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(54) **Title:** THIN GLASS LAMINATES

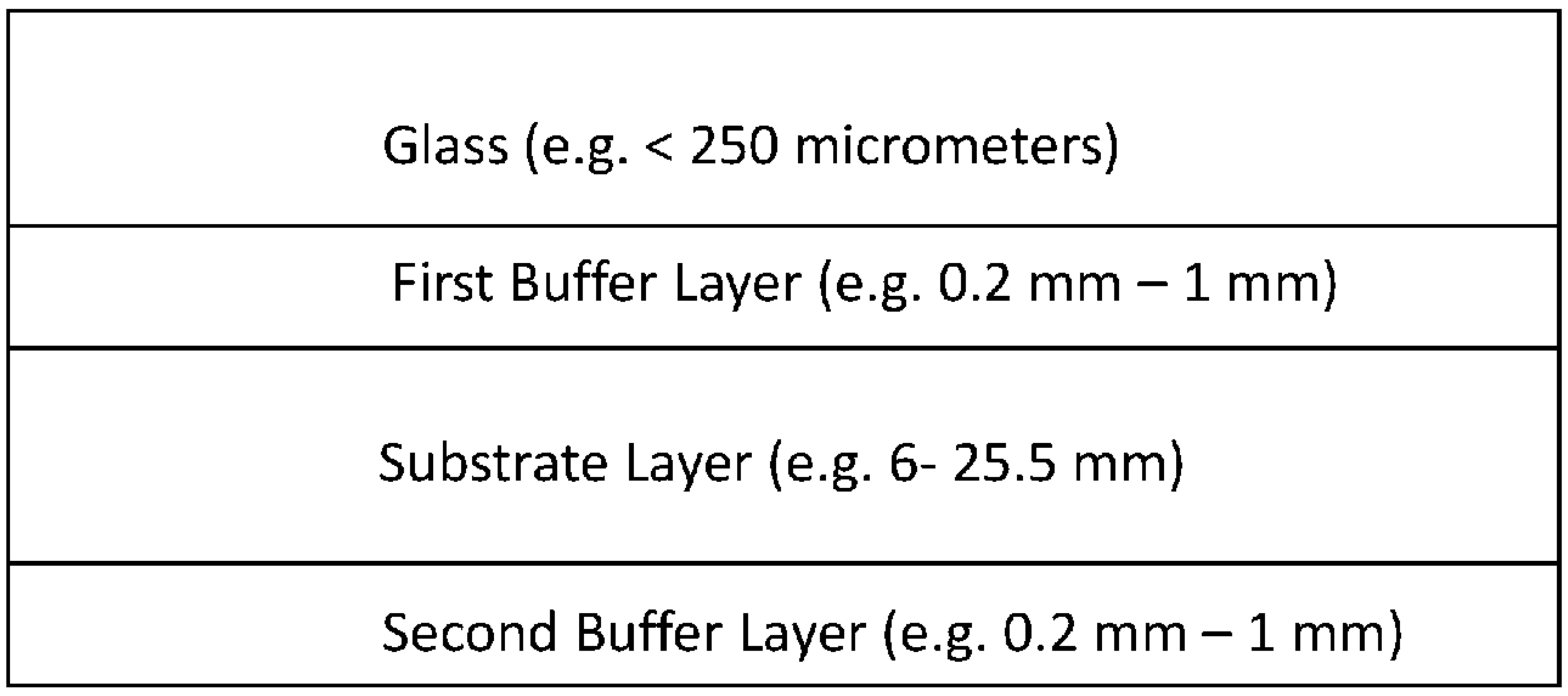


Figure 2

(57) **Abstract:** Systems and methods for providing a laminated structure are disclosed. In one embodiment, the laminated structure includes a substrate layer, a first buffer layer, a second buffer layer, and a glass layer. The first buffer layer is disposed on top of the substrate, in which the first buffer layer includes one or more metals. The second buffer layer is disposed underneath the substrate in which the second buffer layer includes one or more metals. The first buffer layer, the second buffer layer, and the substrate layer are part of a symmetrical stack on which is disposed the glass layer.

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# THIN GLASS LAMINATES

## CROSS-REFERENCE TO RELATED APPLICATIONS

**[0001]** This application claims the benefit of priority under 35 U.S.C. § 119 of U.S. Provisional Application No. 62/940,368, filed November 26, 2019, the content of which is incorporated herein by reference in its entirety.

## FIELD OF THE DISCLOSURE

**[0002]** Certain embodiments of the disclosure relate to systems and methods for providing laminated structures and, in particular, glass laminates.

## BACKGROUND OF THE DISCLOSURE

**[0003]** A conventional glass laminate contains, for example, one substrate, one decorative film, and one adhesive layer that bonds glass to the rest of the structure. Such a laminate suffers from stresses due to thermal expansion mismatch and excessive moisture ingress. These stresses can lead to damage and glass failure. Out-of-plane deformations can also affect the appearance of such laminates and lead to delamination failures due to excessive shearing near the edges.

**[0004]** Further limitations and disadvantages of conventional and traditional approaches will become apparent to one of skill in the art, through comparison of such systems with the present disclosure as set forth in the remainder of the present application with reference to the drawings.

## SUMMARY OF THE DISCLOSURE

**[0005]** Generally, the present disclosure is directed towards laminate configurations having a symmetry (e.g. materials having similar modulus and thickness positioned on either side of the substrate), such that the resulting laminate is configured with improved (reduced) stress (e.g. less than 23 MPa) and improved (reduced) bow displacement (e.g. not greater than 3 mm/m) as compared to non-symmetrical laminate stacks. More specifically, in various embodiments, the substrate is configured with two buffer layers configured on (adjacent to) both major surfaces of the substrate, wherein the buffer layers are configured with either high modulus or low modulus and where the buffer layers each have the same thickness.

**[0006]** In one aspect, a laminated structure is provided, comprising: a substrate layer; a first buffer layer disposed on top of the substrate, wherein the first buffer layer comprises one or more metals; a second buffer layer disposed underneath the substrate, wherein the second buffer layer comprises one or more metals, and wherein the first buffer layer, the second buffer layer, and the substrate layer are part of a symmetrical stack; and a glass layer disposed on top of the symmetrical stack.

**[0007]** In some embodiments, the substrate layer comprises medium density fiber board (MDF).

**[0008]** In some embodiments, the substrate layer comprises one or more of methyl methacrylate (PMMA), an acrylic, and an acrylic glass.

**[0009]** In some embodiments, the substrate layer comprises a high pressure laminate (HPL).

**[0010]** In some embodiments, the substrate layer comprises one or more of a decorative film and a printed surface.

**[0011]** In some embodiments, the substrate layer has a thickness between approximately 6.35 millimeters and approximately 12.7 millimeters.

