



(51) International Patent Classification:

Not classified

(21) International Application Number:

PCT/US2024/031476

(22) International Filing Date:

29 May 2024 (29.05.2024)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

63/472,993 14 June 2023 (14.06.2023) US
18/677,330 29 May 2024 (29.05.2024) US

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(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CV, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IQ, IR, IS, IT, JM, JO, JP, KE, KG,

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

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

Declarations under Rule 4.17:

— as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))

Published:

— without international search report and to be republished upon receipt of that report (Rule 48.2(g))

(54) Title: VAPOR PERMEABLE, WATER RESISTIVE, AND FIRE RESISTIVE ARTICLES

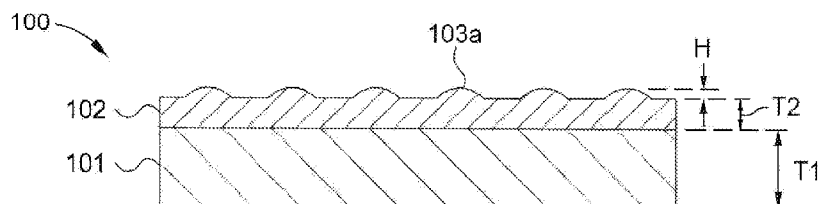


FIG. 1A

(57) Abstract: Embodiments of the present disclosure generally relate to vapor permeable, water resistive, and fire resistive articles for residential and commercial structures and installations. Methods of making such articles are also described herein. In an embodiment, a vapor permeable laminate is provided. The vapor permeable laminate includes a substrate having a first surface and a second surface opposite the first surface, the second surface for facing an interior of a structure. The vapor permeable laminate further includes an intumescent coating disposed over at least a portion of the first surface of the substrate, the intumescent coating having raised features disposed thereon, recessed features formed therein, or combinations thereof, the features for providing a water drainage path. Embodiments described herein also include wrap for a structure or an installation.



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VAPOR PERMEABLE, WATER RESISTIVE, AND FIRE RESISTIVE ARTICLES RELATED APPLICATION DATA

[0001] This application claims benefit to U.S. Provisional Application No. 63/472993, filed June 14, 2023, of which the entire contents of the application are incorporated by reference herein.

FIELD OF THE INVENTION

[0002] Embodiments of the present disclosure generally relate to vapor permeable, water resistive, and fire resistive articles for residential and commercial structures and installations. Embodiments described herein also generally relate to methods of making such articles.

BACKGROUND

[0003] Wood and engineered composite materials are used extensively for wall, floor, and roof applications for residential and commercial construction. Many building structures and dwellings made of such materials are located in areas that experience wildfire events, long durations of heat and sunlight, and other adverse environmental conditions such as rain and snow. Fire resistant products, such as fire shields, have been developed to protect structures in the event of fire. Structural building materials can also absorb and emit heat, increasing the temperature of the inside of the building and leading to energy inefficiencies. To increase energy efficiency, radiant barriers are installed in structures to mitigate the transfer of heat radiation (radiant heat) from one side of the barrier to the other side of the barrier.

[0004] Another important concern for residential and commercial construction is water and moisture control. Water and moisture can build up inside stud and wall cavities due to rain, snow, and condensation, leading to mold, rot, and structural damage. Current technologies to mitigate the effects of water and moisture include water resistant barriers, such as house wraps, that act to prevent rain from moving into the interior of a structure while allowing moisture and water vapor to pass from the structure interior to the exterior. However, moisture permeability, water resistance, and fire resistance in a single article is not available in commercial products.

[0005] There is a need for new and improved vapor permeable, water resistive, and fire resistive articles.

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SUMMARY

[0006] Embodiments of the present disclosure generally relate to vapor permeable, water resistive, and fire resistive articles for residential and commercial structures and installations. Embodiments described herein also generally relate to methods of making such articles. Unlike conventional technologies, embodiments of articles described herein can provide moisture permeability, water resistance, and fire resistance in a single article. Articles described herein can also serve as an air barrier and can reflect radiant heat.

[0007] In an embodiment, a vapor permeable laminate is provided. The vapor permeable laminate includes a substrate having a first surface and a second surface opposite the first surface, the second surface for facing an interior of a structure. The vapor permeable laminate further includes an intumescent coating disposed over at least a portion of the first surface of the substrate, the intumescent coating having raised features disposed thereon, recessed features formed therein, or combinations thereof, the features for providing a water drainage path.

[0008] In another embodiment, a wrap for a structure or an installation is provided. The wrap includes a substrate having a first substrate surface and a second substrate surface opposite the first substrate surface, the second substrate surface for facing an interior of the structure or the installation. The wrap further includes an intumescent coating having a first coating surface and a second coating surface opposite the first coating surface, the second coating surface adjacent to the first substrate surface, the intumescent coating comprising a composition, the composition comprising or being derived from: an intumescent compound; a binder comprising a thermoplastic compound and a thermoset compound; a catalyst; and a blowing agent. The wrap has a water vapor permeance (ASTM E96-16) of at least about $500 \text{ ng} \cdot \text{s}^{-1} \cdot \text{m}^{-2} \cdot \text{Pa}^{-1}$.

[0009] In another embodiment, a method for making a vapor permeable laminate is provided. The method includes forming a layer comprising an intumescent composition on a surface of a substrate, the intumescent composition configured to expand in the presence of heat. The method further includes forming features on or in the layer, the features for providing a water drainage path. The method further includes drying or curing the intumescent composition with the substrate to form the vapor permeable laminate.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] So that the manner in which the recited features of the present disclosure can be understood in detail, a more particular description of the embodiments, briefly summarized above, may be had by reference to embodiments, some of which are illustrated in the appended drawings. It is to be noted, however, that the appended drawings illustrate only typical embodiments of this disclosure and are therefore not to be considered limiting of its scope, for the disclosure may admit to other equally effective embodiments.

[0011] FIG. 1A is a side view of an example article having raised features according to at least one embodiment of the present disclosure.

[0012] FIG. 1B is a side view of an example article having recessed features according to at least one embodiment of the present disclosure.

