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Gougoussis et al.

(54) AUTOMOTIVE GLASS STRUCTURE HAVING FEATURE LINES AND RELATED METHODS OF MANUFACTURE

(71) Applicant: **Tesla, Inc.**, Austin, TX (US)

(72) Inventors: **Christos Gougoussis**, Fremont, CA (US); **William S. Sweney**, Oakland, CA (US); **Rosemary Mottsmith**, Los Angeles, CA (US); **Michael Pilliod**, Los Angeles, CA (US); **Gregoire Hamel**, Paris (FR)

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B60J 1/02	(2006.01)

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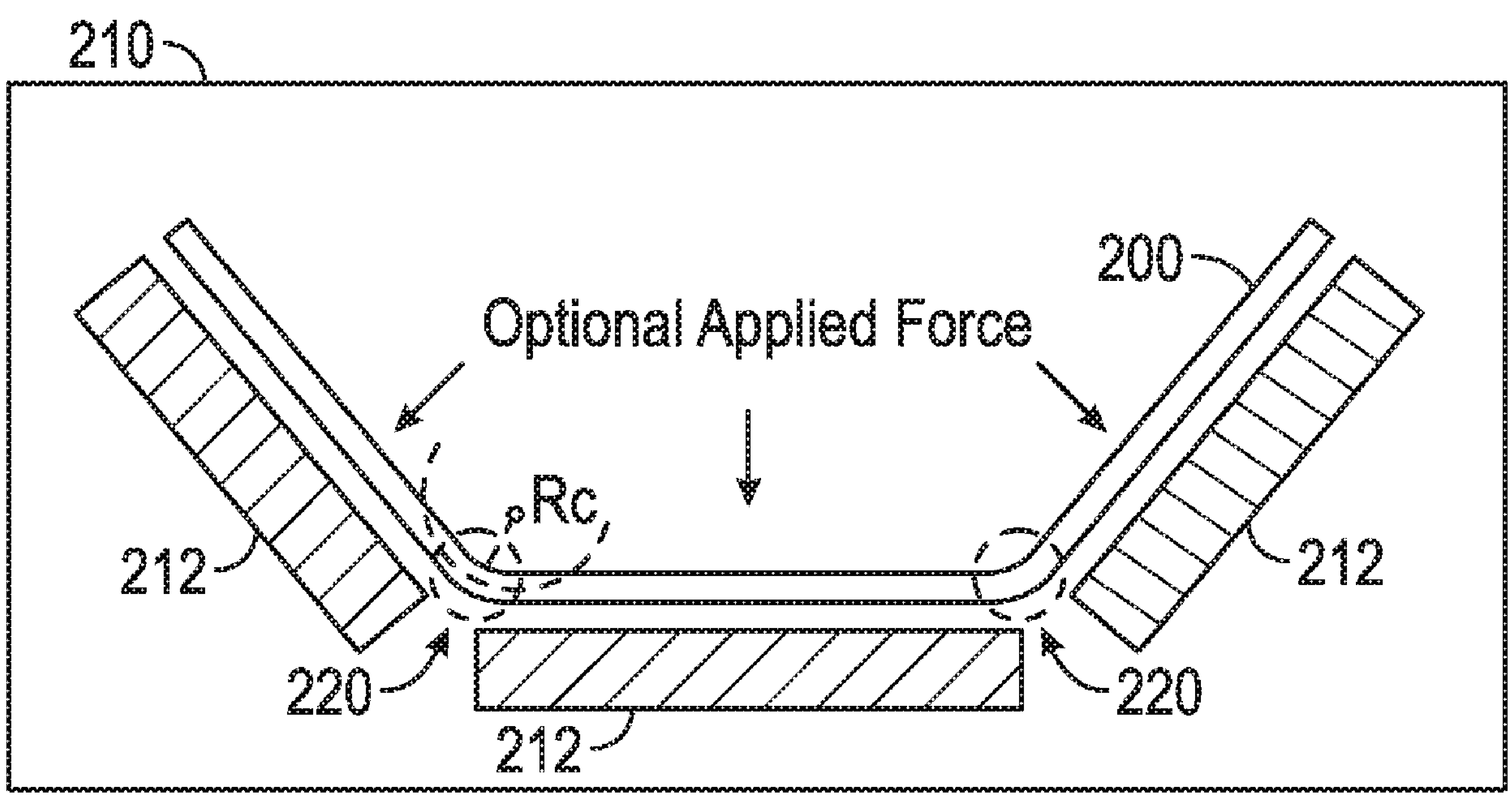
(57) **ABSTRACT**

Automotive glass structures having curves and feature lines and methods for forming the same are provided. An example method includes applying localized heat (e.g., via a laser, heating element) to a location of a substantially planar glass structure and bending the glass structure at that location (e.g., along a line of the planar glass structure) to form a feature line in the glass structure. The bending can be formed to have a radius of curvature of between 2 mm and 5 cm. Additional layers of curved or joined glass layers may further be included to form a curved multi-layer glass structure for automotive use.



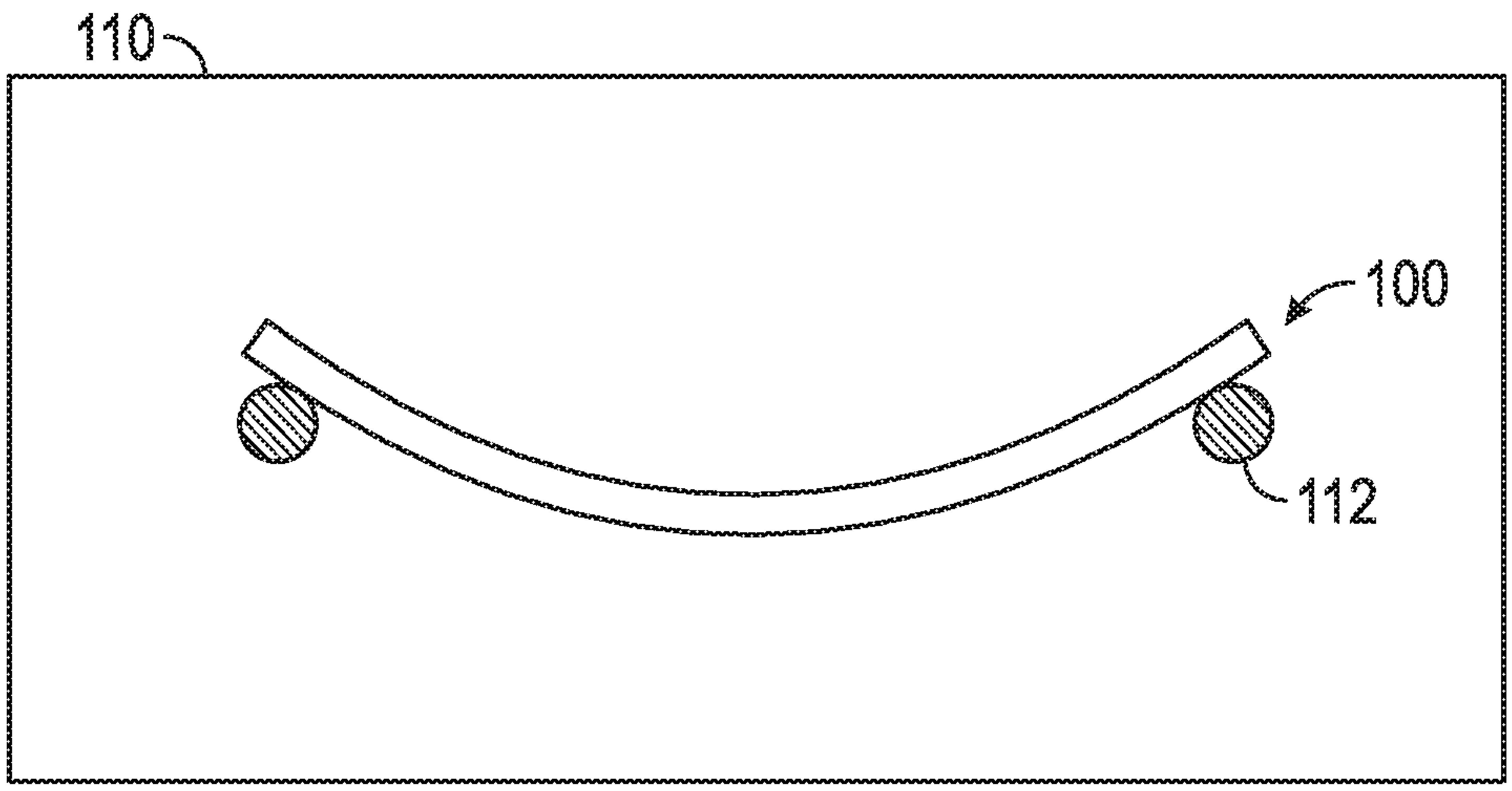


FIG. 1
[PRIOR ART]