**[0012]** In some embodiments, the first buffer layer has a thickness between approximately 0.2 millimeters and approximately 1 millimeters, and wherein the second buffer layer has a thickness between approximately 0.2 millimeters and approximately 1 millimeters, or wherein the first buffer layer has a thickness between approximately 1 millimeters and approximately 3.5 millimeters, and wherein the second buffer layer has a thickness between approximately 1 millimeters and approximately 3.5 millimeters.

**[0013]** In some embodiments, the first buffer layer and the second buffer layer comprise steel.

**[0014]** In some embodiments, the glass layer has a thickness of approximately 250 micrometers.

[0015] In some embodiments, the laminated structure is structured to reduce stress in the glass layer of the laminated structure and to reduce bow deflection of the laminated structure.

[0016] In some embodiments, a first thickness of the substrate, a second thickness of the first buffer layer, a third thickness of the second buffer layer, a first elastic modulus of the first buffer layer, and a second elastic modulus of the second buffer layer are configured to reduce stress in the glass layer of the laminated structure to less than approximately 23 megapascals and to reduce bow deflection of the laminated structure to less than approximately 3 millimeters, wherein the second thickness is substantially equal to the first thickness, and wherein the first elastic modulus is substantially equal to the second elastic modulus.

[0017] In some embodiments, the glass layer of the laminated structure has a glass stress of less than approximately 23 megapascals, and wherein the laminated structure has a bow deflection of less than approximately 3 millimeters.

[0018] In another aspect, a method of manufacturing a laminated structure is provided, comprising: providing a substrate layer; providing a first buffer layer that is disposed on top of the substrate, wherein the first buffer layer comprises one or more metals; providing a second buffer layer that is disposed underneath the substrate, wherein the second buffer layer comprises one or more metals, and wherein the first buffer layer, the second buffer layer, and the substrate layer are part of a symmetrical stack; and providing a glass layer that is disposed on top of the symmetrical stack.

[0019] In some embodiments, providing the substrate layer comprises providing one or more of a methyl methacrylate (PMMA), an acrylic, an acrylic glass, a medium density fiber board (MDF), a high pressure laminate (HPL), a decorative film, and a printed surface.

[0020] In some embodiments, providing the substrate layer comprises providing the substrate layer with a thickness between approximately 6.35 millimeters and approximately 25.4 millimeters.

[0021] In some embodiments, providing the first buffer layer comprises providing the first buffer layer with a thickness between approximately 0.2 millimeters and approximately 1 millimeters, and wherein providing the second buffer layer comprises providing the second buffer layer with a thickness between approximately 0.2 millimeters and approximately 1 millimeters, or wherein providing the first buffer layer comprises providing the first buffer layer with a thickness between approximately 1 millimeters and approximately 3.5 millimeters, and wherein providing the second buffer layer comprises providing the second buffer layer with a thickness between approximately 1 millimeters and approximately 3.5 millimeters.

**[0022]** In some embodiments, providing the first buffer layer comprises providing steel, and wherein providing the second buffer layer comprises providing steel.

**[0023]** In some embodiments, providing the glass layer comprises providing the glass layer with a thickness of approximately 250 micrometers.

**[0024]** In some embodiments, providing a first thickness of the substrate, a second thickness of the first buffer layer, a third thickness of the second buffer layer, a first elastic modulus of the first buffer layer, a second elastic modulus of the second buffer layer to reduce stress in the glass layer of the laminated structure to less than approximately 23 megapascals and to reduce a bow deflection of the laminated structure to less than approximately 3 millimeters, wherein the first thickness is substantially equal to the second thickness, and wherein the first elastic modulus is substantially equal to the second elastic modulus.

**[0025]** In some embodiments, providing the glass layer comprises providing the glass layer of the laminated structure with a glass stress of less than approximately 23 megapascals and the laminated structure with a bow deflection of less than approximately 3 millimeters.

**[0026]** In some embodiments, providing a first adhesive between the substrate layer and the first buffer layer, wherein the first adhesive comprises one or both of an optically clear first adhesive or a pressure sensitive first adhesive; and providing a second adhesive between the first buffer layer and the glass layer, wherein the second adhesive comprises one or both of an optically clear second adhesive or a pressure sensitive second adhesive.

**[0027]** Systems and methods for providing laminated structures and/or the design of laminated structures are provided substantially as illustrated by and/or described in connection with at least one of the figures, as set forth more completely in the claims.

**[0028]** Some embodiments according to the present disclosure provide thin glass laminates with symmetric buffer structures for improved reliability and improved bow resistance (e.g. lower bow displacement, not greater than 3 mm/m) according to the present disclosure.

**[0029]** Some embodiments according to the present disclosure provide thin glass laminates with symmetric buffer structures for improved performance (e.g. stress less than 23 MPa on the laminate) according to the present disclosure.

**[0030]** Some embodiments according to the present disclosure provide symmetric stack structures that protect back surfaces of laminates from moisture entering into the substrates and/or other moisture absorbing layers.

**[0031]** Some embodiments according to the present disclosure enable the use of thin glass as a superstrate in laminates.

**[0032]** Some embodiments according to the present disclosure provide symmetric buffer designs that allow for the use of generic substrate materials.

**[0033]** Some embodiments according to the present disclosure provide an improvement in reliability of glass that include laminate structures.

**[0034]** Some embodiments according to the present disclosure provide greater flexibility in designing architectural surfaces.

**[0035]** Various advantages, aspects and novel features of the present disclosure, as well as details of an illustrated embodiment thereof, will be more fully understood from the following description and drawings.

## BRIEF DESCRIPTION OF SEVERAL VIEWS OF THE DRAWINGS

**[0036]** FIG. 1 is a schematic illustrating an exemplary out-of-plane displacement of laminate due to moisture/thermal expansion, in which one or more embodiment of the present disclosure are configured to prevent, reduce, mitigate, and/or eliminate bow due to expansion.

**[0037]** FIG. 2 shows an exemplary laminated structure according to an embodiment of the present disclosure.

**[0038]** FIG. 3 shows a table including three factorial design points for use in a design of experiments (DOE) approach according to an embodiment of the present disclosure.

**[0039]** FIG. 4 shows a table including predictions and/or optimizations based on a DOE approach and/or an analytical approach according to an embodiment of the present disclosure.

**[0040]** FIG. 5 is a table illustrating optimized symmetric designs of laminated structures according to some embodiments of the present disclosure.

**[0041]** FIG. 6 shows an exemplary contour plot for bow deflection based on a DOE approach according to an embodiment of the present disclosure.

**[0042]** FIG. 7 shows an exemplary contour plot for glass stress based on a DOE approach according to an embodiment of the present disclosure.

**[0043]** FIG. 8 shows an exemplary schematic of multi-layered elastic materials that form a laminate structure according to an embodiment of the present disclosure. The laminate structure of Figure 3 was utilized in the computer modelling completed to model bow and stress of various laminate configurations, including one or more symmetric configurations in accordance with various embodiments of the present disclosure.