[0013] FIG. 1C is an exploded side view of the article shown in FIGS. 1A and 1B.

[0014] FIG. 2 shows a top plan view of an example substrate having a mesh, or open-cell, structure that can be used with articles described herein according to at least one embodiment of the present disclosure.

[0015] To facilitate understanding, identical reference numerals have been used, where possible, to designate identical elements that are common to the figures. It is contemplated that elements and features of one embodiment may be beneficially incorporated in other embodiments without further recitation.

DETAILED DESCRIPTION

[0016] Embodiments of the present disclosure generally relate to vapor permeable, water resistive, and fire resistive articles for residential and commercial structures and installations. Embodiments described herein also generally relate to methods of making such articles. Unlike current technologies, the inventors have found a single article that has the combination of vapor and moisture permeability, exclusion of bulk water, fire resistance. Moreover, the inventors have found a single article that has the combination of vapor and moisture permeability, fire resistance, exclusion of bulk water, and reflection of radiant heat in a single article is not

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available in commercial products. Moreover, the articles can exclude air. Commercially available products do not include such properties in a single article.

[0017] Articles described herein generally include a substrate and a fire resistant coating having features that channel intruding water and moisture away from the structure or installation to which the article is affixed. The fire resistant coating includes an intumescent, that when exposed to high temperatures (for example a fire), expands to provide a protective barrier for the structure or installation to which the article is affixed.

[0018] With respect to water and moisture, proper building envelope designs should promote continual drying by allowing vapor to escape. Moisture can penetrate a building envelope which can cause swelling and distortion of lumber, wood rot, and corrosion of metal, any of which can lead to mold and building deterioration. When using low or non-permeable barriers, the incidence of trapped moisture increases. To solve these and other issues, and in some embodiments, the fire resistant coatings include various features that can channel intruding water and moisture away from the structure or installation to which the article is affixed. Accordingly, embodiments described herein can both prevent rain from moving into the interior of the structure or installation, and can also be permeable to water vapor, enabling water vapor to pass from the structure interior to the exterior and further reducing the possibility of trapped moisture. The articles can thereby serve as a protective barrier between the exterior of the structure and the interior of the structure, and can prevent, or at least mitigate, damage due to fire and moisture. In some examples, and as further described below, the articles can include a material that reflects radiant heat (or infrared (IR) radiation) away from the structure to which the article is affixed. Such action limits heat transfer to a space formed on an interior side to which the article is affixed, for example, an interior space of a building or other structure. By limiting the heat transfer, the temperature of the interior space and the cost of cooling the interior space is reduced.

[0019] As used herein, a "composition" can include component(s) of the composition, reaction product(s) of two or more components of the composition, a remainder balance of remaining starting component(s), or combinations thereof. Compositions of the present disclosure can be prepared by any suitable mixing process.

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[0020] As used herein, the term “coupled” means the joining of two elements directly or indirectly to one another.

Example Articles

[0021] Embodiments of the present disclosure generally relate to vapor permeable, water resistive, and fire resistive articles for residential and commercial structures and installations. The articles can be in the form of a covering such as a wrap, a sleeve, a sheath, a mat, a roll, a wall, a panel, a siding, or the like. The articles can be mounted to, for example, a wall, roof, or floor, or other structure or installation. Additionally, or alternatively, the articles can serve as a structural member of a structure or installation.

[0022] FIGS. 1A and 1B are side views of an article 100 having raised features 103a or recessed features 103b, respectively, according to at least one embodiment of the present disclosure. FIG. 1C is an exploded side view of the article shown in FIGS. 1A and 1B, illustrating the individual layers and surfaces. For clarity, the raised features 103a and recessed features 103b are not shown. Articles described herein, for example, the article 100, can be in the form of a multilayer structure such as a laminate, sheet, membrane, or combinations thereof. The article 100 can be in the form of a cured or dried composite. The article 100 can be, for example, fire resistant, water resistant, vapor permeable, radiant heat reflective, or combinations thereof. As further described below, article 100 can be affixed to a structure or installation, such as a wall, floor, or a ceiling of a structure or installation. After installation, the article 100 can provide protection against fire, can prevent or at least mitigate structural damage due to water and moisture, and can reflect radiant heat in order to improve energy efficiency. At the same time, the article 100 can be vapor permeable and can exclude wind.

[0023] The article 100 includes a substrate 101 (or base layer) having a first surface 101a and a second surface 101b that is opposite the first surface 101a. Illustrative, but non-limiting, examples of materials useful for at least a portion of substrate 101 include fiberglass, polymer(s), glass, concrete, foam, plastics, elastomer(s), rubber(s), cellular solid(s), woven fabrics, non-woven fabrics, metal, clay, shale, lignocellulose, wood, engineered composite material(s), or combinations thereof, among other materials. Suitable polymers useful as at least a portion of substrate 101 include polyolefins (such as polypropylene and polyethylene), polyvinylacetate, polyacrylate, polyamide, polystyrene, polyester, or their copolymers. Wood

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and lignocellulose that can be used as at least a portion of substrate 101 can include, but is not limited to, solid lumber, particle board, plywood, medium density fiberboard, hardboard, parallel strand lumber, oriented strand board, strawboard, or combinations thereof, among others. The substrate 101 can be flexible or moldable substrate. Alternatively, the substrate 101 can be a rigid substrate. The substrate 101 can be porous or non-porous. In some examples, the substrate can have a mesh structure (or open-cell structure). Alternatively, the substrate 101 can have a closed-cell structure.

[0024] In some embodiments, the substrate 101 can be in the form of a scrim, such as a fiberglass scrim or a polyolefin scrim.