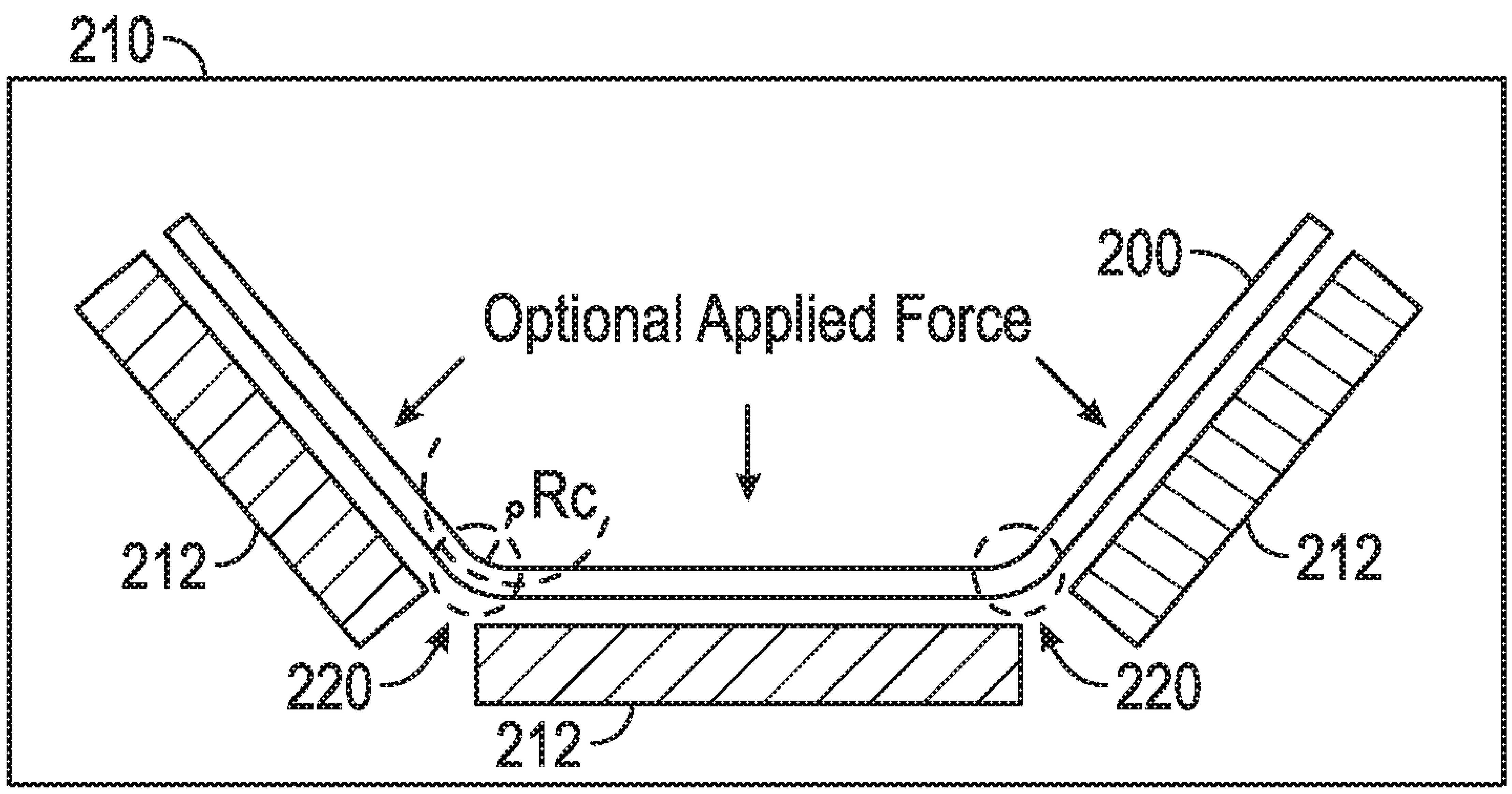


FIG. 2

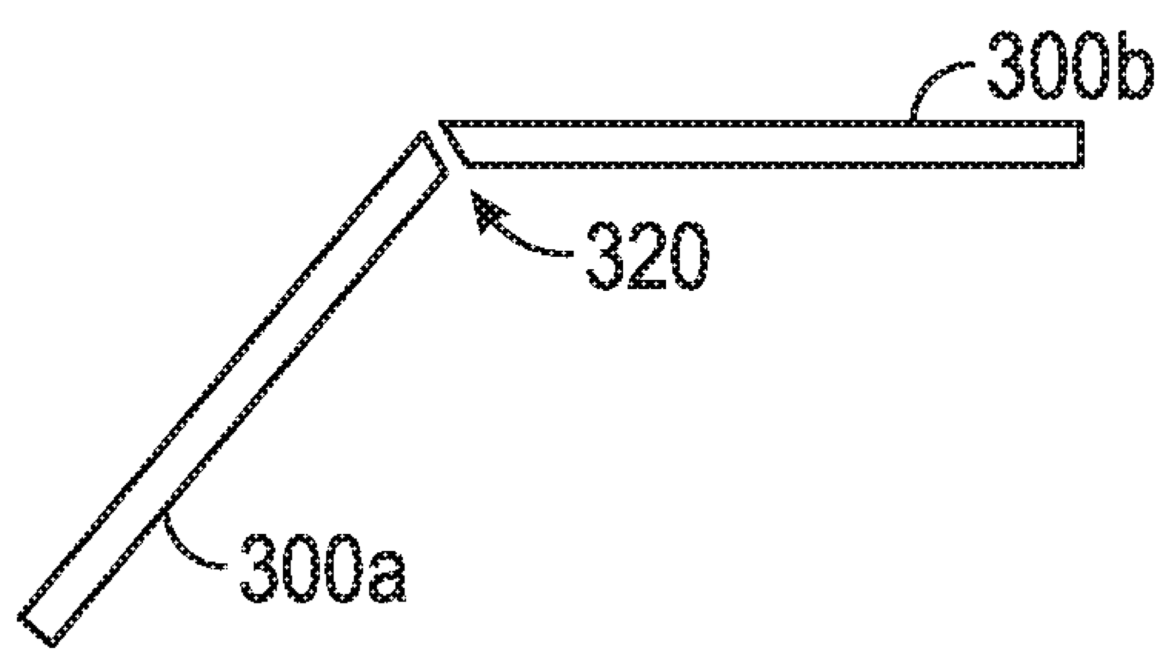


FIG. 3A

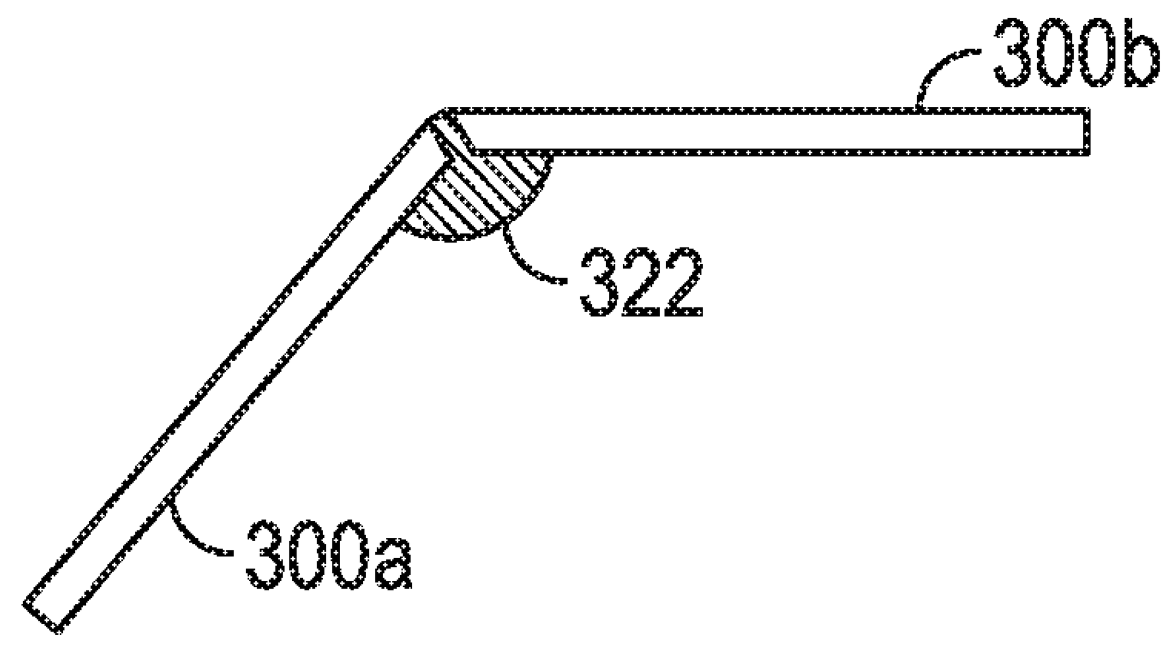


FIG. 3B

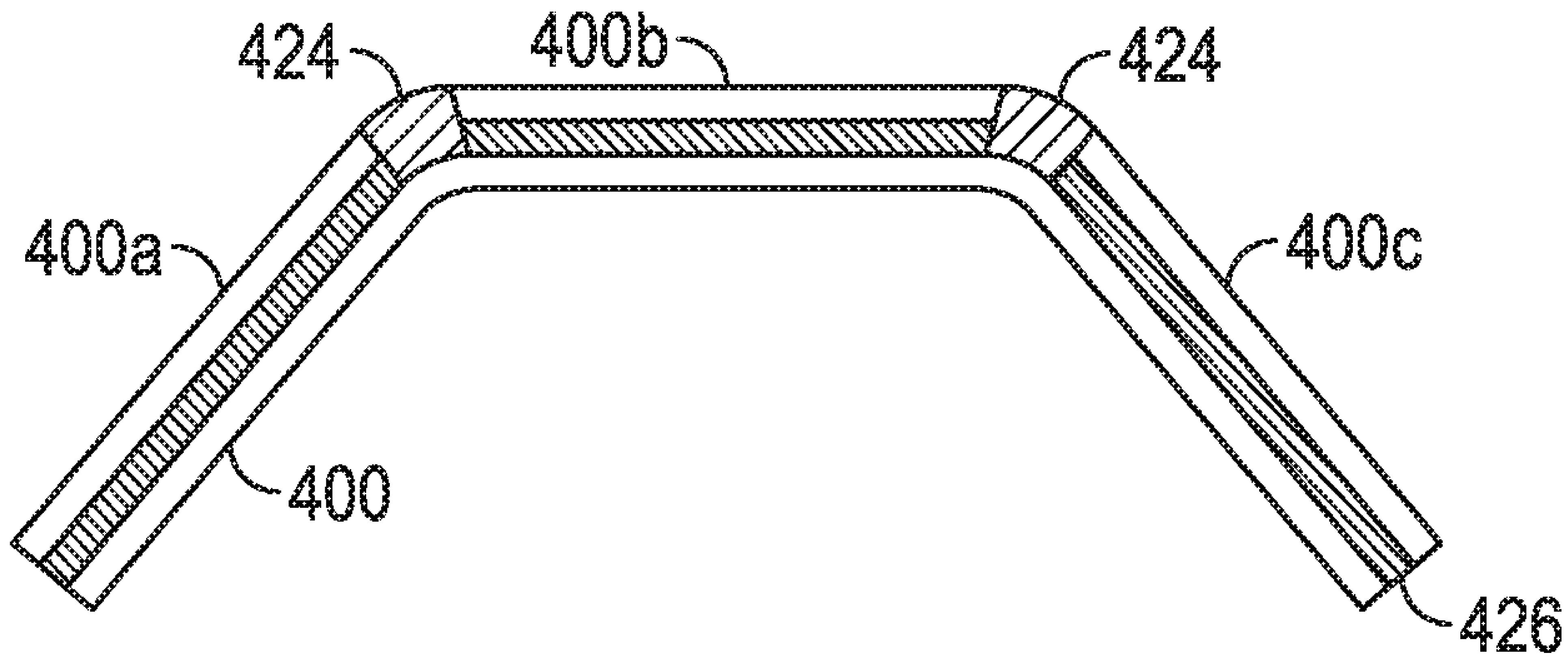


FIG. 4A