## DETAILED DESCRIPTION OF THE DISCLOSURE

**[0044]** Some embodiments of the present disclosure relate to systems and methods that provide laminated structures.

**[0045]** Some embodiments according to the present disclosure provide glass laminate structures that provide a clean, sleek, and/or tough surface that makes the architecture and designs more protective and beautiful. Glass can be applied on a variety of substrates that can have a decorative film layer embedded in it. Not only does the glass protect the decorative film, but the glass also provides a high-end aesthetic top surface to the substrate. Such laminates can be used as decorative walls, office partitions, kitchen back-splash, door panels, or elevator decor, etc.

**[0046]** Glass laminates are subjected to thermal expansion mismatches and/or moisture ingress expansions during use/in installations. Glass laminate configuration can vary, and can include: a substrate, a decorative film, and an adhesive layer that bonds the thin glass to the rest of the structure. FIG. 1 is a schematic illustrating an exemplary out-of-plane displacement (e.g., bow) of laminate due to moisture/thermal expansion. Referring to FIG. 1, the stresses in glass are lower when the laminate is permitted to bow; however, out-of-plane deflection (e.g., bow) of the laminate can cause distortion at the edges and affect overall aesthetics of the laminate. In addition, out-of-plane deformations can lead to delamination failures due to excessive shearing near the edges of the laminated panel. These types of stresses can lead to damage and glass failure. Determining a bow and a stress for a particular stack helps in designing a better laminate structure. Some embodiments include symmetrical stacks having improved properties (e.g. bow not greater than 3 mm/m) and/or stress (e.g. not greater than 23 MPa) across the laminate. More specifically, first and second buffer layers configured on either side (e.g. major surface) of the substrate are configured with a symmetry, such that a low modulus or high modulus material is selected for both buffer layers, with the thicknesses of each buffer layer generally corresponding to each other. For example, thin glass laminates with symmetric buffer structures exhibit tailored properties, including as non-limiting examples: improved reliability, improved stress (e.g. reduced stress), and/or improved bow (e.g. lower bow displacement).

**[0047]** Some embodiments of the present disclosure provide an exemplary multi-layered decorative laminate comprising glass (e.g., Willow® glass or some other glass) as a protective top layer, a decorative film or printed surface, and a substrate layer sandwiched between buffers (e.g., two metal layers). In some embodiments, the substrate layer can include, for example, one or more of the following: a methyl methacrylate (PMMA), an acrylic, an acrylic glass, a medium density fiber board (MDF), a high pressure laminate (HPL), a decorative film, and a printed surface. When the laminate is subjected to a moisture change from approximately 50% relative humidity (RH) to approximately 90% RH, a moisture expansion of approximately

0.167% results. When different materials and thicknesses for the substrates, for example, are considered, it is determined that, for some embodiments, a symmetric design reduces the bow deflections and stresses within the glass and/or glass laminate when the buffer metal layer thickness is carefully designed.

**[0048]** Some embodiments of the present disclosure provide an exemplary symmetric laminate stack formed by sandwiching a substrate layer (e.g., MDF with a thickness between approximately 6.35 mm and approximately 25.4 mm) between buffer layers (e.g., metal layers with thicknesses between approximately 0.2 mm and approximately 1 mm) as shown in FIG. 2. In some embodiments, one or more of the buffer layer can include, for example, laminated decorative steel. FIG. 2 shows an exemplary symmetric buffer stack, used for DOE analysis, that comprises three layers (e.g., two buffer layers and a substrate layer), each separated by an adhesive layer (e.g., an OCA layer). The glass and the symmetric stack are also separated by an adhesive layer (e.g., an OCA layer). In some embodiments, the OCA layers can be approximately 50 μm in thickness. In some embodiments, pressure sensitive adhesive (PSA) layers with similar thicknesses can be used. In some embodiments, the stack includes layers that expand due to humidity and/or moisture. The buffer layers above and below the substrate layer provide mechanical and/or structural symmetry and reduce the relative out-of-plane displacement (e.g., bow) when the laminate is exposed to humid and/or moist environments. When subjected to thermal/moisture expansions, the exemplary stack experiences minimal bow and stresses due, in part, to its symmetric configuration. Using a DOE approach, the stack can be analyzed in which optimum values of buffer material property and/or thickness can be evaluated that do not exceed certain permissible limits of stress and bow.

**[0049]** The stack shown in FIG. 2 can be analyzed using the DOE approach. In some embodiments, the substrate layer comprises MDF. The moisture expansion of MDF can be set at approximately 42 ppm per percent change in RH. Expansion of the all other layers can be set to zero, for example. Further, moisture expansion can be considered as being dominant compared to the thermal expansion, and total moisture expansion can be considered to be approximately 0.167%.

**[0050]** Tabular values of DOE factors are shown in FIG. 3. Referring to FIG. 3, three factorial design points in the DOE are considered in the exemplary example. A total of 15 cases are considered in which the thickness of MDF t_mdf, the thickness of the buffer layer t_buffer, and the elastic modulus of the buffer layer E_buffer are modified within a given range of values.

**[0051]** Some embodiments provide that DOE analysis is performed by DOE circuitry including DOE hardware that performs DOE analysis, calculations, optimizations, and/or other operations described herein. The DOE hardware can include, for example, specialized circuits that perform particular DOE analysis, calculations, optimizations, and/or other operations described herein specifically for laminated structures or other types of structures. Some embodiments provide that DOE analysis is performed by application specific integrated circuits (ASICs), for example, that are customized for a particular use or are coupled to or part of a manufacturing apparatus or system for manufacturing or making laminated structures. Thus, for example, the DOE circuitry can cause a particular layer thickness or a specific material or layer sequence to be disposed within the laminate structure being manufactured. In some embodiments, the DOE circuitry can include one or more processors and/or one or more non-transitory memories that store data and/or processor-executable instructions that perform DOE analysis, calculations, optimizations, and/or other operations described herein. In some embodiments, DOE analysis can be performed using software such as DOE Pro, for example.

**[0052]** Based on the DOE analysis performed by DOE circuitry on the stack shown in FIG. 2, for example, two stacks are proposed, determined, and/or selected as set forth in FIG. 4 that lower the stress in glass while also reducing the bow deflection of the laminate. Referring to FIG. 8, the two stacks comprise a high modulus metal (e.g., a high modulus steel with an elastic modulus of approximately 200 GPa) or a low modulus metal (e.g., a low modulus deco-steel with an elastic modulus of approximately 101 GPa). Via the DOE analysis, thickness values are determined and/or predicted for an MDF thickness of approximately 12.7 mm. Referring to FIG. 4, the buffer thickness can be varied between approximately 0.93 mm to approximately 0.49 mm depending upon the choice of material (e.g., high modulus material or low modulus material) which results in glass stresses less than approximately 23 MPa and bow deflection less than approximately 1 mm.

