(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
26 December 2019 (26.12.2019)

WIPO | PCT

(10) International Publication Number
WO 2019/245809 A1

(51) International Patent Classification:
H01L 21/02 (2006.01) *H01L 21/324* (2006.01)
H01L 21/18 (2006.01) *H01L 21/67* (2006.01)
H01L 21/50 (2006.01)

(21) International Application Number:
PCT/US2019/036647

(22) International Filing Date:
12 June 2019 (12.06.2019)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
62/688,112 21 June 2018 (21.06.2018) US

(71) Applicant: **CORNING INCORPORATED** [US/US]; 1 Riverfront Plaza, Corning, New York 14831 (US).

(72) Inventors: **BADDING, Michael Edward**; 5165 Waters Road, Campbell, New York 14821 (US). **DAWSON-ELLI, David Frances**; 4579 State Route 14, Dundee, New York 14837 (US). **GARNER, Sean Matthew**; 415 Foster Avenue, Elmira, New York 14905 (US). **GORELCHENKO, Petr**; 176 Woods Edge Dr., Painted Post, New York 14870 (US). **KETCHAM, Thomas Dale**; 1467 LeMae Dr., Horseheads, New York 14845 (US). **SHUBIN, Sergey Nikolaevich**; Kollontay 24/2, Apt. #81, Saint-Petersburg, 193231 (RU). **SOROKINA, Ekaterina S**; Kosmonavtov prospekt 65-1, Apt. #122, Saint-Petersburg, 196158 (RU). **ZHUANG, Cheng-Gang**; 3545 Conhocton Road, Painted Post, New York 14870 (US).

(74) Agent: **MAGAZINER, Russell S.**; Corning Incorporated, Intellectual Property Department SP-TI-03-1, Corning, New York 14831 (US).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN,

(54) Title: STIFFENED THIN SUBSTRATES AND ARTICLES FORMED THEREFROM

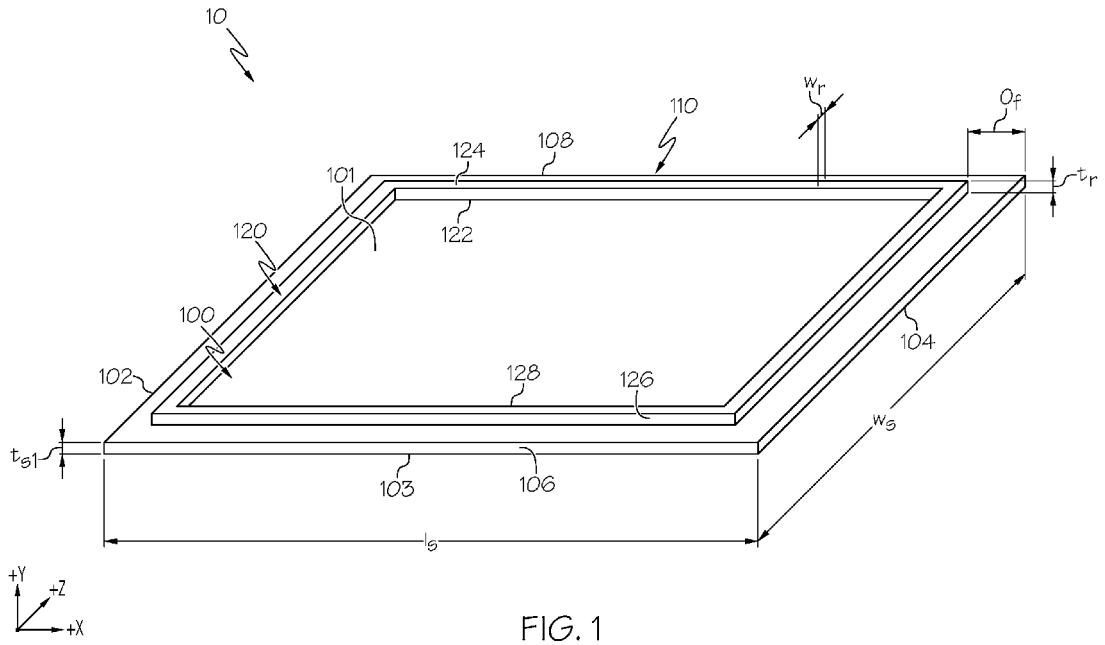


FIG. 1

(57) Abstract: A stiffened thin substrate with a substrate layer and a perimetrical glass frit rib bonded to a first surface of the substrate layer is provided. The perimetrical glass frit rib bonded to the first surface of the substrate layer may per unit length, of the substrate layer subjected to a 5 gram load by at least 15%. An electronic device layer may be thermal bonded to a second surface of the substrate layer opposite the first surface, and the perimetrical glass frit rib bonded to the first surface of the substrate layer may decrease thermal deflection, per unit length, of the substrate layer by at least 50% when the substrate layer with the electronic device layer is cooled from 600°C to 23°C.

WO 2019/245809 A1

[Continued on next page]

HR, HU, ID, IL, IN, IR, IS, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) **Designated States** *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*

STIFFENED THIN SUBSTRATES AND ARTICLES FORMED THEREFROM

Cross-Reference to Related Applications

[0001] This application claims the benefit of priority of U.S. Provisional Application Serial No. 62/688,112 filed on June 21, 2018 the contents of which are relied upon and incorporated herein by reference in their entirety as if fully set forth below.

BACKGROUND

Field

[0002] The present specification generally relates to thin substrates, and, more specifically, to stiffened thin substrates.

Technical Background

[0003] Thick and thin film deposition and patterning techniques are used to form a variety of dielectric, semiconductor, and conductor layers on a substrate during manufacturing of electronic devices such as batteries, sensors, and the like. Example substrates include thin sheets formed from a ceramic composition, a glass composition, and the like.

SUMMARY

[0004] Electronic devices such as batteries, sensors, etc., may be manufactured on substrate layers comprising a ceramic composition, a glass composition or a ceramic/glass composition. Thinner substrate layers are desired thereby reducing weight and cost. However, thin substrate layers may be difficult to handle, transport, etc., during manufacturing of electronic devices on the substrate layers. That is, handling of a thin substrate layer may be problematic due to a lack of stiffness of the substrate layer. Accordingly, problems such as a decrease in pattern resolution during the manufacture of electronic devices on the substrate layer may occur. Thin substrate layers may also suffer from shape deformation (i.e., bowing, curling, warping, cambering) when an additional layer having a different composition than the substrate layers is deposited and thermally bonded to the substrate layer. This shape deformation may be unpredictable and sensitive to small

stress perturbations. Particularly, a difference in the coefficient of thermal expansion (CTE) between a substrate layer and an additional layer (e.g., an electrode layer) deposited and thermally bonded onto the substrate layer at an elevated temperature (e.g., 600°C) results in subsequent shape deformation upon cooling the substrate layer with the additional layer to ambient temperature.

[0005] In one embodiment a stiffened thin substrate comprises a substrate layer formed from a ceramic composition, a glass composition or a ceramic/glass composition. A perimetrical glass frit rib is bonded to a first surface of the substrate layer. The perimetrical glass frit rib may be spaced from a perimeter of the substrate layer and the perimetrical glass frit rib bonded to the first surface of the substrate layer decreases gravitational deflection, per unit length, of the substrate layer by at least 50%. In embodiments, the perimetrical glass frit rib may be bonded to the first surface spaced from the perimeter of the substrate layer by less than or equal to about 2 mm and the perimetrical glass frit rib decreases thermal deflection, per unit length, of the substrate layer by at least 50% when the substrate layer is cooled from about 600°C to about 23°C. In some embodiments, and in addition to the perimetrical glass frit rib, a plurality of glass frit ribs may be bonded to the first surface of the substrate layer such and the perimetrical glass frit rib and the plurality of glass frit ribs may form a plurality of glass frit frames bonded to the first surface of the substrate layer. In such embodiments, the substrate layer with the perimetrical glass frit rib and the plurality of glass frit ribs may comprise a plurality of electronic device substrates and a plurality of electronic devices may be bonded to the plurality of electronic device substrates such that an electronic device is bonded to each of the plurality of electronic device substrates. Also, the plurality of electronic devices may be manufactured on the plurality of electronic device substrates. In embodiments, an electronic device layer may be thermally bonded to a second surface of the substrate layer opposite the first surface. In such embodiments, the perimetrical glass frit rib bonded to the first surface of the substrate layer may decrease thermal deflection, per unit length, of the substrate layer with the electronic device layer by at least 50% when the substrate layer with the electronic device layer is cooled from about 600°C to about 23°C.

[0006] In another embodiment, a stiffened thin substrate comprises a substrate layer formed from a ceramic composition, a glass composition or a ceramic/glass composition. A perimetrical glass frit rib is bonded to a first surface of the substrate layer and an electronic device layer is thermally bonded to a second surface of the substrate layer opposite the first

surface. The perimetrical glass frit rib bonded to the first surface of the substrate layer decreases thermal deflection, per unit length, of the substrate layer with the electronic device layer by at least 50% when the substrate layer with the electronic device layer is cooled from about 600°C to about 23°C. Also, the perimetrical glass frit rib bonded to the first surface of the substrate layer may decrease gravitational deflection, per unit length, of the substrate layer with the electronic device layer by at least 50%. In addition to the perimetrical glass frit rib, a plurality of glass frit ribs may be bonded to the first surface of the substrate layer, and the perimetrical glass frit rib and the plurality of glass frit ribs may form a plurality of glass frit frames bonded to the first surface of the substrate layer. The plurality of glass frit frames may comprise a plurality of electronic device substrates and a plurality of electronic devices may be bonded to the plurality of electronic device substrates such that an electronic device is bonded to each of the plurality of electronic device substrates.

[0007] In yet another embodiment, a process for forming a stiffened thin substrate for a plurality of electronic devices comprises forming, drying and sintering a perimetrical glass frit rib on a first surface of a substrate layer. The perimetrical glass frit rib may be spaced from a perimeter of the substrate layer by less than or equal to about 20 mm, and the perimetrical glass frit rib bonded to the first surface of the substrate layer may decrease gravitational deflection, per unit length, of the substrate layer by at least 50%. In embodiments, the process may further comprise thermally bonding an electronic device layer on a second surface of the substrate layer opposite the first surface. The electronic device layer may have a composition different than the substrate layer and the perimetrical glass frit rib bonded to the first surface of the substrate layer may decrease thermal deflection, per unit length, of the substrate layer with the electronic device layer by at least 50% when the substrate layer with the electronic device layer is cooled from about 600°C to about 23°C. In some embodiments, the perimetrical glass frit rib may be spaced from the perimeter of the substrate layer by less than or equal to about 2 mm. The process may further comprise forming, drying and sintering a plurality of glass frit ribs on the first surface of the substrate layer. The perimetrical glass frit rib and the plurality of glass frit ribs may form a plurality of glass frit frames bonded to the first surface of the substrate layer. The plurality of glass frit frames may form a plurality of electronic device substrates and a plurality of electronic devices may be manufactured on the plurality of electronic device substrates such that an electronic device is manufactured on each of the plurality of electronic device substrates.