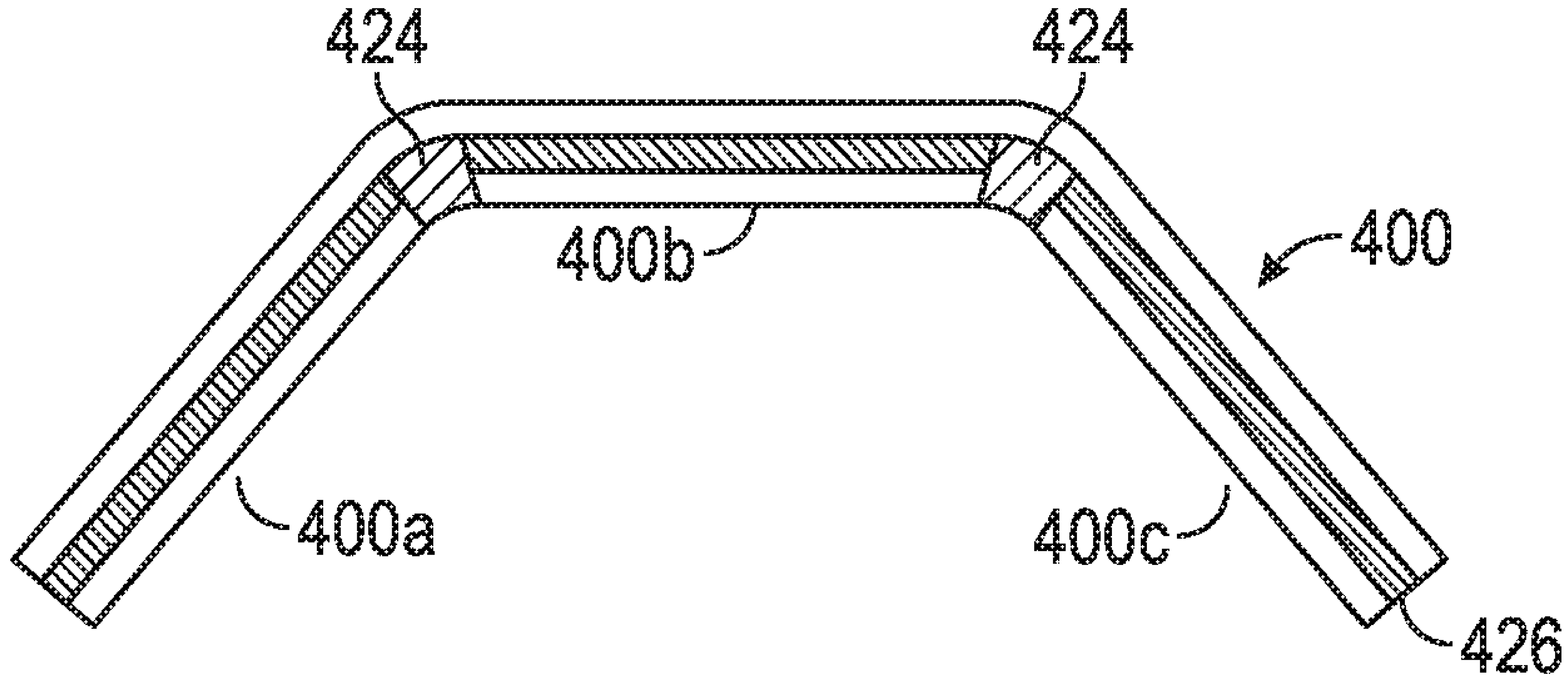


FIG. 4B

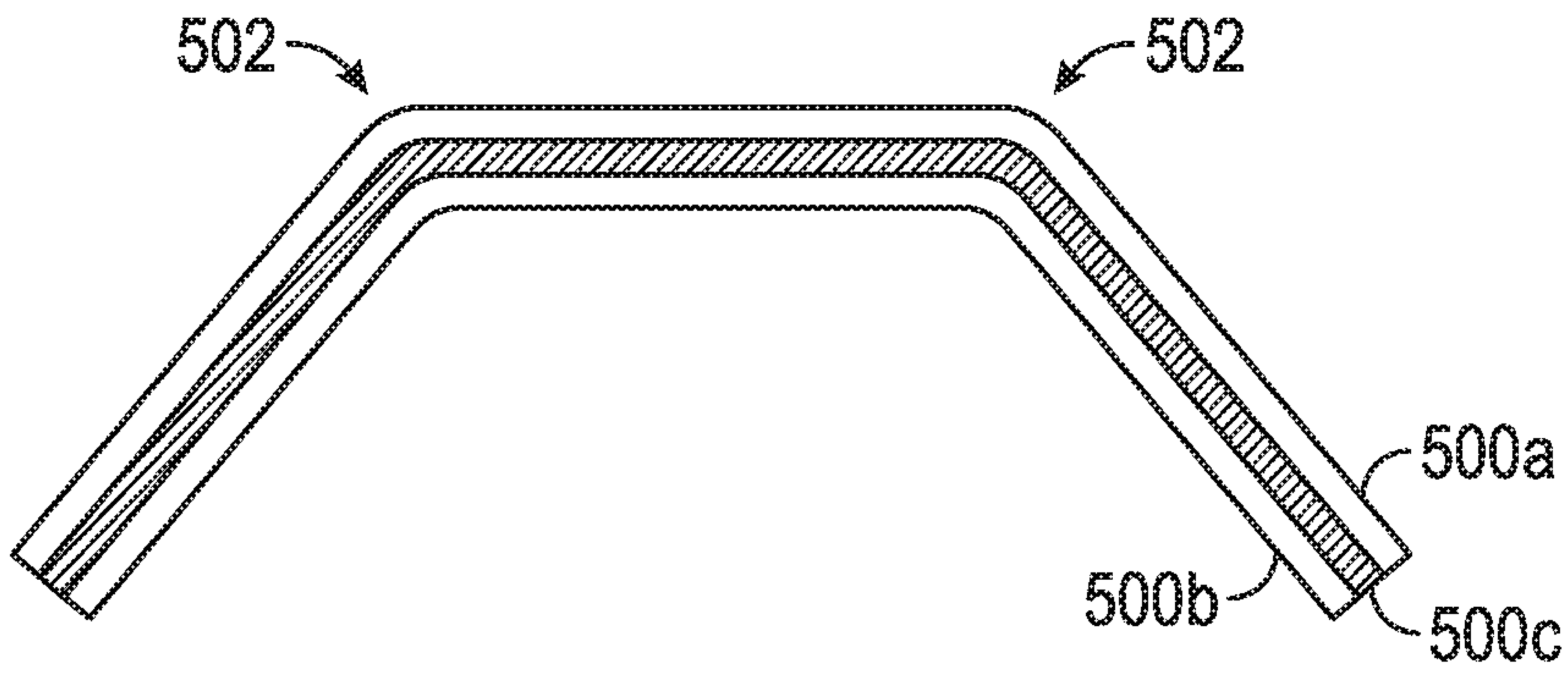


FIG. 5A

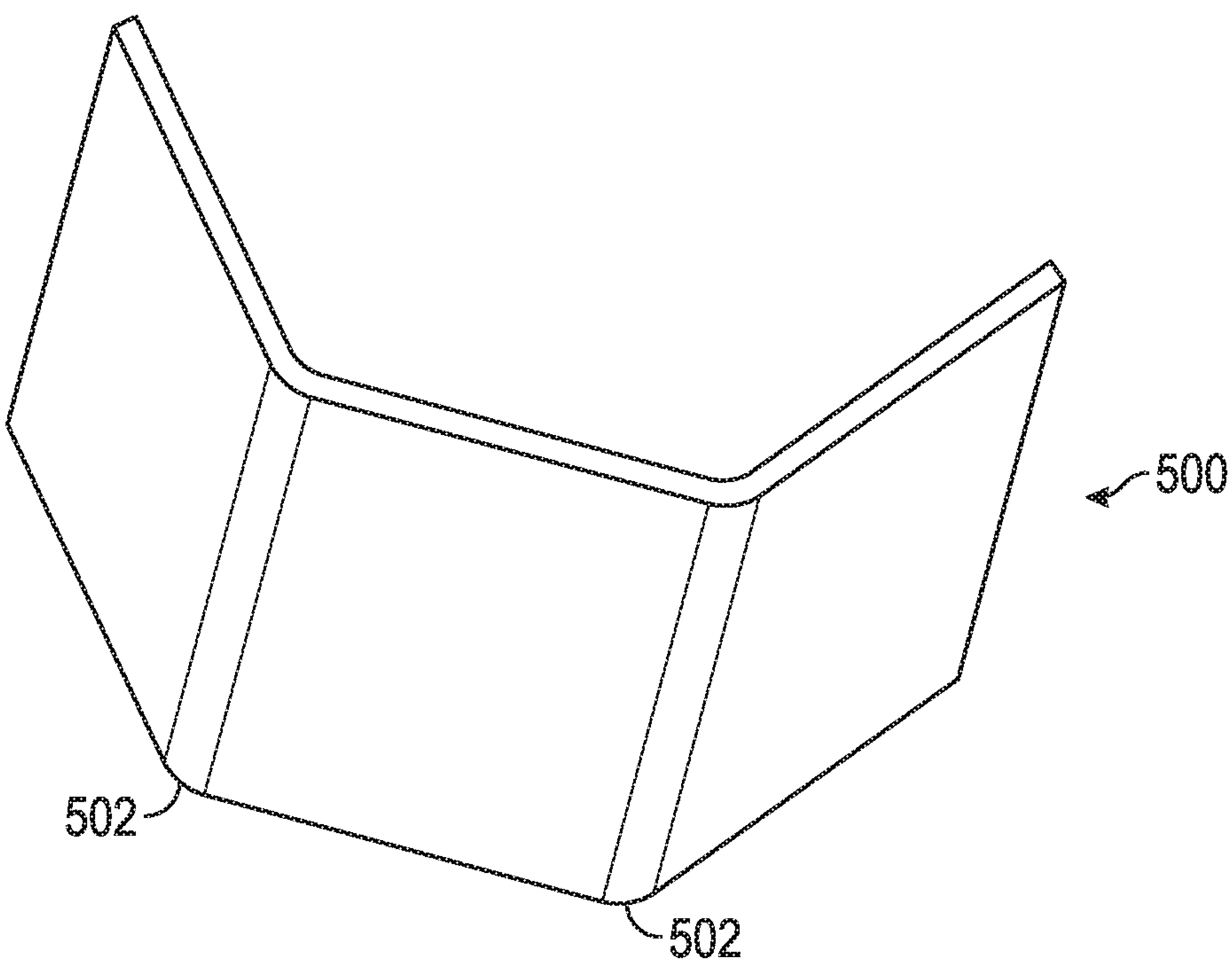


FIG. 5B

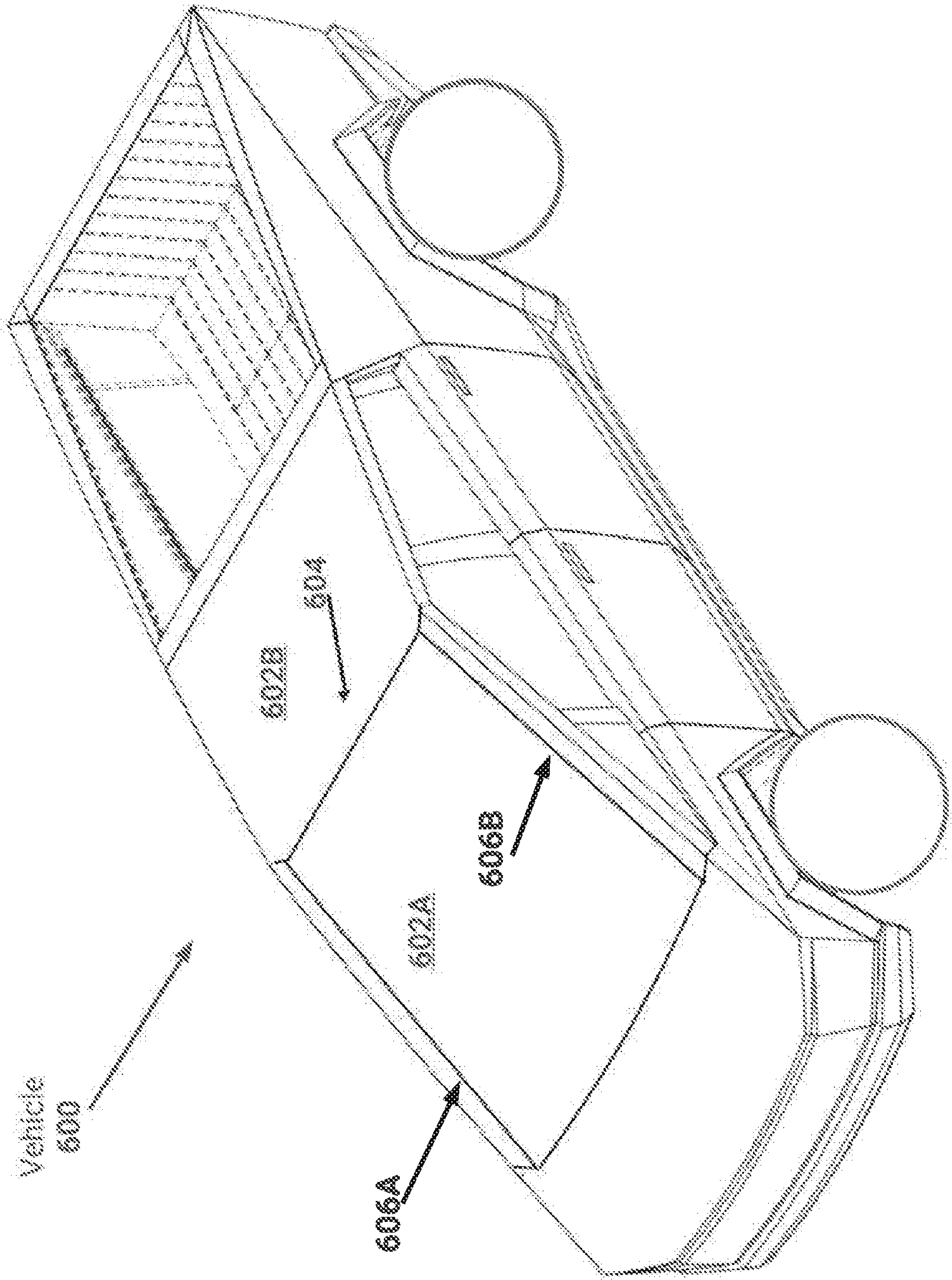


FIG. 6A

