about 100 mm to about 3000 mm, for example, within a range from about

500 mm to about 3000 mm, for example, within a range from about 1000 mm to about 3000 mm, for example, within a range from about 2000 mm to about 3000 mm, for example, within a range from about 2000 mm to about 2500 mm, and all ranges and subranges therebetween.

[0049] **FIG. 2** shows a cross-sectional perspective view of the forming device **101** along line **2-2** of **FIG. 1**. In aspects, the forming device **101** can comprise a trough **201** oriented to receive the molten material **121** from the inlet conduit **141**. For illustrative purposes, cross-hatching of the molten material **121** is removed from **FIG. 2** for clarity. The forming device **101** comprises a pair of weirs **203**, **204** defining an opening **224** in the trough **201**. The forming device **101** comprises a bottom surface **225**, which may be substantially planar, and may extend at least partially between the inlet end **142** and the opposing end **143** (e.g., illustrated in **FIG. 1**). The bottom surface **225** can at least partially define the trough **201**, for example, with the bottom surface **225** extending along a bottom of the trough **201** and the pair of weirs **203**, **204** extending along opposing sides of the trough **201**. The bottom surface **225** can be substantially planar and may form a right angle with the pair of weirs **203**, **204**. The bottom surface **225** can comprise opposing edges that extend along the trough axis **140**, with the opposing edges contacting the pair of weirs **203**, **204**. In aspects, the opposing edges can form a rounded shape with the pair of weirs **203**, **204**, such that the intersection between the bottom surface **225** and the pair of weirs **203**, **204** (e.g., at the opposing edges) comprises a radius of curvature. The forming device **101** can further comprise the forming wedge **209** comprising a pair of downwardly inclined converging surface portions **207**, **208** extending between opposed ends of the forming wedge **209**. The pair of downwardly inclined converging surface portions **207**, **208** of the forming wedge **209** can converge along the ribbon travel direction **154** to intersect along the root **145** (e.g., a bottom edge of the forming wedge **209** where the converging surface portions **207**, **208** meet) of the forming device **101**. A draw plane **213** of the glass manufacturing apparatus **100** can extend through the root **145** along the ribbon travel direction **154**, wherein the glass ribbon **103** can be drawn in the ribbon travel direction **154** along the draw plane **213**. As shown, the draw plane **213** can bisect the forming wedge **209** through the root **145** although, the draw plane **213** can extend at other orientations relative to the root **145**. In aspects, the glass ribbon **103** can move along a ribbon travel path **221** that may be co-planar with the draw plane **213** in the ribbon travel direction **154**.

[0050] Additionally, the molten material **121** can flow in a flow direction **156** into and along the trough **201** of the forming device **101**. The molten material **121** can then overflow from the trough **201** by flowing over corresponding weirs **203**, **204**, through the opening **224**, and downwardly over the outer surfaces **205**, **206** of the corresponding weirs **203**, **204**. Respective streams of molten material **121** can then flow along the downwardly inclined converging surface portions **207**, **208** of the forming wedge **209** and be drawn off the root **145** of the forming device **101**, where the flows converge and fuse into the glass ribbon **103**. The glass ribbon **103** can then be drawn along the ribbon travel direction **154**. In aspects, the glass ribbon **103** comprises one or more states of material based on a vertical location of the glass ribbon **103**, i.e., distance from the root **145**. For example, at a first location, the glass ribbon **103** can comprise the viscous molten material **121**, and at a second location, the glass ribbon **103** can comprise an amorphous solid in a glassy state (e.g., a glass ribbon).

[0051] The glass ribbon **103** comprises a first major surface **215** and a second major surface **216** facing opposite directions and defining a thickness **212** (e.g., average thickness) of the glass ribbon **103** therebetween. In aspects, the thickness **212** of the glass ribbon **103** can be less than or equal to about 2 millimeters (mm), less than or equal to about 1 millimeter, less than or equal to about 0.5 millimeters, for example, less than or equal to about 300 micrometers (μm), less than or equal to about 200 micrometers, or less than or equal to about 100 micrometers, although other thicknesses may be provided in further aspects. For example, he thickness **212** of the glass ribbon **103** can be within a range from about 20 micrometers to about 200 micrometers, within a range from about 50 micrometers to about 750 micrometers, within a range from about 100 micrometers to about 700 micrometers, within a range from about 200 micrometers to about 600 micrometers, within a range from about 300 micrometers to about 500 micrometers, within a range from about 50 micrometers to about 500 micrometers, within a range from about 50 micrometers to about 700 micrometers, within a range from about 50 micrometers to about 600 micrometers, within a range from about 50 micrometers to about 500 micrometers, within a range from about 50 micrometers to about 400 micrometers, within a range from about 50 micrometers to about 300 micrometers, within a range from about 50 micrometers to about 200 micrometers, within a range from about 50 micrometers to about 100 micrometers, within a range from about 25 micrometers to about 125 micrometers, comprising all ranges and subranges of thicknesses therebetween. In addition, the glass ribbon **103** can comprise a variety of compositions, for example, one or more of soda-lime glass, borosilicate glass, alumino-borosilicate glass, alkali-containing glass, alkali-free glass, aluminosilicate, borosilicate, boroaluminosilicate, silicate, glass-ceramic, or other materials comprising glass. In aspects, the glass ribbon **103** can comprise one or more of lithium fluoride (LiF), magnesium fluoride (MgF_2), calcium fluoride (CaF_2), barium fluoride (BaF_2), sapphire (Al_2O_3), zinc selenide (ZnSe), germanium (Ge) or other materials.

[0052] The glass separator **149** (see **FIG. 1**) can separate the glass ribbon **104** from the glass ribbon **103** along the separation path **151** to provide a plurality of separated glass ribbons **104** (i.e., a plurality of sheets of glass). In aspects, a longer portion of the glass ribbon **104** may be coiled onto a storage roll. The separated glass ribbon can then be processed into a desired application, e.g., a display application. For example, the separated glass ribbon can be used in a wide range of display and non-display applications comprising, but not limited to, liquid crystal displays (LCDs), electrophoretic displays (EPD), organic light emitting diode displays (OLEDs), plasma display panels (PDPs), microLED displays, miniLED displays, organic light emitting diode lighting, light emitting diode lighting, augmented reality (AR), virtual reality (VR), touch sensors, photovoltaics, foldable phones, or other applications.

[0053] **FIG. 3** illustrates a sample **301** of the glass ribbon **103** after the sample **301** has been separated by the glass separator **149**. After separation, the sample **301** can be cooled and may comprise one or more discrete edges, such that the sample **301** may comprise a separated glass ribbon **104**. For example, the sample **301** can comprise a first edge **303** and an opposing second edge **305** with the first edge **303** substantially parallel to the second edge **305**. In aspects, the first edge **303** can match a position of the first edge **153** (e.g., illustrated in **FIG. 1**) of the glass ribbon **103** and the second edge **305** can match a position of the second edge **155** of the glass ribbon **103**. Accordingly, prior to separation by the glass separator **149**, the first edges **153**, **303** may be attached, continuous and extending coaxially, and the second edges **305**, **155** may be attached, continuous, and extending coaxially.