[0008] Additional features and advantages will be set forth in the detailed description which follows, and in part will be readily apparent to those skilled in the art from the description or recognized by practicing the embodiments as described in the written description and claims hereof, as well as the appended drawings.

[0009] It is to be understood that both the foregoing general description and the following detailed description are merely exemplary, and are intended to provide an overview or framework to understand the nature and character of the claims. The accompanying drawings are included to provide a further understanding, and are incorporated in and constitute a part of this specification. The drawings illustrate one or more embodiments, and together with the description serve to explain principles and operation of the various embodiments.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] FIG. 1 schematically depicts a stiffened thin substrate with a perimetrical glass frit rib according to one or more embodiments described herein;

[0011] FIG. 2 schematically depicts a stiffened thin substrate with an additional layer according to one or more embodiments described herein;

[0012] FIG. 3 schematically depicts a stiffened thin substrate with a plurality of glass frit ribs, a plurality of glass frit frames, and a plurality of electronic devices manufactured according to one or more embodiments described herein;

[0013] FIG. 4 schematically depicts a process for forming stiffened thin substrates with glass frit ribs according to one or more embodiments described herein;

[0014] FIG. 5 schematically depicts a deflection testing technique according to one or more embodiments described herein;

[0015] FIG. 6 graphically depicts gravitational deflection, per unit length, for a substrate layer with a perimetrical glass frit rib according to one or more embodiments described herein and a substrate layer without a perimetrical glass frit rib;

[0016] FIG. 7A schematically depicts a top view of a deflection testing technique according to one or more embodiments described herein;

[0017] FIG. 7B schematically depicts a section 7B-7B in FIG. 7A;

[0018] FIG. 8 graphically depicts deflection as a function of perimetrical glass frit rib thickness for a substrate layer with a 5 gram load placed thereon according to the deflection testing technique in FIGS. 7A and 7B; and

[0019] FIG. 9 graphically depicts deflection, per unit length, as a function of perimetrical glass frit rib thickness for a substrate layer with a 5 gram load placed thereon according to the deflection testing technique in FIGS. 7A and 7B.

DETAILED DESCRIPTION

[0020] Referring to FIG. 1, a stiffened thin substrate 10 comprises a substrate layer 100 with a perimetrical glass frit rib 120, i.e., a rib 120 extending along or near a perimeter 110 of the surface of the substrate layer 100. The perimetrical glass frit rib 120 is disposed over and bonded to the substrate layer 100. The substrate layer 100 comprises a first surface 101 (also referred to herein as an "upper surface 101" (+Y direction)), a second surface 103 (also referred to herein as a "lower surface 103" (-Y direction)), a first end 102, a second end 104 spaced apart from the first end 102, a first side 106, and a second side 108 spaced apart from the first side 106. A perimeter 110 of the substrate layer 100 extends along an outer edge (not labeled) of the substrate layer 100. The substrate layer 100 has a thickness 't_{s1}' (Y direction) between the upper surface 101 an the lower surface 103, a length 'l_s' (X direction) extending from the first end 102 to the second end 104, and a width 'w_s' (Z direction) extending from the first side 106 to the second side 108. While the substrate layer 100 depicted in FIG. 1 has a rectangular shape, it should be understood that substrate layers with other geometrical shapes such as circles, triangles, ellipses, and the like may be utilized and are included in the instant disclosure.

[0021] In embodiments, the perimetrical glass frit rib 120 comprises a lower surface 122 bonded to the upper surface 101 of the substrate layer 100, an upper surface 124 spaced apart from the lower surface 122, an outer surface 126 and an inner surface 128 spaced apart from the outer surface 126. The perimetrical glass frit rib 120 has a thickness 't_r' between the lower surface 122 and the upper surface 124, and a width 'w_r' between the outer surface 126 and the inner surface 128. Also, the outer surface 126 of the perimetrical glass frit rib 120 may be spaced or offset from the perimeter 110 of the substrate layer 100 by a distance 'O_f'

that is less than or equal to 20 mm, for example, less than or equal to 10 mm, 5 mm, 2 mm or 1 mm. In some embodiments, perimetrical glass frit rib 120 may be positioned on the perimeter 110 of the substrate layer 100, i.e., the distance 'O_f' is equal to zero (e.g., see FIG. 2). Also, the perimetrical glass frit rib 120 may extend continuously along or near a perimeter 110. In the alternative, the perimetrical glass frit rib 120 may extend non-continuously along or near a perimeter 110. That is, the perimetrical glass frit rib 120 may have one or more gaps where so long as the perimetrical glass frit rib 120 provides a stiffness to the substrate layer 100 as described herein.

[0022] In embodiments, the perimetrical glass frit rib 120 reduces deflection due to the force of gravity (hereafter referred to as "gravitational deflection") of a substrate layer 100, per unit length, by at least 50%. For example, in some embodiments, the perimetrical glass frit rib 120 may reduce the gravitational deflection of a substrate layer 100, per unit length, by at least 66%. In other embodiments, the perimetrical glass frit rib 120 may reduce the gravitational deflection of a substrate layer 100, per unit length, by at least 80%. In still other embodiments, the perimetrical glass frit rib 120 may reduce the gravitational deflection of a substrate layer 100, per unit length, by at least 90%. It should be understood that the perimetrical glass frit rib 120 may reduce the gravitational deflection of a substrate layer 100, per unit length, between 50% and 90%. For example, in some embodiments, the perimetrical glass frit rib 120 may reduce the gravitational deflection of a substrate layer 100, per unit length, between 50% and 66%. In other embodiments, the perimetrical glass frit rib 120 may reduce the gravitational deflection of a substrate layer 100, per unit length, between 66% and 80%. In still other embodiments, the perimetrical glass frit rib 120 may reduce the gravitational deflection of a substrate layer 100, per unit length, between 80% and 90%.

[0023] Turning now to FIG. 2, one or more additional layers may be disposed over and bonded to the substrate layer 100. Particularly, a multilayer assembly 112 may be formed from an electronic device layer 140 (i.e., a layer that forms part of an electronic device manufactured on the substrate layer 100) bonded to the substrate layer 100. The electronic device layer 140 comprises an upper surface 142, a lower surface 144, and a thickness 't_{s2}' between the upper surface 142 and the lower surface 144. In embodiments, the upper surface 142 may be thermally bonded to the lower surface 103 of the substrate layer 100. As depicted in FIG. 2, the electronic device layer 140 may have generally the same length l_s and width w_s as the substrate layer 100. The electronic device layer 140 may be formed from a

material that is different than the substrate layer 100. Accordingly, the substrate layer 100 may have a first coefficient of thermal expansion ('CTE_1') and the electronic device layer 140 may have a second 'CTE_2' that is different than the first coefficient of thermal expansion CTE_1 (i.e., $CTE_1 \neq CTE_2$). It should be understood that cooling or heating of the multilayer assembly 112 results in different thermal contraction or thermal expansion, respectively, between the substrate layer 100 and the electronic device layer 140. Also, depending on the amount of thermal contraction difference between the substrate layer 100 and the electronic device layer 140, deflection (e.g., bowing) of the multilayer assembly 112 may occur when the multilayer assembly 112 is cooled from an elevated temperature to ambient temperature as described below.

[0024] In embodiments, the perimetrical glass frit rib 120 reduces deflection of the multilayer assembly 112, per unit length, due to the differences of CTE between the substrate layer 100 and the electronic device layer 140 bonded to the substrate layer 100 and when the multilayer assembly 112 is cooled from an elevated temperature to ambient temperature (hereafter referred to as "thermal deflection"). For example, in embodiments, the perimetrical glass frit rib 120 may reduce the thermal deflection of a multilayer assembly 112, per unit length, by at least 50% when the multilayer assembly is cooled from 600°C to 23°C. In some embodiments, the perimetrical glass frit rib 120 may reduce the thermal deflection of a multilayer assembly 112, per unit length, by at least 66% when the multilayer assembly is cooled from 600°C to 23°C. In other embodiments, the perimetrical glass frit rib 120 may reduce the thermal deflection of a substrate layer 100, per unit length, by at least 80% when the multilayer assembly is cooled from 600°C to 23°C. In still other embodiments, the perimetrical glass frit rib 120 may reduce the thermal deflection of a substrate layer 100, per unit length, by at least 90% when the multilayer assembly is cooled from 600°C to 23°C. It should be understood that the perimetrical glass frit rib 120 may reduce the thermal deflection of a substrate layer 100, per unit length, between 50% and 90%. For example, in some embodiments, the perimetrical glass frit rib 120 may reduce the thermal deflection of a substrate layer 100, per unit length, between 50% and 66%. In other embodiments, the perimetrical glass frit rib 120 may reduce the thermal deflection of a substrate layer 100, per unit length, between 66% and 80%. In still other embodiments, the perimetrical glass frit rib 120 may reduce the thermal deflection of a substrate layer 100, per unit length, by a between 80% and 90%.

[0025] The thickness, length and width of the substrate layer 100 may depend on the intended use of the stiffened thin substrate 10. In embodiments, the substrate layer 100 may have a thickness t_{s1} within the range of about 10 μm and about 100 μm, a length l_s within the range of about 75 mm and about 500 mm, and a width w_s within the range of about 50 mm and about 500 mm. In some embodiments, the thickness of the substrate layer 100 may be between about 10 μm and about 90 μm, for example between about 10 μm and 20 μm, between about 20 μm and 30 μm, between about 30 μm and 40 μm, between about 40 μm and 50 μm, between about 50 μm and 60 μm, between about 60 μm and 70 μm, between about 70 μm and 80 μm, or between about 80 μm and 90 μm. In such embodiments, the length of the substrate layer 100 may be between about 75 mm and about 400 mm, for example between about 75 mm and about 100 mm, between about 100 mm and about 125 mm, between about 125 mm and about 150 mm, between about 150 mm and about 200 mm, between about 200 mm and about 250 mm, between about 250 mm and about 300 mm, between about 300 mm and about 350 mm, or between about 350 mm and about 400 mm. Also, in such embodiments, the width of the substrate layer 100 may be between about 50 mm and about 350 mm, for example between about 50 mm and about 75 mm, between about 75 mm and about 100 mm, between about 100 mm and about 125 mm, between about 125 mm and about 150 mm, between about 150 mm and about 200 mm, between about 200 mm and about 250 mm, between about 250 mm and about 300 mm, or between about 300 mm and about 350 mm.