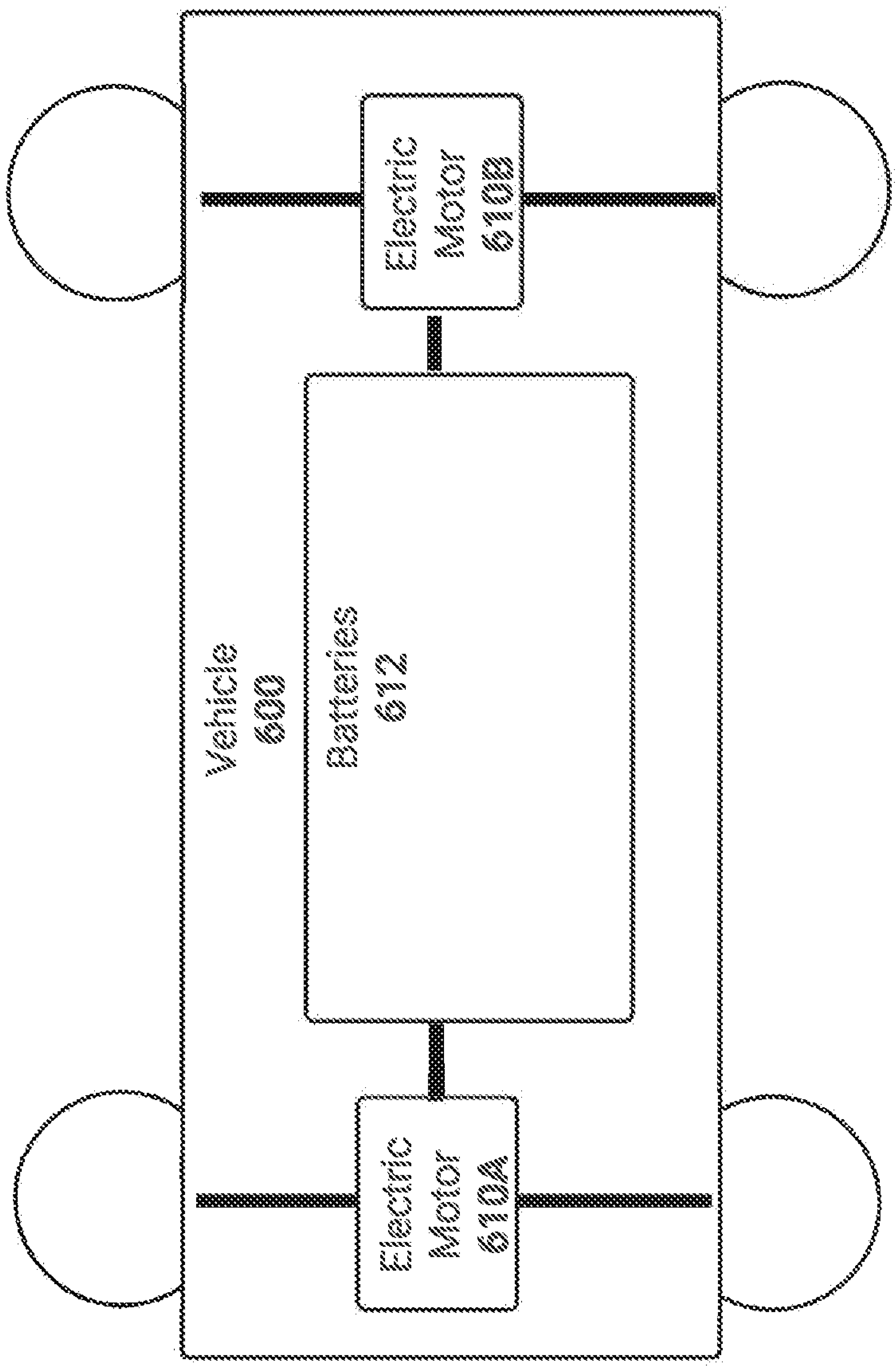

Vehicle
600
Batteries
612
Electric
Motor
610B
Electric
Motor
610A

FIG. 6B

FIG. 7

AUTOMOTIVE GLASS STRUCTURE HAVING FEATURE LINES AND RELATED METHODS OF MANUFACTURE

TECHNICAL FIELD

[0001] The present disclosure relates to glass structures for use in automotive vehicles, and more particularly, to automotive glass structures having curved feature lines and processes for forming the same.