[0054] In aspects, methods of manufacturing glass can comprise determining a first location **309** of a first region **311** from the sample **301** of the glass ribbon **103**, with the first region **311** comprising a first stress outside of a predetermined stress range. For example, determining the first location **309** of the first region **311** can initially comprise analyzing the sample **301** to obtain a stress profile throughout the sample **301**. The stress profile can comprise stress values at a plurality of locations within the sample **301**, with peaks and valleys of stress. In aspects, the stress profile can be obtained in several ways, for example, by non-destructively passing light (e.g., a laser beam) through the sample **301** and, based on a detection of the degree of scattered light, determining a stress at specific locations. The stress profile can comprise a plurality of stresses of the sample **301** at locations along a first axis **311**, which is parallel to the first edge **303** and the second edge **305** and may be along the ribbon travel direction **154** (e.g., illustrated in **FIG. 1**), and at locations along a second axis **312**, which is perpendicular to the first edge **303** and the second edge **305** and may be perpendicular to the ribbon travel direction **154** (e.g., illustrated in **FIG. 1**) and the first axis **311**. A predetermined stress range can be determined for the sample **301**, with the predetermined stress range based on one or more factors such as, for example, the glass composition, the dimensions of the glass, the use or application of the glass, etc. Zero or more locations of the sample **301** may comprise stress peaks or valleys, that is, locations at which the stress is greater than or less than the predetermined stress range.

[0055] In aspects, based on the stress profile, zero or more locations of the sample **301** can be determined to comprise stress regions outside of the predetermined stress range. For example, as illustrated in **FIG. 3**, the first region **311** can comprise a first stress that is outside (e.g., greater than or less than) the predetermined stress range. Determining the first location **309** can comprise measuring one or more of a first distance **315** between the first region **311** and the first edge **303** of the sample **301** or a second distance **317** between the first region **311** and the opposing second edge **305** of the sample **301**. Additional distances can be obtained, for example, distances between the first region **311** and other edges of the sample **301**. While **FIG. 3** illustrates one region comprising a stress outside of the predetermined stress range, the sample **301** may comprise additional regions with stresses outside of the predetermined stress range.

[0056] **FIG. 4** illustrates a sample **401** of the glass ribbon **103** prior to the sample **401** being separated by the glass separator **149**. In this way, the sample **401** may remain attached to and part of the glass ribbon **103** such that the sample **401** can move along a travel path **402** in the ribbon travel direction **154**. The sample **401** may comprise a first edge **403** (e.g., substantially matching a position of the first edge **153** illustrated in **FIG. 1**) and an opposing second edge **405** (e.g., substantially matching a position of the second edge **155**). Determining a first location of a first region of a sample is not limited to analyzing a sample **301** from a separated glass ribbon **104** (e.g., illustrated in **FIG. 3**). Rather, in aspects and as illustrated in **FIG. 4**, determining a first location of a first region of a sample can occur prior to separation of the sample and while the sample is part of the glass ribbon **103** and moving in the ribbon travel direction **154**.

[0057] In aspects, methods of manufacturing glass can comprise determining a first location **409** of a first region **411** from the sample **401** of the glass ribbon **103**, with the first region **411** comprising a first stress outside of a predetermined stress range. For example, determining the first location **409** of the first region **411** can comprise analyzing the sample **401** (e.g., while the sample **401** remains attached to and part of the glass ribbon **103** and moving in the ribbon travel direction **154**) to obtain a stress profile throughout the sample **401**. The stress profile can comprise stress values at several locations within the sample **401**, with peaks and valleys of stress. The stress profile can be obtained by obtaining a temperature profile of the sample **401**. For example, a camera apparatus **407** can be positioned facing the sample **401**, with the sample **401** passing through an optical field of view of the camera apparatus **407**. The sample **401** can emit thermal light energy that can be received by the camera apparatus **407**. The camera apparatus **407** can comprise, for example, an infrared camera that can detect infrared light and generate data based on the detected infrared light. Based on the infrared light and the data generated by the camera apparatus **407**, a temperature at various locations of the sample **401** can be determined, wherein the temperature can be correlated to a stress. For example, a first temperature at a first location of the sample **401** can be correlated to a first stress, while a second temperature at a second location of the sample **401** can be correlated to a second stress.

[0058] Accordingly, the camera apparatus **407** can obtain a stress profile of the sample **401**, with the stress profile comprising a plurality of stresses of the sample **401**

at locations along a first axis **412**, which is parallel to the first edge **403** and the second edge **405** and may be along the ribbon travel direction **154**, and at locations along a second axis **413**, which is perpendicular to the first edge **403** and the second edge **405** and may be perpendicular to the ribbon travel direction **154** and the first axis **412**. The first edge **403** may be continuous with and extending coaxially with the first edge **153** of the glass ribbon **103** (e.g., illustrated in **FIG. 1**), and the second edge **405** may be continuous with and extending coaxially with the second edge **155** of the glass ribbon **103**. In aspects, based on the stress profile, zero or more locations of the sample **401** can be determined to comprise stress regions outside of the predetermined stress range. For example, as illustrated in **FIG. 4**, the first region **411** can comprise a first stress that is outside (e.g., greater than or less than) the predetermined stress range. Determining the first location **409** can comprise measuring one or more of a first distance **415** between the first region **411** and the first edge **403** of the sample **401** or a second distance **417** between the first region **411** and the opposing second edge **405** of the sample **401**. While **FIG. 4** illustrates one region comprising a stress outside of the predetermined stress range, in aspects, the sample **401** may comprise additional regions with stresses outside of the predetermined stress range. Accordingly, the stress within the samples **301**, **401**, can be determined either by analyzing a separated portion of the glass ribbon **103**, for example, the sample **301** in an off-line process, or by analyzing the sample **401** while the sample **401** is part of the glass ribbon **103**, for example, in an on-line process.

[0059] **FIG. 5** illustrates a second camera apparatus **501** that can facilitate determining a location of a region comprising a stress outside of the predetermined stress range at an elevation of the glass ribbon **103** upstream from the samples **301**, **401**. For example, methods can comprise determining a second location **503** of a second region **505** from the glass ribbon **103** based on the first location **309**, **409** from the sample **301**, **401**, with the second region **505** comprising a second stress outside of the predetermined stress range. In aspects, an operator can determine that the second region **505** comprises the second stress outside of the predetermined stress range due to the first regions **311**, **411** comprising the first stress outside of the predetermined stress range and because the process parameters for manufacturing the glass ribbon **103** are the same for the samples **301**, **401** comprising the first regions **311**, **411** as for the glass ribbon **103** comprising the second region **505**.

[0060] Determining the second location **503** can comprise locating one or more of a first distance **507** from the first edge **153** of the glass ribbon **103** or a second distance **509** from the opposing second edge **155** of the glass ribbon **103**. The second camera apparatus **501** may be such that the glass ribbon **103** travels along the ribbon travel path **221** within a field of view of the second camera apparatus **501**. A position of the first location **309** within the sample **301** (e.g., illustrated in **FIG. 3**) and/or a position of the first location **409** within the sample **401** (e.g., illustrated in **FIG. 4**) may already be determined and known. The first edge **153** can match the first edge **303**, **403** of the sample **301**, **401**, and the second edge **155** can match the second edge **305**, **405** of the sample **301**, **401**. As such, the first distance **315**, **415** and/or the second distance **317**, **417** determined from the sample **301**, **401** can be applied to the glass ribbon **103** illustrated in **FIG. 5**. That is, the first distance **507** may be measured from the first edge **153** toward the second edge **155** and/or the second distance **509** may be measured from the second edge **155** toward the first edge **153**. The first distance **507** can match the first distances **315**, **415** of the sample **301**, **401** and the second distance **509** can match the second distances **317**, **417** of the sample **301**, **401**. The distances **507**, **509** may be measured by an operator, or may be obtained via visual inspection by the second camera apparatus **501**.