**[0053]** As described above with respect to some embodiments according to the present disclosure, equations (1)-(4) can be used, for example, to determine strain, stress, and bow (as discussed below with respect to Figure 8). FIG. 5 is a table illustrating optimized symmetric designs of laminated structures that is approximately 900 mm by approximately 900 mm and having a glass surface with a thickness of approximately 250 μm with various substrate materials considered. The low elastic modulus buffer is characterized by an elastic modulus of approximately 101 GPa. The high elastic modulus buffer is characterized by an elastic modulus of approximately 200 GPa. The laminates were subjected to approximately 0.167% moisture expansion with allowable glass stress of less than approximately 23 MPa. The different design iterations used different substrate materials such as, for example, polymethyl methacrylate (PMMA), high pressure laminate (HPL), and MDF.

**[0054]** As described above with respect to some embodiments according to the present disclosure, the DOE circuitry provides a DOE analysis based via three-factorial design points as shown in FIG. 3. The DOE approach generates contour plots that in turn are used to determine the optimum values of bow and stress. FIG. 6 shows an exemplary contour plot for bow deflection (mm) based on DOE analysis of the stack shown in FIG. 2. The bow calculations are performed for the laminate stack that has an MDF substrate as the substrate layer with a thickness of approximately 12.7 mm and a glass with a thickness of approximately 250 μm subjected to approximately 0.167% moisture expansion. FIG. 7 shows a contour plot for glass stress (MPa) based on the DOE analysis of the stack shown in FIG. 2. The contour plot of glass stress is generated by the DOE analysis to assist with determining a suitable material and thickness of the buffers. Then, as described above, optimized values of buffer thickness for different substrate materials and thicknesses can be determined. The results are shown in FIG. 5.

**[0055]** Some embodiments according to the present disclosure provide systems and methods for designing and/or optimizing laminate stack structures. In some embodiments, an analytical model is generated for a multi-layered structure to compute stress in each layer and out-of-plane bow. The results of the analytical model can be compared, for example, with FEA. A DOE matrix can be generated such as the table shown in FIG. 3, for example. The analytical model can be run for each case (e.g., the 15 cases in the table shown in FIG. 3), the results of which can serve as inputs to the DOE analysis (e.g., a DOE solver). The DOE analysis provides, for example, the response surface for a given input parameter (e.g., substrate thickness). Based on the particular requirements of stress and bow, the optimum thickness for buffer layers can be determined.

**[0056]** FIG. 8 shows an exemplary schematic of multi-layered elastic materials that form a laminate structure according to the present disclosure. The bottom layer is called layer 0 characterized by an expansion coefficient $\alpha_0$, an elastic modulus $E_0$, and a thickness $t_0$. The different layers are denoted by subscripts 0 to j, where j is an integer. The expansion coefficient, elastic modulus, and thickness corresponding to a particular layer are denoted as α, E, and t, respectively, with a corresponding subscript j varying from 0 to n depending on the layer. Thus, the laminate structure made up of multiple layers can have layers of different stiffness (e.g., different elastic moduli) and expansion coefficients. The lamination process is performed at a high enough temperature to promote bonding between the adjacent layers. The laminate is then cooled to room temperature. Since different layers within the laminate have different expansion coefficients, a differential strain is generated. After the force and moment equilibrium, the uniform and bending strain components can be given by, for example:

(1) $\varepsilon = \varepsilon\_uniform + (y - t\_bend)/r\_c$

in which ε_uniform is the uniform strain component excluding bending, and the second term of the above equation relates to a bending component of the strain. The term t_bend refers to the location of the bending axis (e.g., the line where bending strain is zero), and r_c is the radius of curvature of the structure. By enforcing the force and bending moment equilibrium, the parameters for the uniform strain component (e.g., ε_uniform) and bending strain components (e.g., t_bend and r_c) can be determined. Based on the strain, the stress in the substrate and other layers can be determined by using, for example:

(2) $\sigma_0 = E_0 * (\varepsilon - \alpha_0 * \Delta T)$; and

(3) $\sigma_j = E_j * (\varepsilon - \alpha_j * \Delta T)$.

These are the exemplary expressions for the exact closed form solutions for determining stress in the substrate and layers.

**[0057]** The out-of-plane displacement (e.g., bow) is determined based on the radius of curvature r_c and length of the laminate L by using, for example:

(4) $\delta\_bow = L * L / (8*r\_c)$.

L in the above equation is the length of the plate. If corner bow deflection is desired, then L'=sqrt(a^2+b^2) can be used instead of L in equation (4), where a and b are the short and long dimensions of the plate.

**[0058]** In order to determine the stress state in a 2-D plate, the elastic modulus can be modified to value of E/(1-nu), if the plate approximation is desired, where nu is Poisson's ratio of the material, and can be used instead of the simple value of E.

**[0059]** This exemplary method according to an embodiment of the present disclosure provides an analytical tool to solve for the stress state and bow deformations, for example, inside the layers and to design a laminate structure that resists the moisture expansion, for example, in the field.

**[0060]** As utilized herein the terms "circuit" and "circuitry" refer to physical electronic components (i.e., hardware) and any software and/or firmware ("code") which may configure the hardware, be executed by the hardware, and/or otherwise be associated with the hardware. As utilized herein, "and/or" means any one or more of the items in the list joined by "and/or". As an example, "x and/or y" means any element of the three-element set {(x), (y), (x, y)}. As another example, "x, y, and/or z" means any element of the seven-element set {(x), (y), (z), (x, y), (x, z), (y, z), (x, y, z)}. As utilized herein, the term "exemplary" means serving as a non-limiting example, instance, or illustration. As utilized herein, the terms "e.g." and "for example" set off lists of one or more non-limiting examples, instances, or illustrations.

**[0061]** The drawings are of illustrative embodiments. They do not illustrate all embodiments. Other embodiments may be used in addition or instead. Details that may be apparent or unnecessary may be omitted to save space or for more effective illustration. Some embodiments may be practiced with additional components or steps and/or without all of the components or steps that are illustrated

**[0062]** While the present disclosure has been described with reference to certain embodiments, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted without departing from the scope of the present disclosure. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the present disclosure without departing from its scope. Therefore, it is intended that the present disclosure not be limited to the particular embodiment disclosed, but that the present disclosure will include all embodiments falling within the scope of the appended claims.

## CLAIMS

What is claimed is:

1. A laminated structure, comprising:

a substrate layer;

a first buffer layer disposed on top of the substrate, wherein the first buffer layer comprises one or more metals;

a second buffer layer disposed underneath the substrate, wherein the second buffer layer comprises one or more metals, and wherein the first buffer layer, the second buffer layer, and the substrate layer are part of a symmetrical stack; and

a glass layer disposed on top of the symmetrical stack.