[0026] Similar to the thickness, length and width of the substrate layer 100, the thickness and width of the perimetrical glass frit rib 120 may depend on the intended use of the stiffened thin substrate 10. In embodiments, the perimetrical glass frit rib 120, and other glass frit ribs described herein, may have a thickness t_r between about 10 μm and about 500 μm and a width w_r between about 1 mm and about 100 mm. In some embodiments, the thickness t_r of the perimetrical glass frit rib 120 may be between about 10 μm and about 300 μm, for example between about 10 μm and 25 μm, between about 25 μm and 50 μm, between about 50 μm and 75 μm, between about 75 μm and 100 μm, between about 100 μm and 150 μm, between about 150 μm and 200 μm, between about 200 μm and 250 μm, or between about 250 μm and 300 μm. In such embodiments, the width w_r of the perimetrical glass frit rib 120 may be between about 2 mm and about 50 mm, for example between about 2 mm and about 5 mm, between about 5 mm and about 10 mm, between about 10 mm and

about 15 mm, between about 15 mm and about 20 mm, between about 20 mm and about 25 mm, between about 25 mm and about 30 mm, between about 30 mm and about 35 mm, between about 35 mm and about 40 mm, between about 40 mm and about 45 mm, or between about 45 mm and about 50 mm.

[0027] The substrate layer 100 may be formed from materials suitable for electronic devices to be manufactured thereon. Non-limiting examples of materials used to form the substrate layer 100 include ceramics such as zirconia, yttrium stabilized zirconia, alumina, and the like, glasses such as alkali-free borosilicate glass, alkaline earth boro-aluminosilicate glass, and the like, and a combination of a ceramic and a glass (herein also referred to as "ceramic/glass"). In some embodiments, the substrate layer 100 may be formed from a single layer of uniform composition. In other embodiments, the substrate layer 100 may be formed from a plurality of layers. In such embodiments, the plurality of layers may comprise a uniform composition, or in the alternative, may comprise layers with different compositions. The perimetrical glass frit rib 120, and other glass frit ribs described herein, may be formed from materials suitable for depositing onto thin ceramic, glass or ceramic/glass substrate layers and being sintered to form a stiffening rib. Non-limiting examples of materials used to form the perimetrical glass frit rib 120 include $SiO_2 \cdot B_2O_3$ glass frit, $Bi_2O_3 \cdot B_2O_3 \cdot SiO2$ glass frit, $Bi_2O_3 \cdot B_2O_3$ glass frit, $Bi_2O_3 \cdot B_2O_3 \cdot Al_2O_3$ glass frit, $Bi_2O_3 \cdot B_2O_3 \cdot ZnO$ glass frit, $ZnO \cdot Bi_2O_3 \cdot B_2O_3$ glass frit, and the like. The glass frit may be a glass, a ceramic, or a glass ceramic material that is compatible with subsequent device fabrication steps that may be used to form a three dimensional surface feature (e.g., a perimetrical glass frit rib 120) on at least one surface (e.g., the upper surface 101 and/or the lower surface 103) of the substrate layer 100. The perimetrical glass frit rib 120 may be formed directly on the upper surface 101 and/or the lower surface 103. In the alternative, the perimetrical glass frit rib 120 may be pre-formed and then bonded to the upper surface 101 and/or the lower surface 103 of the substrate layer 100.

[0028] In embodiments, the physical dimensions and/or CTE of the perimetrical glass frit rib 120, and any additional glass frit rib bonded to the substrate layer 100, may be selected to maintain flatness of the substrate layer 100. For example, a perimetrical glass frit rib 120, and any additional glass frit rib bonded to the substrate layer 100, may comprise a CTE that is less than a CTE of the substrate layer 100 thereby producing tension within the substrate layer 100 during thermal cooling of the substrate layer 100 with the perimetrical glass frit rib

120 bonded thereto. Alternatively, a perimetrical glass frit rib 120, and any additional glass frit rib bonded to the substrate layer 100, may comprise physical dimensions and/or a CTE that result in predictable deformation of the substrate layer 100. For example, a perimetrical glass frit rib 120, and any additional glass frit rib bonded to the substrate layer 100, may result in the substrate layer 100 bending predictably along a given axis, direction, etc., of the substrate layer 100. It should be understood that the perimetrical glass frit rib 120 may not extend completely around the perimeter 110 of the substrate layer 100. That is, in some embodiments, the perimetrical glass frit rib 120 is segmented along the perimeter 110. In the alternative, or in addition to, the perimetrical glass frit rib 120 may extend along the perimeter 110 that is adjacent to one or more, but not all, of the ends 102, 104 and the sides 106, 108 of the substrate layer 100.

[0029] The electronic device layer 140 may be formed from materials suitable for manufacturing electronic devices and components of electronic devices such as cathode electrode materials, anode electrode materials, electrolyte materials, semiconductor materials, dielectric materials, and the like. Non-limiting examples of electrode materials used to form the electronic device layer 140 platinum (Pt), gold (Au), copper (Cu), aluminum (Al), lithium cobalt oxide ($LiCoO_2$), lithium titanate ($LiTiO_3$), lithium phosphorus oxynitride (LiPON), silicon (Si), silicon carbide (SiC), silicon dioxide (SiO_2), aluminum nitride (AlN), gallium nitride (GaN), gallium oxide (Ga_2O_3), boron nitride (BN), molybdenum disulfide (MoS_2), tungsten disulfide (WS_2), and tungsten diselenide (WSe_2), phenyl-C61-butyric acid methyl ester (PCBM), pentacene, carbazole compounds, phthalocyanine, e-poly(vinylidene fluoride-hexafluoropropylene) (e-PVDF-HFP), silicon nitride (SiNx), alumina (Al_2O_3), hafnium oxide (HfO_2), or combinations thereof.

[0030] Referring now to FIG. 3, in embodiments, additional glass frit ribs may be disposed over and bonded to the substrate layer 100 as schematically depicted in FIG. 3. Particularly, a plurality of glass frit ribs 121 bonded to the upper surface 101 and extending in the length direction (X direction) and a plurality of glass frit ribs 123 bonded to the upper surface 101 and extending in the width direction (Z direction) may be included. In some embodiments, the plurality of glass frit ribs 121 and the plurality of glass frit ribs 123 form a plurality of glass frit frames 150. Disposed between each of the plurality of glass frit frames 150 may be an electronic device substrate layer 155 where an electronic device 160, or a portion of an electronic device 160, may be formed. For example, FIG. 3 schematically depicts a plurality

of electronic device substrate layers 155, and a plurality of electronic devices 160 disposed on the plurality of electronic device substrate layers 155. One non-limiting example of the plurality of electronic devices 160 includes a battery 162 with a positive electrode 164, a negative electrode 166 and a battery cell 168 disposed on each of the electronic device substrate layers 155. It should be understood that the plurality of electronic devices 160 may be formed on the plurality of electronic device substrate layers 155 using semiconductor device deposition and patterning techniques. For example, a positive electrode 164 and/or a negative electrode 166 for a plurality of batteries 162 may be deposited on the plurality of electronic device substrate layers 155 at a single manufacturing station, patterned at a single manufacturing station, and the like. Also, the substrate layer 100 with the plurality of electronic device substrate layers 155 may be singulated to form individual electronic devices 160 disposed on individual electronic device substrate layers 155. As used herein, the terms "singulation", "singulated", and "singulating" refer to reducing (e.g., laser cutting) a substrate layer into individual electronic substrate layers with an electronic device.

[0031] Referring now to FIG. 4, a process line 20 for forming perimetrical glass frit ribs 120 on a substrate layer 100 is schematically depicted. The process line 20 comprises a roll 30 of the substrate layer 100 which is transported or fed into a glass frit rib printing station where glass frit ribs, e.g., perimetrical glass frit ribs 120, glass frit ribs 121, and/or glass frit ribs 123 (only glass frit ribs 123 shown) are printed onto the substrate layer 100. In some embodiments, a plurality of glass frit ribs 121 and a plurality of glass frit ribs 123 are printed onto the substrate layer 100 thereby forming a plurality of glass frit frames 150. The substrate layer 100 with the glass frit ribs 123 (and optionally the glass frit ribs 120, 121) enters a rib drying station and then a rib sintering station in order to dry, sinter, and bond the glass frit ribs 123 (and optionally the glass frit ribs 120, 121) onto the substrate layer 100. The substrate layer 100 with the glass frit ribs 123 bonded thereto passes through a singulation station where the substrate layer 100 is singulated into desired shapes and sizes. While FIG. 4 schematically depicts the singulated station as part of the process line 20, it should be understood that the singulated station may be separate from the process line 20. For example, the substrate layer 100 with a plurality of perimetrical glass frit ribs 120, a plurality of glass frit ribs 121 and/or a plurality of glass frit ribs 123 may be rolled back into a roll, stored, transported, etc., and then un-rolled at an electronic device manufacturing line and/or singulation station before being singulated.

EXAMPLES

Comparative Example 1

[0032] Deflection due to the force of gravity (hereafter referred to as "gravitational deflection") of a substrate layer 100, per unit length, without a perimetrical glass frit rib 120, was mathematically modeled. The modeling included a substrate layer 100 formed from yttria stabilized zirconia (zirconia – 3 mole % yttria), and having a thickness t_{s1} of 100 μm, a length l_s of 137 mm and a width of 114 mm. The substrate layer 100 was simply supported at the first end 102, midway, and at the second end 104, midway, and gravitational deflection of the unsupported center was modeled. A schematic depiction of gravitational deflection of this nature is shown in FIG. 5. The length 'L' depicted in FIG. 5 was 68.5 mm, the gravitational deflection 'd' was 1.0 mm, and the gravitational deflection per unit length was 14.6 μm/mm.