[0025] In some embodiments, the substrate 101 comprises, or consists of, a material that reflects heat radiation or infrared (IR radiation). In such cases, substrate 101 can also be referred to as a radiant barrier layer. The radiant barrier layer can have a reflective surface that reflects heat radiation or infrared radiation. The radiant barrier layer can also have low emissivity. The combination of this reflective function, as well as the low emissivity, limits the heat transfer to a space formed on one side of articles described herein, for example, an interior space of a building or other structure. By limiting the heat transfer, the temperature of the interior space and the cost of cooling the interior space is reduced. The radiant barrier layer can include, or consist of, a variety of materials such as metals and metalloids, oxides thereof, salts thereof, alloys thereof, Mylar (polyethylene terephthalate), radiant barrier paints, radiant barrier films, radiant barrier coatings, or combinations thereof. Illustrative, but non-limiting, examples of metals and metalloids used for the radiant barrier layer can include aluminum, titanium, iron, barium, or silicon, in an elemental state, an oxide thereof (of various degrees of oxidation), a salt thereof (hydrated or anhydrous), an alloy thereof, or combinations thereof.

[0026] The materials used for the radiant barrier layer can be in the form of a single sheet, such as a metal foil, such as aluminum foil. Commercially available foils include Reynolds Wrap (Alcoa), among others. A plurality of sheets can also be utilized. In some embodiments, the radiant barrier layer may be a coating.

[0027] In some embodiments, the radiant barrier layer can include a backing layer made from a suitable backing material, such as polymeric film, kraft paper, corrugated paper board, fiber board, or combinations thereof. In at least one embodiment, the radiant barrier layer is,

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or includes, a multilayered material such as a laminate in which a backing material is laminated to a sheet or coating comprising, for example, a metal, a metal oxide, a metal salt, a metal alloy, Mylar, a radiant barrier paint, a radiant barrier film, a radiant barrier coating, or combinations thereof.

[0028] Commercially available materials that can be used for the radiant barrier layer include products made under the name Super R (Innovative Insulation, Inc.). Super R products have two layers of aluminum foil each of which have an aluminum purity of 99%, and a reinforcing member located inside or between the two layers. In some embodiments, the reinforcing member can be a reinforcing scrim or a polymer fabric.

[0029] The article 100 further includes a coating 102 (or layer) that comprises, or consists of, a fire resistant composition. The coating 102 can be referred to as an intumescent coating or a fire resistant coating. Fire resistant compositions are described below. The coating 102 has a first surface 102a and a second surface 102b opposite the first surface 102a. As shown, the second surface 102b of coating 102 is disposed over, or is adjacent to, the first surface 101a of the substrate 101.

[0030] In some examples, the coating 102 can substantially coat, or at least partially coat, at least one surface (for example, first surface 101a or second surface 101b) of the substrate 101. In some examples, a fire resistant composition (or a layer that comprises or consists of such a composition) can be disposed on multiple surfaces of the substrate 101 and/or within of the substrate 101. For example, when the substrate 101 includes pores, multiple layers, or the like, a fire resistant composition, or a coating 102 that comprises or consists of such a composition, can be disposed on one or more surfaces, within one or more pores, on or in one or more layers, or combinations thereof, of the substrate 101.

[0031] In some embodiments, the coating 102 can include features or elements such as channels, embossments, protrusions, indentations, grooves, perforations, recesses, cutouts, or combinations thereof. Other features or elements are contemplated. In FIG. 1A, the coating 102 includes raised features 103a (for example, embossments and protrusions) disposed thereon. The raised features 103a can be made of the same material as the fire resistant composition. In FIG. 1B, the coating 102 includes recessed features 103b (for example, channels or grooves) disposed therein. Such texturing with the features and elements can serve

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to channel intruding water away from the structure or installation to which the article 100 is affixed, enabling, for example, improved water drainage. Combinations of raised features 103a and recessed features 103b can be used together. The raised features 103a and recessed features 103b are collectively referred to as features 103.

[0032] Although the features 103 shown are perpendicular to the article 100, the features can be angled (for example diagonally) along the article, parallel to the article, perpendicular to the article, or combinations thereof. As shown in FIGS. 1A and FIG. 1B, the features 103 can have peaks and valleys.

[0033] The raised features 103a, recessed features 103b, or combinations thereof, provide a path, a plain, or a space for water and moisture drainage. The features 103 allow water and moisture to readily drain from the structure or installation to which the article 100 is affixed. Here, for example, the second surface 101b of the substrate 101 faces an interior of the structure or installation to which it is affixed, while the first surface 102a of the coating 102 faces an exterior of a structure or installation to which the article 100 is to be affixed. That is, the first surface 102a of the coating 102 is an outward facing surface and the second surface 101b of the substrate is an inward facing surface. When the article 100 is installed in a wall system (or floor system or ceiling system, among others), the features 103 act as a path for water and moisture to diffuse and drain, permitting water and moisture to readily exit from the wall system and effectively preventing (or at least mitigating) internal condensation in the wall system. In so doing, the article prevents or at least mitigates rot and mold due to water and moisture.

[0034] The features 103 can be fabricated with an omnidirectional relief pattern or a unidirectional relief pattern. The features 103 can be patterned as a grid, an array, an egg-crate pattern, or be random. The features 103 can be patterned in any suitable shape such as rounded, pyramids, squares, rectangles, squares, squiggles, zig-zag, herringbone, or other geometric or random shapes. The features 103 facilitate water and air flow, thereby improving moisture permeability, improving ventilation, and reducing mold.

[0035] In some embodiments, the features 103 can be positioned on/in or located on/in at least a portion of the coating 102. In at least one embodiment, the features 103 are positioned on/in or located on/in an entirety of the first surface 102a of the coating 102. In some

embodiments, patterned features or elements can be positioned on/in or located on/in a portion, but not all, of the first surface 102a of the coating 102.

[0036] Although only one substrate 101 and only one coating 102 comprising a fire resistant composition are shown, the article 100 can include a plurality of one or both of such layers in any suitable combination. For example, a second coating comprising a fire resistant composition (which can be the same or different fire resistant composition) can be disposed over, or be adjacent to, the second surface 101b of the substrate 101. Moreover, a plurality of substrates (or base layers) can be used if desired. There is no requirement that the number of substrate layers be equivalent to the number of layers comprising a fire resistant composition.

[0037] A thickness ($T1$ in FIG. 1A) of the substrate 101 can be any suitable dry-coating thickness.

[0038] A dry-coating thickness, or a thickness ($T2$ in FIG. 1A), of the coating 102 can be any suitable dry-coating thickness.

