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Declarations under Rule 4.17:

- *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*
- *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*

Published:

- *with international search report (Art. 21(3))*
- *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*

FLAME RETARDANT CLEAR COATINGS FOR BUILDING PANELS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is a PCT International Application of U.S. Provisional Application No. 62/513,115, filed on May 31, 2017. The disclosure(s) of the above application(s) is (are) incorporated herein by reference.

BACKGROUND

[0002] Building products for interior room environments balance interests with respect to cosmetic value, material cost, structural integrity, and fire safety. Previously, maximizing one or two of the aforementioned interests required sacrificing the remaining interests. For example, a building panel that uses natural materials (e.g., natural grain from real wood, as compared to replica grain from printed wood texture) may have superior cosmetic value. However, such building panels also previously had associated safety concerns as either the entire building panel would be made from wood, thereby increasing flammability concerns, thereby endangering individuals by further fueling a fire.

[0003] Previous attempts at imparting fire repellency involved applied flame retardant compositions to the major surfaces of the cellulosic materials. However, such previous attempts resulted in degradation of the aesthetic value of the cellulosic substrate due to the flame retardant compositions interfering with the appearance of the resulting building product. Thus, there is a need for building panels that can be formed from natural materials and exhibit superior cosmetic value without degradation the natural aesthetic appearance imparted by such materials.

BRIEF SUMMARY

[0004] The present invention is directed to a flame-retardant building panel comprising a body having a first major surface opposite a second major surface, an inorganic coating atop the first major surface, the inorganic coating being optically transparent and flame retardant and comprising a blend of a borate compound and a phosphate compound; and wherein the inorganic flame retardant coating is substantially transparent such that the first major surface of the body is visible through the inorganic coating.

[0005] Other embodiments of the present invention include a flame-retardant building panel comprising a body having a first major surface opposite a second major surface, an inorganic coating applied to the first major surface, the inorganic coating formed from a composition

comprising a blend of a borate compound and a phosphate compound; and wherein the composition has a maximum pH of 5.

[0006] In other embodiments, the present invention is directed to a flame-retardant coating composition comprising a liquid carrier, an inorganic blend comprising a borate compound and a phosphate compound, and wherein the coating composition has a maximum pH of 5 and comprises up to about 2.5 wt. % of organic components based on the total weight of the coating composition.

[0007] Other embodiments of the present invention include a flame-retardant building panel comprising a body having a first major surface opposite a second major surface, a top coat comprising a first sub-layer and a second sub-layer, the first sub-layer atop the first major surface of the body and the second sub-layer atop the first sub-layer, and wherein the first sub-layer is an organic coating and the second sub-layer is an inorganic coating comprising a blend of a borate compound and a phosphate compound.

[0008] Other embodiments of the present invention include a method of forming a flame-retardant building panel comprising a) applying an inorganic coating composition to a major surface of a body, b) drying the inorganic coating composition at an elevated temperature ranging from about 200 °F to about 300 °F to form a flame-retardant coating atop the body; and wherein the inorganic coating composition comprises a liquid carrier, a borate compound and a phosphate compound, and the flame-retardant coating has a solids content of at least 99 wt. % based on the total weight of the flame-retardant coating.

[0009] Further areas of applicability of the present invention will become apparent from the detailed description provided hereinafter. It should be understood that the detailed description and specific examples, while indicating the preferred embodiment of the invention, are intended for purposes of illustration only and are not intended to limit the scope of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] The present invention will become more fully understood from the detailed description and the accompanying drawings, wherein:

[0011] Figure 1 is top perspective view of the building panel according to the present invention;

[0012] Figure 2 is a cross-sectional view of the building panel according to the present invention, the cross-sectional view being along the II line set forth in Figure 1;

[0013] Figure 3 is cross-sectional view of a building panel according to other embodiments of the present invention, the cross-sectional view being along the II line set forth in Figure 1;

[0014] Figure 4 is cross-sectional view of a building panel according to other embodiments of the present invention, the cross-sectional view being along the II line set forth in Figure 1;

[0015] Figure 5 is a ceiling system comprising the building panel of the present invention;

[0016] Figure 6 is top perspective view of the building panel according to another embodiment of the present invention;

[0017] Figure 7 is a cross-sectional view of the building panel according to the present invention, the cross-sectional view being along the VII line set forth in Figure 6; and

[0018] Figure 8 is a ceiling system comprising the building panel of Figure 6.

DETAILED DESCRIPTION

[0019] The following description of the preferred embodiment(s) is merely exemplary in nature and is in no way intended to limit the invention, its application, or uses.

[0020] As used throughout, ranges are used as shorthand for describing each and every value that is within the range. Any value within the range can be selected as the terminus of the range. In addition, all references cited herein are hereby incorporated by referenced in their entirety. In the event of a conflict in a definition in the present disclosure and that of a cited reference, the present disclosure controls.

[0021] Unless otherwise specified, all percentages and amounts expressed herein and elsewhere in the specification should be understood to refer to percentages by weight. The amounts given are based on the active weight of the material.

[0022] The description of illustrative embodiments according to principles of the present invention is intended to be read in connection with the accompanying drawings, which are to be considered part of the entire written description. In the description of embodiments of the invention disclosed herein, any reference to direction or orientation is merely intended for convenience of description and is not intended in any way to limit the scope of the present invention. Relative terms such as “lower,” “upper,” “horizontal,” “vertical,” “above,” “below,” “up,” “down,” “top,” and “bottom” as well as derivatives thereof (e.g., “horizontally,” “downwardly,” “upwardly,” etc.) should be construed to refer to the orientation as then described or as shown in the drawing under discussion. These relative terms are for convenience of

description only and do not require that the apparatus be constructed or operated in a particular orientation unless explicitly indicated as such.

[0023] Terms such as “attached,” “affixed,” “connected,” “coupled,” “interconnected,” and similar refer to a relationship wherein structures are secured or attached to one another either directly or indirectly through intervening structures, as well as both movable or rigid attachments or relationships, unless expressly described otherwise. Moreover, the features and benefits of the invention are illustrated by reference to the exemplified embodiments. Accordingly, the invention expressly should not be limited to such exemplary embodiments illustrating some possible non-limiting combination of features that may exist alone or in other combinations of features; the scope of the invention being defined by the claims appended hereto.

[0024] Unless otherwise specified, all percentages and amounts expressed herein and elsewhere in the specification should be understood to refer to percentages by weight. The amounts given are based on the active weight of the material. According to the present application, the term “about” means +/- 5% of the reference value. According to the present application, the term “substantially free” less than about 0.1 wt. % based on the total of the referenced value.

[0025] Referring to Figures 1 and 5, the present invention includes a ceiling system 1 as well as a building panel 10 that may be used in the ceiling system 1. The ceiling system 1 may comprise at least one or more of the building panels 10 installed in an interior space, whereby the interior space comprises a plenum space 3 and an active room environment 2. The plenum space 3 is defined by the space occupied between a structural barrier 4 between floors of a building and the lower major surface 12 of the building panel 10. The plenum space 3 provides space for mechanical lines within a building (e.g., HVAC, electrical lines, plumbing, telecommunications, etc.). The active space 2 is defined by the space occupied beneath the upper major surface 11 of the building panel 10 for one floor in the building. The active space 2 provides room for the building occupants during normal intended use of the building (e.g., in an office building, the active space would be occupied by offices containing computers, lamps, etc.).

[0026] Each of the building panels 10 may be supported in the interior space by one or more supports 5. Each of the building panels 10 are installed such that the upper major surface 11 of the building panel 10 faces the active room environment 2 and the lower major surface 12 of the building panel 10 faces the plenum space 3. The building panels 10 of the present invention have superior fire safety performance – particularly when a fire originates in the active room

environment 2 – without sacrificing the desired aesthetic appearance of the building panel 10, as discussed herein.

[0027] Referring to Figure 1, the present invention is a building panel 10 having an upper major surface 11, a lower major surface 12 that is opposite the upper major surface 11, and major side surfaces 13 that extend from the upper major surface 11 to the lower major surface 12 to form a perimeter of the building panel 10. The major side surfaces 13 may comprise first and second longitudinal side surfaces 41, 42 extending substantially parallel to each other. The major side surfaces 13 may further comprise first and second transverse side surfaces 31, 32 extending substantially parallel to each other. The first and second longitudinal side surfaces 41, 42 may extend substantially orthogonal to the first and second transverse side surfaces 31, 32.

[0028] The building panel 10 may have a panel thickness “ t_p ” as measured from the upper major surface 11 to the lower major surface 12. The panel thickness t_p may range from about 25 mils to about 3,000 mils – including all values and sub-ranges there-between. In some embodiments, the panel thickness t_p may range from about 25 mils to about 600 mils – including all values and sub-ranges there-between. In some embodiments, the panel thickness t_p may range from about 700 mils to about 2,000 mils – including all values and sub-ranges there-between.

[0029] The building panel 10 may have a panel length “ L_p ” as measured from the first transverse side surface 31 to the second transverse side surface 32 – i.e., the distance along one of the first or second longitudinal side surfaces 41, 42. The panel length L_p may range from about 6 inches to about 100 inches – including all values and sub-ranges there-between. The building panel 10 may have a panel width “ W_p ” as measured from the first longitudinal side surface 41 to the second longitudinal side surface 42 – i.e., the distance along one of the first or second transverse side surfaces 31, 32. The panel width W_p may range from about 2 inches to about 60 inches – including all values and sub-ranges there-between. In some embodiments, the panel width W_p may range from about 12 inches to about 60 inches – including all values and sub-ranges there-between.

[0030] The building panel 10 of the present invention comprises a body 100 having a coating 500 applied thereto. The body 100 may comprise a first major surface 111 opposite a second major surface 112 and a side surface 113 extending there-between. The body 100 may be formed from a cellulosic material (e.g., wood), metal, organic polymer, inorganic polymer, and combinations thereof. The body 100 may be formed from a single layer of material (also

referred to as an integral structure) or the body 100 may have a laminate structure formed from at least two layers. As discussed in greater detail herein, the body 100 having a laminate structure may comprise one or more layers of a cellulosic layer 400, a substrate layer 200, and/or an adhesive layer 300. Although not pictured, the coating 500 of the present invention may be applied to a non-woven scrim. Non-limiting examples of non-woven scrim include fiberglass non-woven scrims. The non-woven scrim may form at least one of the first or second major surface 11, 12 of the building panel 10.

[0031] The building panel 10 may comprise a decorative pattern 30 that is visible from the upper major surface 11, the lower major surface 12, and/or the major side surface 13. The decorative pattern 30 may comprise a pattern formed from natural materials, such as cellulosic materials (e.g., wood grain, knots, burl, etc.) or synthetic materials, such as a printed ink. The decorative pattern 30 may be a body decorative pattern that exists on one of the first major surface 111, second major surface 112, or side surface 113 of the body 100, whereby the body decorative pattern is visible through the coating 500.

[0032] The coating 500 may be independently applied to each of the first major surface 111, the second major surface 112, and/or the side surface 113 of the body 100. In a preferred embodiment, the coating 500 is applied to the first major surface 111 of the body 100 – as shown in Figure 2. In another preferred embodiment, the coating 1500 may be applied to each of the first major surface 1111, the second major surface 1112, and the side surface 1113 of the body 1100 such that the coating 1500 encapsulates the body 100 – as shown in Figures 6 and 7.

[0033] The coating 500 may be clear or substantially clear. For the purposes of this application, the phrases “substantially clear” or “substantially transparent” refers to materials that have the property of transmitting light in such a way that a normal, human eye (i.e., one belonging to a person with so-called “20/20” vision) or a suitable viewing device can see through the material distinctly. The level of transparency should generally be one which permits a normal, human eye to distinguish objects having length and width on the order of at least 0.5 inches, and should not significantly distort the perceived color of the original object. The coating 500 should be substantially clear (or substantially transparent) such that the underlying body decorative feature can be visible from the upper major surface 11 of the building panel 10 as the decorative pattern 30 on the overall building panel 10, as discussed further herein. The term “substantially clear” or “substantially transparent” may also refer to the coating having at least 70% optical clarity,

whereby 100% optical clarity refers to an underlying surface being completely unhindered visually by the coating 500.

[0034] Referring now to Figures 2, the coating 500 may comprises an upper coating surface 511 opposite a lower coating surface 512. The coating 500 may comprise a coating side surface 513 that extends from the upper coating surface 511 to the lower coating surface 512 and forms a perimeter of the coating 500. The coating side surface 513 may form a portion of the major side surface 13 of the building panel 10. Stated otherwise, the major side surface 13 of the building panel 10 may comprise the coating side surface 513. The coating 500 may have a coating thickness “ t_c ” ranging from about 0.5 mils to about 3.0 mils – including all values and sub-ranges there-between – as measured from the upper coating surface 511 to the lower coating surface 512.

[0035] The coating 500 may comprise an inorganic composition that is substantially clear. According to the present invention, the phrase “inorganic composition” refers to a dry-state composition having less than 3 wt. % of organic compounds present based on the total dry-weight of the referenced inorganic composition, preferably less than 1.5 wt. % of organic compounds present based on the total dry-weight of the referenced inorganic composition. According to the present invention, the phrase “inorganic composition” may also refer to a wet-state composition that has less than 5.0 wt. % of organic compounds present based on the total wet-weight of the referenced inorganic composition, preferably less than 3.0 wt. % of organic compounds present based on the total wet-weight of the referenced inorganic composition.