[0061] **FIG. 6** illustrates a laser apparatus **601** comprising a laser source **603**. The laser source **603** can provide an initial laser beam **605** comprising a power and a wavelength. The laser apparatus **601** can comprise an optical lens **607** positioned within the path of the initial laser beam **605** such that the initial laser beam **605** may pass through the optical lens **607**. In aspects, the optical lens **607** can comprise a cylindrical lens that can focus light passing through the optical lens **607** and transform the initial laser beam **605** into a focused laser beam **609**. The laser apparatus **601** can comprise a mirror **611** positioned within the path of the focused laser beam **609** that can receive and deflect the focused laser beam **609**, upon which a laser beam **613** is reflected from the mirror **611** toward the glass ribbon **103**. The mirror **611** can be tiltable or rotatable (e.g., as indicated by arrow **615**) around an axis in order to deflect the laser beam **613** to a desired location at the glass ribbon **103**. In aspects, the laser beam **613** may be in the form of a single spot comprising a laser spot area that impinges upon the glass ribbon **103**. The laser beam **613** can comprise, for example, a single point, a single point with a profiled laser power, and/or a scanning with an adjustable laser power profile. The mirror **611** may comprise, for example, a micro-electromechanical system (MEMS) scanning mirror. In aspects, the laser apparatus **6011** can comprise a CO_2 laser. Though not illustrated, the laser apparatus **601** can comprise additional components that function to deliver the laser beam **613**, for example, optical lenses, diffractive optical elements, spatial light modulators, galvanometers, acoustic-optical beam deflectors, piezo-driven fast-scan mirrors, polygon scanners, etc. Further, the laser apparatus **601** can comprise an articulated arm that is movable based on a desired position of the laser beam **613** relative to the glass ribbon **103**.

[0062] The laser apparatus **601** can comprise a control apparatus **619** that can control the laser beam **613**, the mirror **611**, etc. For example, the control apparatus **619** can comprise a processor **623** coupled with a memory **625**. The processor **623** can be configured with executable instructions stored in the memory **625** to enable operations of the laser source **603**, the mirror **611**, etc. The processor **623** may be one of any form of general-purpose computer processors that can be used in an industrial setting for controlling various manufacturing equipment used in glass processing. The memory **625** may be in the form of a computer-readable medium and may be one or more of readily available memory such as random-access memory (RAM), read only memory (ROM), floppy disk, hard disk, or any other form of digital storage, local or remote. Support circuits (not shown) may be coupled to the processor **623** for supporting the processor in a conventional manner. These support circuits can include cache, power supplies, clock circuits, input/output circuitry and subsystems, and the like. The control apparatus **619** can control one or more of the power or the wavelength of the laser beam **613** to heat the glass ribbon **103** at a desired heating rate. Values for the laser power and wavelength can be stored and processed in the memory **625** and the processor **623**. The laser source **601** can comprise a continuous wave laser or a pulsed laser. When the laser source **601** comprises a pulsed laser, the control apparatus **619** can control the pulse rate and/or the frequency of the pulsed laser, and the memory **625** and processor **623** can store and process values for the pulse rate and frequency.

[0063] In aspects, process routines for scanning the glass ribbon **103** with the laser beam **613** can be stored in the memory **625** as a software routine that, when executed by the processor **623**, causes the laser apparatus **601** to perform processes disclosed herein. One or more components of the laser apparatus **601** can be moved with respect to the glass ribbon **103**, though, the laser apparatus **601** can remain stationary while movement of the mirror **611** can cause the laser beam **613** to move relative to the glass ribbon **103**. In aspects, the control apparatus **619** can calculate or convert vector data to movement information, which may be communicated to the mirror **611** to deflect the mirror in at least one plane (e.g., an X-Y plane, for example). While the laser apparatus **601** is illustrated as comprising one laser source, more than one laser source can be provided such that the laser apparatus **601** can produce a plurality of laser beams.

[0064] The laser apparatus **601** may be positioned downstream from the forming device **101** and, in aspects, may be positioned downstream from the second camera apparatus **501** of **FIG. 5**. The forming device **101** and the glass ribbon **103** may be positioned within a fusion machine bounded by one or more walls. The one or more walls can comprise one or more openings through which the laser beam **613** can pass to impinge upon the glass ribbon **103**. A cross-sectional size of one of the one or more openings can be less than about 100 mm. A temperature within the fusion machine (e.g., within the environment within which the forming device **101** and the glass ribbon **103** are located) may be within a range from about 400° C to about 900° C.

[0065] Methods can comprise heating the second region **505** (e.g., comprising a stress outside of the predetermined stress range) of the glass ribbon **103** by irradiating the second region **505** with the laser beam **613** while the glass ribbon **103** travels along the ribbon travel path **221** in the ribbon travel direction **154**. As such, the second region **505** can be heated from a first temperature, which is greater than or equal to a transition temperature of the glass ribbon **103**, to a second temperature. In aspects, a position of the laser beam **613** can be adjusted to reach the second location **503**. For example, based on the first locations **309**, **409** (e.g., illustrated in **FIGS. 3-4**), the second location **503** can be determined, for example, with the second location **503** located the first distance **507** from the first edge **153** and/or the second distance **509** from the second edge **155**. Methods can comprise moving the laser beam **613** relative to the glass ribbon **103** in a first laser travel direction **631** along the ribbon travel path **221** in the ribbon travel direction **154**. For example, the first laser travel direction **631** may be in a vertical direction substantially parallel to the first edge **153** and the second edge **155**. In aspects, the laser beam **613** can irradiate the second region **505** by pulsing (e.g., on and off), for example, by being on for a period of time (e.g., one second to five seconds), followed by being off for a period of time (e.g., one second to five seconds), and repeating. In aspects, the laser beam **613** may continue to irradiate the portion of the glass ribbon **103** that is the first distance **507** from the first edge **153** and the second distance **509** from the second edge **509** as the glass ribbon **103** moves in the ribbon travel direction **154** such that the second region **505** and areas upstream and downstream from the second region **505** may be irradiated by the laser beam **613** (e.g., with the laser beam **613** maintained in a fixed position and the glass ribbon **103** moving relative to the laser beam **613**).

[0066] In aspects, methods can comprise moving the laser beam **613** relative to the glass ribbon **103** in a second laser travel direction **633** across the ribbon travel path **221** perpendicular to the ribbon travel direction **154**. For example, the second laser travel direction **633** may be in a horizontal direction substantially perpendicular to the first edge **153** and the second edge **155**. The laser beam **613** can be moved in the first laser travel direction **631** and the second laser travel direction **633** in several ways, for example, by moving the laser apparatus **601** relative to the glass ribbon **103** and/or by adjusting the mirror **611** (e.g., by tilting **615**) to move the laser beam **613**. By moving the laser beam **613** relative to the glass ribbon **103**, the laser beam **613** may reach the second location **503** and impinge upon the second region **505** to irradiate the second region **505**. Accordingly, the laser beam **613** irradiate the second region **505** while not irradiating other areas of the glass ribbon **103**. As such, areas of the glass ribbon **103** that comprise a stress within the predetermined stress range may not be irradiated by the laser beam **613** while areas of the glass ribbon **103** that comprise a stress outside the predetermined stress range (e.g., at the second location **503**) may be irradiated by the laser beam **613**.