DESCRIPTION OF RELATED ART

[0002] Passenger vehicles such as cars, trucks, or the like, typically include a curved front windshield to protect the driver and provide reduced wind resistance during use. Vehicles typically include various side and rear windows as well, including various shapes and curvatures. Processes for making such windows, and windshields in particular, typically begin with a flat sheet of glass that is cut to desired dimensions and then heated in an oven to sufficient temperatures to slightly bend or curve the glass to a desired shape. The glass may be supported on one or more sides by railings such that gravity pulls and curves the glass there between. Alternatively, the glass may be placed over a mold and heated in an oven to bend around the mold and take the shape thereof

[0003] Generally, such processes for making glass structures are limited by the amount of curvature or bending achievable with the glass. For example, typically only smooth, high radius of curvatures (e.g., radius of curvature of 1-3 meters or more), are used for automotive glass structures.

SUMMARY

[0004] In some embodiments, a process for forming an automotive glass structure having one or more feature lines (or curves/bends) includes applying localized heat to one or more locations of the glass structure, whereby the glass structure bends at the location of the localized heat. In some examples, the glass structure is supported by a support tool such that as localized heat is applied gravity forces the glass structure to bend at the one or more locations (e.g., along a longitudinal line of the glass), thereby forming a feature line or bend in the glass. In some examples, additional forces may be applied to the glass structure, e.g., via a press, vacuum air suction, or the like to aid in bending or shaping of the glass structure. In some examples, a radius of curvature of the feature line or bend in the glass structure at the one or more locations is between 2 mm and 5 cm.

[0005] In another embodiment, a glass structure includes a first layer of glass having a feature line or bend in at least one location thereof. The feature line having a radius of curvature between 2 mm and 5 cm. In some examples, the glass structure is a multilayer glass structure and includes a second layer of glass including a first portion of glass and a second portion of glass, the first and second portions meeting at the feature line or bend in the first layer of glass. A polymer may be disposed between the first layer of glass and the second layer of glass.

[0006] Various other glass structures and processes are provided herein.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] FIG. **1** illustrates a conventional process for bending automotive glass structures.

[0008] FIG. **2** illustrates a process for forming one or more features lines in a glass structure according to one embodiment.

[0009] FIGS. **3**A and **3**B illustrate a process for forming a glass structure according to another embodiment.

[0010] FIGS. **4**A and **4**B illustrate a process for forming a glass structure according to another embodiment.

[0011] FIGS. **5**A and **5**B illustrate an exemplary glass structure according to another embodiment.

[0012] FIGS. **6**A-**6**B illustrate an example vehicle which includes one or more glass structures according to the techniques described herein.

[0013] FIG. **7** illustrates an example of an interior of a vehicle

[0014] Embodiments of the present disclosure and their advantages are best understood by referring to the detailed description that follows. It should be appreciated that like reference numerals are used to identify like elements illustrated in one or more of the figures, wherein showings therein are for purposes of illustrating embodiments of the present disclosure and not for purposes of limiting the same.

DETAILED DESCRIPTION OF THE DISCLOSURE

[0015] This application describes example techniques for forming glass structures for use in a vehicle (e.g., a car, a truck, a semi-truck, and so on) or other apparatus. Example glass structures may include exterior glass for the vehicle. As an example, a glass structure may include a windshield (e.g., a front or rear windshield). As another example, a glass structure may include a window (e.g., a passenger or driver side window). Example glass structures may also include an interior glass for the vehicle. For example, interior glass for a dash (e.g., dashboard) in the front portion of the interior of the vehicle may be formed. As another example, interior glass used for gauges, displays (e.g., electronic displays), instrument clusters, inside panels for doors, consoles, and so on, may be formed and are part of the present embodiments.

[0016] As will be described, the techniques described herein may allow for forming glass structures with aggressive curves or folds (e.g., herein also referred to as 'feature lines'). For example, a faceted windshield with aggressive feature lines may be formed. Without being constrained by way of example, a glass structure may have a feature line with an example radius of curvature of between 2 mm and 5 cm. Thus, glass structures may be formed in shapes and configurations which were previously unavailable through conventional bending methods. In this way, the techniques described herein may provide for stronger glass structures with more aesthetic options not available with conventional automotive glass structure processes.

[0017] With respect to forming the glass structures, glass (e.g., borosilicate glass) may be locally heated to allow for aggressive feature lines where the bend in the glass may be between 5 and 120 degrees, or between 45 to 60 degrees, or for example, 30, 42, 55, 62, 68 degrees. An example of such local heating is described below with respect to FIG. **2**. Additionally, and as described at least in FIGS. **3**A-**3**B, glass pieces or portions may be connected using, for example, adhesive. This adhesive may be similarly locally heated to allow for aggressive feature lines. The above-described glass may be single layer, for example as utilized in an interior of a vehicle. In some embodiments, the single layer glass (e.g., single ply glass) may between about 0.7 mm to about 1.5 mm in thickness. A film (e.g., a polymer) may be applied to the single layer. The glass may additionally be multi-layer glass, such as illustrated in FIGS. **4**A-**5**B. For example, multi-layer glass may be used to form exterior glass structures as described herein.

[0018] Reference will now be made in detail to specific aspects or features, examples of which are illustrated in the accompanying drawings. Like reference numerals refer to corresponding parts throughout the figures.

[0019] FIG. **1** illustrates a side view of a typical process for forming automotive glass structures, e.g., a windshield. In particular, a substantially planar sheet of glass **100** is heated in an oven **110**, while supported by a ring tool **112** (e.g., a ring tool made of steel). As glass **100** reaches a sufficient temperature, glass **100** will bend or curve between while being supported by tool **112**. By varying the time, heat, and the shape of tool **112**, the amount of curvature or bend can be varied to a desired curvature, however, generally such radius of curvatures are limited to having a radius of curvature of about 1-3 meters. Such systems and processes are not well adapted for processing glass to have sharp bends or to have localized bends or curves in the glass structure.

[0020] FIG. **2** illustrates a side view of glass bending process according to one embodiment described herein. In this example, a substantially planar sheet of glass **200** (e.g., cut and sized to approximate dimensions for use in a vehicle windshield) is heated in an oven **210** similar to that described above to a temperature of approximately 650 degrees Celsius or more, the temperature depending on the softening point of the glass used. Glass **200** may include various materials suitable for automotive use, for example, annealed soda lime glass, alumino-silicate, borosilicate, or the like. Further, glass **200** may include a single pane of glass or multiple panes of glass that are stacked together, the different panes being laminated together using a polymer film (e.g. polyvinyl butyral, thermoplastic urethane, polyethylene terephthalate, ionomer, polycarbonate or the like). Further, after bending, glass **200** may be paired with other piece(s) of glass, with PC or another polymer, and can be laminate with PVB, EVA, or the like. In one example suitable for automotive windshields, glass **200** can be approximately 1 by 2 meters and approximately 0.5 mm to 5 mm or more in thickness.