[0036] The phrase “dry-weight” refers to the weight of a referenced component or composition without the weight of any carrier. Thus, when calculating the amounts of components based on dry-weight, the calculation are to be based solely on the solid components (e.g., binder, filler, hydrophobic component, fibers, etc.) and should exclude any amount of residual carrier (e.g., water, VOC solvent) that may still be present from a wet-state, which will be discussed further herein. Additionally, according to the present invention, the phrase “dry-state” refers to a component or composition that is substantially free of carrier, as compared to the phrase “wet-state,” which refers to that component still containing various amounts of carrier. The term “weight-state” refers to a component or composition that further comprises a carrier. Similarly, the phrase “wet-weight” refers to a total weight of component or composition that includes the weight of the carrier when in the wet-state.

[0037] The inorganic composition may be a glass-forming composition. According to the present invention, a “glass-forming composition” comprises a first glass component and a second glass component that together react to form an inorganic glass-like surface when exposed to elevated temperatures – such as elevated temperatures during a fire. The inorganic composition of the present invention exhibits a pH ranging from about 1.5 to about 5 – including all pHs and sub-ranges there-between. In a preferred embodiment, the pH ranges from about 1.7 to about 4 – including all pHs and sub-ranges there-between. In a preferred embodiment, the pH is less than about 3.

[0038] The first glass component comprises a phosphate compound. The second glass component comprises a borate compound. The first glass component and the second glass component may be present in a weight ratio ranging from about 5:1 to about 80:1 – including all ratios and sub-ranges there-between.

[0039] The first glass component may be present in an amount ranging from about 40.0 wt. % to about 80.0 wt. % - including all wt. % and sub-ranges there-between – based on the total weight of the inorganic composition in the dry-state. In a preferred embodiment, the first glass component may be present in an amount ranging from about 55.0 wt. % to about 75.0 wt. % - including all wt. % and sub-ranges there-between – based on the total weight of the inorganic composition in the dry-state. The second glass component may be present in an amount ranging from about 0.5 wt. % to about 15.0 wt. % - including all wt. % and sub-ranges there-between – based on the total weight of the inorganic composition in the dry-state. In a preferred embodiment, the second glass component may be present in an amount ranging from about 1.0 wt. % to about 10.5 wt. % - including all wt. % and sub-ranges there-between – based on the total weight of the inorganic composition in the dry-state.

[0040] Non-limiting examples of the phosphate compound of the first glass component include phosphoric acid (H_3PO_4), pyrophosphoric acid ($\text{H}_4\text{P}_2\text{O}_7$), polyphosphoric acid, sodium phosphate, potassium phosphate, aluminum tris (dihydrogen phosphate), other phosphate-ion forming compounds, and combinations thereof. Non-limiting examples of the borate compound of the second glass component include boron trioxide (B_2O_3), zinc borate, and other soluble borate forming compound at pH between 1 and 5, and combinations thereof. Several variants of zinc borate exist and include Zinc borate Firebrake ZB ($2\text{ZnO} \cdot 3 \text{B}_2\text{O}_3 \cdot 3.5\text{H}_2\text{O}$), Zinc borate Firebrake 500 ($2\text{ZnO} \cdot 3 \text{B}_2\text{O}_3$), Zinc borate Firebrake 415 ($4\text{ZnO} \cdot \text{B}_2\text{O}_3 \cdot \text{H}_2\text{O}$), ZB-467

($4\text{ZnO} \cdot 6\text{B}_2\text{O}_3 \cdot 7\text{H}_2\text{O}$), and ZB-223 ($2\text{ZnO} \cdot 2\text{B}_2\text{O}_3 \cdot 3\text{H}_2\text{O}$). According to some embodiments the zinc borate may also serve as a fungicide.

[0041] Upon exposure to elevated temperatures, the first and second glass compositions react to form a phosphoborate glass layer (also referred to as the “glass layer”). The glass layer forms a hard protective and heat-insulative barrier that is especially helpful in preventing the body 100 from igniting at elevated temperatures, for example when the body 100 is formed from a cellulosic material as discussed further herein. The heat-insulative barrier formed by the coating 500 is especially useful when the upper major surface 11, lower major surface 12, and/or side surface 13 of the building panel 10 is exposed to heat from a fire that exists in the active room environment 2 of the ceiling system 1 (as shown in Figure 5). The heat-insulative barrier created by the inorganic composition slows and prevents further propagation of heat and flame through the coating 500 and, therefore, through the rest of the body 100 of the building panel 10.

[0042] The inorganic composition may optionally comprise other additives or fillers such as, but not limited to fire retarding compounds (also referred to as “flame retardant”), adhesion promoters, viscosity modifying agents, wetting agents, catalyst, cross-linkers, and ultra-violet stabilizers. According to some embodiments, the inorganic composition may further comprise organic compounds so long as the overall inorganic composition includes less than 5 wt. % of organic compounds in the overall inorganic composition. According to some embodiments, the inorganic composition may be substantially free of blowing-agent. The wetting agent may be present in a non-zero amount that is less than about 0.1 wt. % - based on the total dry-weight of the inorganic composition.

[0043] The filler may be present in the inorganic coating in an amount ranging from about 15 wt. % to about 75 wt. % - including all amounts and sub-range there-between – based on the total dry weight of the inorganic coating. Non-limiting examples of filler may include calcium carbonate (CaCO_3), aluminum carbonate ($\text{Al}_2(\text{CO}_3)_3$), lithium carbonate (LiCO_3), magnesium carbonate (MgCO_3), fumed silica, aluminum oxide (Al_2O_3), and combinations thereof.

[0044] The flame retardants may be present in the coating 500 in an amount ranging from about 0 wt. % to about 50 wt. % – including all values and sub-ranges there-between – based on the total weight of the coating 500. Non-limiting examples of flame retardant may include ammonium hydroxide, magnesium hydroxide, huntite, hydromagnesite, silica, polyphosphate,

chloride salts – such as sodium chloride, antimony oxide, and borates, such as calcium borate, magnesium borate, zinc borate, and combinations thereof.

[0045] A non-limiting example of viscosity modifying agent may include hydroxyethyl cellulose, bentonite, polyacrylic rheology modifier, polyurethane rheology modifier, silica, and combination thereof. Hydroxyethyl cellulose is an organic compound – therefore, the hydroxyethyl cellulose may be present in the inorganic composition in an amount that ranges from a non-zero amount to less than 5 wt. % based on the total dry-weight of the inorganic composition. In a preferred embodiment, the hydroxyethyl cellulose may be present in the inorganic composition in an amount that ranges from a non-zero amount to less than 3 wt. % based on the total dry-weight of the inorganic composition.

[0046] The inorganic composition may further comprise a cross-linker that facilitates curing of the coating at lower temperatures. Non-limiting example of cross-linker include triethanolamine, polyol, amine or polyamine, as well as other suitable crosslinker that do not inhibit film formation of the coating. In a preferred embodiment, the crosslinker comprises triethanolamine, which is an organic compound. Therefore, the triethanolamine may be present in the inorganic composition in an amount that ranges from a non-zero amount to less than 5 wt. % based on the total wet-weight of the inorganic composition (i.e., before cross-linking). In a preferred embodiment, the triethanolamine may be present in the inorganic composition such that the total organic content ranges from a non-zero amount to less than 3 wt. % based on the total wet-weight of the inorganic composition.

[0047] According to the present invention, the coating 500 may be comprised of a single integral layer (Figure 2) or a plurality of sub-layers 540, 550, 560 (Figures 3 and 4). The coating 500 shown in Figure 2 having a single integral layer comprises the inorganic composition of the present invention.

[0048] Referring now to Figure 3, the coating 500 of the present invention may comprise a first sub-layer 540 and a second sub-layer 550, whereby the first sub-layer 540 is directly atop one or more of the first major surface 111, second major surface 112, and/or side surface 113 of the body 100. The second sub-layer 550 may be directly atop the first sub-layer 540. The second sub-layer 550 comprises the inorganic composition of the present invention. In such embodiments, the inorganic composition may be present in an amount ranging from about

95 wt. % to about 100 wt. % – including all values and sub-ranges there-between – based on the total dry-weight of the second sub-layer 550.

[0049] Referring now to Figure 4, the coating 500 of the present invention may comprise may comprise a first sub-layer 540, a second sub-layer 550, and a third sub-layer 560, whereby the first sub-layer 540 is directly atop one or more of the first major surface 111, second major surface 112, and/or side surface 113 of the body 100. The second sub-layer 550 may be directly atop the first sub-layer 540, and the third sub-layer 560 may be directly atop the second sub-layer 550. The second sub-layer 550 may comprise the inorganic composition of the present invention. In such embodiments, the inorganic composition may be present in an amount ranging from about 95 wt. % to about 100 wt. % – including all values and sub-ranges there-between – based on the total dry-weight of the second sub-layer 550.

[0050] According to the present invention, the first sub-layer 540 may also be referred to as a “base coating.” The first sub-layer 540 may be an organic coating. According to the present invention, the term “organic coating” refers to a coating in the dry-state that comprises at least 10 wt. % of organic compounds based on the total weight of the referenced organic coating in the dry-state, preferably at least 15 wt. % of organic compounds based on the total weight of the referenced organic coating in the dry-state.

[0051] The first sub-layer 540 may comprise a polymer binder in an amount ranging from about 70 wt. % to about 95 wt. % – including all values and sub-ranges there-between – based on the total dry-weight of the first sub-layer 540.

[0052] The polymer binder may comprise polymer produced from unsaturated monomers. Specifically, the polymer may be a homopolymer or copolymer produced from ethylenically unsaturated monomers, such as styrene, alpha-methylstyrene, polymethylsiloxane, vinyl toluene, ethylene, propylene, vinyl acetate, vinyl chloride, vinylidene chloride, acrylonitrile, acrylamide, methacrylamide, acrylic acid, methacrylic acid, (meth)acryloxy-propionic acid, itaconic acid, aconitic acid, maleic acid, monomethyl maleate, monomethyl fumarate, monomethyl itaconate, various (C₁-C₂₀) alkyl or (C₃-C₂₀) alkenyl esters of (meth)acrylic acid, various lacquers, latex-based binders and the like. The expression (meth)acrylic, as used herein, is intended to serve as a generic expression embracing both acrylic and methacrylic acid and esters thereof e.g., methyl (meth)acrylate, ethyl (meth)acrylate, butyl (meth)acrylate, isobutyl (meth)acrylate, 2-ethyl hexyl(meth)acrylate, benzyl (meth)acrylate, lauryl (meth)acrylate, oleyl (meth)acrylate, palmityl

(meth)acrylate, stearyl (meth)acrylate and the like. In other embodiments, the coating polymer binder may include polymer comprising polyurethane, polyester, polyester-modified polyurethane, or a combination thereof.

[0053] The polymer binder of the first sub-layer 540 may have a glass transition temperature T_g ranging from about 10 °F to about 115 °F – including all values and sub-ranges there-between.

[0054] The first sub-layer 540 may further comprise one or more nonionic surfactants in the amount of 0.1 wt. % to about 1.0 wt. % - based on the total dry-weight of the first sub-layer 540 – including all amount and sub-ranges there-between. The nonionic surfactant component can be a single surfactant or a mixture of two or more nonionic surfactants, the mixture having appropriate HLB values. Suitable nonionic surfactants include but are not limited to ethoxylated nonylphenols, ethoxylated alcohols, ethoxylated castor oil, polyethylene glycol fatty acid esters, and ethyleneglycol-propyleneglycol copolymers. The contemplated nonionic surfactants include ethoxylated nonylphenols and polyethylene glycol fatty acid esters.

[0055] The second sub-layer 550 may be an inorganic coating that comprises the inorganic glass-forming composition of the present invention. The second sub-layer 550 may be a combination of multiple coatings of the inorganic glass-forming composition. The second sub-layer 550 may be substantially clear. According to the present invention, the phrase “inorganic coating” refers to the coating having less than 5 wt. % of organic compounds present based on the total dry weight of the referenced inorganic coating, preferably less than 3 wt. % of organic compounds present based on the total weight of the referenced inorganic coating in the dry-state. According to some embodiments, the inorganic coating of the second sub-layer 550 may be formed entirely from the inorganic composition of the present invention.

[0056] The third sub-layer 560 may be referred to as “topcoat.” The third sub-layer 560 may be an inorganic coating according to the present invention or an organic coating. The third sub-layer 560 may comprise a sealant composition. The sealant composition may comprise a sealant polymer binder and a flame retardant. Referring now to Figure 4, other embodiments provide that the coating 500 may further comprise a third sub-layer 560 atop the second sub-layer 550, which is atop the first sub-layer 540 that is atop the cellulosic layer 400. The third sub-layer 560 may be formed from a moisture barrier composition that imparts moisture barrier properties to the resulting third sub-layer 560. The moisture barrier composition may be comprised of

hydrophobic polymeric binder, which may or may not be cross-linked, as well as various additives and fillers.

[0057] The sealant polymer binder may be present in an amount ranging from about 10 wt. % to about 100 wt. % – including all values and sub-ranges there-between – based on the total weight of the sealant composition in the dry-state. The flame retardant may be present in the cellulosic-layer sealant composition in an amount ranging from about 0 wt. % to about 50 wt. % – including all values and sub-ranges there-between – based on the total dry-weight of the cellulosic-layer sealant composition.