[0067] In aspects, properties of the glass ribbon **103**, for example, properties at the second location **503**, can change due to the laser beam **613** irradiating the second region **505** while properties outside of or away from the second location **503** may not change due to the laser beam **613** not irradiating those areas. For example, the glass ribbon **103**, during a cooling process, can undergo compaction (e.g., thermal stability or dimensional change), which is a dimensional change or shrinkage of the glass ribbon **103** due to changes in a fictive temperature of the glass ribbon **103**. The fictive temperature is used to indicate a structural state of the glass ribbon **103**, such that glass that is cooled quickly from a high temperature may comprise a higher fictive temperature due to a “frozen in” nature of the higher temperature structure, and glass that is cooled more slowly (e.g., annealed by holding for a time near an annealing point) can comprise a lower fictive temperature. In aspects, fluctuations of the fictive temperature of the glass ribbon **103** can result in residual stress, which, when measured with a polarized plane wave, can result in a glass retardance value (MRV). Reduction in fictive temperature fluctuations can reduce MRV. The glass ribbon **103** comprises a glass transition temperature (T_g) at which glass transition occurs. The glass transition is the gradual and reversible transition in amorphous materials from hard and relatively brittle “glassy” state to a viscous or rubbery state as the temperature is increased. At a temperature below the glass transition temperature, the molecular chains of the amorphous materials are frozen in place and behave like solid glass. For example, the glass ribbon **103** can comprise a glass transition temperature (T_g) within a range from about 620° C to about 780° C, and a viscosity range at the glass transition temperature (T_g) may be within a range from about 10^6 poise to about 10^{12} poise.

[0068] In aspects, the second region **505** comprises a first viscosity prior to heating with the laser beam **613** and a second viscosity after heating with the laser beam **613**. In aspects, the first viscosity is different than the second viscosity, with the difference between the first viscosity and the second viscosity being less than about 1×10^{12} poise. For example, the laser apparatus **601** may be positioned relative to the glass ribbon **103** such that the laser beam **613** irradiates the glass ribbon **103** upstream from the separator **149** and while the glass ribbon **103** is at the first temperature, which may be greater than or equal to a transition temperature of the glass ribbon **103**. In aspects, the second region **505** comprises a first temperature prior to heating with the laser beam **613** and a second temperature after heating with the laser beam **613**. The first temperature may be different than the second temperature, with the difference between the first temperature and the second temperature being less than about 10° C. In aspects, the second region **505** comprises a first fictive temperature prior to heating with the laser beam **613** and a second fictive temperature after heating with the laser beam **613**. In aspects, the first fictive temperature may be different than the second fictive temperature, with the second fictive temperature less than the first fictive temperature. For example, in aspects, the glass ribbon **103** may initially have a first fictive temperature, but, upon heating, the fictive temperature may increase, while lagging the temperature of the glass ribbon **103**. As the glass ribbon **103** is cooled, the fictive temperature may decrease, again lagging the temperature of the glass ribbon **103**. As the glass ribbon **103** reaches a temperature at which the glass ribbon **103** cannot be accommodated, the fictive temperature may stabilize. In aspects, the fictive temperature of the glass ribbon **103** may initially increase (e.g., to be greater than the first fictive temperature) upon heating, and may reach the second fictive temperature upon cooling of the glass ribbon **103**. The laser beam **613** can irradiate portions of the glass ribbon **103** as the glass ribbon **103** is at an elevated temperature and moving along the ribbon travel direction **154**. As such, a reduced laser power of the laser beam **613** is required to heat the glass ribbon **103** to the desired second temperature as compared to if the laser beam **613** heated the glass ribbon **103** from room temperature to the second temperature.

[0069] In aspects, methods can comprise cooling the second region **505** from the second temperature such that the second region **505** comprises a third stress within the predetermined stress range. The third stress may be different than the second stress, with the second stress outside of the predetermined stress range and the third stress within the predetermined stress range. In aspects, heating the second region **505** can comprise setting a wavelength of the laser beam **613** irradiating the second region **505** based on a difference between the second stress and the third stress. For example, heating the second region can comprise setting a power of the laser beam **613** irradiating the second region **505** based on a difference between the second stress and the third stress. In this way, the power and wavelength of the laser beam **613** can be determined based on the stress (e.g., outside of the predetermined stress range) of the sample **301**, **401**, and a stress within the predetermined stress range, and the temperature to which the second region **505** must be heated to obtain the desired stress upon cooling. The power and wavelength of the laser beam **613** may be set as follows. Initially, a region of stress that is outside of the predetermined stress range can be determined, and the laser beam **613** (at a first power and first wavelength) can irradiate the region of stress. An operator may analyze and inspect the glass ribbon after cooling to determine if the first power and the first wavelength were sufficient to change the region of stress to a stress that is within the predetermined stress range. If the region of stress is within the predetermined stress range, then the laser beam **613** may continue to be operated at the first power and first wavelength. If the region of stress is still outside the predetermined stress range, then one or more of the power or the wavelength of the laser beam **613**

may be adjusted and the process can repeat. As such, in aspects, an iterative and empirical process comprising a feedback loop may be used to correlate the power and wavelength of the laser beam **613** to the desired change in stress of the glass ribbon **103**. In aspects, the wavelength of the laser beam **613** may be maintained as constant while the power of the laser beam **613** can be adjusted. In addition, or in the alternative, other properties of the laser beam 613 can also be adjusted, such as, for example, a dimension and/or beam shape of the laser beam.

[0070] While some properties of the glass ribbon **103** may change, for example, the stress, fictive temperature, etc., due to the laser beam **613** impinging upon portions of the glass ribbon **103**, a thickness of the glass ribbon **103** does not change. For example, despite the laser beam **613** irradiating the second location **503**, a thickness of the glass ribbon **103** at the second location **503** may substantially match a thickness of the glass ribbon **103** at other portions of the glass ribbon **103** outside of and away from the second location **503**. In this way, the laser beam **613** may not impact or change the thickness of the glass ribbon **103**.

[0071] It should be understood that while various aspects have been described in detail relative to certain illustrative and specific examples thereof, the present disclosure should not be considered limited to such, as numerous modifications and combinations of the disclosed features are possible without departing from the scope of the following claims.

What is claimed is:

1. A method of manufacturing glass comprising:

determining a first location of a first region from a sample of a glass ribbon, the first region comprising a first stress outside of a predetermined stress range;

determining a second location of a second region from the glass ribbon based on the first location from the sample, the second region comprising a second stress outside of the predetermined stress range;

heating the second region of the glass ribbon by irradiating the second region with a laser beam while the glass ribbon travels along a ribbon travel path in a ribbon travel direction such that the second region is heated from a first temperature, which is greater than or equal to a transition temperature of the glass ribbon, to a second temperature; and

cooling the second region from the second temperature such that the second region comprises a third stress within the predetermined stress range.

2. The method of claim 1, wherein the second region comprises a first viscosity prior to heating with the laser beam and a second viscosity after heating with the laser beam, and a difference between the first viscosity and the second viscosity is less than about 1×10^{12} poise.

3. The method of any one of claims 1-2, wherein a difference between the first temperature and the second temperature is less than about 10° C.

4. The method of any one of claims 1-3, wherein the second region comprises a first fictive temperature prior to heating with the laser beam and a second fictive temperature after heating with the laser beam, the second fictive temperature different than the first fictive temperature.

5. The method of any one of claims 1-4, wherein the determining the first location comprises measuring one or more of a first distance between the first region and a first edge of the sample or a second distance between the first region and an opposing second edge of the sample.