[0021] In this example, a tool **212**, which may include a silica material (or other material with a higher melting temperature than glass), is used to selectively support the glass **200** and promote bending in localized regions, e.g., to create desired feature lines therein. In particular, tool **212** is generally formed in a shape desired for glass **200** after processing/bending. In some examples, portions of tool **212** may be movable, e.g., from a flat or planar orientation to the curved or trench shape shown. The articulated tool **212** can move as the glass softens to promote bending in selected areas. Furthermore, the tool **212** may include fewer or more areas to form additional feature lines, and may also include large radius of curvature surfaces (e.g., 1 m or more) similar to conventional molds.

[0022] In this example, localized heating **220** is applied to the glass **200**, in particular, applied to locations longitudinally along glass **200** where sharp curves or feature lines are desired. Localized heat **220** can be provided via laser, heating resistors (e.g., tungsten wire, rod), flame, plasma, radiative (e.g., diode), or the like. In some examples, a CO**2** laser can be used and scanned along glass **200** where the bending is desired, here along **220**. Such a laser bending step can be done before the glass enters inside the oven **210**, which reduces or eliminates the local stress generated by the local heating inside the oven **210**. In other examples, a heating resistor, e.g., a wire or rod, can be used and the glass **200** placed there over, where the glass **200** bends around the heating resistor via gravity pull and/or with the aid of a support tool, such as tool **212**.

[0023] The localized heat **220** causes regions or locations of glass **200** to reach a higher temperature (e.g., 700 degrees Celsius or greater) than the surrounding glass **200**. Thus, these regions or locations can bend or curve more easily than would occur based on the heat within oven **210** alone (e.g., 650 degrees Celsius). Heating the glass **200** in a localized manner, e.g., along a narrow region, allows for bending of the glass **200** in a sharp manner, e.g., with a small radius of curvature, to form feature lines. For example, the achievable radius of curvature at the location of the localized heat **220** for typical automotive glass (e.g., via a process as shown in FIG. **2**) having a thickness of 0.5-5.5 mm, is in the range of 2 mm to 5 cm.

[0024] In some examples, a downward force may also be applied to glass **200**, for example, via air suction below the tool **212** to pull the glass **200** against the tool **212**. In other examples, a press or mold may be brought down onto the glass **200** to press the glass **200** into the tool **212**. In yet other examples, the tool **212** could be oriented downward, e.g., forming a convex instead of concave shape, and the glass **200** bent downward over the tool **212** to form sharp curves similar to that of FIG. **2**.

[0025] FIGS. **3**A and **3**B illustrate a process for forming a glass structure having a feature line according to another embodiment. In this example, two glass portions **300***a* and **300***b* are brought together at a desired angle at joint **320**. Glass portions **300***a* and **300***b* can be the same or different type of glass and can be joined together in a miter joint at joint **320**. Glass **300***a* and **300***b* may then joined at the joint **320** via an adhesive **322** as shown in FIG. **3**B. Adhesive **322** may include a thermally applied UV cured material such as silicon, polycarbonate transparent plastic, or other suitable adhesive material. In other examples, glass **300***a* and **300***b* may be glass welded together by localized heat applied when brought together, e.g., via laser, torch, resistive heating, or the like.

[0026] As shown in FIG. **3**B, glass **300***a* and **330***b* are adhered together with a small gap there between filled with adhesive **322**, however, in other examples, glass **300***a* and **300***b* can be brought together in direct contact. For example, direct contact may be achieved using glass welding or with adhesive **322** on the planar surfaces thereof. In a similar manner, additional glass portions may be joined with glass **300***a* and/or **300***b* to form additional bends or feature lines (e.g., similar to the shape shown in FIG. **2** or other shapes).

[0027] The final structure shown in FIG. **3**B may similarly have a small radius of curvature at the joint as described herein. Additionally, the final structure may have various interior angles formed between glass **300***a* and **300***b* (e.g., greater than 0 and less than 180 degrees). In some embodiments, glass **300***a* and **300***b* may form an angle between 5 degrees and 120 degrees.

[0028] FIGS. **4**A and **4**B illustrate a glass structure according to additional embodiments. In these embodiments, a first layer of glass **400** formed similarly to the embodiment of FIG. **2** is combined with a second layer of glass **400***a*-**400***c* formed similarly to the embodiment of FIG. **3**B.

[0029] In particular, FIG. **4**A illustrates a structure having the first glass layer **400** as having two feature lines or curved portions similar to glass **200** described above. Adjacent the first glass layer **400**, a second layer of glass made of glass **400***a*, **400***b*, and **400***c* is disposed and offset by an interlayer **426**. The interlayer **426**, for example, may include a suitable polymer such as PVB, EVA, or other suitable material, e.g., that can be autoclaved. Glass **400***a*, **400***b*, and **400***c* can be joined together in various fashions as described with respect to FIGS. **3**A and **3**B (e.g., by adhesive **424**), which may include various thermally applied or UV cured materials. Additionally, glass **400***a*, **400***b*, and **400***c* may also be heat welded together. As an example, the first layer of glass **400** formed as described in FIG. **2** may have a radius of curvature of between 2 mm and 5 cm.

[0030] The example shown in FIG. **4**A may provide for a sharper feature line on the outside or exterior of the curved portion via a mitered join between glass **400***a*, **400***b*, and **400***c*, relative to the curved glass **400**. Such a structure may provide for relatively sharp feature lines (e.g., relative to conventional process) for an automotive glass structure (e.g., a windshield, rear window, display, glass for a dash, and so on). Alternatively, as shown in FIG. **4**B, a sharper feature line on the inside of the curved portion can be achieved with glass **400***a*, **400***b*, and **400***c* disposed on the exterior. Furthermore, in some examples, two or more layers formed of glass portions may be used to create sharper feature lines on the interior and exterior of the final glass structure. Additionally, two or more layers formed of glass layers similar to FIG. **2** may be used for softer feature lines on the interior and exterior of the final glass structure.

[0031] The second layer of glass **400***a*, **400***b*, **400***c*, may additionally be used to adjust a color or visual character associated with the glass structure. For example, each of the portions **400***a*-**400***c* may vary in a visual spectrum which is apparent to a viewer. In this example, the portions may appear darker or lighter to a viewer.

[0032] The examples shown in FIG. **4**A and FIG. **4**B may have improved optical distortion over conventional glass bending processes. For example, optical distortion may be reduced or minimized to a very narrow band, with the achieved feature line being very sharp relative to conventionally bended glass structures. Additionally, functionality can be added into or with the adhesive **424** such as a light guide or embedding of structural elements.

[0033] FIGS. **5**A and **5**B illustrate an exemplary finished glass structure having feature lines **502** according to one embodiment, which is similar to FIGS. **4**A and **4**B. In particular, FIG. **5**A illustrates a side view of glass structure **500**, which may include various layers **500***a*, **500***b*, and **500***c*. The layers **500***a*-**500***c* may include glass layers **500***a*-**500***b* with a polymer layer **500***c* disposed there between. Other possible constructions include a layer of glass **500***a* with polymer layers **500***b* and **500***c*, or a layer of glass **500***b* with polymer layers **500***a* and **500***c*. Additional layers of glass and or polymers may be included.

[0034] In the illustrated embodiment, the glass layers **500***a*-**500***b* may each optionally be formed according to the techniques described in FIG. **2**. For example, each of the glass layers **500***a*-**500***b* may have two feature lines or curved portions similar to glass **200** described above. These glass layers **500***a*-**500***b* may then be connected via layer **500***c* (e.g., an interlayer, such as layer **426** described above). Thus, each of the glass layers **500***a*-**500***b* may have a radius of curvature of between 2 mm and 5 cm.

[0035] FIGS. **6**A-**6**B illustrate an example vehicle **600** which includes a glass structure according to the techniques described herein. In FIG. **6**A, vehicle **600** (e.g., a truck) is depicted. In some embodiments, the vehicle **600** may be an electric vehicle. The vehicle **600** includes a first glass structure **602**A and a second glass structure **602**B.