[0058] The sealant polymer binder may comprise one or more vinyl or acrylic homopolymers or copolymers formed from ethylenically unsaturated monomers such as ethylene or butadiene and vinyl monomers such as styrene, vinyl esters such as vinyl acetate, vinyl propionate, vinyl butyrate, acrylic acid, methacrylic acid, or esters of acrylic acid and/or esters of methacrylic acid. The esters of acrylic or methacrylic acid may have an alkyl ester portion containing 1 to 12 carbon atoms as well as aromatic derivatives of acrylic and methacrylic acid, and can include, for example, acrylic and methacrylic acid, methyl acrylate and methyl methacrylate, ethyl acrylate and ethyl methacrylate, butyl acrylate and butyl methacrylate, propyl acrylate and propyl methacrylate, 2-ethyl hexyl acrylate and 2-ethyl hexyl methacrylate, cyclohexyl acrylate and cyclohexyl methacrylate, decyl acrylate and decyl methacrylate, isodecyl acrylate and isodecyl methacrylate, benzyl acrylate and benzyl methacrylate and various reaction products such as butyl, phenyl, and cresyl glycidyl ethers reacted with acrylic and methacrylic acids. In a preferred embodiment, the sealant binder comprises a self-crosslinking acrylic binder. Non-limiting examples of hydrophobic polymeric binder produced from unsaturated monomers. Specifically, the hydrophobic polymer may be a homopolymer or copolymer produced from ethylenically unsaturated monomers, such as styrene, alpha-methylstyrene, vinyl toluene, ethylene, propylene, vinyl acetate, vinyl chloride, vinylidene chloride, acrylonitrile, acrylamide, methacrylamide, acrylic acid, methacrylic acid, (meth)acryloxy-propionic acid, itaconic acid, aconitic acid, maleic acid, monomethyl maleate, monomethyl fumarate, monomethyl itaconate, various (C₁-C₂₀) alkyl or (C₃-C₂₀) alkenyl esters of (meth)acrylic acid and the like. The expression (meth)acrylic, as used herein, is intended to serve as a generic expression embracing both acrylic and methacrylic acid and esters thereof e.g., methyl (meth)acrylate, ethyl (meth)acrylate, butyl (meth)acrylate, isobutyl (meth)acrylate, 2-ethyl hexyl(meth)acrylate,

benzyl (meth)acrylate, lauryl (meth)acrylate, oleyl (meth)acrylate, palmityl (meth)acrylate, stearyl (meth)acrylate and the like. In other embodiments, the hydrophobic polymeric binder may include polymer comprising polyurethane, polyester, polyester-modified polyurethane, epoxy or a combination thereof.

[0059] The hydrophobic polymer may be present in an amount ranging from about 70 wt. % to about 100 wt. % - including all values and sub-ranges there-between – based on the total weight of the moisture barrier composition.

[0060] The flame retardant of the first sub-layer 540 may include ammonium hydroxide, magnesium hydroxide, huntite, hydromagnesite, silica, polyphosphate, melamine cyanurate, chloride salts – such as sodium chloride, antimony oxide, and borates, such as calcium borate, magnesium borate, zinc borate, and combinations thereof.

[0061] Generally, the coating 500 may be applied directly to one of the first major surface 111, second major surface 112, and/or side surface 113 of the body 100, optionally with the addition of a carrier such as water. The coating 500 – including each sub-layer 540, 550, 560 – may be applied by spray, roll-coating, dip coating, curtain coating, brushing, blade coating, or the like, followed by drying and/or curing (optionally with the addition of heat) for a period of time to form the coating 500 atop the cellulosic layer 400 – as discussed in greater detail herein.

[0062] The first sub-layer 540 may be applied in the wet-state directly to at least one of the first major surface 111, second major surface 112, and/or side surface 113 of the body 100. In the wet-state, the first sub-layer 540 may comprise a carrier in an amount ranging from about 35 wt. % to about 55 wt. % – including all values and sub-ranges there-between – based on the total weight of the wet-state first sub-layer 540. In the wet-state, the first sub-layer 540 may be applied in an amount such that the first sub-layer 540 has a wet thickness ranging from about 0.5 mils to about 2.5 mils – including all values and sub-ranges there-between. The carrier may be selected from water, an organic solvent, or a combination thereof. In a preferred embodiment, the wet-state sealant composition is a waterborne system having a carrier of water and a low VOC (i.e., volatile organic compound) content – i.e. substantially free of VOC solvents. The first sub-layer 540 in the wet-state may then be cured or dried (optionally with the addition of heat) for a first time period, thereby forming the first sub-layer 540 atop the body 100.

[0063] The resulting first sub-layer 540 may comprise a first sub-layer upper surface 541 and a first sub-layer lower surface 542 opposite the first sub-layer upper surface 541. The first sub-

layer 540 may have a first sub-layer thickness “ t_{C1} ” as measured from the first sub-layer upper surface 541 to the first sub-layer lower surface 542. The first sub-layer thickness t_{C1} may range from 0.1 mils to 1.0 mils – including all values and sub-ranges there-between. The first sub-layer 540 may comprise a first sub-layer side surface 543 that extends from the first sub-layer upper surface 541 to the first sub-layer lower surface 542 and forms a perimeter of the first sub-layer 540.

[0064] As previously discussed, the body 100 may be formed from a cellulosic material, which comprises pores. Thus, once the first sub-layer 540 is applied to one of the first major surface 111, second major surface 112, and/or side surface 113 of the body 100, at least a portion of the first sub-layer 540 may penetrate into and seal the pores in a direct extending from one of the first major surface 111, second major surface 112, and/or side surface 113 of the body 100 toward the center of the body 100. The first sub-layer 540 in the wet-state may then be dried, optionally, at an elevated temperature, thereby rendering the first sub-layer 540 in the dry state.

[0065] The second sub-layer 550 may be formed by directly applying the previously discussed inorganic composition in the wet-state to the first sub-layer upper surface 541 of the first sub-layer 540. In the wet-state, the second sub-layer 550 may be applied in an amount such that the second sub-layer 550 has a wet thickness ranging from about 0.1 mils to about 1.0 mils – including all values and sub-ranges there-between.

[0066] The inorganic composition may then be dried (optionally with the addition of heat) for a second time period of time, thereby forming the second sub-layer 550 atop the first sub-layer 540. The resulting second sub-layer 550 may comprise a second sub-layer upper surface 551 and a second sub-layer lower surface 552 opposite the second sub-layer upper surface 551. The second sub-layer 550 in the wet-state may be dried at a temperature ranging from about 190 °F to about 300 °F – including all temperatures and sub-ranges there-between. In a preferred embodiment, the second sub-layer 550 in the wet-state may be dried at a temperature ranging from about 200 °F to about 290 °F – including all temperatures and sub-ranges there-between.

[0067] The second sub-layer 550 may have a second sub-layer thickness “ t_{C2} ” as measured from the second sub-layer upper surface 551 to the second sub-layer lower surface 552. The second sub-layer thickness t_{C2} may range from about 0.02 mils to about 0.7 mils. The second sub-layer 550 may comprise a second sub-layer side surface 553 that extends from the second sub-layer

upper surface 551 to the second sub-layer lower surface 552 and forms a perimeter of the second sub-layer 550.

[0068] The first sub-layer side surface 543 and the second sub-layer side surface 553 may form at least a portion of the coating side surface 513. Stated otherwise, the coating side surface 513 may comprise the first sub-layer side surface 543 and the second sub-layer side surface 553. The overall coating thickness t_C of coating 500 may be the summation of the first sub-layer thickness t_{C1} and the second sub-layer thickness t_{C2} – as follows:

$$t_C = t_{C1} + t_{C2}$$

[0069] According to these embodiments, the first sub-layer lower surface 542 of the first sub-layer 540 may contact the upper cellulosic surface 411 of the cellulosic layer 400. The first sub-layer upper surface 541 may contact the second sub-layer lower surface 552 of the second sub-layer 550. The second sub-layer upper surface 551 may form at least part of the upper coating surface 511 of the coating 500. The first sub-layer lower surface 542 may form at least part of the lower coating surface 512 of the coating 500. The second sub-layer upper surface 551 may form at least part of the upper major surface 11 of the building panel 10.

[0070] The first sub-layer 540 may form a physical barrier that at least partially separates the body 100 from the second sub-layer 550. The physical barrier formed by the first sub-layer 540 may prevent at least some of the second sub-layer 550 (which comprises the glass-forming composition) from penetrating into the body 100 (e.g., a cellulosic body 100 having porous surfaces). According to some embodiments, the phosphoborate glass heat-insulative barrier that is created by glass-forming composition of the second sub-layer 540 may be separated from at least one of the first major surface 111, second major surface 112, and/or side surface 113 of the body 100 by a distance equal to the first sub-layer thickness t_{C1} .

[0071] The third sub-layer 560 may be formed by applying the moisture barrier composition with the addition of one or more organic solvents. Non-limiting examples of organic solvents include toluene, ethanol, acetone, butyl acetate, methyl ethyl ketone, ethyl 3-ethoxypropionate. The barrier composition may be present relative to the organic solvent in a weight ratio ranging from about 5:1 to about 1:20. After application to the second sub-layer upper surface 551, the moisture barrier composition may be dried for a third period of time, optionally at an elevated temperature, sufficient to drive off any organic solvent. The resulting third sub-layer 560 may be

a continuous or discontinuous coating having an third sub-layer upper surface 561 and a third sub-layer lower surface 562 opposite the third sub-layer upper surface 561.

[0072] In the wet-state, the third sub-layer 560 may be applied in an amount such that the third sub-layer 560 has a wet thickness ranging from about 1.0 mils to about 10.0 mils – including all values and sub-ranges there-between. After drying, the third sub-layer 560 in the dry-state may have a third sub-layer thickness “ t_{C3} ” as measured from the third sub-layer upper surface 561 to the third sub-layer lower surface 562. The third sub-layer thickness t_{C3} may range from about 1 mils to about 6 mils. The third sub-layer 560 may comprise a third sub-layer side surface 563 that extends from the third sub-layer upper surface 561 to the third sub-layer lower surface 562 and forms a perimeter of the second sub-layer 560.

[0073] According to such embodiments, the overall coating thickness t_C of coating 500 may be the summation of the first sub-layer thickness t_{C1} , the second sub-layer thickness t_{C2} , and the third sub-layer thickness t_{C3} – as follows:

$$t_C = t_{C1} + t_{C2} + t_{C3}$$

[0074] According to these other embodiments, the first sub-layer lower surface 542 of the first sub-layer 540 may contact the upper cellulosic surface 411 of the cellulosic layer 400. The first sub-layer upper surface 541 may contact the second sub-layer lower surface 552 of the second sub-layer 550. The second sub-layer upper surface 551 may contact the third sub-layer lower surface 562 of the second sub-layer 560. The third sub-layer upper surface 561 may form at least part of the upper coating 511 of the coating 500. The first sub-layer lower surface 542 may form at least part of the lower coating surface 512 of the coating 500. The third sub-layer upper surface 561 may form at least part of the upper major surface 11 of the building panel 10.

[0075] According to other embodiments, the coating 500 may comprise only the second sub-layer 550 and the third sub-layer 560 without the first sub-layer 540 (not pictured). In such embodiments, the second sub-layer 550 may be directly atop one of the first major surface 111, second major surface 112, and/or side surface 113 of the body 100 and the third sub-layer 560 may be directly atop the second sub-layer upper surface 551 of the second sub-layer 550. In such embodiments, the second sub-layer 550 acts as a sealant and is capable of sealing the one of the first major surface 111, second major surface 112, and/or side surface 113 of the body 100, while simultaneously acting as an insulative barrier created from the glass-forming composition of the inorganic composition.

[0076] According to other embodiments, the coating 500 may comprise only the second sub-layer 550. In such embodiments, the second sub-layer 550 acts as a sealant and is capable of sealing one of the first major surface 111, second major surface 112, and/or side surface 113 of the body 100, while simultaneously acting as a insulative barrier created from the glass-forming composition of the inorganic composition, in situations where moisture resistance of the coating is not required.

[0077] Referring now to Figures 2-4, the body 100 may comprise a cellulosic layer 400, whereby the coating 500 is applied directly to the cellulosic layer 400 of the body 100. In other embodiments where the body 100 may be a laminate structure comprising multiple layers that includes a cellulosic layer 400 atop a substrate layer 200 with an adhesive layer 300 positioned there-between. The body 100 may also comprise the substrate layer 200 without the cellulosic layer 400 or adhesive layer 200, whereby the coating 500 is applied to at least one surface of the substrate layer 200 – as discussed further herein.

[0078] Referring to Figure 2, the cellulosic layer 400 may comprise an upper cellulosic surface 411 and a lower cellulosic surface 412 opposite the upper cellulosic surface 411. The cellulosic layer 400 may comprise a cellulosic side surface 413 that extends from the upper cellulosic surface 411 to the lower cellulosic surface 412 and forms a perimeter of the cellulosic layer 400. The cellulosic side surface 413 may form a portion of the side surface 113 of the body 100. Stated otherwise, the side surface 113 of the body 100 may comprise the cellulosic side surface 413. The side surface 113 of the body 100 may form a major side surface 13 of the building panel 10. The first major surface 111 of the body 100 may comprise the upper cellulosic surface 411.

[0079] The cellulosic layer 400 may have a cellulosic layer thickness “ t_{CL} ” as measured by the distance between the upper and lower cellulosic surfaces 411, 412. The cellulosic layer thickness t_{CL} may range from about 10 mils to about 3,000 mils – including all values and sub-ranges there-between. In some embodiments, the cellulosic layer 400 may form a veneer that is bonded to the substrate layer 200 by the adhesive layer 300, whereby the cellulosic thickness t_{CL} may range from about 10 mils to about 100 mils – including all values and sub-ranges there-between. In other embodiments, the cellulosic layer 400 may form the entirety of the body 100, whereby the cellulosic thickness t_{CL} may range from about 300 mils to about 3,000 mils – including all values and sub-ranges there-between.