6. The method of claim 5, wherein the determining the second location comprises locating one or more of the first distance from a first edge of the glass ribbon or the second distance from an opposing second edge of the glass ribbon.

7. The method of any one of claims 5-6, wherein the heating the second region comprises setting a wavelength of the laser beam irradiating the second region based on a difference between the second stress and the third stress.

8. The method of any one of claims 5-7, wherein the heating the second region comprises setting a power of the laser beam irradiating the second region based on a difference between the second stress and the third stress.

9. The method of any one of claims 1-8, further comprising moving the laser beam relative to the glass ribbon in a first laser travel direction along the ribbon travel path in the ribbon travel direction.

10. The method of any one of claims 1-9, further comprising moving the laser beam relative to the glass ribbon in a second laser travel direction across the ribbon travel path perpendicular to the ribbon travel direction.

11. A method of manufacturing glass comprising:

heating a region of a glass ribbon comprising a first stress outside of a predetermined stress range by irradiating the region with a laser beam as the glass ribbon moves along a ribbon travel path in a ribbon travel direction such that the region is heated from a first temperature greater than or equal to a transition temperature of the glass ribbon to a second temperature, the region comprising a first viscosity prior to heating with the laser beam and a second viscosity after heating with the laser beam such that a difference between the first viscosity and the second viscosity is less than about 1×10^{12} poise and a difference between the first temperature and the second temperature is less than about 10° C; and

cooling the region from the second temperature such that the region comprises a second stress within the predetermined stress range.

12. The method of claim 11, wherein the region comprises a first fictive temperature prior to heating with the laser beam and a second fictive temperature after heating with the laser beam, the second fictive temperature different than the first fictive temperature.

13. The method of any one of claims 11-12, wherein the heating the region comprises setting a wavelength of the laser beam irradiating the region based on a difference between the first stress and the second stress.

14. The method of any one of claims 11-13, wherein the heating the region comprises setting a power of the laser beam irradiating the region based on a difference between the first stress and the second stress.

15. The method of any one of claims 11-14, further comprising moving the laser beam relative to the glass ribbon in a first laser travel direction along the ribbon travel path in the ribbon travel direction.

16. The method of any one of claims 11-15, further comprising moving the laser beam relative to the glass ribbon in a second laser travel direction across the ribbon travel path perpendicular to the ribbon travel direction.

17. The method of any one of claims 11-16, further comprising determining a first location of a first region from a sample of the glass ribbon, the first region comprising a first stress outside of the predetermined stress range, the determining the first location comprising measuring one or more of a first distance between the first region and a first edge of the sample or a second distance between the first region and an opposing second edge of the sample.

18. The method of claim 17, wherein, prior to heating the region, further comprising determining a location of the region based on the first location from the sample.

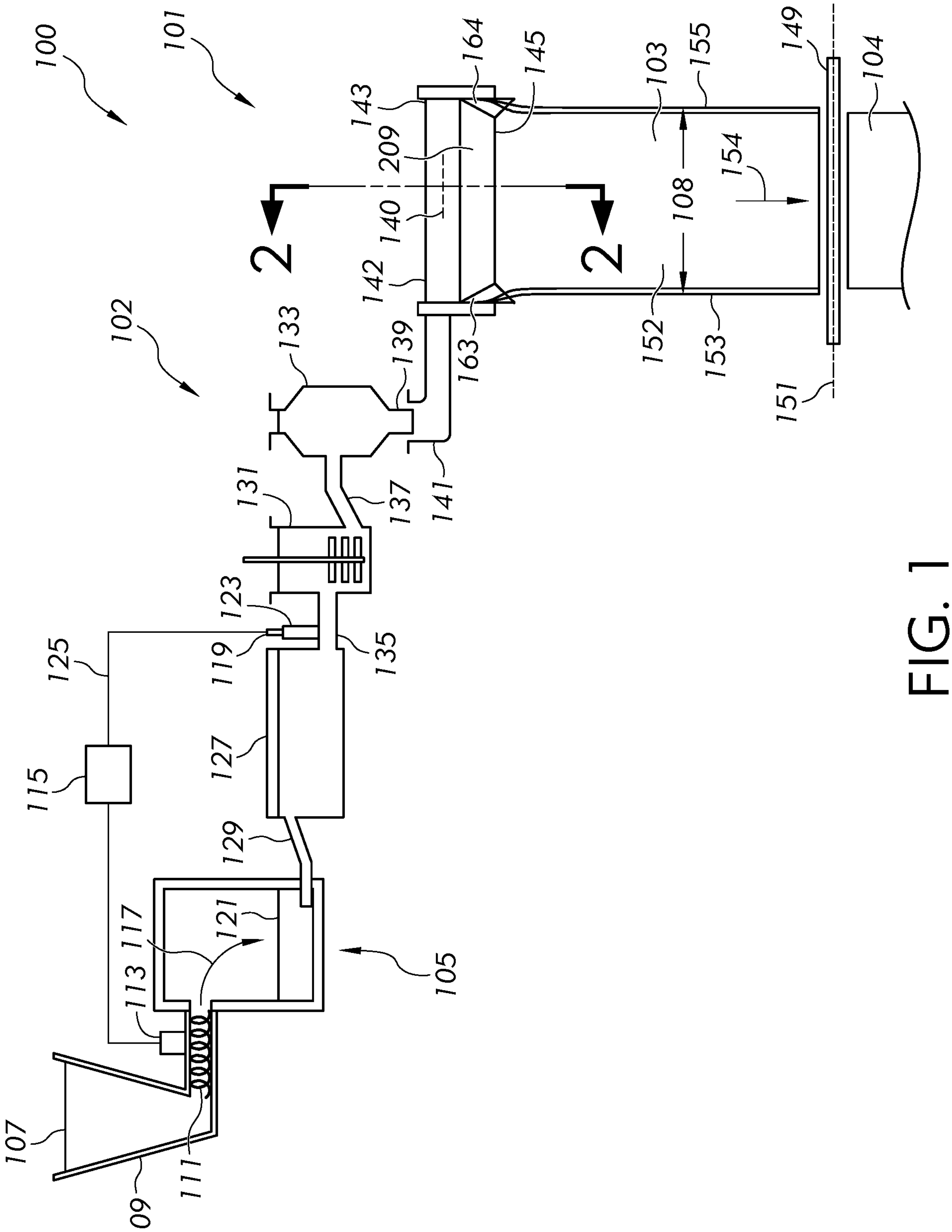
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FIG. 1