[0039] A coating weight of the coating 102 can be from about 0.015 g/cm^2 ($\sim 0.1 \text{ g/in}^2$) to 0.19 g/cm^2 ($\sim 1.2 \text{ g/in}^2$), such as from about 0.03 g/cm^2 ($\sim 0.2 \text{ g/in}^2$) to 0.17 g/cm^2 ($\sim 1.1 \text{ g/in}^2$), such as from about 0.05 g/cm^2 ($\sim 0.3 \text{ g/in}^2$) to 0.15 g/cm^2 ($\sim 1 \text{ g/in}^2$), such as from about 0.06 g/cm^2 ($\sim 0.4 \text{ g/in}^2$) to 0.14 g/cm^2 ($\sim 0.9 \text{ g/in}^2$), such as from about 0.08 g/cm^2 ($\sim 0.5 \text{ g/in}^2$) to 0.12 g/cm^2 ($\sim 0.8 \text{ g/in}^2$), such as from about 0.09 g/cm^2 ($\sim 0.6 \text{ g/in}^2$) to 0.11 g/cm^2 ($\sim 0.7 \text{ g/in}^2$). In at least one embodiment, the thickness (in units of g/cm^2) of the coating 102 can be 0.015, 0.03, 0.04, 0.05, 0.06, 0.07, 0.08, 0.09, 0.1, 0.11, 0.12, 0.13, 0.14, 0.15, 0.16, 0.17, 0.18, or 0.19, or ranges thereof, though other values are contemplated. Each of the foregoing numbers can be preceded by the word “about,” “at least about,” “less than about,” or “more than about,” and any of the foregoing numbers can be used singly to describe an open-ended range or in combination to describe a close-ended range.

[0040] A height (H , shown in FIG. 1A) of raised features 103a can be any suitable height. In some embodiments, the height (H) of the raised features 103a can, individually, be from about 0.5 mm ($\sim 0.02 \text{ in}$) to about 10 mm ($\sim 0.4 \text{ in}$), such as from about 1 mm ($\sim 0.04 \text{ in}$) to about 8 mm ($\sim 0.3 \text{ in}$), such as from about 2 mm ($\sim 0.08 \text{ in}$) to about 5 mm ($\sim 0.2 \text{ in}$), such as from about 3 mm ($\sim 0.12 \text{ in}$) to about 4 mm ($\sim 0.16 \text{ in}$). In at least one embodiment, the height (H)

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of the raised features 103a can, individually, be from about 1.6 mm (~1/16 in) to about 4.8 mm (~3/16 in), such as about 3.2 mm (~1/8 in). In some embodiments, the height (H) of the raised features 103a can (in units of mm) can, individually, be can be 0.5, 1, 1.5, 2, 2.5, 3, 3.5, 4, 4.5, 5, 5.5, 6, 6.5, 7, 7.5, 8, 8.5, 9, 9.5, or 10, or ranges thereof, though other values are contemplated. Each of the foregoing numbers can be preceded by the word “about,” “at least about,” “less than about,” or “more than about,” and any of the foregoing numbers can be used singly to describe an open-ended range or in combination to describe a close-ended range.

[0041] A depth (D , shown in FIG. 1B) of the recessed features 103b can be any suitable depth. In some embodiments, the depth (D) of the recessed features 103b can, individually, be from about 0.5 mm (~0.02 in) to about 10 mm (~0.4 in), such as from about 1 mm (~0.04 in) to about 8 mm (~0.3 in), such as from about 2 mm (~0.08 in) to about 5 mm (~0.2 in), such as from about 3 mm (~0.12 in) to about 4 mm (~0.16 in). In at least one embodiment, the depth (D) of the recessed features 103b can, individually, be from about 1.6 mm (~1/16 in) to about 4.8 mm (~3/16 in), such as about 3.2 mm (~1/8 in). In some embodiments, the depth (D) of the recessed features 103b (in units of mm) can, individually, be can be 0.5, 1, 1.5, 2, 2.5, 3, 3.5, 4, 4.5, 5, 5.5, 6, 6.5, 7, 7.5, 8, 8.5, 9, 9.5, or 10, or ranges thereof, though other values are contemplated. Each of the foregoing numbers can be preceded by the word “about,” “at least about,” “less than about,” or “more than about,” and any of the foregoing numbers can be used singly to describe an open-ended range or in combination to describe a close-ended range.

[0042] The height (H) of the raised features 103a is measured as the distance from the first surface 102a of the coating 102 to a top (or peak) of a raised feature. The depth (D) of the recessed features 103b is based on the distance from the first surface 102a of the coating 102 to a bottom of a recessed feature.

[0043] FIG. 2 shows a top plan view 200 of a substrate 101 having a mesh structure that can be used with articles described herein. The mesh structure, or open-cell structure, of the substrate 101 is indicated by voids 204. Although the voids 204 are shown as having a hexagonal shape, the voids 204 can be of any suitable shape, such as circle, oval, square, or other polygon, or combinations thereof, and can be arranged in a random or irregular arrangement. The voids 204 can enable improved moisture control. The voids 204 can also allow the intumescent to expand and fill the voids 204 when exposed to heat from, for example,

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a fire. Voids 204 are optional such that the substrate 101 is free of voids, do not have a mesh structure, or do not have an open cell structure. The coating 102, as described above, can be disposed on the mesh structure of the substrate.

[0044] Layer(s), coating(s), or combinations thereof, of the multilayer structure can be coupled to or adhered to one another by using suitable materials including, but not limited to, binders and adhesives. The binders and adhesives can act as a binding agent, such as a phenolic resin, or a bonding agent, such as an epoxy resin. Binders and adhesives that are useful include: a hot-melt adhesive; a resin, such as an epoxy resin, a polyvinyl acetate resin, ethylene vinyl acetate copolymer (EVA) resin, a phenolic resin (for example, a phenol-formaldehyde resin), an amino resin, a polyurethane resin, an isocyanate-based resin, combinations thereof, among others. The binders, adhesives, or other materials can be dried or cured under ambient conditions; heat, light, electromagnetic radiation, or combinations thereof can be used for drying or curing the binders, adhesives, or other materials. The adhesive or binding agent cures or dries and adheres the one or more layers (or coatings) together. For example, an adhesive, binding agent, or both, can be used to adhere coating 102 to the substrate 101.