[0080] The cellulosic layer 400 may be formed from a cellulosic material such as wood, bamboo, and a combination thereof, and may be naturally occurring or engineered. Non-limiting examples of wood include cherry, maple, oak, walnut, pine, poplar, spruce, chestnut, mahogany, rosewood, teak, ash, hickory, beech, birch, cedar, fir, hemlock, basswood, alder wood, obeche wood, and combinations thereof. The cellulosic layer 400 may comprise pores that are not only present within the body of the cellulosic layer 400 but also exposed on at least one of the upper cellulosic surface 411, lower cellulosic surface 412, and/or the cellulosic side surface 413. The porosity of the cellulosic layer 400 will depend on the bamboo or type of wood selected as the material that forms the cellulosic layer 400.

[0081] The benefit of using a cellulosic layer 400 is that the resulting building panel 10 will exhibit authentic decorative features 30 of real wood and/or bamboo (e.g., wood grain, knots, burl, etc.) while minimizing the overall thickness required for the building panel 10 without necessitating artificial print layers. Artificial print layers, such as those on various papers or plastics, have been used as a way to recreate wood grain, knots, burl, etc., while minimizing layer thickness. Such print layers, however, are undesirable because of the limited amount of variation the cellulosic pattern across a large number of panels as compared to the same large number of panels that use cellulosic layers formed from real wood and/or bamboo. Stated otherwise, artificial print layers are not preferred because of the repetition in the decorative pattern over large installation areas.

[0082] Although not limited to this embodiment, the coating 500 may be directly atop the upper cellulosic surface 411, the lower cellulosic surface 412, and/or the cellulosic side surface 413 of the cellulosic layer 400. The coating 500 may be applied to the cellulosic layer 400 such that the lower coating surface 512 is in direct contact with the upper cellulosic layer surface 412. In such embodiments, the lower coating surface 512 may directly contact the upper cellulosic surface 411, such that the upper coating surface 511 forms at least a portion of the upper major surface 11 of the building panel 10.

[0083] Referring now to Figure 2, according to some embodiments of the present invention the building panel 10 may include cellulosic layer 400 being adhesively bonded to the substrate layer 200 by an adhesive layer 300. The combination of layers 200, 300, 400, 500 of the present invention creates a laminate structure having high lamination integrity in a ceiling system under

both standard conditions (i.e. daily operation of an interior building environment) but also during exposure to the extreme heat and temperature that may result from a fire.

[0084] The substrate layer 200 may comprises an upper substrate surface 211 and a lower substrate surface 212 that is opposite the upper substrate surface 211. The substrate layer 200 may comprise a substrate side surface 213 that extends from the upper substrate surface 211 to the lower substrate surface 212 and forms a perimeter of the substrate layer 200. The substrate side surface 213 may form a portion of the side surface 113 of the body 100. Stated otherwise, the side surface 113 of the body 100 may comprise the substrate side surface 213.

[0085] The substrate layer 200 may be formed from a metallic material, ceramic material, or composite material. Non-limiting examples of metallic material include aluminum, steel, and iron. In a preferred embodiment, the substrate layer 200 is formed from aluminum. The substrate layer 200 may have a substrate thickness “ t_s ” ranging from about 20 mils to about 100 mils – including all values and sub-ranges there-between. The substrate thickness t_s may range from about 25 mils to about 80 mils. In a preferred embodiment, the substrate thickness t_s ranges from about 30 mils to about 65 mils – including all values and sub-ranges there-between.

[0086] The adhesive layer 300 may comprises an upper adhesive surface 311 and a lower adhesive surface 312 opposite the upper adhesive surface 311. The adhesive layer 300 may comprise an adhesive side surface 313 that extends from the upper adhesive surface 311 to the lower adhesive surface 312 and forms a perimeter of the adhesive layer 300. The adhesive side surface 313 may form a portion of the side surface 113 of the body 100. Stated otherwise, the side surface 113 of the body 100 may comprise the adhesive side surface 213. The adhesive layer 300 may have an adhesive thickness “ t_A ” ranging from about 2 mils to about 20 mils – including all values and sub-ranges there-between – as measured from the upper adhesive surface 311 to the lower adhesive surface 312. In a preferred embodiment, the adhesive thickness t_A ranges from about 5 mils to about 15 mils – including all values and sub-ranges there-between.

[0087] According to embodiments where the building panel 10 has the laminate structure, the overall panel thickness t_P of the building panel 10 may be the summation of the substrate thickness t_s , the adhesive thickness t_A , the cellulosic layer thickness t_{CL} , and the coating thickness t_C as follows:

$$t_P = t_s + t_A + t_{CL} + t_C$$

[0088] The upper substrate surface 211 of the substrate layer 200 may directly contact the lower adhesive surface 312 of the adhesive layer 300 and the upper adhesive surface 311 of the adhesive layer 300 may directly contact the lower cellulosic surface 412 of the cellulosic layer 400 such that the adhesive layer 300 adhesively bonds together the cellulosic layer 400 and the substrate layer 200. The lower coating surface 512 may directly contact the upper cellulosic surface 411, such that the upper coating surface 511 forms at least a portion of the upper major surface 11 of the building panel 10. In such embodiments, the lower substrate surface 212 may form at least a portion of the lower major surface 12 of the building panel 10.

[0089] The adhesive layer 300 may be formed from an adhesive composition that is a hot-melt composition, water-based polyvinyl acetate adhesive, and combinations thereof. According to the purposes of the present invention, the term “hot-melt adhesive composition” means a composition having a melt viscosity that ranges from about 10,000 centipoise to about 40,000 centipoise at a temperature of about 275 °F – including all values and sub-ranges there-between. The hot-melt adhesive composition may be solid at room temperature and be substantially free of solvent. The adhesive composition may comprise adhesive polymer in an amount ranging from about 50 wt. % to about 100 wt. % based on the total weight of the adhesive composition – including all values and sub-ranges there-between.

[0090] The adhesive polymer according to the present invention may be a thermoplastic polymer. Non-limiting examples of the thermoplastic polymer may include moisture cured polyester modified polyurethane polymers. Such polyester modified polyurethanes may be formed by reacting organic diisocyanate with difunctional polyester polyol and low molecular weight diols (as chain-extending agents) at a non-limiting NCO:OH ratio of about 0.7:1 to about 1.3:1 – including all sub-ranges and ratios there-between.

[0091] Non-limiting examples of polyester polyol include di-functional polyester diols containing alcoholic hydroxyl groups. Suitable polyester diols are polyester having average molecular weights of from 800 to 5000 and preferably from 2000 to 4000 produced from (i) dicarboxylic acids containing at least 6 carbon atoms, such as adipic acid, pimelic acid, suberic acid, azelaic acid and/or sebacic acid (preferably adipic acid, as the sole acid component) and (ii) alkane diols that may contain at least 4 carbon atoms, such as, for example, 1,4-dihydroxybutane, 1,5-dihydroxypentane and/or 1,6-dihydroxyhexane. Polycondensates of ω -

hydroxyalkane-mono-carboxylic acids and the polymers of their lactones are also suitable, although less preferred.

[0092] Low molecular weight diols suitable as chain-extending agents in accordance with the present invention include, in particular, aliphatic diols having average molecular weight of from 62 to 400 or mixtures thereof. Non-limiting examples of such diols include ethylene glycol, 1,3-dihydroxy-propane, 1,4-dihydroxy-butane, 1,5-dihydroxypentane, 1,6-dihydroxyhexane, and the like.

[0093] Non-limiting examples of suitable aromatic polyisocyanates include all isomers of toluylene-diisocyanate (TDI), naphthalene-1,5-diisocyanate, diphenylmethane-4,4'-diisocyanate (MDI), diphenylmethane-2,4'-diisocyanate and mixtures of 4,4'-diphenylmethane-diisocyanate with the 2,4' isomer or mixtures thereof with oligomers of higher functionality (so-called crude MDI), xylylene-diisocyanate (XDI), 4,4'-diphenyl-dimethylmethane-diisocyanate, di- and tetra-alkyl-diphenylmethane-diisocyanate, 4,4'-dibenzyl-diisocyanate, 1,3-phenylene-diisocyanate and 1,4-phenylene-diisocyanate. Examples of suitable cycloaliphatic polyisocyanates are the hydrogenation products of the above-mentioned aromatic diisocyanates, such as 4,4'-dicyclohexylmethane-diisocyanate (H₁₂MDI), 1-isocyanatomethyl-3-isocyanato-1,5,5-trimethylcyclohexane (isophorone-diisocyanate, IPDI), cyclohexane-1,4-diisocyanate, hydrogenated xylylene-diisocyanate (H₆XDI), 1-methyl-2,4-diisocyanato-cyclohexane, m- or p-tetramethylxylene-diisocyanate (m-TMXDI, p-TMXDI) and dimer-fatty acid diisocyanate. Examples of aliphatic polyisocyanates are tetramethoxybutane-1,4-diisocyanate, butane-1,4-diisocyanate, hexane-1,6-diisocyanate (HDI), 1,6-diisocyanato-2,2,4-trimethylhexane, 1,6-diisocyanato-2,4,4-trimethylhexane and 1,2-dodecane-diisocyanate (C₁₂DI).

[0094] The adhesive composition of the present invention may further comprise additives selected from the group consisting of 2,2'-dimorpholinethyl ether catalyst, di(2,6-dimethylmorpholinoethyl)ether catalyst, adhesion promoters, diluents, plasticizers, fillers, antioxidants pigments, UV absorbers and combinations thereof. In other embodiments, the adhesive composition may further comprise a flame retardant. Non-limiting examples of flame retardant may include ammonium hydroxide, magnesium hydroxide, huntite, hydromagnesite, silica, polyphosphate, melamine cyanurate, chloride salts – such as sodium chloride, antimony oxide, and borates, such as calcium borate, magnesium borate, zinc borate, and combinations thereof. The flame retardant may be present in the adhesive composition in an amount ranging

from about 0 wt. % to about 50 wt. % based on the total weight of the adhesive composition – including all values and sub-ranged there-between.

[0095] The building panel 10 of Figure 2 may be formed heating the adhesive composition to an application temperature ranging from about 245 °F to about 330 °F, and applying the adhesive composition to at least one of the upper substrate surface 211 or the lower cellulosic surface 412. The adhesive composition may be applied by roll coating, spray coating, dip coating, or the like. Within the open time of the adhesive (typically 30 to 60 seconds), the upper substrate surface 211 is mated to the lower cellulosic surface 412 with the adhesive composition being present there-between, thereby bonding the upper substrate surface 211 to the lower cellulosic surface 412 via the adhesive composition. Pressure may then be applied to at least one of the upper cellulosic surface 411 of the cellulosic layer 400 or the lower substrate surface 212 of the substrate layer 200 to ensure proper adhesive bonding.

[0096] Each sub-layer 540, 550, 560 may be individually applied by spray, roll-coating, dip coating, curtain coating, brushing, blade coating, or the like. Specifically, the first sub-layer 540 may be applied to the upper cellulosic surface 411 of the cellulosic layer 400. The first sub-layer 540 may then be optionally heated to a temperature ranging from about 68 °F to about 150 °F to partially or fully cure the first sub-layer 540. The second sub-layer 550 may then be applied to the first sub-layer upper surface 541. The second sub-layer 550 may then be optionally heated to a temperature ranging from about 190 °F to about 320 °F to partially or fully cure the second sub-layer 550. The third sub-layer 560 may then be applied to the second sub-layer upper surface 551. The third sub-layer 560 may then be optionally heated to a temperature ranging from about 190 °F to about 320 °F to partially or fully cure the third sub-layer 560 – thereby resulting in the laminate structure of the present invention. The laminate structure may then be heated in an oven to fully cure the adhesive layer 300 and the coating 500 for a fourth period of time.

[0097] According to the present invention, the coating 500 applied to the cellulosic layer 400 provides an aesthetically pleasing building panel 10 such that the underlying body decorative features on the body 100 are visible from the upper major surface 11 of the building panel 10 as the decorative features 30, because the decorative coating 500 is substantially clear. Furthermore, the inorganic composition of the coating 500 helps provide an insulative heat-

barrier to the cellulosic layer 400, thereby helping prevent the cellulosic layer 400 from igniting during a fire and propagating through the building panel 10.

[0098] The multi-layered coating 500 comprising the first sub-layer 540 may also at least partially seal the pores and the upper cellulosic surface 411 such that at least a portion of the phosphoborate glass layer is formed at a distance separated from the upper cellulosic surface 411 of the cellulosic layer 400 – further protecting the cellulosic layer 400 from igniting in a fire. Additionally, the moisture sealant composition of the third sub-layer 560 ensures that the glass-forming composition of the underlying sub-layers 540, 550 remains active for prolonged periods of time in case an interior space catches fire years after initial installation.

[0099] Referring to Figure 5, the building panel 10 of the present invention may be a ceiling panel (as shown installed in the ceiling system of Figure 5), a wall panel, or the like. The lower major surface 12 of the ceiling panel 10 of the present invention may face the plenum space 3 of an interior space of a ceiling system 1. The upper major surface 11 of the ceiling panel 10 of the present invention may face the active space 2 of an interior space of a ceiling system 1.

[0100] In non-exemplified embodiments, the present invention may include a building panel having an upper major surface opposite a lower major surface, the building panel comprising a cellulosic layer (also referred to as “cellulosic body” in this embodiment) and a coating. The cellulosic body is self-supporting and comprises an upper cellulosic surface and a lower cellulosic surface opposite the upper cellulosic body. Non-limiting examples of a cellulosic body may include MDF board, wooden planks, or the like. The cellulosic body may have a cellulosic body thickness as measured from the lower cellulosic surface to the upper cellulosic surface that ranges up to about 3 inches – including all values and sub-ranges there-between.