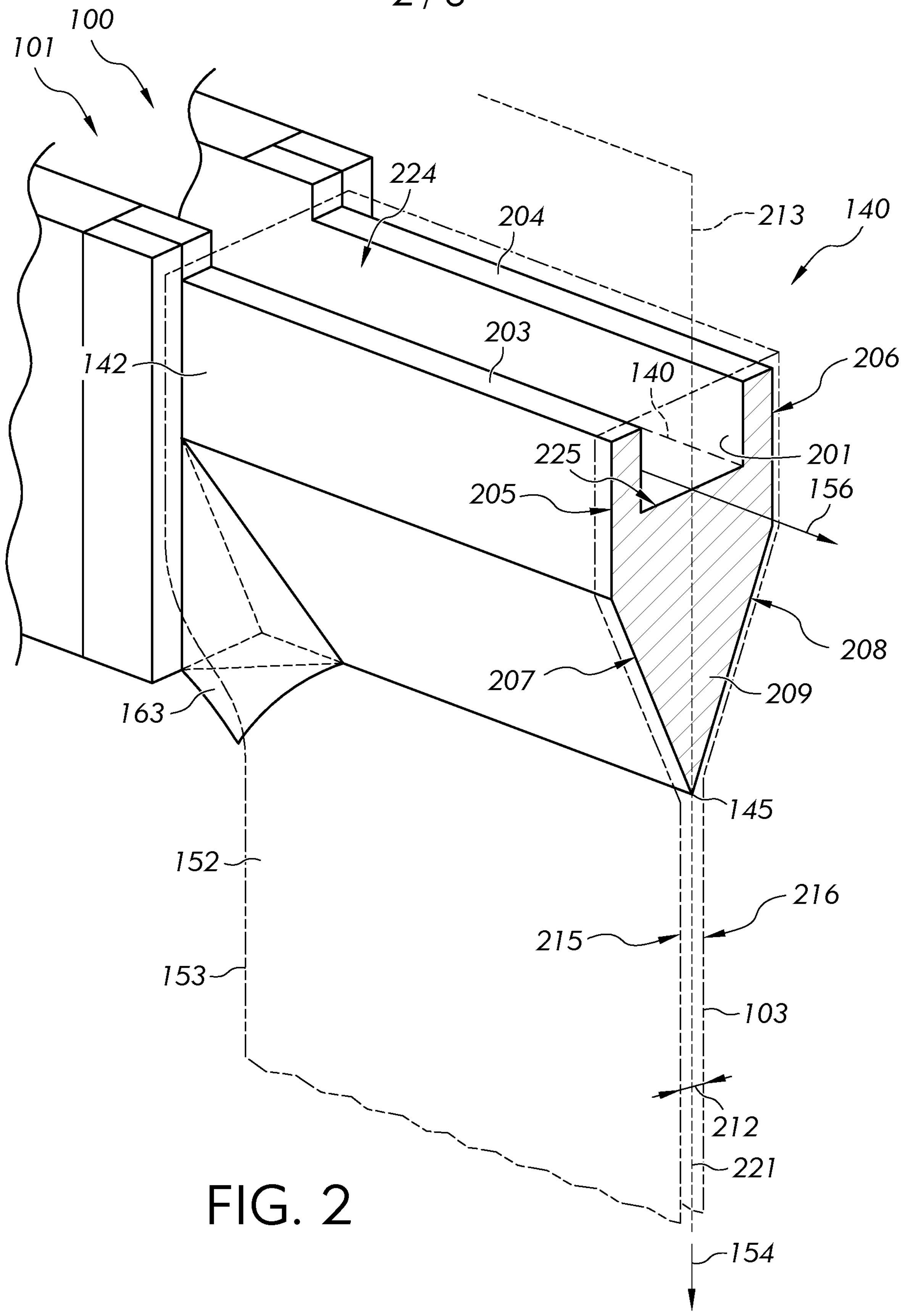
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FIG. 2