Non-Comparative Example 1

[0033] Gravitational deflections, per unit length, of substrate layers 100 with perimetrical glass frit ribs 120 of different thicknesses were modeled. The modeling included substrate layers 100 formed from yttria stabilized zirconia (zirconia – 3 mole % yttria), and having a thickness t_{s1} of 25 μm, a length l_s of 137 mm and a width of 114 mm. Perimetrical glass frit ribs 120 having a width of 10.0 mm (w_r = 10.0 mm) and thicknesses (t_r) between 0.0 mm (i.e., no perimetrical glass frit rib 120) to 105 μm were bonded to an upper surface 101 of the substrate layers 100. Particularly, substrate layers 100 (t_{s1} = 25 μm) without a perimetrical glass frit rib 120 (t_r = 0.0 mm), with a perimetrical glass frit rib 120 having a thickness equal to 35 μm (t_r = 35.0 μm), a perimetrical glass frit rib 120 having a thickness equal to 70 μm (t_r = 70.0 μm), and a perimetrical glass frit rib 120 having a thickness equal to 105 μm (t_r = 105.0 μm) were modeled for gravitational deflection per unit length. Table 1 below shows the gravitational deflection and the gravitation deflection per unit length for each of the substrate layers 100, with and without the perimetrical glass frit ribs 120, under the same conditions as Comparative Example 1. As shown in Table 1, a substrate layer 100 with a thickness of 25 μm and a perimetrical glass frit rib 120 with a width of 10 mm and a thickness of 35 μm reduced the gravitational deflection, per unit length, of the substrate layer 100 (without a perimetrical glass frit rib 120) by about 66%. That is, the perimetrical glass frit rib 120 with a width of 10 mm and a thickness of 35 μm bonded to the substrate layer 100 reduced the gravitational deflection, per unit length, of the substrate layer 100 without the

perimetrical glass frit rib 120 from 170.8 μm/mm to 56.9 μm/mm and (170.8 - 56.9)/170.8 x 100 ≈ 66%. The perimetrical glass frit rib 120 with a width of 10 mm and a thickness of 70 μm bonded to the substrate layer 100 reduced the gravitational deflection, per unit length, of the substrate layer 100 by about 84%. The perimetrical glass frit rib 120 with a width of 10 mm and a thickness of 105 μm bonded to the substrate layer 100 reduced the gravitational deflection, per unit length, of the substrate layer 100 by about 91%. Also, the perimetrical glass frit rib 120 with a width of 10 mm and a thickness of 105 μm provided the substrate layer 100 with a thickness of 25 μm the same stiffness (i.e., gravitational deflection per unit length) as the substrate layer 100 with a thickness of 100 μm as graphically depicted in FIG. 6. Accordingly, perimetrical glass frit ribs 120 described herein allow for a reduction in thickness of a substrate layer 100 needed to exhibit a desired stiffness (i.e., gravitational deflection per unit length). It should be understood that using thinner substrate layers, e.g., substrate layers with thicknesses less than or equal to 100 μm, that have a stiffness that enables handling, desired pattern resolution, etc., reduces the costs and weight of electronic devices manufactured on the thinner substrate layers.

Table 1.

Glass Frit Rib Size		Gravitational Deflection (mm)	Gravitational Deflection Per Unit Length (μm/mm)
w_r (mm)	t_r (μm)		
0.0	0.0	11.7	170.8
10.0	35	3.9	56.9
10.0	70	1.9	27.7
10.0	105	1.0	14.6

Comparative Example 2

[0034] Deflection per unit length due to the differences of CTE between a substrate layer 100 and an electronic device layer 140 bonded to the substrate layer 100 (i.e., a multilayer assembly 112) upon cooling of the multilayer assembly 112 from an elevated temperature to ambient temperature (hereafter referred to as "thermal deflection") was modeled. Particularly, thermal deflection, per unit length, of a substrate layer 100, without a perimetrical glass frit rib 120, and an electronic device layer 140 bonded to the lower surface 103, upon cooling from 600°C to 23°C was mathematically modeled. The substrate layer 100 was modeled as being formed from yttria stabilized zirconia (zirconia – 3 mole % yttria) and having a thickness t_{s1} of 100 μm, a length l_s of 137 mm, a width of 114 mm. The electronic

device layer 140 bonded to the lower surface 103 of the substrate layer 100 was modeled as being formed from lithium cobalt oxide ($LiCoO_2$) and having a thickness t_{s2} of 8 μm, a length l_s of 137 mm, a width of 114 mm. The multilayer assembly 112 was rigidly supported at a center position between the first end 102, the second end 104, the first side 106 and the second side 108 (i.e., the center of the substrate layer 100), and the ends 102, 104 and sides 106, 108 were allowed to freely deform as the multilayer assembly 112 was cooled from 600°C to 23°C. The maximum thermal deflection occurred at the corners of the substrate layer 100 and the length between the center of the substrate layer 100 and the corners of substrate layer 100 was 89.1 mm. The thermal deflection at the corners was 12.4 mm and the thermal deflection per unit length was 139.2 μm/mm.

Non-Comparative Example 2

[0035] Thermal deflections per unit length of multilayer assemblies 112 with perimetrical glass frit ribs 120 of different thicknesses bonded were modeled. The substrate layers 100 were modeled as being formed from yttria stabilized zirconia (zirconia – 3 mole % yttria) and having a thickness t_{s1} of 25 μm, a length l_s of 137 mm, and a width of 114 mm. The electronic device layers 140 bonded to the lower surface 103 of the substrate layers 100 were modeled as being formed from lithium cobalt oxide ($LiCoO_2$) and having a thickness t_{s2} of 8 μm, a length l_s of 137 mm, a width of 114 mm. The perimetrical glass frit ribs 120 were modeled as having a width of 10.0 mm (w_r = 10.0 mm) and thicknesses (t_r) between 35.0 μm to 105 μm. Particularly, multilayer assemblies 112 comprising a substrate layer 100 with a thickness equal to 25.0 μm (t_{s1} = 25 μm), an electronic device layer 140 with a thickness equal to 8.0 μm (t_{s2} = 8.0 μm), and perimetrical glass frit ribs 120 having thicknesses equal to 35 μm (t_r = 35.0 μm), 70 μm (t_r = 70.0 μm), and 105 μm (t_r = 105.0 μm) were modeled for cooling from 600°C to 23°C. The maximum thermal deflection occurred at the first and second ends 102, 104 of the substrate layer 100. The length between the center of the substrate layer 100 and the first and second ends 102, 104 of the substrate layer 100 was 68.5 mm. Table 2 below shows the thermal deflection and the thermal deflection per unit length for each of the multilayer assembly 112 with the perimetrical glass frit ribs 120 of different thicknesses. As shown in Table 2, a multilayer assembly 112 with a substrate layer 100 having a thickness of 25 μm and a perimetrical glass frit rib 120 with a width of 10 mm and a thickness of 35 μm has a thermal deflection per unit length upon cooling from 600°C to 23°C of 729.9 μm/mm. The same substrate layer 100 (i.e., a substrate layer 100 with a thickness of

25 μm) with a perimetrical glass frit rib 120 with a width of 10 mm and a thickness of 70 μm has a thermal deflection per unit length of 369.3 μm/mm. The same substrate layer 100 with a perimetrical glass frit rib 120 with a width of 10 mm and a thickness of 105 μm has a thermal deflection per unit length of 173.7 μm/mm. The perimetrical glass frit rib 120 with a width of 10 mm and a thickness of 105 μm provided the multilayer assembly 112 with the 25 μm thick substrate layer 100 the same thermal stiffness (i.e., thermal deflection per unit length) as the multilayer assembly 112 with the 100 μm thick substrate layer 100. Accordingly, perimetrical glass frit ribs 120 described herein allow for a reduction in thickness of a substrate layer 100 needed to exhibit a desired thermal stiffness (i.e., gravitational deflection per unit length). It should be understood that using thinner substrate layers, e.g., substrate layers with thicknesses less than or equal to 100 μm, that have a thermal stiffness resulting in reduced thermal deflection during cooling from elevated temperatures reduces the costs and weight of electronic devices manufactured on the thinner substrate layers.

Table 2.

Glass Frit Rib Size		Thermal Deflection (mm)	Thermal Deflection Per Unit Length (μm/mm)
w_r (mm)	t_r (μm)		
10.0	35	50.0	729.9
10.0	70	25.3	369.3
10.0	105	11.9	173.7

Example 3

[0036] The effect of distance between the perimeter 110 of the substrate layer 100 and the perimetrical glass frit rib 120 on the thermal deflection was modeled. Particularly, thermal deflection upon cooling from 600ºC to 23ºC of substrate layers 100 with a perimetrical glass frit rib 120 spaced from the perimeter 110 by 1 mm and 2 mm were mathematically modeled. The substrate layers were modeled as being formed from yttria stabilized zirconia (zirconia – 3 mole % yttria) and having a thickness t_{s1} of 20 μm, a length l_s of 50 mm, and a width of 30 mm. The perimetrical glass frit rib 120 was modeled as having a thickness t_r equal to 250 μm and a width w_r equal to 0.5 mm. The substrate layers 100 were modeled as being rigidly supported at the center of the substrate layers 100, i.e., midway between the first and second ends 102, 104 and midway between the first and second sides 106, 108. The maximum thermal deflections for the substrate layer 100 with the perimetrical glass frit rib 120 spaced

from the perimeter 110 by 1.0 mm and 2.0 mm were 0.67 mm and 0.71 mm, respectively. The distance between the location of rigid support at the center of the substrate layers 100 and the point of maximum deflection was 29.2 mm and the thermal deflection ratio per unit length of the substrate layer 100 with the perimetrical glass frit rib 120 spaced from the perimeter 110 by 1.0 and 2.0 mm was 22.9 μm/mm and 24.3 μm/mm, respectively. Accordingly, forming and bonding the perimetrical glass frit rib 120 closer to the perimeter 110 reduces the thermal deflection of the substrate layer 100.

Example 4

[0037] Referring now to FIGS. 7A and 7B, deflection due to a load 300 positioned on a substrate layer 100 as a function of perimetrical glass frit rib 120 thickness t_r was measured. The measurements included a substrate layer 100 formed from yttria stabilized zirconia (zirconia – 3 mole % yttria), and having a thickness t_{s1} of 100 μm, a length l_s of 137 mm and a width of 114 mm. The substrate layer 100 was placed on a support ring 200 with a height 'h1' and an inner surface 210 with an diameter equal to 77.8 mm (3.0625 inches). The load 300 was placed on the substrate layer 100 in the center of the support ring 200 as schematically depicted in FIGS. 7A and 7B. Substrate layers 100 with a perimetrical glass frit rib 120 having a thickness t_r equal to 0 μm (i.e., no perimetrical glass frit rib 120), 150 μm, 220 μm and 420 μm were tested and the deflection 'h2' at the center of the substrate layer 100 was physically measured. The length of the substrate layer 100 between the inner surface 210 of the support ring 200 and the location of deflection measurement was 38.9 mm, i.e., the location of deflection was the center of the support ring 200. Referring now to FIG. 8, deflection of substrate layers 100 subjected to a 5 gram load (i.e., the load 300 was a 5 gram weight) with no perimetrical glass frit rib 120 and with perimetrical glass frit ribs having a thickness t_r equal to 150 μm, 220 μm and 420 μm are graphically depicted (i.e., deflection = h1 – h2). As shown in FIG. 8, increasing the thickness t_r of the perimetrical glass frit rib 120 from 0 μm to 150 μm decreased the deflection of the substrate from about 1.5 mm to about 1.25 mm (i.e., a reduction of about 16.7%). Also, increasing the thickness t_r of the perimetrical glass frit rib 120 from 0 μm to 220 μm decreased the deflection of the substrate from about 1.5 mm to about 1.1 mm (i.e., a reduction of about 26.7%), and increasing the thickness t_r of the perimetrical glass frit rib 120 from 0 μm to 420 μm decreased the deflection of the substrate from about 1.5 mm to about 1.0 mm (i.e., a reduction of about 33.3%). Overall, the decrease in deflection (mm) of the substrate layer 100,

subjected to a 5 gram load, per increase in thickness t_r (μm) of the perimetrical glass frit rib 120 (i.e., the slope of line shown in FIG. 8) is about 1.1 x 10^{-3} mm/μm.