[0101] With the coating 500 being formed at drying temperatures as low as 150 °F, the cellulosic body may at least partially retain pre-existing moisture already contained within the cellulosic body. The surprising benefit of retaining the pre-existing moisture is that during exposure to high-heat, the retained moisture is converted to steam and driven out of the cellulosic body. As the steam escapes from the body 100, the glass layer formed from the coating 500 is pushed outward from the body 100, thereby increasing the distance between the body 100 and the surrounding flame or high-heat – thereby decreasing the likelihood that the body 100 ignites. Stated otherwise, it has been surprisingly discovered that the coatings 500 of the present

invention further enhance fire repellency in the building panels 10 by allowing for drying temperatures below 212 °F under atmospheric conditions (at 1 atm).

[0102] The building panel 10 of such embodiments may have the coating 500 applied to at least one of the upper cellulosic surface 411 or the lower cellulosic surface 412 of the cellulosic body 400. The coating 500 comprises an upper coating surface 511 opposite a lower coating surface 512, whereby the lower coating surface 512 of the coating 500 may directly contact the upper cellulosic surface 411 of the cellulosic body 400. The coating 500 comprises at least the second sub-layer 550 and optionally the first sub-layer 540 and/or the third sub-layer 560, as previously discussed. The upper major surface 11 of the building panel 10 may comprise the upper coating surface 511 of the coating 500. According to some embodiments, the lower major surface 12 of the building panel 10 may be uncoated, whereby the lower major surface 12 of the building panel 10 does not comprise the coating 500, but rather the lower cellulosic surface 412 or the lower substrate surface 212.

[0103] Referring now to Figures 6-8, a building panel 1010 and ceiling system 1001 are illustrated in accordance with another embodiment of the present invention. The building panel 1010 is similar to the building panel 10 except as described herein below. The description of the building panel 10 above generally applies to the building panel 1010 described below except with regard to the differences specifically noted below. A similar numbering scheme will be used for the building panel 1010 as with the building panel 10 except that the 1000-series of numbers will be used. Additionally, the ceiling system 1001 is similar to the ceiling system 1 except as described herein below. The description of the ceiling system 1 above generally applies to the ceiling system 1001 described below except with regard to the differences specifically noted below. A similar numbering scheme will be used for the ceiling system 1001 as with the ceiling system 1 except that the 1000-series of numbers will be used.

[0104] The coating 1500 of the present invention may be applied to one of the first major surface 1111, second major surface 1112, and/or side surface 1113 of the body 1100. In a preferred embodiment, the coating 1500 is applied to each of the first major surface 1111, the second major surface 1112, and the side surface 1113 of the body 1100 such that the coating 1500 encapsulates the body 1100. Stated otherwise, the coating 1500 may form a continuous barrier that substantially surrounds the entire body 1100.

[0105] Although not pictured, the coating 1500 of this embodiment comprises the second sub-layer 550, and may further comprise each of the first sub-layer 540 and/or third sub-layer 560, as previously discussed with respect to Figures 2-4.

[0106] In these embodiments, the body 1100 may be formed entirely from the cellulosic body 400 or the substrate layer 200. The body 1100 may alternatively be formed from the laminate structure. According to the embodiments where the body 1100 is formed entirely from the cellulosic body 400, the overall panel thickness t_p may be the summation of cellulosic body thickness t_{CL} , and the coating thickness t_C as follows:

$$t_p = t_{CL} + [n \times t_C]$$

[0107] whereby the “n” refers to the number of major surfaces of the body 1100 coated with the coating 1500. In this embodiment, the first and second major surfaces 1111, 1112 of the body 1100 are coated and $n = 2$. In such embodiments, the panel thickness t_p may range from about 500 mils to about 2,000 mils – including all values and sub-ranges there-between.

[0108] According to the embodiments where the body 1100 is formed entirely from the substrate layer 200, the overall panel thickness t_p may be the summation of substrate layer thickness t_S , and the coating thickness t_C as follows:

$$t_p = t_S + [n \times t_C]$$

[0109] whereby the “n” refers to the number of major surfaces of the body 1100 coated with the coating 1500. In this embodiment, the first and second major surfaces 1111, 1112 of the body 1100 are coated and $n = 2$. In such embodiments, the panel thickness t_p may range from about 100 mils to about 600 mils – including all values and sub-ranges there-between.

[0110] Referring now to Figure 8, the building panel 1010 of these embodiments may be installed into a ceiling system 1001 comprising a support 1005 that includes a first support member 1005a and a second support member 1005b. The first and second support members 1005a, 1005b may be arranged in an intersecting pattern to form a support grid. A plurality of the building panels 1010 may be arranged in an array and attached to the support grid such that the upper major surface of one building panel 1010 faces the lower major surface of a second building panel 1010 that is adjacent to the first building panel 1010. The plurality of the building panels 1010 may also be arranged and attached to the support grid such that the plurality of building panels 1010 comprises a first side 1041 opposite a second side 1042, whereby the first side 1041 faces the plenum 1003 and the second side 1042 faces the room environment 1002 –

the first and second sides 1041, 1042 comprises the side surface 1013 of the building panels 1010.

[0111] The following examples are prepared in accordance with the present invention. The present invention is not limited to the examples described herein.

EXAMPLES

[0112] Experiment 1

[0113] A first set of experiments was performed by coating a number of cellulosic bodies with the inorganic composition of the present invention in the wet-state. Specifically, a major surface of each cellulosic body had the dimensions of 3.75" x 29.875", which were coated by the coating of the present invention. Each coated body was then dried at a temperature ranging between 200 °F to 275 °F. Each specimen was then positioned above a Bunsen burner angled at 30°, whereby the coated major surface faces the flame from the Bunsen burner. Each surface was exposure for a set predetermined amount of time, after which the amount of flame spread on each specimen was measured and assigned a value – the lower the Flame Spread Rating (“FSR”) value, the better the coating was at imparting flame-retardancy to the underlying substrate.

[0114] Additionally, using a correlation between measured FSR values and known flame spread and smoke index values generated by an ASTM E-84 test, the FSR values were able to be correlated to Class A, B, or C flame retardancy. Specifically, FSR values < 25 translate to high probability of a Class A fire rating. FSR values between 25 and 40 translate to a moderate probability of Class A fire rating. FSR values > 40 translate to a low probability of Class A fire rating.

Table 1

Component (wt. %)	Ex. 1	Ex. 2	Ex. 3	Ex. 4	Ex. 5	Ex. 6	Ex. 7	Ex. 8	Ex. 9	Ex. 10	Ex. 11	Ex. 12	Ex. 13
	14A	14B	14C	23B	32A	50D	50E	103B	103C	107F	115A	115C	131B
Water	77.3	71.3	67.2	68.6	53.9	68.4	68.1	65.8	70.4	63.7	64.7	66.0	45.1
H ₃ PO ₄	13.6	17.2	20.4	20.9	32.3	20.7	20.7	23.0	17.0	21.3	21.5	22.0	35.7
HNO ₃	-	-	-	-	-	0.2	0.2	-	-	-	-	-	-
B ₂ O ₃	1.8	1.6	1.5	-	1.6	0.3	0.3	-	-	-	-	-	2.0
2ZnO·3 B ₂ O ₃ ·3.5H ₂ O	-	-	-	-	-	-	-	3.3	3.2	2.8	2.9	4.4	-
CaCO ₃	-	-	-	-	-	-	0.3	-	-	0.6	0.6	0.6	0.9
Al ₂ (CO ₃) ₃	-	-	-	-	-	-	-	-	-	2.8	-	-	4.8
Li ₂ CO ₃	-	-	-	3.1	6.1	-	-	-	-	-	-	-	-
MgCO ₃	7.3	9.9	10.9	7.4	6.1	10.4	10.4	6.6	6.5	5.7	8.6	4.7	7.6
Fumed SiO ₂	-	-	-	-	-	-	-	1.3	-	1.4	-	0.6	1.0
Hydroxyethylcellulose	-	-	-	-	-	-	-	-	2.9	-	-	-	-
Triethanolamine	-	-	-	-	-	-	-	-	-	1.7	1.7	1.7	2.9
Total	100	100	100	100	100	100	100	100	100	100	100	100	100
Total Amount of Organic	0.0	0.0	0.0	0.0	0.0	0.2	0.2	0.0	2.9	1.7	1.7	1.7	2.9
pH	3.5	3.83	3.47	3.90	2.26	2.87	2.65	2.51	2.51	2.46	2.50	2.50	2.10

[0115] With the formulations set forth in Table 1, the following heat and flame performance are provided below in Table 2.

Table 2

	Ex. 7	Ex. 11	Ex. 12	Ex. 13	Organic Sealer
Wet Density (g/ml)	1.23	1.24	-	1.29	1.02
Wet Thickness (mil)	0.2	0.35	0.35	0.5	1.6
Dry Thickness (mil)	0.05	0.12	0.12	0.28	0.50
Total Amount of Organic (Dry)	0.2	1.7	1.7	2.9	100%
FSR	37	87	87	29	Very Poor
Optical Clarity	-	78%	-	100%	108%
Gloss (60°)	-	59.3	-	51.5	25.0

[0116] As shown in Table 2, the coating comprising the inorganic composition of the present invention comprising minor amounts of organic composition (i.e., ≤ 1.0 wt. % based on total dry-weight) resulted in superior FSR of 37, as compared to Examples 11 and 12 having greater amounts of organic composition (> 4 wt. %), which resulted in an FSR of 87 – even at small application amounts (dry thicknesses as low as 0.05 mils). Additionally, each inorganic coating compositions of the present invention allows for superior flame resistance while still maintaining high visual clarity (i.e., $> 70\%$).

[0117] Furthermore, as demonstrated by Example 13, it has been surprisingly discovered that greater amounts of organic composition (i.e., about 5 wt. % based on the dry-weight) may be added to the inorganic composition while still maintaining desirable FSR performance when the inorganic composition further comprises aluminum carbonate $\text{Al}_2(\text{CO}_3)_3$.

[0118] Furthermore, while the gloss value of the present invention may increase relative to the organic coating, such values still remain within an acceptable range of increase of such values compared to the organic coating. More importantly, the coatings of the present invention provide coatings having superior changes in optical clarity. According to the present invention, the percent change in optical clarity is a measure of color values before and after application of the coating, whereby when the color values improve (i.e., increase) there is a corresponding increase in optical clarity as the appearance of the underlying substrate has become more apparent. Thus, achieving $>100\%$ optical clarity is possible as it represents an improvement in discernible color of the underlying substrate through the respective coating.

[0119] Experiment 2

[0120] A second set of experiments was performed by coating a number of cellulosic bodies with a multi-layered coating comprising the inorganic composition of the present invention in the

wet-state. Each building panel was then subjected to color and gloss measurements as well as pencil hardness tests. The results are provided below in Table 3.

Table 3

	Phosphate Coating System	Control	Untreated Wood
Base Coat	Organic	Organic	None
Intermediate Coat	Ex. 13	Flame-Retardant Organic	None
Topcoat	Ex. 11	Flame-Retardant Organic	None
Gloss (60°)	19.4	21	3.2
Color			
L	65.4	80.4	71.95
a	7.16	2.7	3.85
b	23.92	23	20.22
Pencil Hardness	8H	2H	None

[0121] As demonstrated by Table 3, the multi-layered coating comprising the inorganic composition of the present invention (referred to as “Phosphate Coating System”) demonstrates desirable color and gloss performance when compared to the flame-retardant organic coating. Specifically, the Phosphate Coating System exhibits slight darkening (as measured by the decreased “L” value) as well as an increase in red color (as measured by the increase in “a” value”) however, such values remain within an acceptable range of optical performance – especially when considering the drastic improvement in flame retardancy of the Phosphate Coating System compared to the Flame-Retardant Organic coating – as demonstrated in Experiment 3.

[0122] Experiment 3

[0123] A third experiment was performed by subjecting each of the panels of Experiment 2 to the FSR test. The results are provided below in Table 4.

Table 4

	Phosphate Coating System	Control	Untreated Wood
Base Coat	Organic Coating	Organic Coating	None
Intermediate Coat	Ex. 13	Flame-Retardant Organic	None
Topcoat	Ex. 11	Flame-Retardant Organic	None

FSR	29	90-97	99

[0124] As demonstrated by Table 4, the multi-layered coating of the present invention resulted in superior FSR performance as compared to the organic based multi-layered coating of the Control.

CLAIMS

WHAT IS CLAIMED IS:

1. A flame-retardant building panel comprising:
 - a body having a first major surface opposite a second major surface;
 - an inorganic coating atop the first major surface, the inorganic coating being optically transparent and flame retardant and comprising a blend of a borate compound and a phosphate compound; and
 - wherein the inorganic flame retardant coating is substantially transparent such that the first major surface of the body is visible through the inorganic coating.
2. The flame-retardant building panel according to claim 1, wherein the first major surface of the body is formed from a material selected from the group consisting of wood, metal, or non-woven scrim.
3. The flame-retardant building panel according to any one of claims 1 to 2, wherein the inorganic coating is glass-forming.
4. The flame-retardant building panel according to any one of claims 1 to 3, wherein the inorganic coating has a solids content of at least 99% based on the total weight of the inorganic coating.
5. The flame-retardant building panel according to any one of claims 1 to 4, wherein the inorganic coating comprises up to about 5 wt. % of organic components based on the total weight of the inorganic coating.
6. The flame-retardant building panel according to any one of claims 1 to 5, wherein the inorganic coating has a thickness ranging from about 0.3 mils to about 3.0 mils.
7. The flame-retardant building panel according to any one of claims 1 to 6, wherein the borate compound is selected from the group consisting of boron trioxide, zinc borate, and combinations thereof.

8. The flame-retardant building panel according to any one of claims 1 to 7, wherein the phosphate compound is selected from the group consisting of phosphoric acid, pyrophosphoric acid, polyphosphoric acid, aluminum tris (dihydrogen phosphate), sodium phosphate, potassium phosphate, and combinations thereof.