[0045] Non-limiting, commercially available examples of binders and adhesives include Vinnapas EP 6300 which is a vinyl acetate and ethylene copolymer dispersion available from Wacker Chemie Ag.

[0046] In some embodiments, the substrate 101 and the coating 102 can be coupled without the use of an adhesive or a binding agent. For example, the fire resistant composition used to form the coating 102 can be introduced to the substrate 101 in a liquid state and upon the curing or drying of the fire resistant composition, the coating 102 forms and adheres to substrate 101.

[0047] The article 100 can be in the form of a wrap, a sleeve, a mat, a roll, a wall, a siding, a panel, a sheath, or other structure. For example, the article 100 can be a house wrap. The article 100 can be secured to a wall, roof, or floor, or other feature of a structure or installation. Other applications for the article 100 are contemplated.

[0048] If desired, fasteners or clips can be placed onto article 100 to facilitate fastening or mounting to a structure or installation. Additionally, or alternatively, holes can be disposed in the article 100. The holes can facilitate use of nails or screws to secure the article 100 to a

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structure or installation. Additionally, or alternatively, the article 100 is free of fasteners, clips, and holes, and the article 100 is mounted to a structure or installation at the work site by suitable fasteners.

[0049] In some embodiments, articles described herein can have one or more of the following properties:

[0050] (a) Articles described herein can have any suitable water vapor transmission.

[0051] (b) Articles described herein can have a water vapor permeance that is at least about $50 \text{ ng} \cdot \text{s}^{-1} \cdot \text{m}^{-2} \cdot \text{Pa}^{-1}$ (nanogram per second per square meter per pascal), at least about $100 \text{ ng} \cdot \text{s}^{-1} \cdot \text{m}^{-2} \cdot \text{Pa}^{-1}$, such as at least about $500 \text{ ng} \cdot \text{s}^{-1} \cdot \text{m}^{-2} \cdot \text{Pa}^{-1}$ to about $2,000 \text{ ng} \cdot \text{s}^{-1} \cdot \text{m}^{-2} \cdot \text{Pa}^{-1}$, such as from about $800 \text{ ng} \cdot \text{s}^{-1} \cdot \text{m}^{-2} \cdot \text{Pa}^{-1}$ to about $1,600 \text{ ng} \cdot \text{s}^{-1} \cdot \text{m}^{-2} \cdot \text{Pa}^{-1}$, such as from about $1,000 \text{ ng} \cdot \text{s}^{-1} \cdot \text{m}^{-2} \cdot \text{Pa}^{-1}$ to about $1,300 \text{ ng} \cdot \text{s}^{-1} \cdot \text{m}^{-2} \cdot \text{Pa}^{-1}$. In at least one embodiment, the water vapor transmission (in units of $\text{ng} \cdot \text{s}^{-1} \cdot \text{m}^{-2} \cdot \text{Pa}^{-1}$) of articles described herein can be 50, 100, 200, 300, 400, 500, 600, 700, 800, 900, 1,000, 1,100, 1,200, 1,300, 1,400, 1,500, 1,600, 1,700, 1,800, 1,900, or 2,000, or ranges thereof, though other values are contemplated. Each of the foregoing numbers can be preceded by the word “about,” “at least about,” “less than about,” or “more than about,” and any of the foregoing numbers can be used singly to describe an open-ended range or in combination to describe a close-ended range. Water vapor permeance is determined as described in the Examples.

[0052] In use, for example, articles described herein in the form of a wrap, a sheath, a sleeve, a mat, a roll, a wall, a panel, a siding, or other structure, can be affixed to a structure or installation that can benefit from fire resistance, water resistance, vapor permeability, air/wind exclusion, and/or radiant barrier properties (for example, energy efficiency) such as infrastructure equipment, residential building materials and structures, commercial building materials and structures, among other structures and installations. Residential and commercial building materials and structures can include roofing, walls, floors, I-joists, underlayment, and siding. The structures and installations can be new or existing structures or installations. Additionally, or alternatively, articles described herein can serve as a structural member of a structure or installation, when for example, the substrate 101 includes wood, engineered composite, concrete, among other materials.

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[0053] The article 100 can be installed in wall systems, floor systems, ceiling systems, or other various places, by any suitable method. For example, the article 100 in the form of a house wrap can be attached to, for example, sheathing panels or other structures/installations with staples or nails. The article 100 can be attached to a framing member in a building structure such as an exterior wall, roof, or floor. The article 100 can be attached to an exterior sheathing such as plywood. Articles of the present disclosure can be utilized in roofing systems as an underlayment and as a window flashing adhered around window flanges and jambs. In each of these applications, the article 100 serves to prevent the intrusion of air and bulk moisture but allow for the outward passage of vapor. At the same time, the article 100 protects the structure it is attached to from fire, radiant heat, or both. Other benefits of the article 100 are described herein.

Example Fire Resistant Composition

[0054] As described above, the coating 102 comprises, consists of, or consists essentially of, a fire resistant composition. The fire resistant composition is interchangeably referred to as an intumescent composition. Intumescent compositions are substances that expand as a result of heat exposure, thus increasing in volume and decreasing in density. A description of example fire resistant compositions (or intumescent compositions) that can be used with embodiments described herein is now provided.

[0055] The fire resistant composition can include an intumescent (such as expandable graphite) and a binder. In some embodiments, the fire resistant composition can optionally include additives, water, or combinations thereof.

[0056] One or more intumescent(s) (or intumescent compounds) can be utilized in fire resistant compositions. The intumescent(s) can include expandable graphite. Expandable graphite is a synthesized intercalation compound of graphite that expands when heated. Expandable graphite is formed by treating crystalline graphite, which is composed of stacks of parallel planes of carbon atoms, with intercalants such as sulfuric acid and nitric acid. Since no covalent bonding exists between the planes of the carbon atoms, the intercalant can be inserted between them. This allows the intercalant to be positioned within the graphite lattice. When the intercalated graphite is exposed to heat or flame, the inserted molecules decompose and release gases. The graphite layer planes are pushed apart by the gas and the graphite

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expands up to 300 times its original thickness, its bulk density is lowered, and its surface area is increased. This results in a low-density thermal insulation layer. Expandable graphite can also be referred to as expandable flake graphite, intumescent flake graphite, or expandable flake.