2. The laminated structure according to claim 1, wherein the substrate layer comprises medium density fiber board (MDF).

3. The laminated structure according to claim 1 or 2, wherein the substrate layer comprises one or more of methyl methacrylate (PMMA), an acrylic, and an acrylic glass.

4. The laminated structure according to any of claims 1 to 3, wherein the substrate layer comprises a high pressure laminate (HPL).

5. The laminated structure according to any of claims 1 to 4, wherein the substrate layer comprises one or more of a decorative film and a printed surface.

6. The laminated structure according to any of claims 1 to 5, wherein the substrate layer has a thickness between approximately 6.35 millimeters and approximately 12.7 millimeters.

7. The laminated structure according to any of claims 1 to 6,

wherein the first buffer layer has a thickness between approximately 0.2 millimeters and approximately 1 millimeters, and wherein the second buffer layer has a thickness between approximately 0.2 millimeters and approximately 1 millimeters, or

wherein the first buffer layer has a thickness between approximately 1 millimeters and approximately 3.5 millimeters, and wherein the second buffer layer has a thickness between approximately 1 millimeters and approximately 3.5 millimeters.

8. The laminated structure according to any of claims 1 to 7, wherein the first buffer layer and the second buffer layer comprise steel.

9. The laminated structure according to any of claims 1 to 8, wherein the glass layer has a thickness of approximately 250 micrometers.

10. The laminated structure according to any of claims 1 to 9, wherein the laminated structure is structured to reduce stress in the glass layer of the laminated structure and to reduce bow deflection of the laminated structure.

11. The laminated structure according to any of claims 1 to 10, wherein a first thickness of the substrate, a second thickness of the first buffer layer, a third thickness of the second buffer layer, a first elastic modulus of the first buffer layer, and a second elastic modulus of the second buffer layer are configured to reduce stress in the glass layer of the laminated structure to less than approximately 23 megapascals and to reduce bow deflection of the laminated structure to less than approximately 3 millimeters, wherein the second thickness is substantially equal to the first thickness, and wherein the first elastic modulus is substantially equal to the second elastic modulus.

12. The laminated structure according to any of claims 1 to 11, wherein the glass layer of the laminated structure has a glass stress of less than approximately 23 megapascals, and wherein the laminated structure has a bow deflection of less than approximately 3 millimeters.

13. A method of manufacturing a laminated structure, comprising:

providing a substrate layer;

providing a first buffer layer that is disposed on top of the substrate, wherein the first buffer layer comprises one or more metals;

providing a second buffer layer that is disposed underneath the substrate, wherein the second buffer layer comprises one or more metals, and wherein the first buffer layer, the second buffer layer, and the substrate layer are part of a symmetrical stack; and

providing a glass layer that is disposed on top of the symmetrical stack.

14. The method according to claim 13, wherein providing the substrate layer comprises providing one or more of a methyl methacrylate (PMMA), an acrylic, an acrylic glass, a medium density fiber board (MDF), a high pressure laminate (HPL), a decorative film, and a printed surface.

15. The method according to claim 13 or claim 14, wherein providing the substrate layer comprises providing the substrate layer with a thickness between approximately 6.35 millimeters and approximately 25.4 millimeters.

16. The method according to any of claims 13 to 15,

wherein providing the first buffer layer comprises providing the first buffer layer with a thickness between approximately 0.2 millimeters and approximately 1 millimeters, and wherein providing the second buffer layer comprises providing the second buffer layer with a thickness between approximately 0.2 millimeters and approximately 1 millimeters, or

wherein providing the first buffer layer comprises providing the first buffer layer with a thickness between approximately 1 millimeters and approximately 3.5 millimeters, and wherein providing the second buffer layer comprises providing the second buffer layer with a thickness between approximately 1 millimeters and approximately 3.5 millimeters.

17. The method according to any of claims 13 to 16, wherein providing the first buffer layer comprises providing steel, and wherein providing the second buffer layer comprises providing steel.

18. The method according to any of claims 13 to 17, wherein providing the glass layer comprises providing the glass layer with a thickness of approximately 250 micrometers.

19. The method according to any of claims 13 to 18, wherein providing a first thickness of the substrate, a second thickness of the first buffer layer, a third thickness of the second buffer layer, a first elastic modulus of the first buffer layer, a second elastic modulus of the second buffer layer to reduce stress in the glass layer of the laminated structure to less than approximately 23 megapascals and to reduce a bow deflection of the laminated structure to less than approximately 3 millimeters, wherein the first thickness is substantially equal to the second thickness, and wherein the first elastic modulus is substantially equal to the second elastic modulus.

20. The method according to any of claims 13 to 19, wherein providing the glass layer comprises providing the glass layer of the laminated structure with a glass stress of less than approximately 23 megapascals and the laminated structure with a bow deflection of less than approximately 3 millimeters.

21. The method according to any of claims 13 to 20, comprising:

providing a first adhesive between the substrate layer and the first buffer layer, wherein the first adhesive comprises one or both of an optically clear first adhesive or a pressure sensitive first adhesive; and

providing a second adhesive between the first buffer layer and the glass layer, wherein the second adhesive comprises one or both of an optically clear second adhesive or a pressure sensitive second adhesive.