9. The flame-retardant building panel according to any one of claims 1 to 8, wherein the borate compound and the phosphate compound are present in a weight ratio ranging from about 1:1 to about 1:1000.

10. The flame-retardant building panel according to any one of claims 1 to 9, wherein the body is encapsulated by the inorganic coating.

11. The flame-retardant building panel according to claim 10, wherein the inorganic coating further comprises filler selected from the group consisting of calcium carbonate, aluminum carbonate, lithium carbonate, magnesium carbonate, silica, fumed silica, and combinations thereof.

12. The flame-retardant building panel according to any one of claims 1 to 11, wherein the inorganic coating further comprises an organic component in an amount ranging from a non-zero value up to about 5 wt. %

13. The flame-retardant building panel according to claim 12, wherein the organic component is selected from the groups consisting of wetting agent, hydroxyethylcellulose, triethanolamine, and combinations thereof.

14. The flame-retardant building panel according to any one of claims 1 to 13, wherein the composition is formed from a composition having a maximum pH of about 5.

15. A flame-retardant building panel comprising:

a body having a first major surface opposite a second major surface;

an inorganic coating applied to the first major surface, the inorganic coating formed from a composition comprising a blend of a borate compound and a phosphate compound; and

wherein the composition has a maximum pH of 5.

16. The flame-retardant building panel according to claim 15, wherein the first major surface of the body is wood.

17. The flame-retardant building panel according to any one of claims 15 to 16, wherein the inorganic coating is glass-forming.

18. The flame-retardant building panel according to any one of claims 15 to 17, wherein the inorganic coating has a solids content of at least 99% based on the total weight of the inorganic coating.

19. The flame-retardant building panel according to any one of claims 15 to 18, wherein the inorganic coating comprises up to about 5 wt. % of organic components based on the total weight of the inorganic coating.

20. The flame-retardant building panel according to any one of claims 16 to 19, wherein the inorganic coating has a thickness ranging from about 0.3 mils to about 3.0 mils.

21. The flame-retardant building panel according to any one of claims 16 to 20, wherein the borate compound is selected from the group consisting of boron trioxide, zinc borate, and combinations thereof.

22. The flame-retardant building panel according to any one of claims 16 to 21, wherein the phosphate compound is selected from the group consisting of phosphoric acid, pyrophosphoric acid, polyphosphoric acid, aluminum tris (dihydrogen phosphate), sodium phosphate, potassium phosphate, and combinations thereof.

23. The flame-retardant building panel according to any one of claims 16 to 22, wherein the borate compound and the phosphate compound are present in a weight ratio ranging from about 1:1 to about 1:1000.

24. The flame-retardant building panel according to any one of claims 16 to 23, wherein the body is encapsulated by the inorganic coating.

25. The flame-retardant building panel according to claim 24, wherein the inorganic coating further comprises filler selected from the group consisting of calcium carbonate, aluminum carbonate, lithium carbonate, magnesium carbonate, silica, fumed silica, and combinations thereof.

26. The flame-retardant building panel according to any one of claims 16 to 25, wherein the inorganic coating further comprises an organic component in an amount ranging from a non-zero value up to about 5 wt. %

27. The flame-retardant building panel according to claim 26, wherein the organic component is selected from the groups consisting of wetting agent, hydroxyethylcellulose, triethanolamine, and combinations thereof.

28. The flame-retardant building panel according to any one of claims 16 to 27, wherein the composition has a maximum pH of about 4.

29. The flame-retardant building panel according to any one of claims 16 to 28, wherein the inorganic flame retardant coating is substantially transparent such that the first major surface of the body is visible through the inorganic coating.

30. A flame-retardant coating composition comprising:

a liquid carrier;

an inorganic blend comprising a borate compound and a phosphate compound; and

wherein the coating composition has a maximum pH of 5 and comprises up to about 2.5 wt. % of organic components based on the total weight of the coating composition.

31. The flame-retardant coating composition according to claim 30, wherein the liquid carrier is present in an amount ranging from about 40 wt. % to about 80 wt. % based on the total weight of the coating composition.

32. The flame-retardant coating composition according to any one of claims 30 to 31, wherein the liquid carrier is water.

33. The flame-retardant coating composition according to any one of claims 30 to 32, wherein the liquid carrier is substantially free of volatile organic solvent.

34. The flame-retardant coating composition according to any one of claims 30 to 33, wherein the borate compound is selected from the group consisting of boron trioxide, zinc borate, and combinations thereof.

35. The flame-retardant coating composition according to any one of claims 30 to 34, wherein the phosphate compound is selected from the group consisting of phosphoric acid, pyrophosphoric acid, polyphosphoric acid, aluminum tris (dihydrogen phosphate), sodium phosphate, potassium phosphate, and combinations thereof.

36. The flame-retardant coating composition according to any one of claims 30 to 35, wherein the inorganic coating further comprises filler.

37. The flame-retardant coating composition according to claim 36, wherein the filler is selected from the group consisting of calcium carbonate, aluminum carbonate, lithium carbonate, magnesium carbonate, silica, fumed silica, and combinations thereof.

38. The flame-retardant coating composition according to any one of claims 30 to 37, wherein the coating composition comprises an organic component in an amount ranging from a non-zero value up to about 5 wt. %

39. The flame-retardant coating composition according to claim 38, wherein the organic component is selected from the groups consisting of wetting agent, hydroxyethylcellulose, triethanolamine, and combinations thereof.

40. The flame-retardant coating composition according to any one of claims 30 to 39, wherein the composition has a maximum pH of about 4.

41. A flame-retardant building panel comprising:

a body having a first major surface opposite a second major surface;

a top coat comprising a first sub-layer and a second sub-layer, the first sub-layer atop the first major surface of the body and the second sub-layer atop the first sub-layer; and

wherein the first sub-layer is an organic coating and the second sub-layer is an inorganic coating comprising a blend of a borate compound and a phosphate compound.

42. The flame-retardant building panel according to claim 41, wherein the inorganic coating is flame retardant.

43. The flame-retardant building panel according to any one of claims 41 to 42, wherein top coat is optically transparent such that the first major surface of the body is visible through the top coat.

44. The flame-retardant building panel according to any one of claims 41 to 43, wherein the inorganic coating is formed from a composition comprising the blend of the borate compound and the phosphate compound, wherein the composition has a maximum pH of about 5.

45. The flame-retardant building panel according to any one of claims 41 to 44, wherein the inorganic coating comprises up to about 5 wt. % of organic components based on the total weight of the inorganic coating.

46. The flame-retardant building panel according to any one of claims 41 to 45, wherein the inorganic coating further comprises an organic component in an amount ranging from a non-zero value up to about 5 wt. %

47. The flame-retardant building panel according to claim 46, wherein the organic component is selected from the groups consisting of wetting agent, hydroxyethylcellulose, triethanolamine, and combinations thereof.

48. The flame-retardant building panel according to any one of claims 41 to 47, wherein the organic coating of the first sub-layer comprises an organic component selected from the group consisting of a wax emulsion, latex polymer, and combinations thereof.

49. The flame-retardant building panel according to any one of claims 41 to 48, wherein the top coat further comprises a third sub-layer that is atop the second sub-layer.

50. The flame-retardant building panel according to claim 50, wherein the third sub-layer is a sealant and impervious to moisture.

51. The flame-retardant building panel according to any one of claims 41 to 50, wherein the first major surface of the body is wood.

52. A method of forming a flame-retardant building panel comprising

a) applying an inorganic coating composition to a major surface of a body;

b) drying the inorganic coating composition at an elevated temperature ranging from about 200 °F to about 300 °F to form a flame-retardant coating atop the body; and

wherein the inorganic coating composition comprises a liquid carrier, a borate compound and a phosphate compound, and the flame-retardant coating has a solids content of at least 99 wt. % based on the total weight of the flame-retardant coating.

53. The method according to claim 52, wherein the inorganic coating composition has a maximum pH of about 5.

54. The method according to any one of claims 52 to 53, wherein the liquid carrier is present in an amount ranging from about 40 wt. % to about 80 wt. % based on the total weight of the inorganic coating composition.

55. The method according to any one of claims 52 to 54, wherein the liquid carrier comprises water.

56. The method according to any one of claims 52 to 55, wherein the liquid carrier is substantially free of volatile organic solvent.

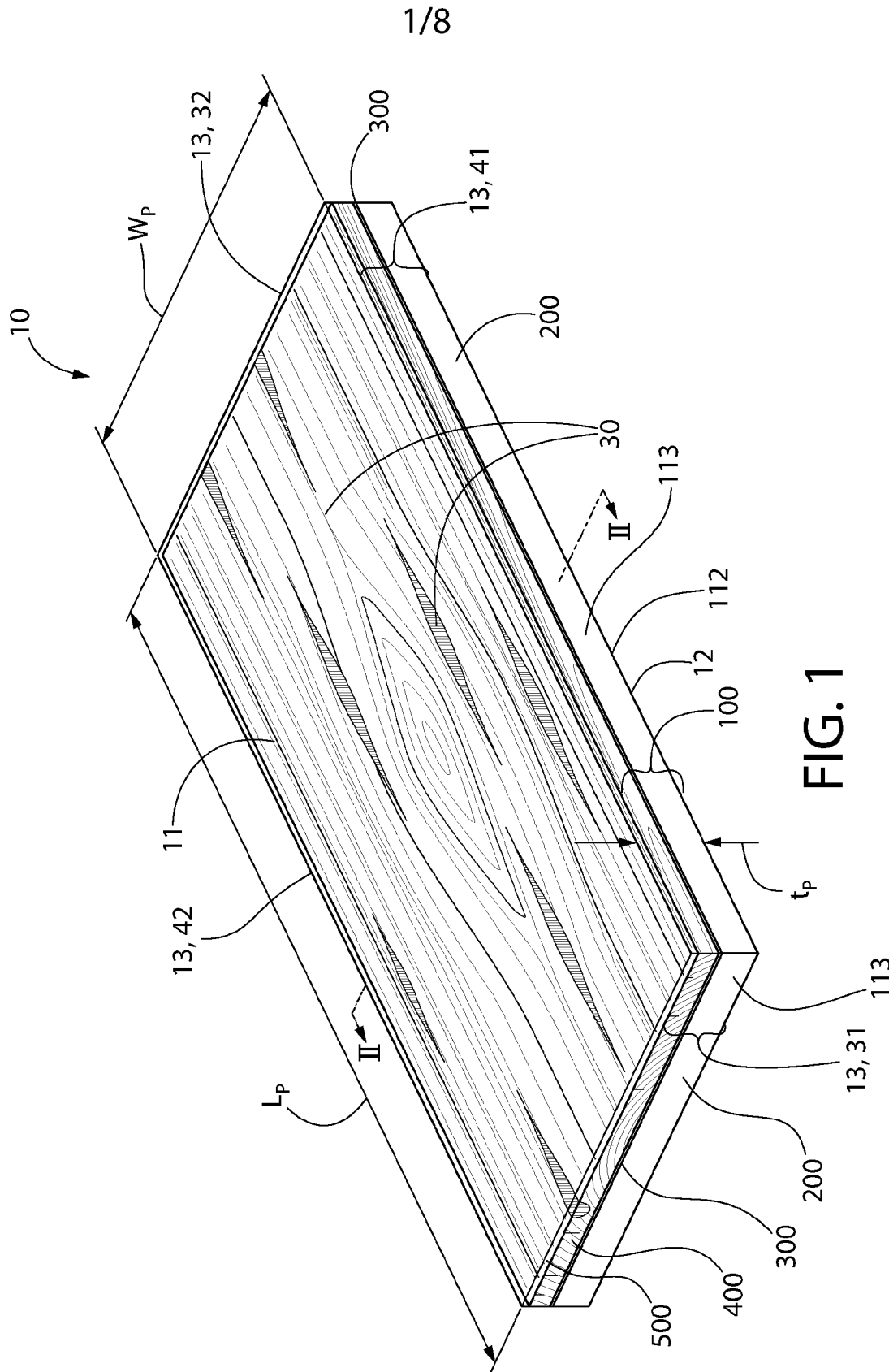
57. The method according to any one of claims 52 to 56, wherein the inorganic coating has a thickness ranging from about 0.7 mils to about 4.0 mils.

58. The method according to any one of claims 52 to 57, wherein the inorganic coating has a thickness ranging from about 0.3 mils to about 3.0 mils.

59. The method according to any one of claims 52 to 58, wherein the v comprises a wood body coated with an organic coating, wherein the organic coating forms the major surface of the body.

60. The method according to any one of claims 52 to 59, wherein the coating composition comprises up to about 2.5 wt. % of organic components based on the total weight of the inorganic coating composition.

61. The method according to any one of claims 52 to 60, wherein the elevated temperature ranges from about 200 °F to about 250 °F.