[0057] Expandable graphite can be available in a variety of particle size distributions. This varies with the manufacturer and grade. For example, NYAGRAPH® 251 has a particle distribution of the following: below 150 microns - 1-5%, 150 microns – 300 microns: 9-15%, 300 microns – 710 microns: 79-85%, and over 710 microns: 1-5%.

[0058] The intumescent(s) can include an expandable graphite compound having a mean particle size in the range of about 300 μm to about 1,000 μm , such as from about 375 μm to about 950 μm , such as from about 400 μm to about 800 μm , such as from about 450 μm to about 700 μm , such as from about 500 μm to about 600 μm . The intumescent(s) can include an expandable graphite compound having a mean particle size in the range of about 0.5 μm to about 250 μm , such as from about 5 μm to about 200 μm , such as from about 20 μm to about 175 μm , such as from about 50 μm to about 150 μm , such as from about 75 μm to about 125 μm .

[0059] The intumescent(s) can include (a) a first expandable graphite compound having a mean particle size in the range of from 300 microns to 1000 microns; and (b) a second expandable graphite compound having a mean particle size in the range of from 0.5 microns to 250 microns. A weight ratio of the first expandable graphite compound to the second expandable graphite compound can be about 10:1 to about 1:10, such as from about 5:1 to about 1:5, such as from about 4:1 to about 1:4, such as from about 3:1 to about 1:3, such as from about 2:1 to about 1:2, such as about 1:1, though higher or lower weight ratios are contemplated.

[0060] Examples of expandable graphite can include, but are not limited to, Nyagraph 35, Nyagraph 251, Nyagraph 351 (commercially available from Nyacol Nano Technologies, Inc., Ashland, Mass.), Grafguard 160-50N, and Grafguard 200-100N (commercially available from Graf Tech International, Brooklyn Heights, Ohio).

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[0061] A total amount of the intumescent(s) (for example, a total amount of expandable graphite compound(s)) in a fire resistant composition can be from about 1 wt% to about 50 wt%, such as from about 5 wt% to about 40 wt%, such as from about 10 wt% to about 30 wt%, such as from about 15 wt% to about 25 wt%, based on the total weight of the fire resistant composition. The total weight of the fire resistant composition does not exceed 100 wt%. In some embodiments, a total amount, in wt%, of the intumescent(s) in a fire resistant composition, based on the total weight of the fire resistant composition, can be 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, or 50, or ranges thereof, though higher or lower amounts are contemplated. Each of the foregoing numbers can be preceded by the word "about," "at least about," "less than about," or "more than about," and any of the foregoing numbers can be used singly to describe an open-ended range or in combination to describe a close-ended range.

[0062] Fire resistant compositions useful to form at least a portion of coating 102 also include a binder or a plurality of binders. Binders can perform several functions. The binder can act as a matrix in which the other components of the fire resistant composition are dispersed. The binder can also bind the coating 102 to the substrate 101 (when used). Additionally, the binder can contribute to the insulating char layer formed by the expansion of the fire resistant composition. Unlike conventional, commercially available compositions rated for fire resistance which include inorganic compounds and minerals as a binder, the fire resistant compositions include organic materials.

[0063] In some embodiments, the binder includes, consists of, or consists essentially of, at least one thermoplastic compound, at least one thermoset compound, or a combination thereof. The thermoplastic compound can be present as a dispersion. The dispersion can be prepared by any suitable method known to those skilled in the art. In various embodiments, the dispersion is prepared via an emulsion.

[0064] Illustrative, but non-limiting, examples of thermoplastic compounds that can be used include ethylene vinyl acetate copolymer, polyvinyl acetate, poly(methyl acrylate), poly(methyl methacrylate), poly(ethyl acrylate), poly(ethyl methacrylate), poly(n-butyl acrylate), poly(n-butyl methacrylate), poly(isobutyl acrylate), poly(isobutyl methacrylate),

poly(tert-butyl acrylate), poly(tert-butyl methacrylate), poly(2-hydroxyethyl acrylate), poly(2-hydroxyethyl methacrylate), poly(2-hydroxypropyl acrylate), poly(2-hydroxypropyl methacrylate), poly(2-ethylhexyl acrylate), poly(2-ethylhexyl methacrylate), or combinations thereof. Commercially available thermoplastic compounds include Multibond 1P2 (which is a crosslinking polyvinyl acetate available from Franklin Adhesives and Polymers) and Covinax FR-A 707 (a styrene acrylic thermoplastic compound commercially available from Franklin International), among others.

[0065] The thermoset compound is optionally present in the fire resistant composition as a dispersion. The thermoset dispersion can be prepared by any suitable method known to those skilled in the art, such as by slow addition of a resin into a system that contains an emulsifying agent.

[0066] Illustrative, but non-limiting, examples of thermoset compounds that can be used include, phenol formaldehyde resin, phenol resorcinol formaldehyde resin, urea formaldehyde resin, melamine formaldehyde resin, melamine reinforced urea formaldehyde resin, isocyanate reinforced urea formaldehyde resin, resorcinol formaldehyde resin, polyacrylic latex resin, isocyanate resin, an organopolysiloxane, ethylene glycol, a bisphenol-A epoxy resin, a bisphenol-F epoxy resin, an unsaturated polyester, polyurethane, or combinations thereof. Commercially available thermoset compounds include Cascorez resins (Hexion, Inc.) such as Cascorez NA 707. Other commercially available thermoset compounds can include, but are not limited to, XB-91MO (Hexion, Inc.), which is a phenolic thermoset compound, Cascophen phenol formaldehyde resin, Cascophen phenol resorcinol formaldehyde resin, Cascomel melamine formaldehyde resin, and Casco urea formaldehyde resin, among others, each of which is commercially available from Hexion, Inc. The thermoset compound can be free of paragon or include paragon.