[0036] The first glass structure **602**A may be, for example, the glass structure illustrated in FIG. **5**B and described above. As an example, the first glass structure **602**A may represent a windshield positioned on the vehicle and formed according to the techniques described herein. In some embodiments, the first glass structure **602**A may be multilayer. Optionally, the first glass structure **602**A may be single layer and formed as described herein with respect to FIG. **2**. Thus, the first glass structure **602**A may have feature lines (e.g., facets) **606**A-**606**B. As an example, these feature lines **600**A-**600**B may have radii of curvatures of between 2 mm and 5 cm. In some embodiments, the feature lines **600**A-**600**B may represent an angle of between 45-60 degrees, or 50-75 degrees, and so on.

[0037] In some embodiments, the first glass structure and second glass structure **602**A-**602**B may be connected via an adhesive (e.g., at feature line **604**). For example, the glass structures **602**A-**602**B may be connected as described, at least, in FIGS. **3**A-**3**B. As another example, the glass structures **602**A-**602**B may represent the glass structure of FIG. **4**A-**4**B. For example, glass structure **602**A may represent a top or bottom layer with glass structure **602**B representing a remaining layer. In this example, either glass structure **602**A or **602**B may be formed from a multitude of pieces connected via adhesive. The remaining glass structure (e.g., the bottom or top layer) may be formed from a single sheet of glass as described in FIG. **2**.

[0038] While not illustrated, it may be appreciated that the vehicle **600** may include an interior glass structure. For example, the vehicle **600** may include a glass dash positioned in the front of the vehicle **600** which is formed as described herein. In this example, the glass may optionally be a single layer glass with a film (e.g., polymer film) on top. As another example, a display (e.g., a touch-sensitive electronic display) may be formed from glass as described herein. The display may advantageously be curved or extend across substantially a length of the vehicle **600** due to the enhanced forming techniques described herein.

[0039] FIG. **6**B illustrates a block diagram of the vehicle **600**. The vehicle **600** may include one or more electric motors **610**A-**610**B which cause movement of the vehicle **600**. The electric motors **610**A-**610**B may include, for example, induction motors, permanent magnet motors, and so on. Batteries **612** (e.g., one or more battery packs each comprising a multitude of batteries) may be used to power the electric motors **610**A-**610**B as is known by those skilled in the art.

[0040] FIG. **7** illustrates an example of an interior **700** of a vehicle, such as the vehicle **600** described above. The interior **700** includes a glass dash **702** with a feature line **704**. As described above, the feature line **704** may have a radius of curvature of between 2 mm and 5 cm. In some embodiments, the feature line **704** may represent an angle of between 45-60 degrees, or 50-75 degrees, and so on.

[0041] The glass dash **702** may be formed according to the techniques described above. For example, the glass dash **702** may be formed as described in FIG. **2**. Thus, a single layer of glass may be used and locally heated to form the feature line **704**. In some embodiments, a film or layer may be positioned below the glass dash **702**. For example, the film or layer may be used to present a visual design and/or may be used to ensure the glass does not shatter (e.g., a safety or security film).

[0042] The foregoing disclosure is not intended to limit the present disclosure to the precise forms or particular fields of use disclosed. As such, it is contemplated that various alternative embodiments and/or modification to the present disclosure, whether explicitly described or implied herein, are possible in light of the disclosure. Having thus described embodiments of the present disclosure, a person of ordinary skill in the art will recognize that changes may be made in form and detail without departing from the scope of the present disclosure.

[0043] In the foregoing specification, the disclosure has been described with reference to specific embodiments. However, as one skilled in the art will appreciate, various embodiments disclosed herein can be modified or otherwise implemented in various other ways without departing from the spirit and scope of the disclosure. Accordingly, this description is to be considered as illustrative and is for the purpose of teaching those skilled in the art the manner of making and using various embodiments of the glass structure. It is to be understood that the forms of disclosure herein shown and described are to be taken as representative embodiments. Equivalent elements, or materials may be substituted for those representatively illustrated and described herein. Moreover, certain features of the disclosure may be utilized independently of the use of other features, all as would be apparent to one skilled in the art after having the benefit of this description of the disclosure. Expressions such as "including", "comprising", "incorporating", "consisting of", "have", "is" used to describe and claim the present disclosure are intended to be construed in a non-exclusive manner, namely allowing for items, components or elements not explicitly described also to be present. Reference to the singular is also to be construed to relate to the plural.

[0044] Additionally, numerical terms, such as, but not limited to, "first", "second", "third", "primary", "secondary", "main" or any other ordinary and/or numerical terms, should also be taken only as identifiers, to assist the reader's understanding of the various elements, embodiments, variations and/ or modifications of the present disclosure, and may not create any limitations, particularly as to the order, or preference, of any element, embodiment, variation and/or modification relative to, or over, another element, embodiment, variation and/or modification.

[0045] It will also be appreciated that one or more of the elements depicted in the drawings/figures can also be implemented in a more separated or integrated manner, or even removed in certain cases, as is useful in accordance with a particular application.

What is claimed is:

1. A method for forming a glass structure for a vehicle, the method comprising:

applying localized heat to first location of a substantially planar glass structure; and

bending the glass structure at the first location, wherein a radius of curvature of the glass at the first location is between 2 mm and 5 cm.

2. The method of claim **1**, wherein the first location is along a line of the planar glass structure.

3. The method of claim **1**, further comprising:

applying heat to at least a second location of the glass structure; and

bending the glass structure at the second location.

4. The method of claim **1**, wherein the planar glass structure is supported by a mold when applying the localized heat.

5. The method of claim **1**, wherein the localized heat is supplied by a laser.

6. The method of claim **5**, wherein the laser is scanned over the glass structure.

7. The method of claim **1**, wherein the localized heat is supplied by a heating element.

8. The method of claim **1**, wherein the glass structure is heated in an oven operating at least 600 degrees Celsius, and the localized heat heats the first location to at least 650 degrees Celsius.

9. A glass structure for a vehicle, comprising:

a first layer of glass formed of a substantially planar layer of glass, the first layer of glass including at least one curved region having a radius of curvature of 2 mm to 5 cm;

a second layer of glass formed of at least two portions of glass, wherein the two portions of glass meet at the at least one curved region; and

a polymer disposed between the first layer of glass and the second layer of glass.

10. The structure of claim **9**, wherein the at least two panes of glass are joined together by a polymer.

11. The structure of claim **9**, wherein the at least two portions of glass are glass welded together.

12. The structure of claim **9**, wherein the two portions of glass form an angle of between 5 degrees and 120 degrees.

13. The structure of claim **9**, wherein the two portions of glass form a mitered joint.

14. A vehicle comprising:

one or more electric motors;

a battery pack connected to the electric motors; and

a glass structure positioned on the vehicle, wherein the glass structure comprises a first layer of glass which has at least one feature line with a radius of curvature of 2 mm to 5 cm.

15. The vehicle of claim **14**, wherein the first layer of glass is a substantially planar layer of glass, and wherein the first layer of glass includes the at least one feature line.

16. The vehicle of claim **15**, wherein the glass structure further comprises:

a second layer of glass formed of at least two portions of glass, wherein the two portions of glass meet at the at least one feature line; and

a polymer disposed between the first layer of glass and the second layer of glass.

17. The vehicle of claim **14**, wherein the glass structure comprises at least two panes of glass which are joined together by a polymer.

18. The vehicle of claim **14**, wherein the glass structure comprises at least two portions of glass which are glass welded together.

19. The vehicle of claim **14**, wherein the glass structure comprises two portions of glass which form an angle of between 5 degrees and 120 degrees.

20. The vehicle of claim **14**, wherein the glass structure is a windshield of the vehicle or a dash positioned inside the vehicle.

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