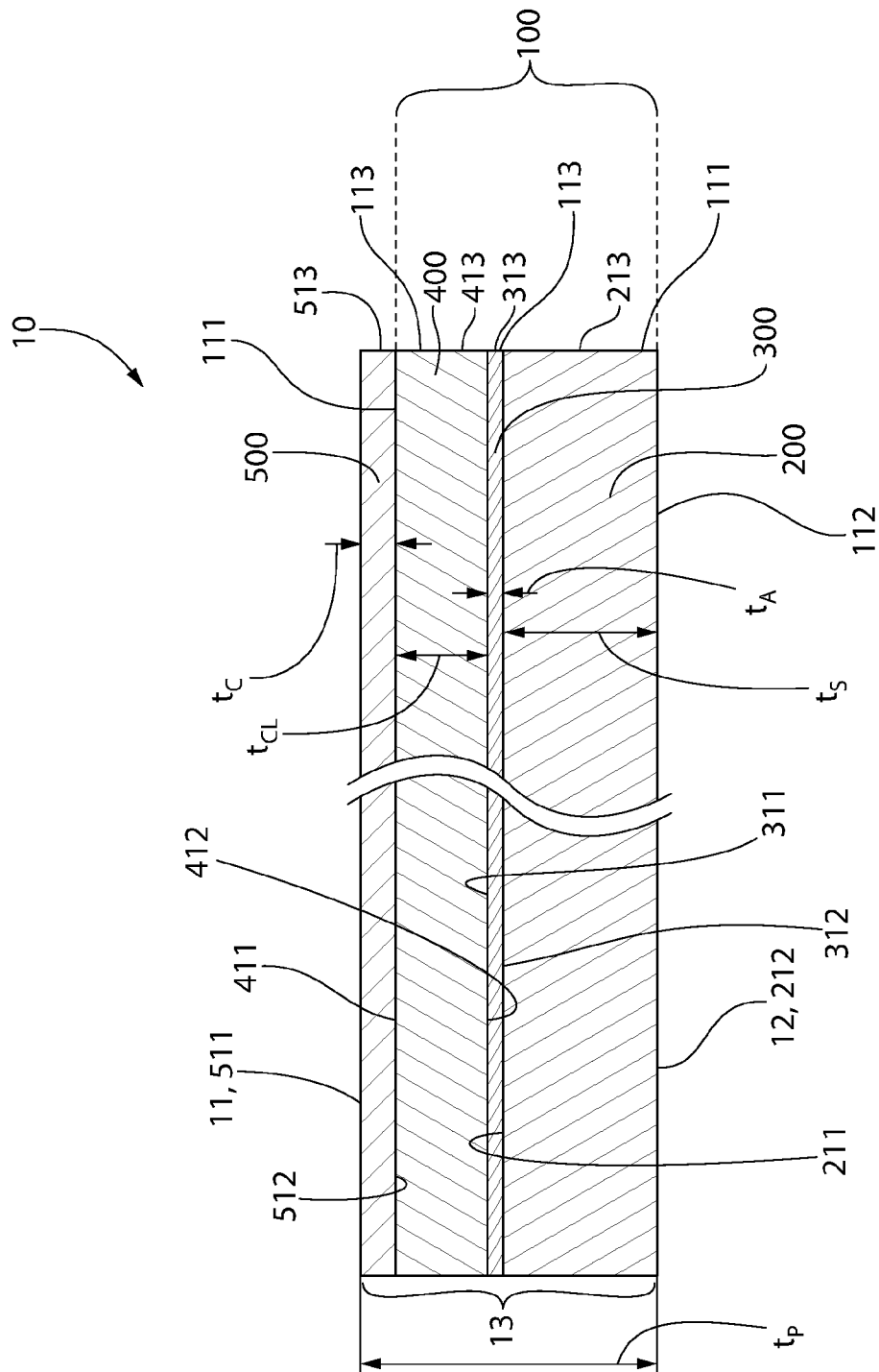
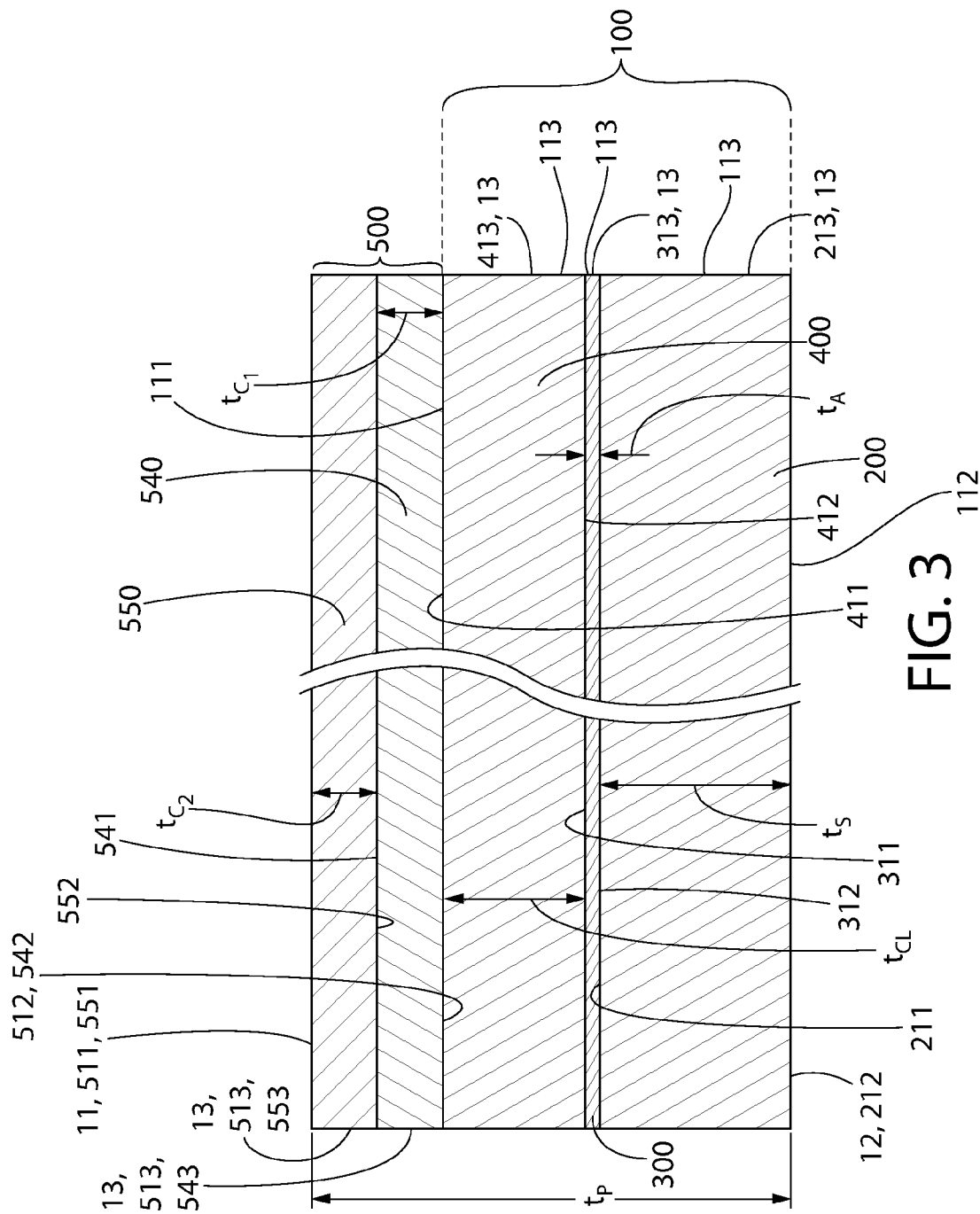