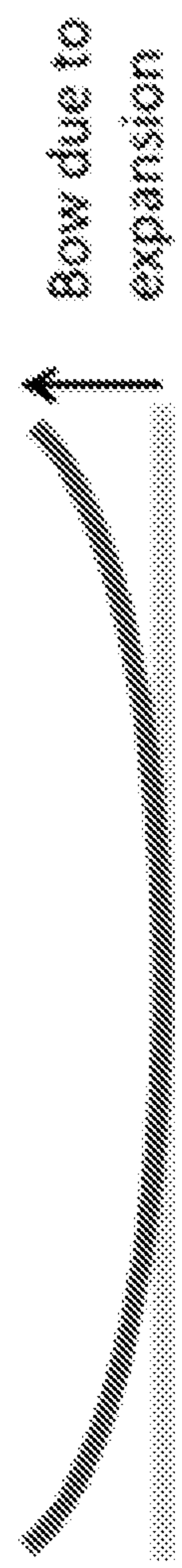


Figure 1

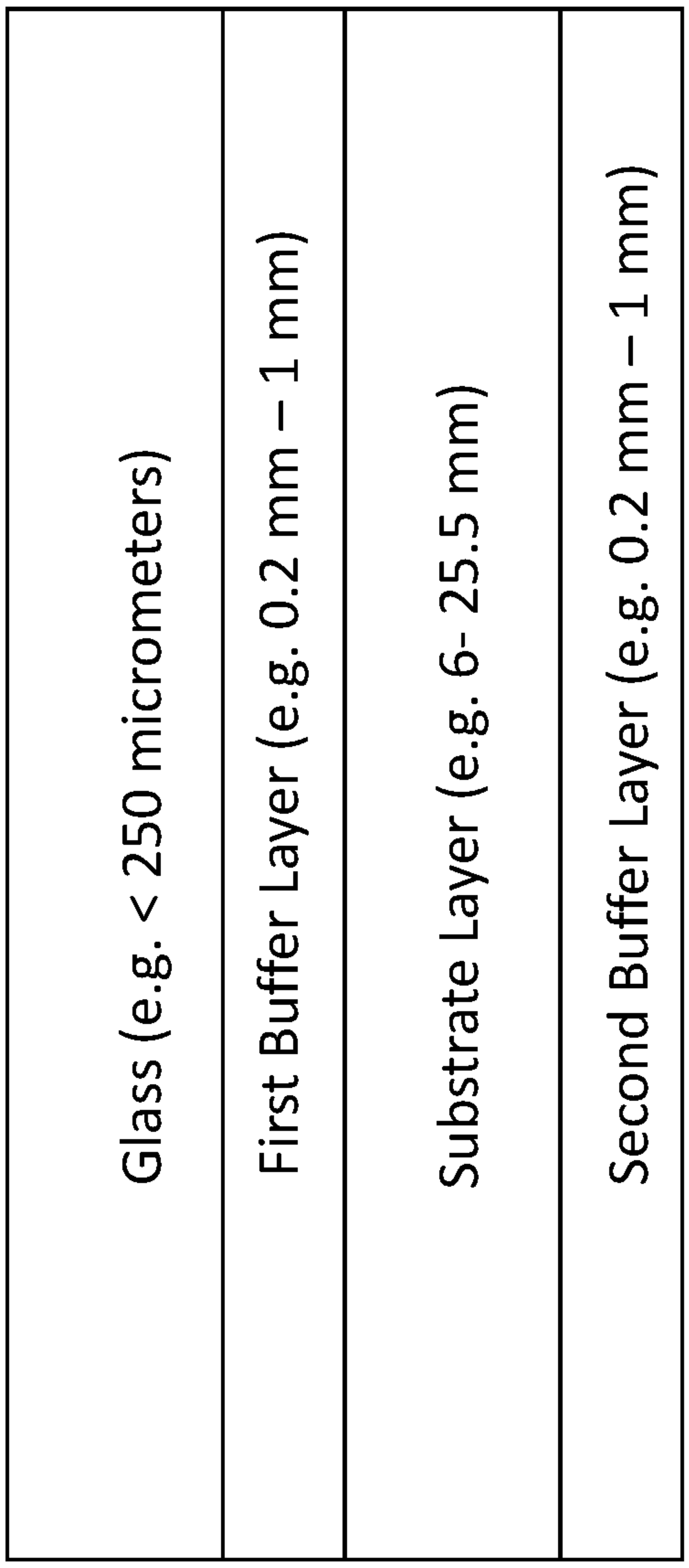
Glass (e.g. < 250 micrometers)
First Buffer Layer (e.g. 0.2 mm – 1 mm)
Substrate Layer (e.g. 6- 25.5 mm)
Second Buffer Layer (e.g. 0.2 mm – 1 mm)

Figure 2

| Factor | A | B | C |
|---|---|---|---|
| Row # | t_mdf | t_buffer | E_buffer |
| 1 | 6.35 | 0.2 | 70 |
| 2 | 6.35 | 0.2 | 210 |
| 3 | 6.35 | 1 | 70 |
| 4 | 6.35 | 1 | 210 |
| 5 | 25.4 | 0.2 | 70 |
| 6 | 25.4 | 0.2 | 210 |
| 7 | 25.4 | 1 | 70 |
| 8 | 25.4 | 1 | 210 |
| 9 | 15.875 | 0.6 | 140 |
| 10 | 6.35 | 0.6 | 140 |
| 11 | 25.4 | 0.6 | 140 |
| 12 | 15.875 | 0.2 | 140 |
| 13 | 15.875 | 1 | 140 |
| 14 | 15.875 | 0.6 | 70 |
| 15 | 15.875 | 0.6 | 210 |

Figure 3

For E = 200 GPa, t ~ 0.45-0.49

For E = 101 GPa, t ~ 0.89-0.93

Stress <=23 MPa and bow <3 mm/m

DoE Predictions for t_mdf = 12.7 mm

| Buffer layer E-mod and thickness | Stress (MPa) | Bow (mm/m) |
|---|---|---|
| E = 200 GPa, Thickness >= 0.488 mm | <= 22.99 | <= -0.32 |
| E = 101 GPa, Thickness >= 0.925 mm | <= 23.00 | <= -0.29 |

Analytical Calculation Predictions* for t_mdf = 12.7 mm

| | Stress (MPa) | Bow (mm/m) |
|---|---|---|
| E = 200 GPa, Thickness >= 0.449 mm | <= 23.00 | <= -0.65 |
| E = 101 GPa, Thickness >= 0.884 mm | <= 22.99 | <= -0.65 |

Figure 4

**Optimized symmetric designs for laminates (900 x 900 mm) with 250 um glass surface. Laminates subjected to 0.167% of moisture expansion with allowable glass stress of less than 23 MPa.**

| Substrate Material | Substrate Thickness (mm) | Low E-mod buffer thickness (mm) | High E-mod buffer thickness (mm) | Max. bow (mm) |
|---|---|---|---|---|
| PMMA<br>E = 2.5 GPa, v = 0.4 | 12.7 | 0.81 | 0.41 | < 1 |
| PMMA<br>E = 2.5 GPa, v = 0.4 | 6 | 0.372 | 0.189 | < 3 |
| MDF<br>E = 2.9 GPa, v = 0.38 | 12.7 | 0.93 | 0.49 | < 1 |
| MDF<br>E = 2.9 GPa, v = 0.38 | 6.35 | 0.39 | 0.2 | < 3 |
| HPL<br>E = 15 GPa, v = 0.38 | 8 | 3.35 | 1.71 | < 1 |
| HPL<br>E = 15 GPa, v = 0.38 | 6.35 | 2.63 | 1.33 | < 1 |