[0038] Referring now to FIG. 9, deflection, per unit length, of the substrate layer 100 due to the force of the 5 gram weight as a function of the perimetrical glass frit rib 120 thicknesses is graphically depicted. As used herein, the phrase "deflection per unit length" refers to the amount of deflection divided by the length of the substrate layer 100 between the inner surface 210 of the support ring 200 and the location of deflection measurement. As noted above, the length of the substrate layer 100 between the inner surface 210 of the support ring 200 and the location of deflection measurement was 38.9 mm. As shown in FIG. 9, increasing the thickness t_r of the perimetrical glass frit rib 120 from 0 μm to 150 μm decreased the deflection, per unit length, of the substrate from about 0.0386 mm/mm to about 0.0321 mm/mm (i.e., a reduction of about 16.7%). Also, increasing the thickness t_r of the perimetrical glass frit rib 120 from 0 μm to 220 μm decreased the deflection, per unit length, of the substrate layer 100 from about 0.0386 mm/mm to about 0.0283 mm/mm (i.e., a reduction of about 26.7%), and increasing the thickness t_r of the perimetrical glass frit rib 120 from 0 μm to 420 μm decreased the deflection, per unit length, of the substrate layer 100 from about 0.0386 mm/mm to about 0.0257 mm/mm (i.e., a reduction of about 33.3%). Accordingly, in some embodiments the perimetrical glass frit rib 120 bonded to the upper surface 101 of the substrate layer 100 decreases deflection, per unit length, of the substrate layer 100 subjected to a 5 gram load by at least 15%. In other embodiments, the perimetrical glass frit rib 120 bonded to the upper surface 101 of the substrate layer 100 decreases deflection, per unit length, of the substrate layer 100 subjected to a 5 gram load by at least 25%. In still yet other embodiments, the perimetrical glass frit rib 120 bonded to the upper surface 101 of the substrate layer 100 decreases deflection, per unit length, of the substrate layer 100 subjected to a 5 gram load by at least 30%. For example, the perimetrical glass frit rib 120 bonded to the upper surface 101 of the substrate layer 100 may decrease deflection, per unit length, of the substrate layer 100 subjected to a 5 gram load between about 10% and about 20%, between about 20% and about 30%, or between about 30% and about 40%. Overall, the decrease in deflection, per unit length (mm/mm), of the substrate layer 100, subjected to a 5 gram load, per increase in thickness t_r (μm) of the perimetrical glass frit rib 120 (i.e., the slope of line shown in FIG. 9) is about 2.2 x 10^{-5} μm^{-1}.

[0039] In the above detailed description, numerous specific details have been set forth in order to provide a thorough understanding of embodiments described above. However, it will be clear to one skilled in the art when embodiments may be practiced without some or all of these specific details. In other instances, well-known features or processes may not be described in detail so as not to unnecessarily obscure the disclosure. Moreover, unless otherwise defined, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this disclosure belongs. In case of conflict, the present specification, including the definitions herein, will control.

[0040] Although other methods can be used in the practice or testing of the embodiments described herein, certain suitable methods and materials are described herein.

[0041] Disclosed are materials, compounds, compositions, and components that can be used for, can be used in conjunction with, can be used in preparation for, or are embodiments of the disclosed method and compositions. These and other materials are disclosed herein, and it is understood that when combinations, subsets, interactions, groups, etc. of these materials are disclosed that while specific reference of each various individual and collective combinations and permutation of these compounds may not be explicitly disclosed, each is specifically contemplated and described herein.

[0042] As used herein, the terms "upper" and "lower" refer to orientations shown in the drawings and do not refer to an exact orientations of articles or processes recited in the claims unless expressly stated otherwise. Also, the term "about" as used herein means that amounts, sizes, formulations, parameters, and other quantities and characteristics are not and need not be exact, but may be approximate and/or larger or smaller, as desired, reflecting tolerances, conversion factors, rounding off, measurement error and the like, and other factors known to those of skill in the art. In general, an amount, size, formulation, parameter or other quantity or characteristic is "about" or "approximate" whether or not expressly stated to be such.

[0043] The indefinite articles "a" and "an" are employed to describe elements and components of the invention. The use of these articles means that one or at least one of these elements or components is present. Although these articles are conventionally employed to signify that the modified noun is a singular noun, as used herein the articles "a" and "an" also include the plural, unless otherwise stated in specific instances. Similarly, the definite article

"the", as used herein, also signifies that the modified noun may be singular or plural, again unless otherwise stated in specific instances.

[0044] It will be apparent to those skilled in the art that various modifications and variations can be made to the embodiments described herein without departing from the spirit and scope of the claimed subject matter. Thus it is intended that the specification cover the modifications and variations of the various embodiments described herein provided such modification and variations come within the scope of the appended claims and their equivalents.

CLAIMS

1. A stiffened thin substrate comprising:

a substrate layer comprising a ceramic composition, a glass composition or a ceramic/glass composition, a thickness less than or equal to about 100 μm, a width greater than or equal to about 50 mm, and a length greater than or equal to about 75 mm; and

a perimetrical glass frit rib bonded to a first surface of the substrate layer, the perimetrical glass frit rib comprising a thickness between about 10 μm and about 300 μm and a width of less than or equal to about 20 mm; wherein,

the perimetrical glass frit rib is spaced from a perimeter of the substrate layer by less than or equal to about 20 mm, and

the perimetrical glass frit rib bonded to the first surface of the substrate layer decreases deflection, per unit length, of the substrate layer subjected to a 5 gram load by at least 15%.

2. The stiffened thin substrate of claim 1, wherein the perimetrical glass frit rib has a width less than or equal to about 10 mm and a thickness between about 25 μm and about 250 μm.

3. The stiffened thin substrate of claim 2, wherein the perimetrical glass frit rib bonded to the first surface of the substrate layer decreases deflection, per unit length, of the substrate layer subjected to a 5 gram load by at least 25%.

4. The stiffened thin substrate of claim 1, wherein the perimetrical glass frit rib is spaced from the perimeter of the substrate layer by less than or equal to about 2 mm.

5. The stiffened thin substrate of claim 1, further comprising a plurality of glass frit ribs bonded to the first surface of the substrate layer, wherein the perimetrical glass frit rib and the plurality of glass frit ribs form a plurality of glass frit frames bonded to the first surface of the substrate layer.

6. The stiffened thin substrate of claim 5, wherein the substrate layer with the perimetrical glass frit rib and the plurality of glass frit ribs comprises a plurality of electronic device substrates.

7. The stiffened thin substrate of claim 6, further comprising a plurality of electronic devices bonded to the plurality of electronic device substrates such that an electronic device is bonded to each of the plurality of electronic device substrates.

8. The stiffened thin substrate of claim 7, wherein the plurality of electronic devices are manufactured on the plurality of electronic device substrates.

9. The stiffened thin substrate of claim 1, further comprising an electronic device layer with a thickness between about 5 μm and about 50 μm bonded to a second surface of the substrate layer opposite the first surface.

10. The stiffened thin substrate of claim 9, wherein the perimetrical glass frit rib bonded to the first surface of the substrate layer decreases thermal deflection, per unit length, of the substrate layer with the electronic device layer by at least 50% when the substrate layer with the electronic device layer is cooled from about 600°C to about 23°C.

11. A stiffened thin substrate comprising:

a substrate layer comprising a ceramic composition, a glass composition or a ceramic/glass composition, the substrate layer comprising a thickness less than or equal to about 100 μm, a width greater than or equal to about 50 mm, and a length greater than or equal to about 75 mm;

a perimetrical glass frit rib bonded to a first surface of the substrate layer, the perimetrical glass frit rib comprising a thickness between about 10 μm and about 300 μm and a width of less than or equal to about 20 mm;

an electronic device layer thermally bonded to a second surface of the substrate layer opposite the first surface, the electronic device layer comprising a thickness between about 5 μm and about 50 μm; wherein,

the perimetrical glass frit rib is spaced from a perimeter of the substrate layer by less than or equal to about 20 mm, and

the perimetrical glass frit rib bonded to the first surface of the substrate layer decreases deflection, per unit length, of the substrate layer subjected to a 5 gram load by at least 15%.

12. The stiffened thin substrate of claim 11, wherein the perimetrical glass frit rib has a thickness between about 25 μm and about 250 μm and a width less than or equal to about 10 mm.

13. The stiffened thin substrate of claim 11 or 12, wherein the perimetrical glass frit rib is spaced from the perimeter of the substrate layer by less than or equal to about 2 mm.

14. The stiffened thin substrate of claim 11, further comprising a plurality of glass frit ribs bonded to the first surface of the substrate layer, wherein the perimetrical glass frit rib and the plurality of glass frit ribs form a plurality of glass frit frames bonded to the first surface of the substrate layer, and the plurality of glass frit frames comprise a plurality of electronic device substrates.

15. The stiffened thin substrate of claim 14, further comprising a plurality of electronic devices bonded to the plurality of electronic device substrates such that an electronic device is bonded to each of the plurality of electronic device substrates.

16. A process for forming a stiffened thin substrate for a plurality of electronic devices, the process comprising:

forming, drying and sintering a perimetrical glass frit rib on a first surface of a substrate layer, the perimetrical glass frit rib comprising a thickness between about 10 μm and about 300 μm and a width of less than or equal to about 20 mm, the substrate layer comprising a ceramic composition, a glass composition or a ceramic/glass composition, a thickness less than or equal to about 100 μm, a width greater than or equal to about 50 mm, and a length greater than or equal to about 75 mm; wherein,

the perimetrical glass frit rib is spaced from a perimeter of the substrate layer by less than or equal to about 20 mm, and

the perimetrical glass frit rib bonded to the first surface of the substrate layer decreases deflection, per unit length, of the substrate layer subjected to a 5 gram load by at least 15%.

17. The process of claim 16, further comprising thermally bonding an electronic device layer on a second surface of the substrate layer opposite the first surface, the electronic device layer comprising a composition different than the substrate layer and a thickness between about 5 μm and about 50 μm, wherein the perimetrical glass frit rib bonded to the first surface of the substrate layer decreases thermal deflection, per unit length, of the substrate layer with the electronic device layer by at least 50% when the substrate layer with the electronic device layer are cooled from about 600°C to about 23°C.

18. The process of claim 16 or 17, wherein the perimetrical glass frit rib has a width less than or equal to about 10 mm and a thickness between about 25 μm and about 250 μm.

19. The process of claim 16, further comprising forming, drying and sintering a plurality of glass frit ribs on the first surface of the substrate layer, wherein the perimetrical glass frit rib and the plurality of glass frit ribs form a plurality of glass frit frames bonded to the first surface of the substrate layer, and the plurality of glass frit ribs comprise a plurality of electronic device substrates.