FIG. 2



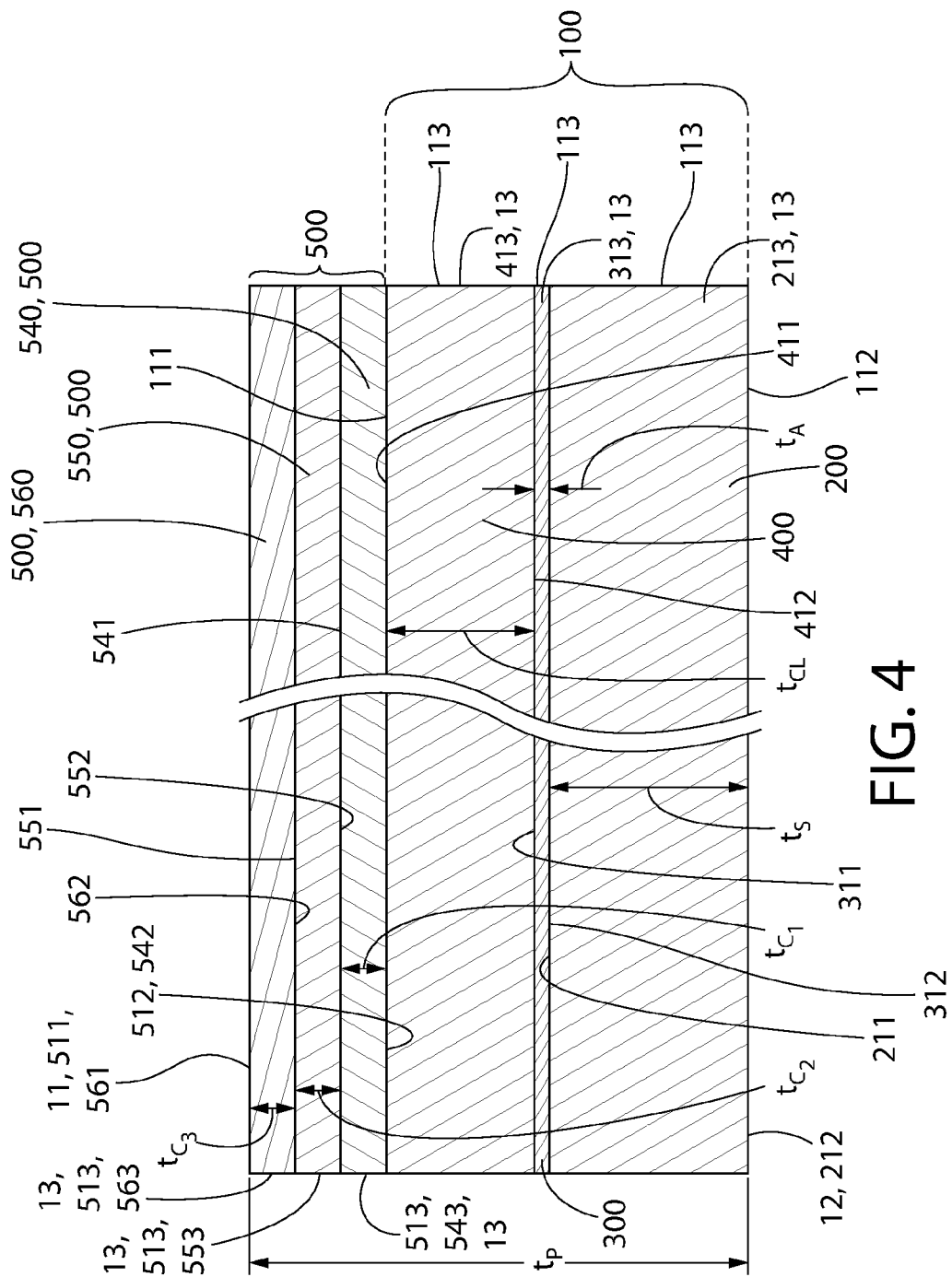


FIG. 4

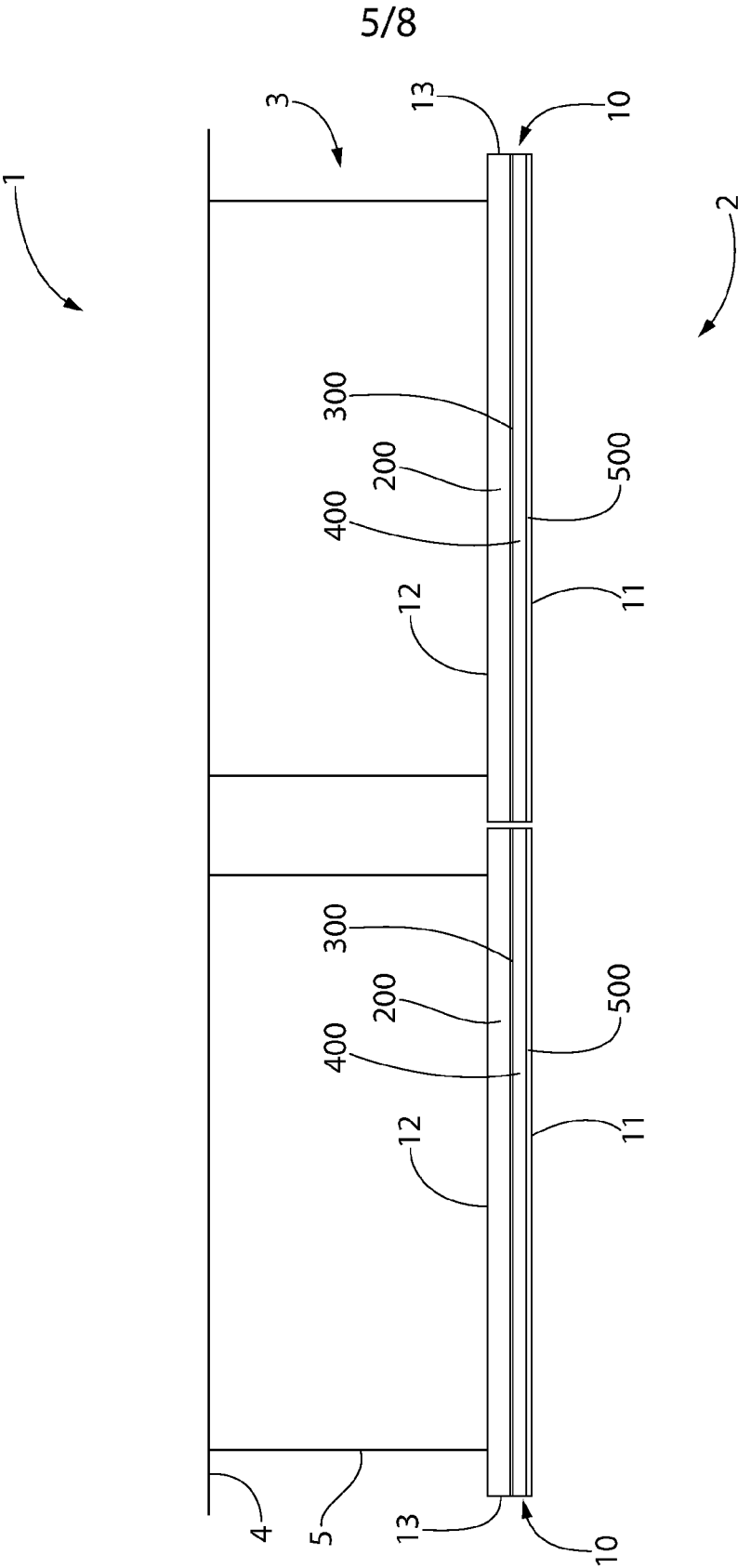


FIG. 5

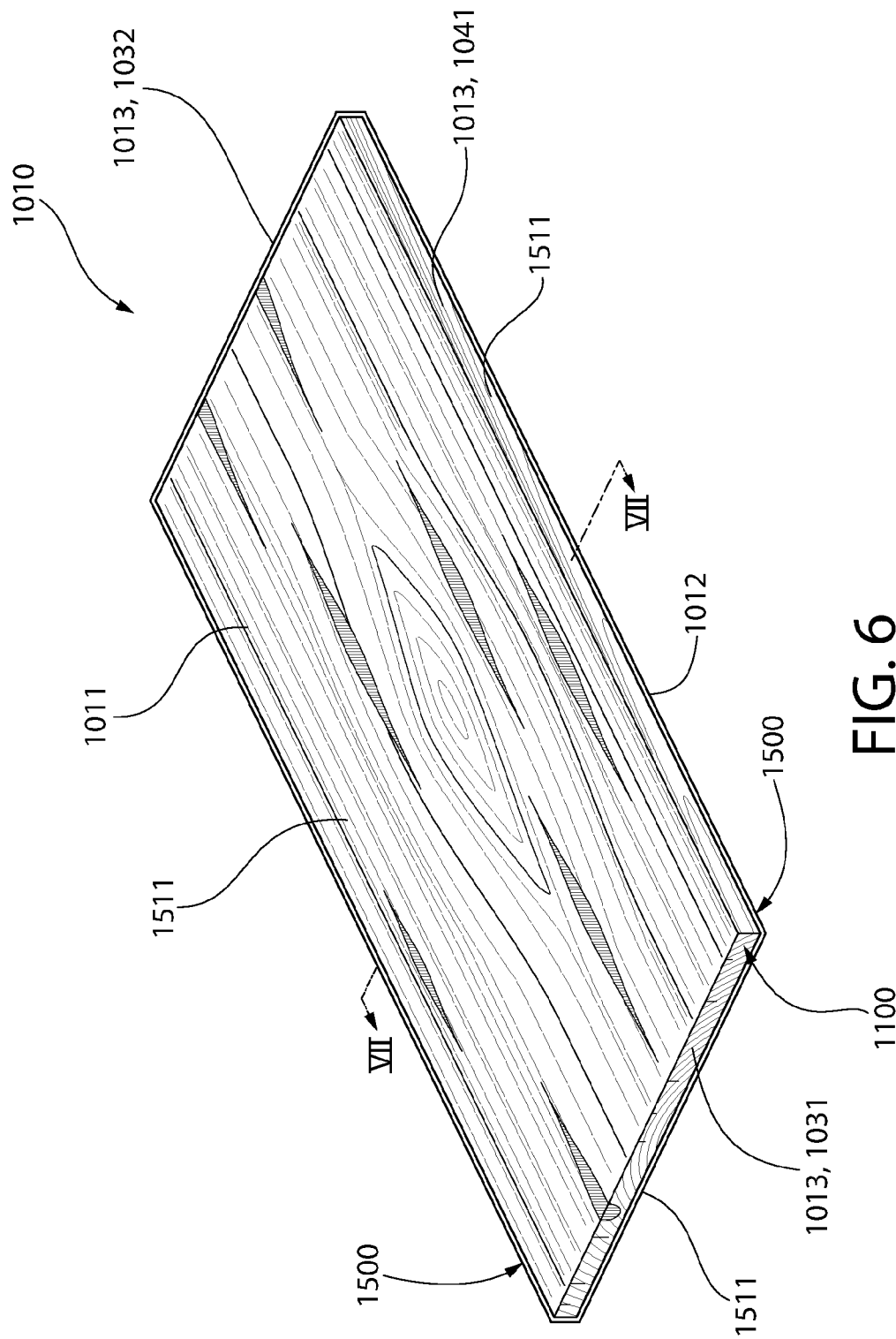


FIG. 6

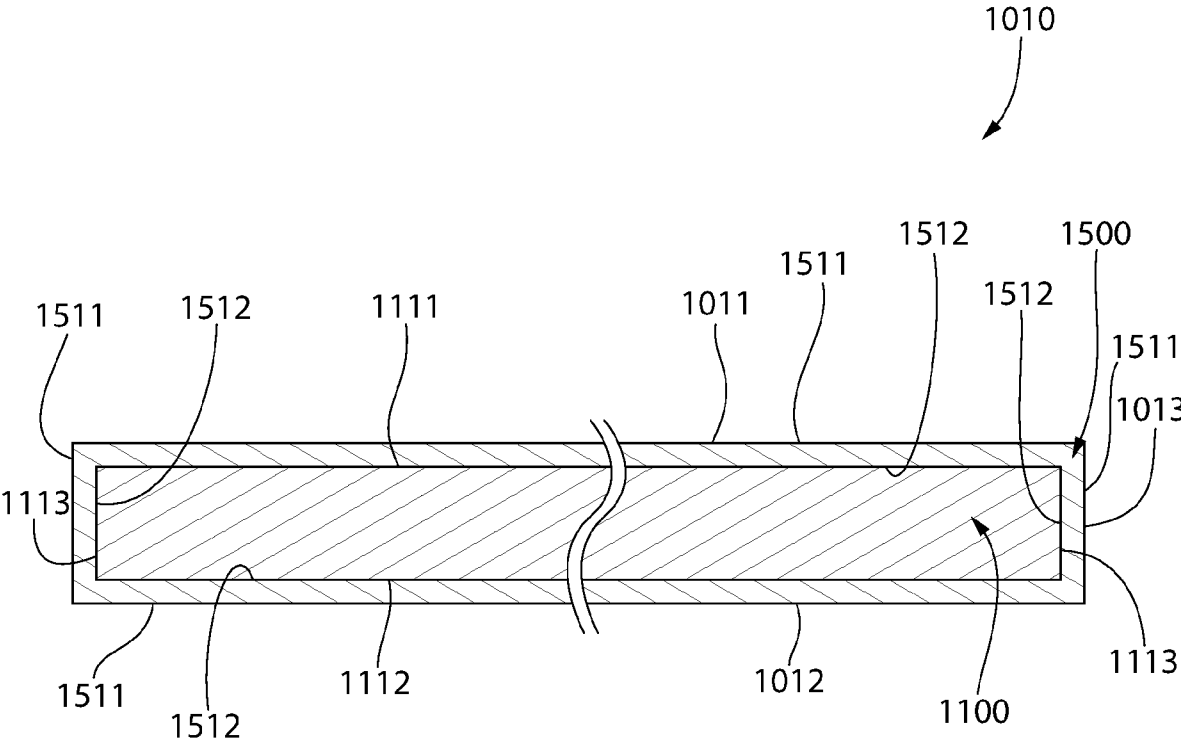


FIG. 7

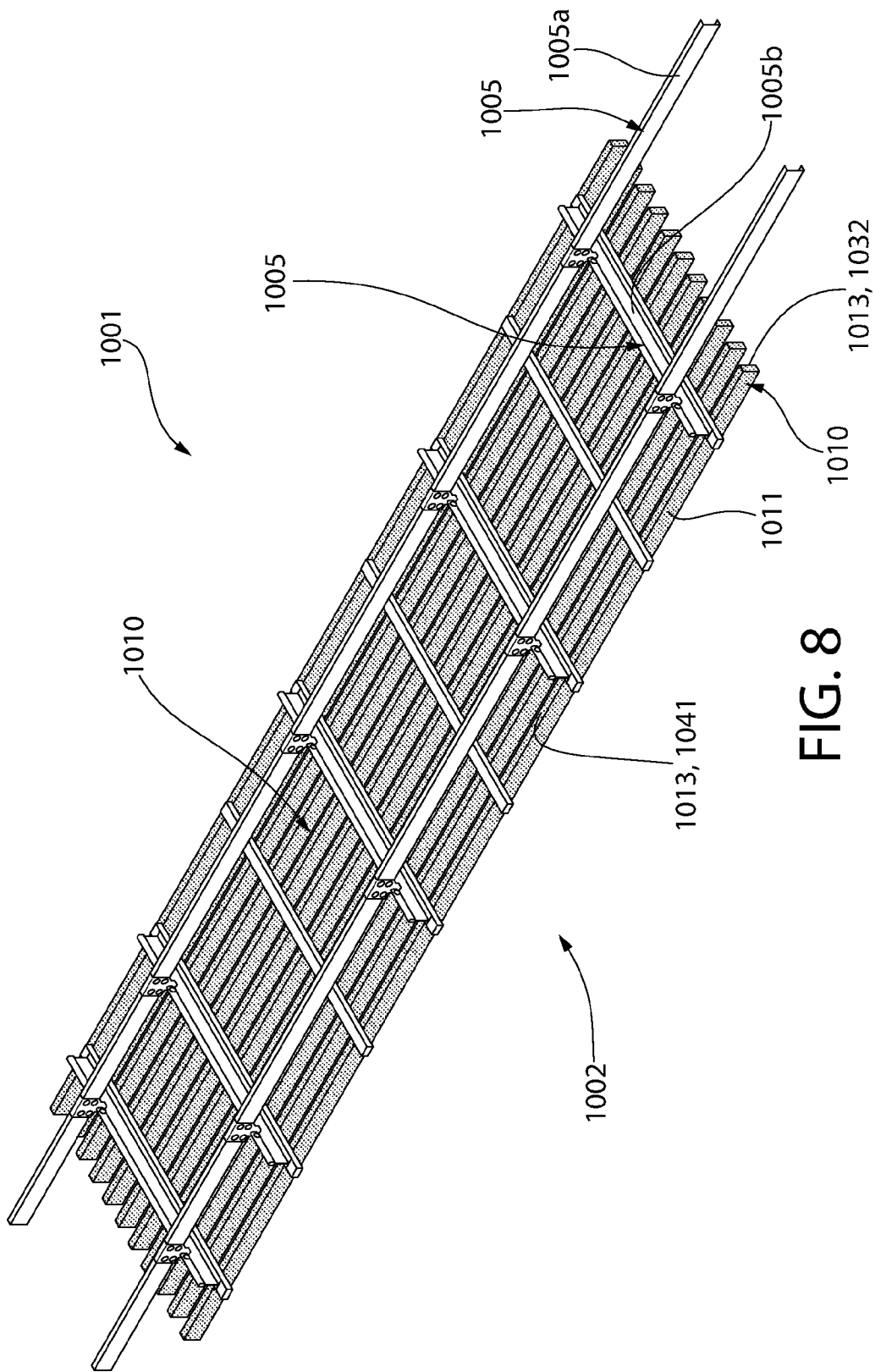


FIG. 8

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2018/035338

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.: 11, 13, 25, 27, 37, 39, 47, 50
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
Claims 11, 13, 25, 27, 37, 39, 47 and 50 are not clear because they refer to claims 10, 12, 24, 26, 36, 38, 46 and 49 respectively, which do not comply with PCT Rule 6.4(a).

3. ☒ Claims Nos.: 4-10, 12, 14, 18-24, 26, 28-29, 33-36, 38, 40, 44-46, 48-49, 51, 55-61
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of any additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2018/035338**A. CLASSIFICATION OF SUBJECT MATTER****E04B 1/94(2006.01)i, C09D 1/00(2006.01)i, C09D 5/18(2006.01)i, C09K 21/04(2006.01)i, C09D 7/61(2018.01)i, C09D 7/63(2018.01)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)

E04B 1/94; E04C 2/38; E06B 1/04; A62C 3/02; B32B 37/12; A62C 2/10; C09K 21/04; E04C 2/26; C09D 1/00; C09D 5/18; C09D 7/61; C09D 7/63

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: build panel, flame, inorganic coating, retardant, wood, liquid carrier, borate, phosphate

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	KR 10-1723600 B1 (KIM, JOUNG GOO) 07 April 2017 See paragraphs [0020], [0040]-[0041]; claims 4, 7; and figure 1.	1-3, 15-17, 30-32 , 41-43, 52-54
Y	KR 10-2005-0012942 A (CERA CHEM CO., LTD. et al.) 02 February 2005 See page 1; and claims 1, 3.	1-3, 15-17, 30-32 , 41-43, 52-54
A	US 2010-0146887 A1 (WIKER et al.) 17 June 2010 See paragraphs [0010]-[0013]; claim 1; and figure 2.	1-3, 15-17, 30-32 , 41-43, 52-54
A	US 2014-0076587 A1 (OSMOSE HOLDINGS, INC.) 20 March 2014 See claims 1, 7-8.	1-3, 15-17, 30-32 , 41-43, 52-54
A	US 2002-0162298 A1 (CHURCHILL et al.) 07 November 2002 See claims 1-12; and figure 1.	1-3, 15-17, 30-32 , 41-43, 52-54



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

"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

21 September 2018 (21.09.2018)

Date of mailing of the international search report

21 September 2018 (21.09.2018)

Name and mailing address of the ISA/KR

International Application Division

Korean Intellectual Property Office

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2018/035338

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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