Figure 5

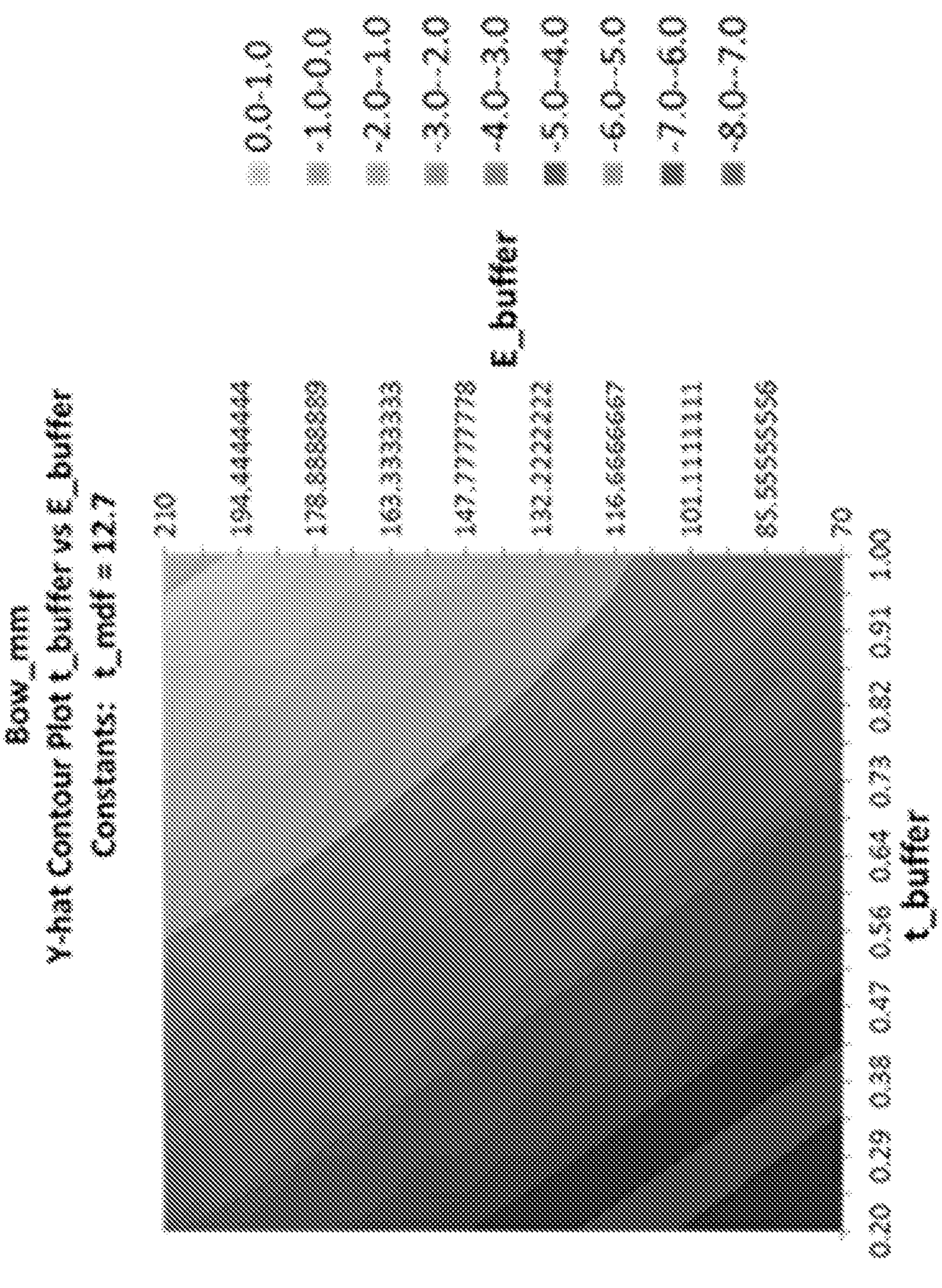
Bow_mm
Y-hat Contour Plot t_buffer vs E_buffer
Constants: t_mdf = 12.7
E_buffer
210
194.4444444
178.8888889
163.3333333
147.7777778
132.2222222
116.6666667
101.1111111
85.5555556
70
t_buffer
0.20
0.29
0.38
0.47
0.56
0.64
0.73
0.82
0.91
1.00
0.0-1.0
-1.0-0.0
-2.0--1.0
-3.0--2.0
-4.0--3.0
-5.0--4.0
-6.0--5.0
-7.0--6.0
-8.0--7.0

Figure 6

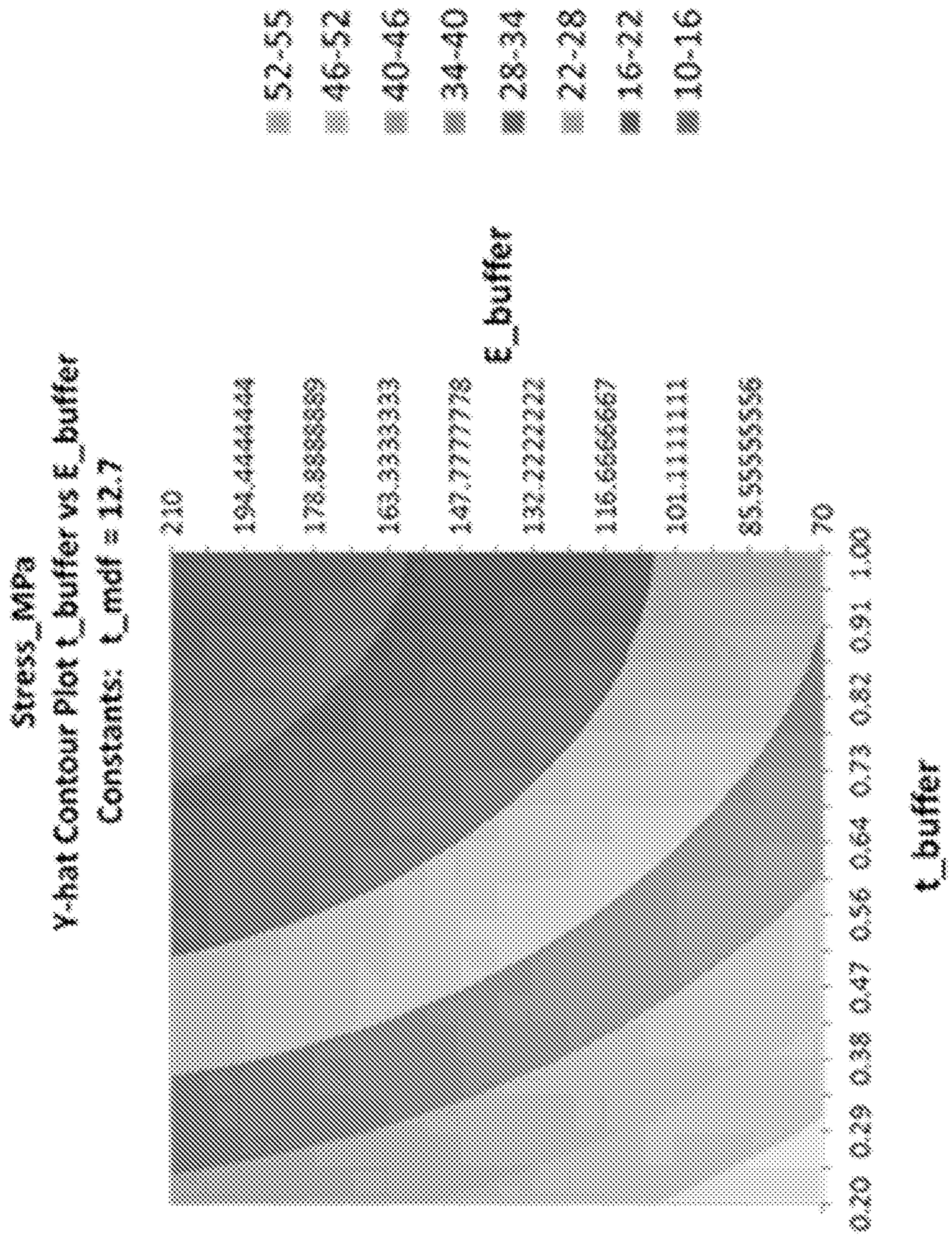
Stress_MPa
Y-hat Contour Plot t_buffer vs E_buffer
Constants: t_mdf = 12.7
210
194.4444444
178.8888889
163.3333333
147.7777778
132.2222222
116.6666667
101.1111111
85.5555556
70
E_buffer
0.20 0.29 0.38 0.47 0.56 0.64 0.73 0.82 0.91 1.00
t_buffer
52-55
46-52
40-46
34-40
28-34
22-28
16-22
10-16