20. The process of claim 19, further comprising manufacturing a plurality of electronic devices on the plurality of electronic device substrates such that an electronic device is manufactured on each of the plurality of electronic device substrates.

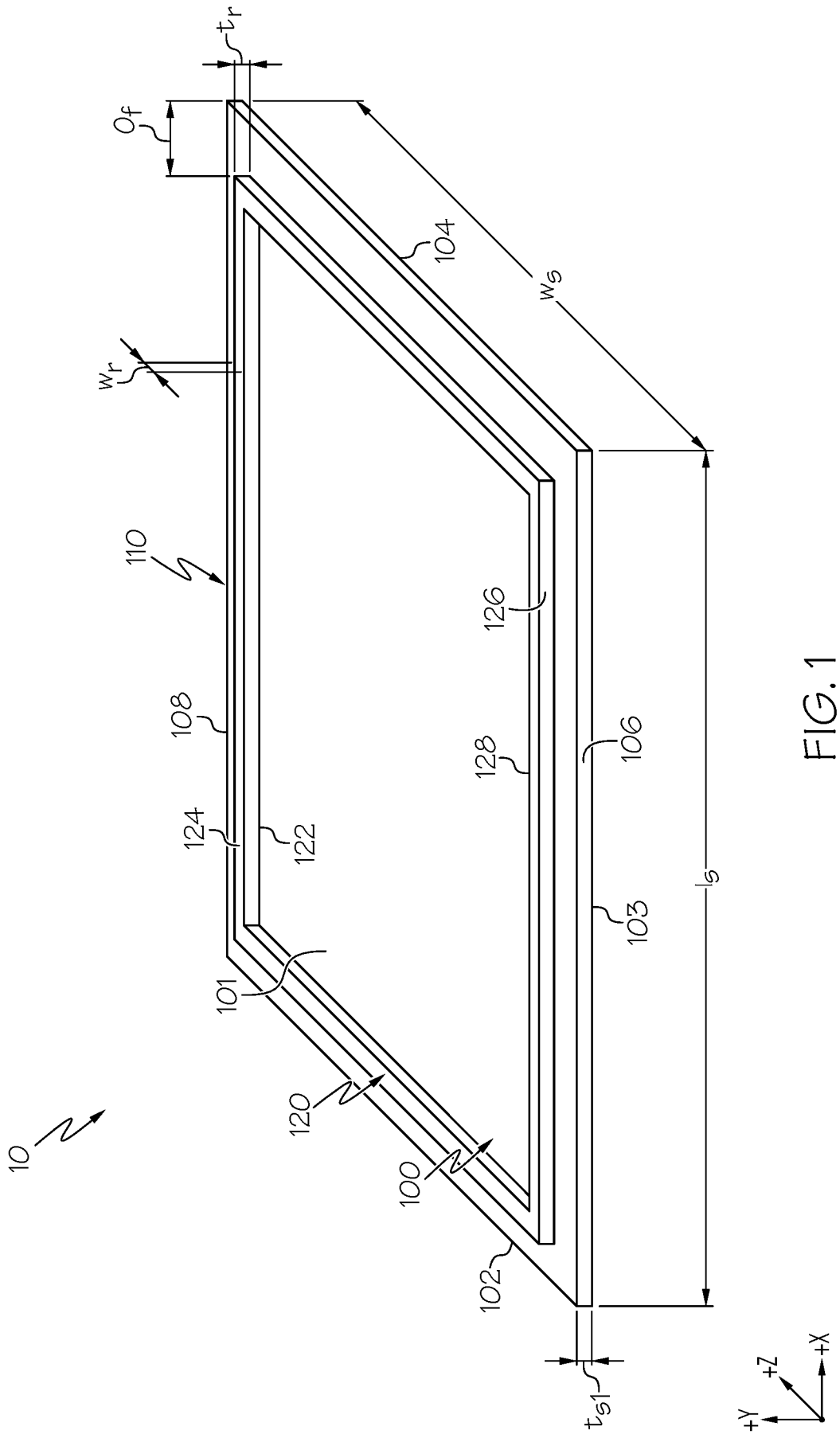

t_r
O_f
104
w_s
w_r
110
126
108
128
106
124
122
l_s
103
101
120
100
102
t_{s1}
10
+Z
+X
+Y