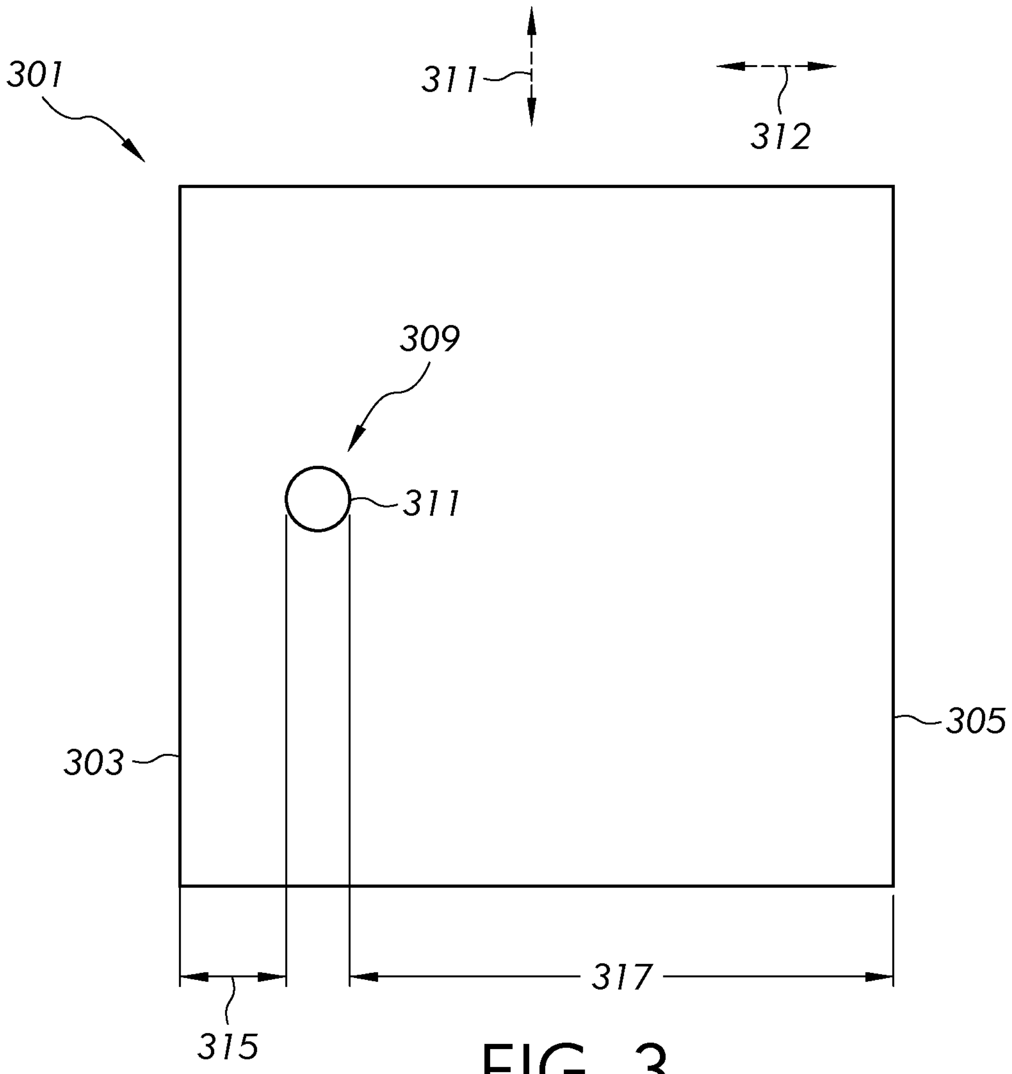

FIG. 3

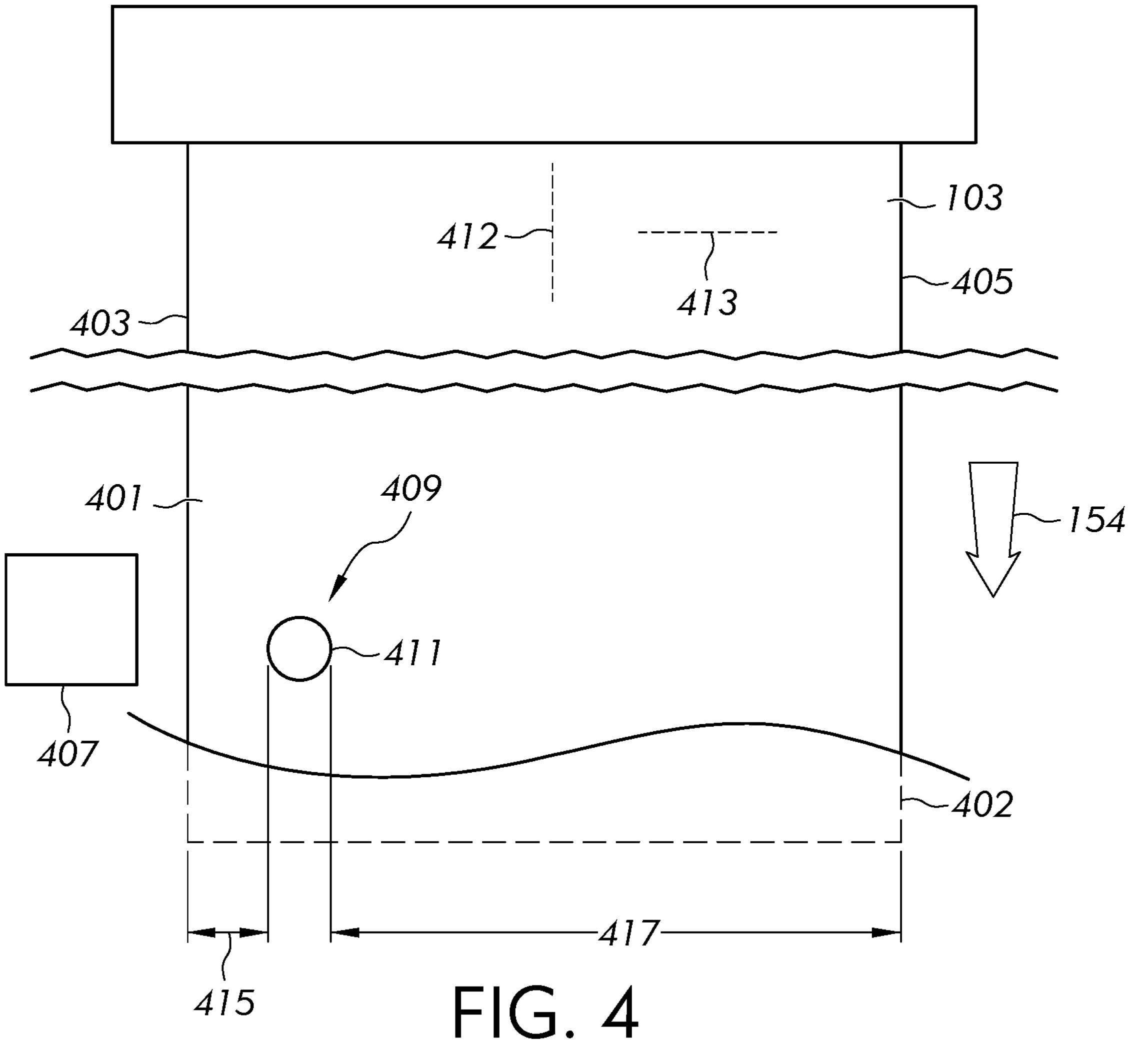

FIG. 4

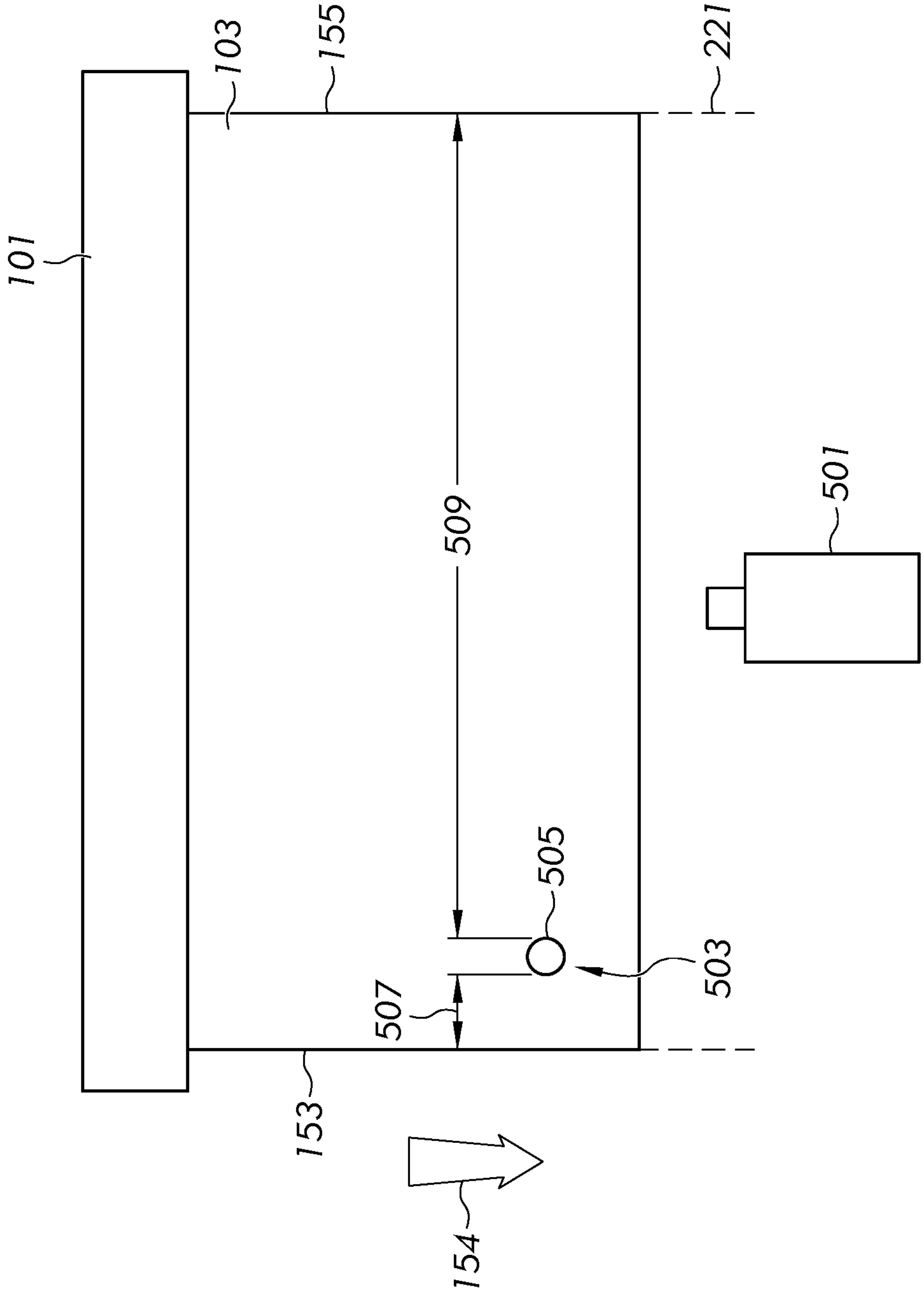

FIG. 5

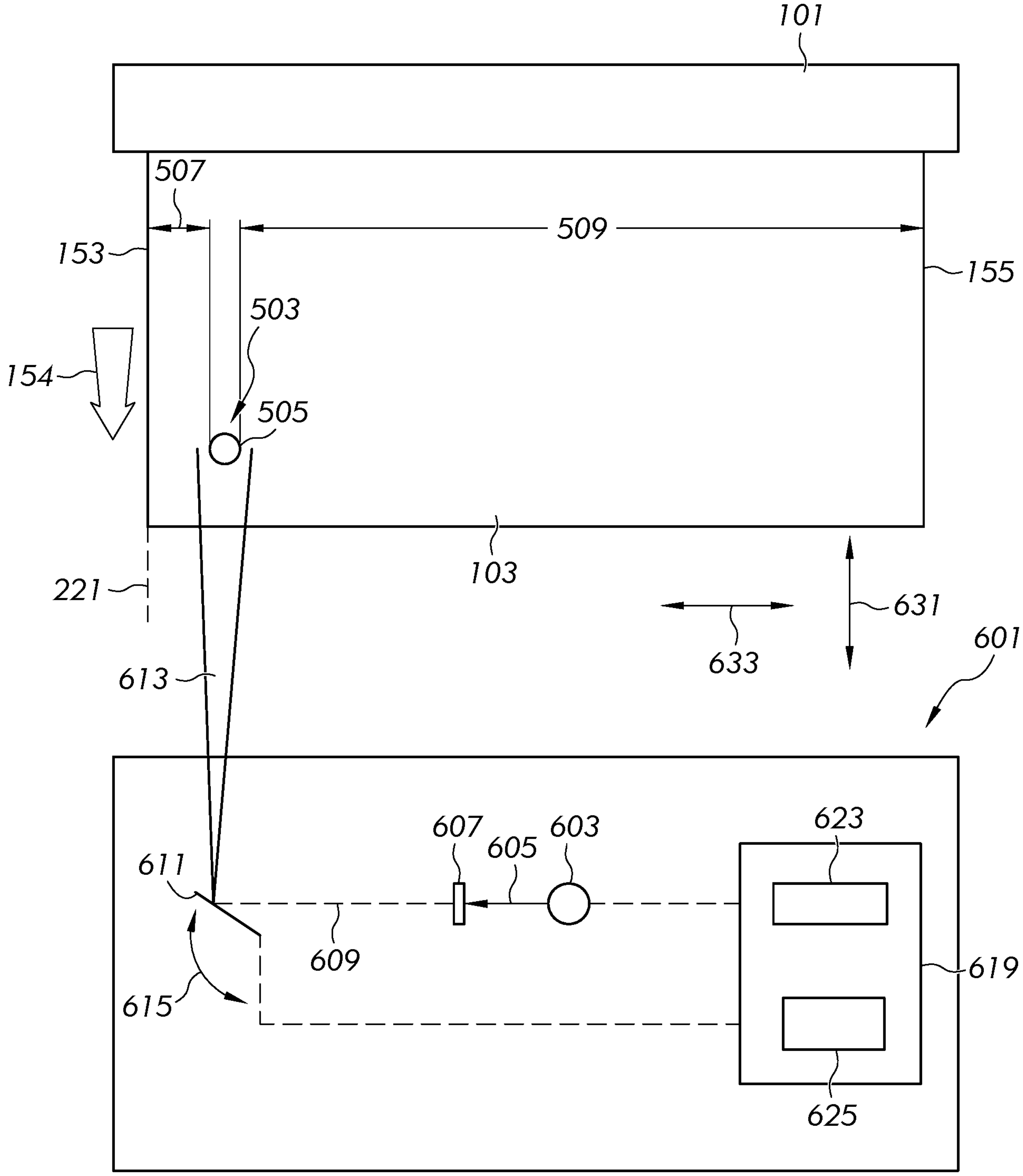
101
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FIG. 6

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2023/082800

A. CLASSIFICATION OF SUBJECT MATTER

C03B 17/06(2006.01)i

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 17/06(2006.01); C03B 18/02(2006.01); C03B 18/04(2006.01); C03B 29/02(2006.01); C03B 33/02(2006.01); C03B 33/09(2006.01); C03C 23/00(2006.01)

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

Korean utility models and applications for utility models
Japanese utility models and applications for utility models

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

eKOMPASS(KIPO internal) & Keywords: glass, ribbon, laser, stress, viscosity

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2021-257642 A1 (CORNING INCORPORATED) 23 December 2021 (2021-12-23) claims 1-12; paragraphs [0101]-[0137]; figure 6	1-3,11-13
A	WO 2010-099304 A2 (CORNING INCORPORATED et al.) 02 September 2010 (2010-09-02) the whole document	1-3,11-13
A	EP 3741731 A1 (SCHOTT AG) 25 November 2020 (2020-11-25) the whole document	1-3,11-13
A	WO 2009-060875 A1 (ASAHI GLASS CO., LTD. et al.) 14 May 2009 (2009-05-14) the whole document	1-3,11-13
A	WO 2019-173358 A1 (CORNING INCORPORATED) 12 September 2019 (2019-09-12) the whole document	1-3,11-13

☐ Further documents are listed in the continuation of Box C. ☑ See patent family annex.

*	Special categories of cited documents:	"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
"A"	document defining the general state of the art which is not considered to be of particular relevance	"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
"D"	document cited by the applicant in the international application	"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
"E"	earlier application or patent but published on or after the international filing date	"&"	document member of the same patent family
"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)		
"O"	document referring to an oral disclosure, use, exhibition or other means		