Figure 7


Layer j $\alpha_{j=n}$, $E_{j=n}$, $t_{j=n}$
...
Layer 2 $\alpha_{j=2}$, $E_{j=2}$, $t_{j=2}$
Layer 1, $\alpha_{j=1}$, $E_{j=1}$, $t_{j=1}$
Layer 0, $\alpha_0$, $E_0$, $t_0$

Figure 8

## INTERNATIONAL SEARCH REPORT

International application No.
**PCT/US2020/061159**

**A. CLASSIFICATION OF SUBJECT MATTER**

**B32B 17/06**(2006.01)i; **B32B 15/10**(2006.01)i; **B32B 15/082**(2006.01)i; **B32B 15/18**(2006.01)i; **B32B 7/12**(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)

B32B 17/06(2006.01); B32B 15/04(2006.01); B32B 17/10(2006.01); B32B 27/32(2006.01); B32B 33/00(2006.01); E04B 9/32(2006.01)

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

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

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

eKOMPASS(KIPO internal) & keywords: glass laminate, buffer, substrate, thickness, symmetrical stack

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| X | WO 2017-210412 A1 (CORNING INCORPORATED) 07 December 2017 (2017-12-07) claims 16, 20-21, 24; paragraph [0072]; table 4; figure 4 | 1-3,13-15 |
| A | JP 2009-248466 A (SANKO CO., LTD.) 29 October 2009 (2009-10-29) the whole document | 1-3,13-15 |
| A | US 2016-0176163 A1 (CORNING INCORPORATED) 23 June 2016 (2016-06-23) the whole document | 1-3,13-15 |
| A | US 7927706 B2 (FISHER, W. K.) 19 April 2011 (2011-04-19) the whole document | 1-3,13-15 |
| A | US 4822684 A (HOTTA, M. et al.) 18 April 1989 (1989-04-18) the whole document | 1-3,13-15 |

☐ 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 |
|---|---|
| **22 March 2021** | **22 March 2021** |


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**INTERNATIONAL SEARCH REPORT**

International application No.

**PCT/US2020/061159**

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

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

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

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

3. ☑ Claims Nos.: **4-12,16-21**
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

**INTERNATIONAL SEARCH REPORT**
**Information on patent family members**

International application No.
**PCT/US2020/061159**

| Patent document cited in search report | | | Publication date (day/month/year) | Patent family member(s) | | | Publication date (day/month/year) |
|---|---|---|---|---|---|---|---|
| WO | 2017-210412 | A1 | 07 December 2017 | CN | 109414909 | A | 01 March 2019 |
| | | | | EP | 3463864 | A1 | 10 April 2019 |
| | | | | EP | 3463864 | B1 | 17 February 2021 |
| | | | | KR | 10-2019-0004367 | A | 11 January 2019 |
| | | | | KR | 10-2035165 | B1 | 22 October 2019 |
| | | | | TW | 201742750 | A | 16 December 2017 |
| JP | 2009-248466 | A | 29 October 2009 | | None | | |
| US | 2016-0176163 | A1 | 23 June 2016 | EP | 3027407 | A1 | 08 June 2016 |
| | | | | JP | 2016-533924 | A | 04 November 2016 |
| | | | | JP | 2020-006689 | A | 16 January 2020 |
| | | | | JP | 6599325 | B2 | 30 October 2019 |
| | | | | JP | 6786672 | B2 | 18 November 2020 |
| | | | | US | 10011094 | B2 | 03 July 2018 |
| | | | | US | 10773495 | B2 | 15 September 2020 |
| | | | | US | 2018-0272659 | A1 | 27 September 2018 |
| | | | | WO | 2015-017198 | A1 | 05 February 2015 |
| US | 7927706 | B2 | 19 April 2011 | AU | 2004-300188 | A1 | 30 June 2005 |
| | | | | AU | 2004-300188 | B2 | 25 February 2010 |
| | | | | BR | PI0417588 | A | 20 March 2007 |
| | | | | CA | 2549757 | A1 | 30 June 2005 |
| | | | | CN | 1906531 | A | 31 January 2007 |
| | | | | CN | 1906531 | C | 31 January 2007 |
| | | | | EP | 1700155 | A1 | 13 September 2006 |
| | | | | JP | 2007-520592 | A | 26 July 2007 |
| | | | | KR | 10-2006-0111575 | A | 27 October 2006 |
| | | | | RU | 2006124194 | A | 10 January 2008 |
| | | | | RU | 2009101108 | A | 20 July 2010 |
| | | | | RU | 2363970 | C2 | 10 August 2009 |
| | | | | SG | 133596 | A1 | 30 July 2007 |
| | | | | TW | 200604260 | A | 01 February 2006 |
| | | | | US | 2005-0136243 | A1 | 23 June 2005 |
| | | | | US | 2007-0128452 | A1 | 07 June 2007 |
| | | | | US | 7179535 | B2 | 20 February 2007 |
| | | | | WO | 2005-059638 | A1 | 30 June 2005 |
| | | | | WO | 2008-097741 | A1 | 14 August 2008 |
| US | 4822684 | A | 18 April 1989 | EP | 0287709 | A2 | 26 October 1988 |
| | | | | EP | 0287709 | A3 | 14 June 1989 |
| | | | | EP | 0287709 | B1 | 24 June 1992 |
| | | | | JP | 04-019178 | B2 | 30 March 1992 |
| | | | | JP | 63-248749 | A | 17 October 1988 |