FIG. 1

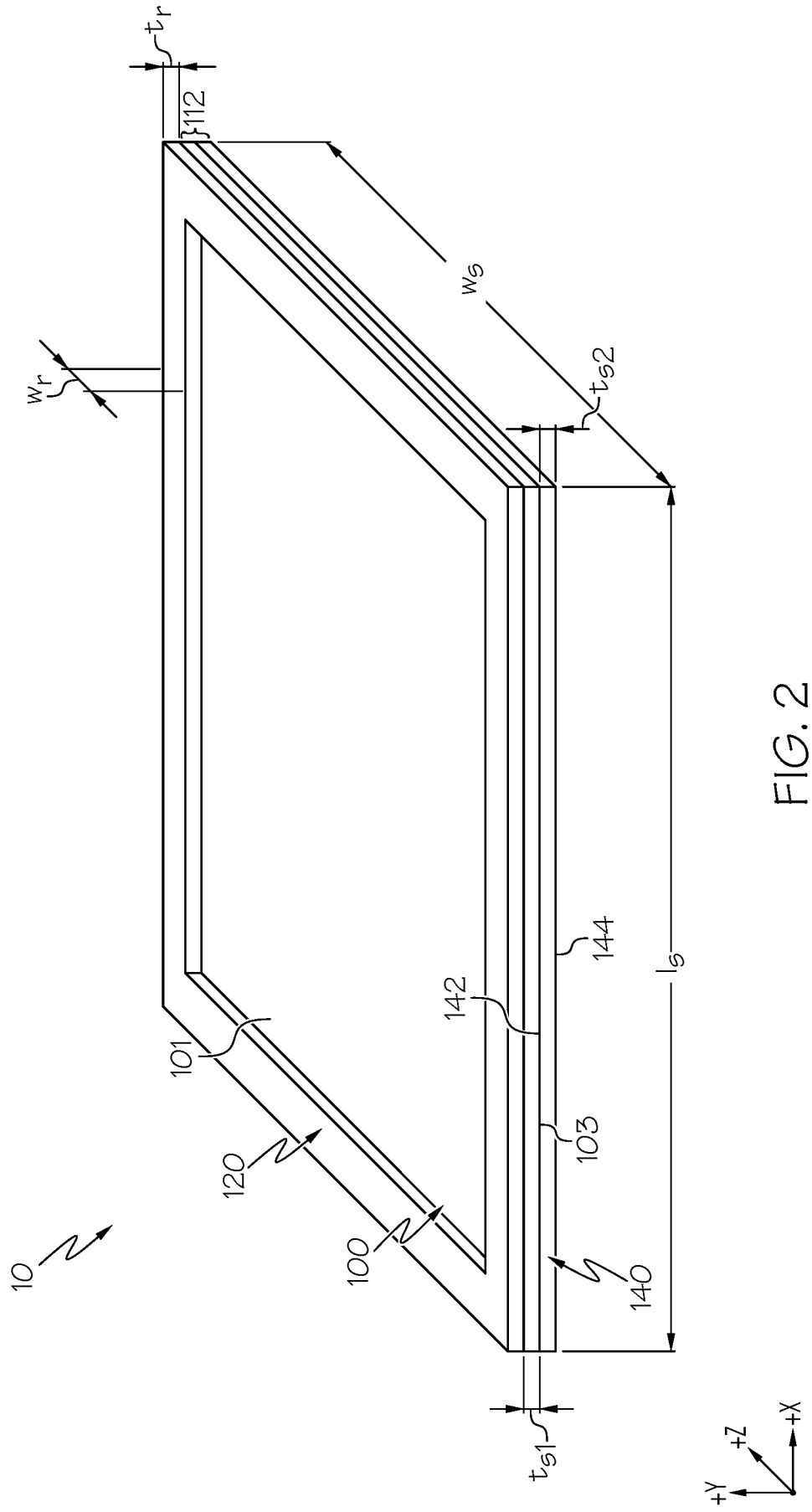


FIG. 2

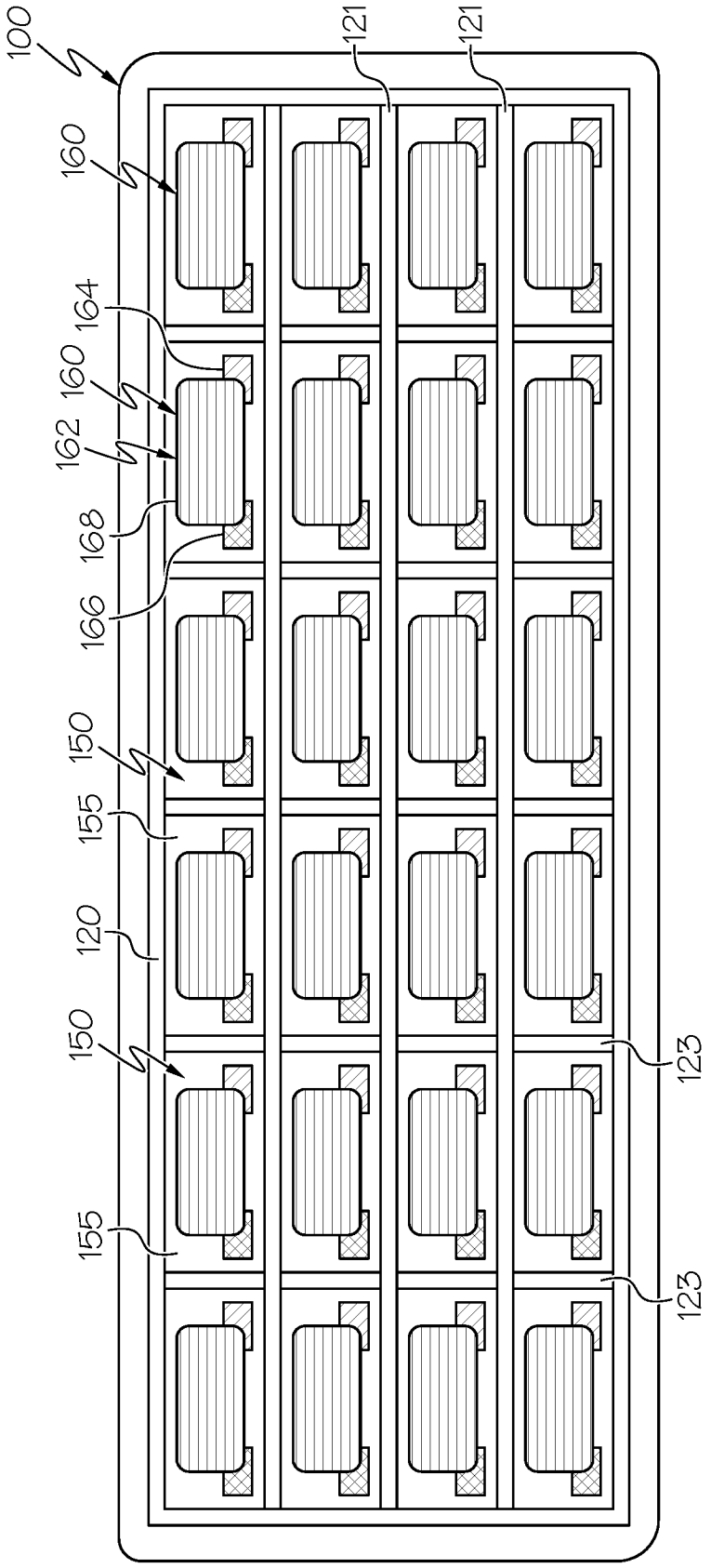


FIG. 3

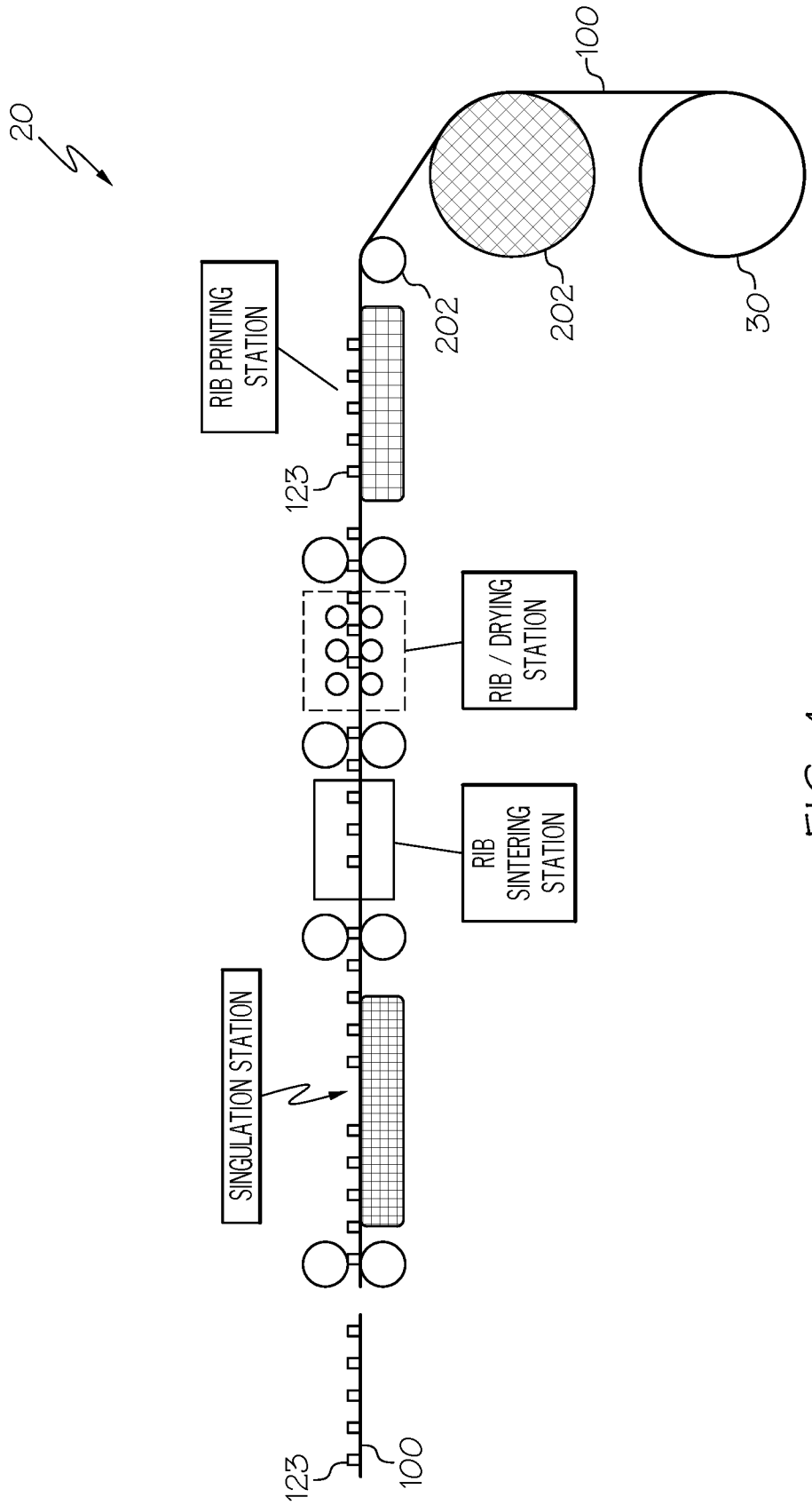

20
100
202
202
30
RIB PRINTING STATION
123
RIB / DRYING STATION
RIB SINTERING STATION
SINGULATION STATION
123
100

FIG. 4

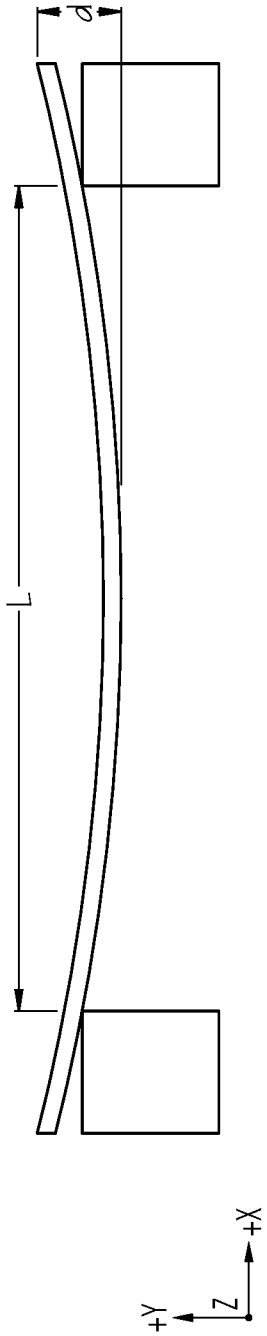

d
L
+Y
Z
+X

FIG. 5

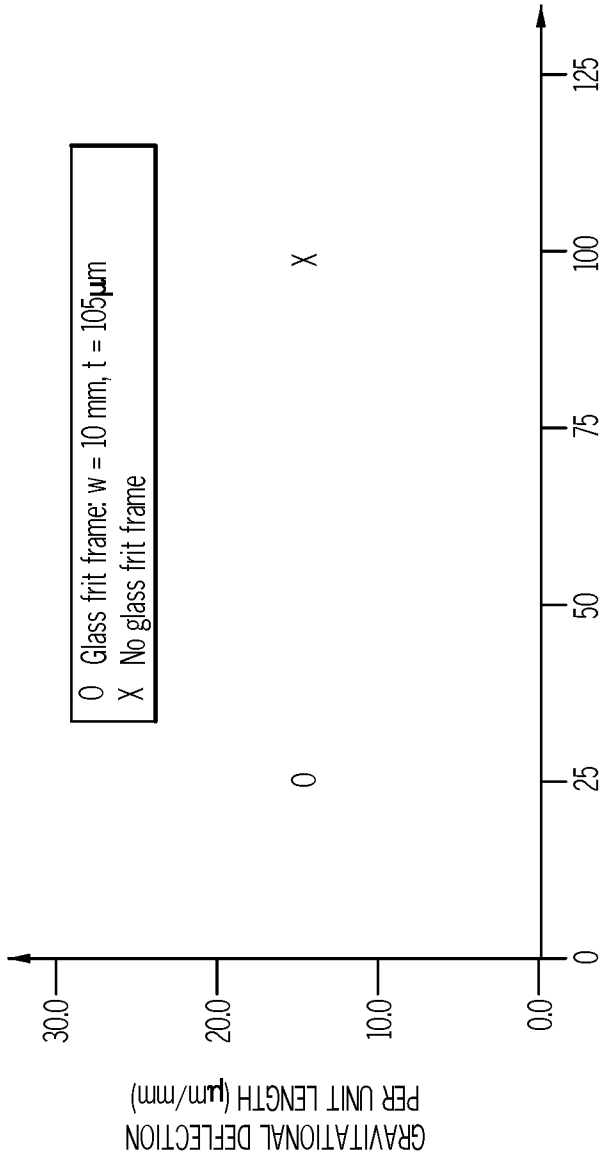

O Glass frit frame: w = 10 mm, t = 105μm
X No glass frit frame
GRAVITATIONAL DEFLECTION PER UNIT LENGTH (μm/mm)
30.0
20.0
10.0
0.0
0
25
50
75
100
125
Sheet Thickness (μm)