"P"	document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search **15 April 2024**	Date of mailing of the international search report **16 April 2024**
Name and mailing address of the ISA/KR **Korean Intellectual Property Office** **189 Cheongsa-ro, Seo-gu, Daejeon** **35208, Republic of Korea** Facsimile No. **+82-42-481-8578**	Authorized officer **HEO, Joo Hyung** Telephone No. **+82-42-481-5373**

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2023/082800

Box No. II **Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)**

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☑ Claims Nos.: **6, 18**
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

Claims 6, 18 are regarded to be unclear because it refers to a claim which does not comply with PCT Rule 6.4(a).

3. ☑ Claims Nos.: **4, 5, 7-10, 14-17**
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/US2023/082800

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
WO 2021-257642 A1	23 December 2021	CN 115734947 A	03 March 2023
		JP 2023-531448 A	24 July 2023
		KR 10-2023-0029824 A	03 March 2023
		TW 202212276 A	01 April 2022
		US 2023-0295031 A1	21 September 2023
WO 2010-099304 A2	02 September 2010	CN 102414134 A	11 April 2012
		CN 102414134 B	21 January 2015
		JP 2012-519136 A	23 August 2012
		JP 5746641 B2	08 July 2015
		KR 10-2011-0121651 A	07 November 2011
		TW 201038498 A	01 November 2010
		TW I468352 B	11 January 2015
		WO 2010-099304 A3	06 January 2011
EP 3741731 A1	25 November 2020	CN 111977953 A	24 November 2020
		CN 111977953 B	12 March 2024
		DE 102019113635 A1	26 November 2020
		KR 10-2020-0135733 A	03 December 2020
		KR 10-2445072 B1	19 September 2022
		US 2020-0369551 A1	26 November 2020
WO 2009-060875 A1	14 May 2009	CN 101855182 A	06 October 2010
		CN 101855182 B	05 December 2012
		JP 5347969 B2	20 November 2013
		KR 10-1271292 B1	04 June 2013
		KR 10-2010-0086471 A	30 July 2010
		TW 200927682 A	01 July 2009
		TW I400202 B	01 July 2013
WO 2019-173358 A1	12 September 2019	CN 112088146 A	15 December 2020
		JP 2021-516207 A	01 July 2021
		JP 7264908 B2	25 April 2023
		KR 10-2020-0129140 A	17 November 2020
		TW 201941326 A	16 October 2019
		TW I821250 B	11 November 2023
		US 2021-0053858 A1	25 February 2021