[0067] In some examples, the binder includes one or more of ethylene vinyl acetate copolymer (EVA), urea formaldehyde resin, melamine formaldehyde resin, melamine reinforced urea formaldehyde resin, phenol resin, phenol formaldehyde resin, phenol resorcinol formaldehyde resin, polyurethane, or combinations thereof.

[0068] A total amount of binder in a fire resistant composition can be from about 1 wt% to about 80 wt%, such as from about 5 wt% to about 75 wt%, such as from about 10 wt% to about

70 wt%, such as from about 15 wt% to about 65 wt%, such as from about 20 wt% to about 55 wt%, such as from about 25 wt% to about 50 wt%, such as from about 30 wt% to about 45 wt%, based on the total weight of the fire resistant composition. In some examples, the total amount of binder in a fire resistant composition can be from about 15 wt% to about 70 wt%, such as from about 25 wt% to about 60 wt%, such as from about 35 wt% to about 55 wt%, based on the total weight of the fire resistant composition. The total amount of binder in the fire resistant composition is the total weight of the thermoplastic compound(s) and the thermoset compound(s).

[0069] In some embodiments, a total amount (in wt%) of binder in a fire resistant composition, based on the total weight of the fire resistant composition, can be 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, or 80, or ranges thereof, though higher or lower amounts are contemplated. Each of the foregoing numbers can be preceded by the word “about,” “at least about,” “less than about,” or “more than about,” and any of the foregoing numbers can be used singly to describe an open-ended range or in combination to describe a close-ended range.

[0070] As described above, the binder can include at least one thermoplastic compound and at least one thermoset compound. A weight ratio of the thermoplastic compound(s) to the thermoset compound(s) in the binder can be in the range of about 10:1 to about 1:3, such as from about 8:1 to about 1:2.5, such as from about 6.5:1 to about 1:2, such as from about 6:1 to about 1:1.5, such as from about 5:1 to about 1:1, such as from about 3:1 to about 1.5:1. In some embodiments, the weight ratio of the thermoplastic compound to the thermoset compound in the binder can be 10:1, 9.5:1, 9:1, 8.5:1, 8:1, 7.5:1, 7:1, 6.5:1, 6:1, 5.5:1, 5:1, 4.5:1, 4:1, 3.5:1, 3:1, 2.5:1, 2:1, 1.5:1, 1:1, 1:1.5, 1:2, 1:2.5, or 1:3, or ranges thereof, though other weight ratios are contemplated. Each of the foregoing numbers can be preceded by the word “about,” “at least about,” “less than about,” or “more than about,” and any of the foregoing numbers can be used singly to describe an open-ended range or in combination to describe a close-ended range.

[0071] Fire resistant compositions useful to form at least a portion of coating 102 can also include a variety of optional additives, depending on the application. Illustrative, but non-limiting, examples of optional additives can include a catalyst, a blowing agent, a defoamer, a rheological modifier, a dispersant, a pigment, a fire barrier additive, a coalescing agent, a viscosity reducer, a water softener, a toxic gas absorbing material, an absorbent promoter, a wetting agent, a nucleating agent, an accelerator, a filler, a buffer, a reinforcing additive, a surfactant, a thickener, and/or combinations thereof in any suitable amounts or proportions. Other optional additives are contemplated.

[0072] Some of the optional additives can have multiple purposes in the fire resistant compositions. For example, magnesium oxide can serve as both a pigment and a fire barrier additive.

[0073] The fire resistant composition can include one or more catalysts. Catalysts can be useful to assist with the intumescent expansion of the composition. Illustrative, but non-limiting, examples of catalysts include perchloric acid, hydroiodic acid, hydrobromic acid, sulfuric acid, hydrochloric acid, nitric acid, sulfurous acid, phosphoric acid, nitrous acid, sulfonic acid, hydrochloric acid, sulfuric acid, phosphoric acid, formic acid, acetic acid, maleic acid, malic acid, tartaric acid, citric acid, ammonium phosphates, ammonium polyphosphates, metal phosphates, metal polyphosphates, paratoluene sulfonic acid, or combinations thereof. One or more types of catalysts can be used with fire resistant compositions. Commercially available catalysts can include, but are not limited to, Exolit AP 422 (an ammonium polyphosphate, Clariant International Ltd). Ammonium polyphosphate can also act as a blowing agent.

[0074] When a catalyst is used, a total amount of catalyst(s) in a fire resistant composition can be from about 0.5 wt% to about 25 wt%, such as from about 1 wt% to about 20 wt%, such as from about 2 wt% to about 15 wt%, such as from about 3 wt% to about 12 wt%, such as from about 4 wt% to about 10 wt%, such as from about 6 wt% to about 8 wt%, based on the total weight of the fire resistant composition. In some embodiments, the total amount (in wt%) of catalyst(s) in a fire resistant composition, based on the total weight of the fire resistant composition, can be 0.5, 1, 1.5, 2, 2.5, 3, 3.5, 4, 4.5, 5, 5.5, 6, 6.5, 7, 7.5, 8, 8.5, 9, 9.5, 10, 10.5, 11, 11.5, 12, 12.5, 13, 13.5, 14, 14.5, 15, 15.5, 16, 16.5, 17, 17.5, 18, 18.5, 19, 19.5, 20, 21.5,

22, 22.5, 23, 23.5, 24, 24.5, or 25, or ranges thereof, though higher or lower amounts are contemplated. Each of the foregoing numbers can be preceded by the word "about," "at least about," "less than about," or "more than about," and any of the foregoing numbers can be used singly to describe an open-ended range or in combination to describe a close-ended range.

[0075] Fire resistant compositions can include one or more blowing agents. Blowing agents can be useful for expanding the binder in order to increase the thickness of the fire resistant composition. The blowing agent can also serve to dilute the concentrations of combustible gasses that are released when a wood material (e.g., a utility pole made of wood) burns. Examples of blowing agents that can be used include, but are not limited to, melamine, urea, butyl urea, alumina trihydrate, dicyandiamide, benzene sulfonyl-hydrazide, azobisisobutyronitrile, 1,1-azobisformamide, 4,4'-oxybis(benzene sulfonhydrazide), dinitroisopentamethylene tetraamine, or combinations thereof. One or more types of blowing agents can be used with fire resistant compositions.