FIG. 6

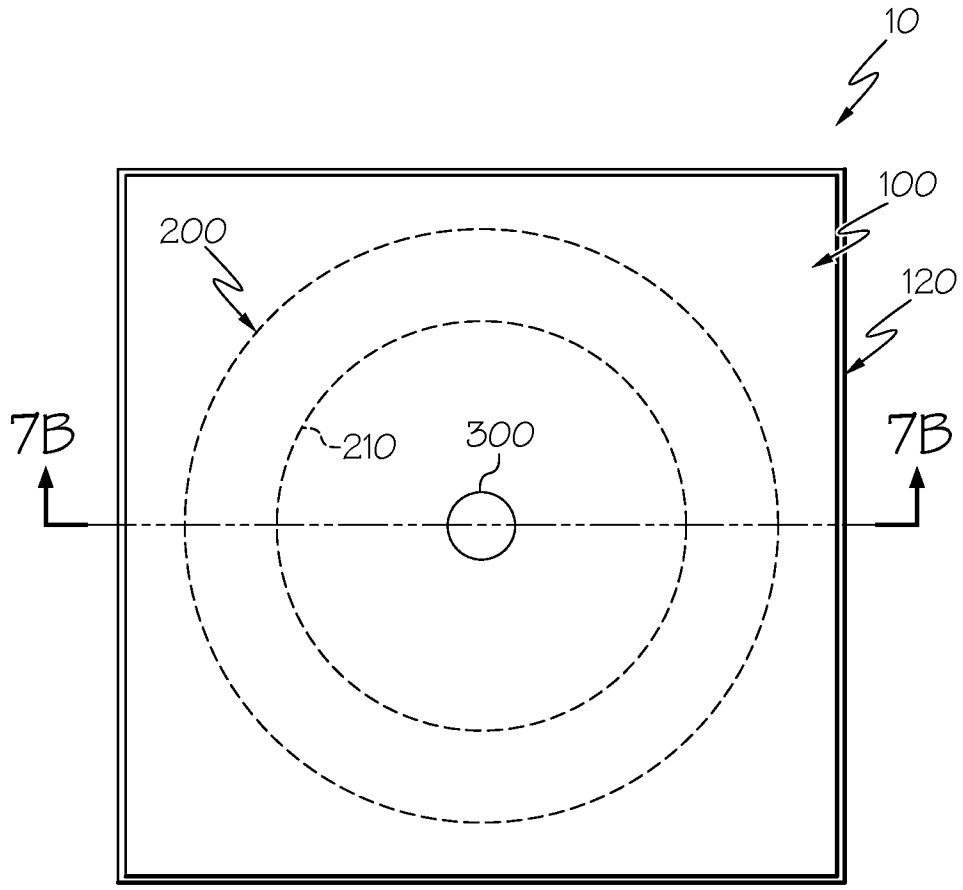


FIG. 7A

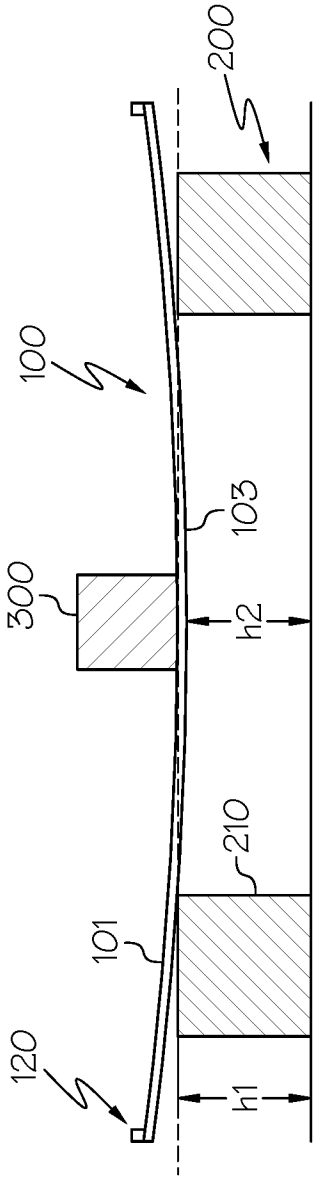


FIG. 7B

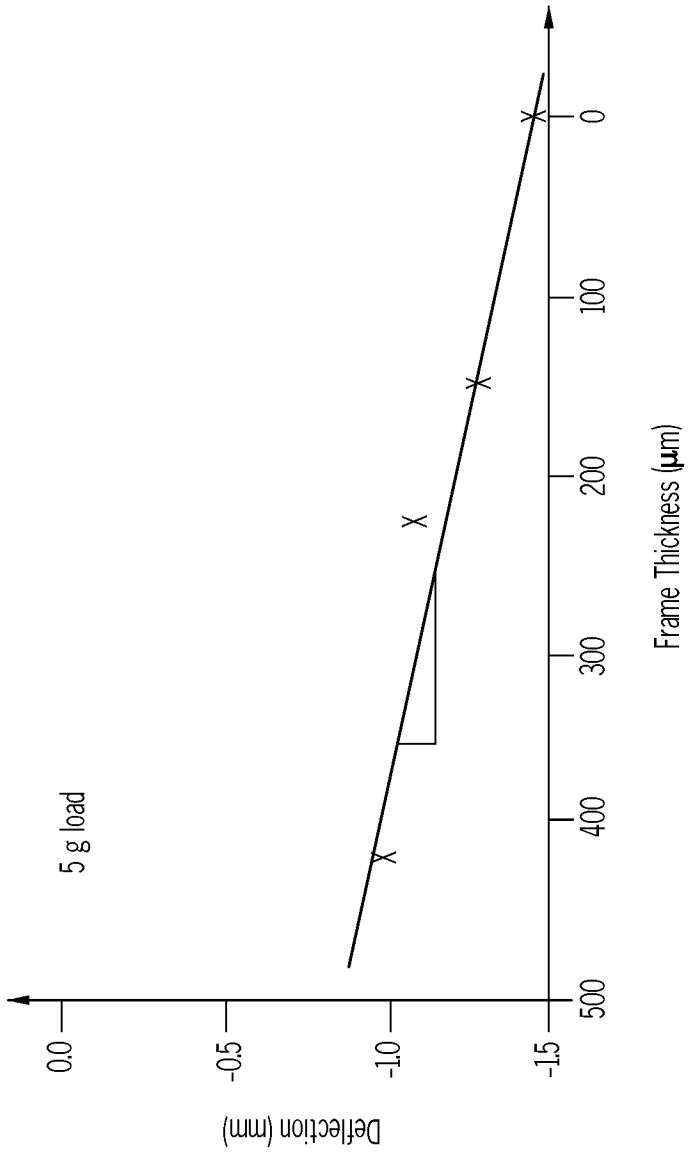

5 g load
Deflection (mm)
0.0
-0.5
-1.0
-1.5
500
400
300
200
100
0
Frame Thickness (μm)

FIG. 8

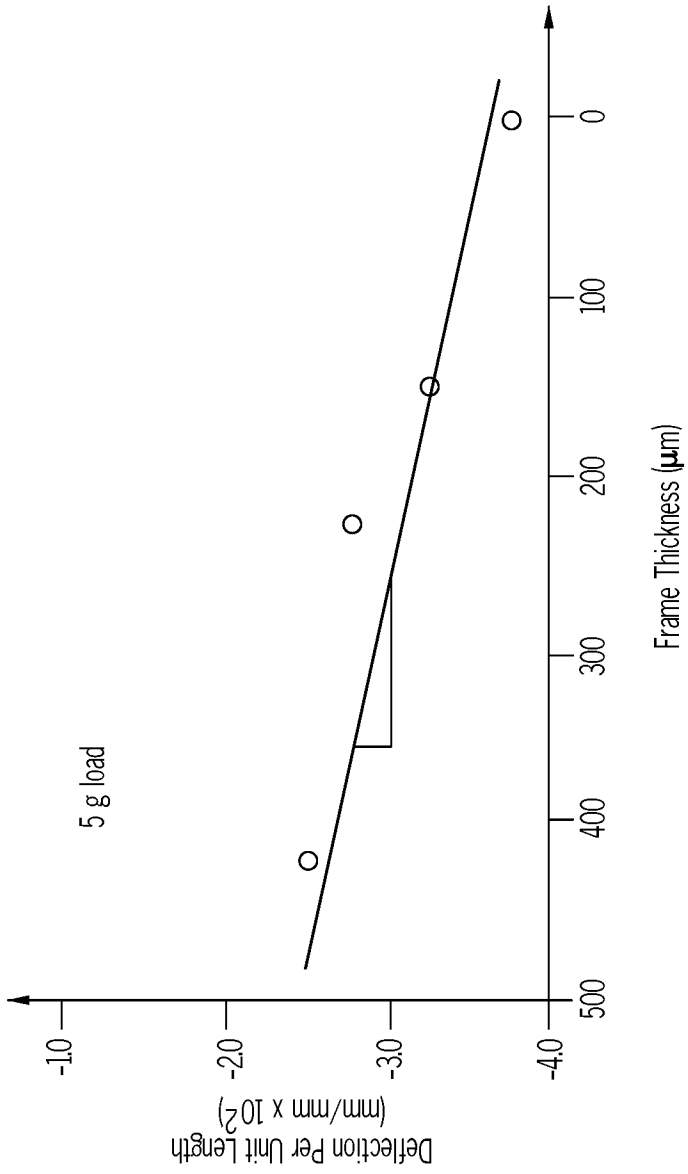

Deflection Per Unit Length
(mm/mm x 10^2)
-1.0
-2.0
-3.0
-4.0
5 g load
0
100
200
300
400
500
Frame Thickness (μm)

FIG. 9

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2019/036647

A. CLASSIFICATION OF SUBJECT MATTER

H01L 21/02(2006.01)i, H01L 21/18(2006.01)i, H01L 21/50(2006.01)i, H01L 21/324(2006.01)i, H01L 21/67(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)
H01L 21/02; C23C 16/24; C23C 16/513; G01L 9/12; G02F 1/13; H01L 21/00; H01L 21/683; H01L 21/768; H01L 21/78; H01L 33/00; H01L 21/18; H01L 21/50; H01L 21/324; H01L 21/67

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: stiffened thin substrate, ceramic, glass, deflection, sinter, perimetrical, rib

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2009-0064790 A1 (JEROME VIVIEN DAVIDOVITS et al.) 12 March 2009 See paragraph [0030] and claims 1-3, 10.	1-20
A	US 2010-0127297 A1 (HWAN HEE JEONG) 27 May 2010 See paragraphs [0041]-[0044], claim 1 and figures 3-5, 8.	1-20
A	KR 10-1341326 B1 (SYSTEMS TECHNOLOGY INCORPORATED) 13 December 2013 See claim 1 and figures 1-2.	1-20
A	CN 101748378 A (BEIJING NMC CO., LTD.) 23 June 2010 See claims 1-7 and figures 2-5.	1-20
A	US 2010-0317151 A1 (CHANG JUN PARK) 16 December 2010 See claims 1, 4 and figures 2-3.	1-20

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

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"D" document cited by the applicant in the international application
"E" earlier application or patent but published on or after the international filing date
"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
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
30 September 2019 (30.09.2019)	**30 September 2019 (30.09.2019)**

Name and mailing address of the ISA/KR
International Application Division
Korean Intellectual Property Office
189 Cheongsa-ro, Seo-gu, Daejeon, 35208, Republic of Korea
Facsimile No. +82-42-481-8578

Authorized officer
PARK, Hye Lyun
Telephone No. +82-42-481-3463

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2019/036647

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2009-0064790 A1	12/03/2009	EP 1979080 A2	15/10/2008
		EP 1979080 A4	05/10/2011
		JP 2009-522550 A	11/06/2009
		KR 10-2008-0083039 A	12/09/2008
		WO 2007-079072 A2	12/07/2007
		WO 2007-079072 A3	03/01/2008
		WO 2007-079072 A9	14/10/2010
US 2010-0127297 A1	27/05/2010	CN 101740701 A	16/06/2010
		CN 101740701 B	29/05/2013
		EP 2190037 A2	26/05/2010
		EP 2190037 A3	28/01/2015
		KR 10-1064070 B1	08/09/2011
		KR 10-2010-0058979 A	04/06/2010
		US 8101958 B2	24/01/2012
KR 10-1341326 B1	13/12/2013	KR 10-2013-0068373 A	26/06/2013
CN 101748378 A	23/06/2010	CN 101748378 B	07/12/2011
US 2010-0317151 A1	16/12/2010	KR 10-0963617 B1	16/06/2010
		KR 10-2009-0056553 A	03/06/2009
		US 2009-0140392 A1	04/06/2009
		US 7795718 B2	14/09/2010
		US 7989264 B2	02/08/2011