[0076] In various embodiments, the melamine used can be Melafine (available from OCI Nitrogen). Blowing agents can include solid carbonate species such as calcium carbonate, sodium carbonate, sodium bicarbonate, potassium carbonate, or combinations thereof. Liquid carbonates can also be used as blowing agents such as propylene carbonate and solutions or slurries of calcium carbonate sodium carbonate, sodium bicarbonate, potassium carbonate, or combinations thereof. Commercially available blowing agents can also include, but are not limited to, Microna 3 (calcium carbonate) commercially available from Columbia River Carbonates, and Imasco 5H (limestone) commercially available from Imasco Minerals Inc.

[0077] When a blowing agent is used, a total amount of blowing agent(s) in a fire resistant composition can be from about 1 wt% to about 35 wt%, such as from about 5 wt% to about 30 wt%, such as from about 10 wt% to about 25 wt%, such as from about 15 wt% to about 20 wt%, based on the total weight of the fire resistant composition. In some embodiments, the total amount (in wt%) of blowing agent(s) in a fire resistant composition, based on the total weight of the fire resistant composition, can be 0.5, 1, 1.5, 2, 2.5, 3, 3.5, 4, 4.5, 5, 5.5, 6, 6.5, 7, 7.5, 8, 8.5, 9, 9.5, 10, 10.5, 11, 11.5, 12, 12.5, 13, 13.5, 14, 14.5, 15, 15.5, 16, 16.5, 17, 17.5, 18, 18.5, 19, 19.5, 20, 20.5, 21, 21.5, 22, 22.5, 23, 23.5, 24, 24.5, 25, 25.5, 26, 26.5, 27, 27.5, 28, 28.5, 29, 29.5, 30, 30.5, 31, 31.5, 32, 32.5, 33, 33.5, 34, 34.5, or 35, or ranges thereof,

though higher or lower amounts are contemplated. Each of the foregoing numbers can be preceded by the word “about,” “at least about,” “less than about,” or “more than about,” and any of the foregoing numbers can be used singly to describe an open-ended range or in combination to describe a close-ended range.

[0078] Fire resistant compositions can include one or more defoamers. In some embodiments, a total amount of defoamer(s) in fire resistant compositions can be from about 0 wt% to about 11 wt%, such as from about 0 wt% to about 10 wt%, such as from about 0.05 wt% to about 8 wt%, such as from about 0.05 wt% to about 2 wt%, such as from about 0.1 wt% to about 1.5 wt%, such as from about 0.2 to about 1 wt% based on the total weight of the fire resistant composition. In at least one embodiment, the total amount (in wt%) of defoamer(s) in a fire resistant composition, based on the total weight of the fire resistant composition, can be 0, 0.01, 0.03, 0.05, 0.1, 0.2, 0.25, 0.5, 0.75, 1, 1.5, 2, 2.5, 3, 3.5, 4, 4.5, 5, 5.5, 6, 6.5, 7, 7.5, 8, 8.5, 9, 9.5, 10, 10.5, or 11, or ranges thereof, though other amounts are contemplated. Each of the foregoing numbers can be preceded by the word “about,” “at least about,” “less than about,” or “more than about,” and any of the foregoing numbers can be used singly to describe an open-ended range or in combination to describe a close-ended range.

[0079] Illustrative, but non-limiting, examples of defoamers can include Byk-037 (a volatiles-free, silicone-containing defoamer commercially available from BYK-Chemie GmbH).

[0080] Fire resistant compositions can include one or more rheological modifiers. Rheological modifiers can serve to prevent flotation of the particles during, for example, agitation and mixing. In some embodiments, a total amount of rheological modifier(s) in a fire resistant composition can be from about 0 wt% to about 10 wt%, such as from about 0.01 wt% to about 10 wt%, 0.25 wt% to about 10 wt%, such as from about 0.5 wt% to about 7 wt%, such as from about 0.75 wt% to about 5 wt%, such as from about 1 wt% to about 2 wt% based on the total weight of the fire resistant composition. In some examples, the total amount of rheological modifier(s) in a fire resistant composition can be from about 0.01 wt% to about 1 wt%, based on the total weight of the fire resistant composition. In at least one embodiment, the total amount (in wt%) of rheological modifier(s) in a fire resistant composition, based on the total weight of the fire resistant composition, can be 0, 0.1, 0.25, 0.5, 0.75, 1, 1.5, 2, 2.5, 3,

3.5, 4, 4.5, 5, 5.5, 6, 6.5, 7, 7.5, 8, 8.5, 9, 9.5, or 10, or ranges thereof, though other amounts are contemplated. Each of the foregoing numbers can be preceded by the word “about,” “at least about,” “less than about,” or “more than about,” and any of the foregoing numbers can be used singly to describe an open-ended range or in combination to describe a close-ended range.

[0081] Illustrative, but non-limiting, examples of rheological modifiers can include Thixol 53L (a liquid acrylic thickener or rheological modifier, commercially available from Arkema), Rheotech 3800 (a thickener or rheological modifier commercially available from Arkema), Natrosol 250 HR (a thickener or rheological modifier commercially available from Ashland Global Specialty Chemicals Inc.), or combinations thereof.

[0082] Fire resistant compositions can include one or more dispersants. In some embodiments, a total amount of dispersant(s) in a fire resistant composition can be from about 0 wt% to about 10 wt%, such as from about 0.1 wt% to about 8 wt%, such as from about 0.25 wt% to about 3 wt%, such as from about 0.5 wt% to about 2 wt%, such as from about 0.75 wt% to about 1.5 wt% based on the total weight of the fire resistant composition. In at least one embodiment, the total amount (in wt%) of dispersant(s) in a fire resistant composition, based on the total weight of the fire resistant composition, can be 0, 0.25, 0.5, 0.75, 1, 1.5, 2, 2.5, 3, 3.5, 4, 4.5, 5, 5.5, 6, 6.5, 7, 7.5, 8, 8.5, 9, 9.5, or 10, or ranges thereof, though other amounts are contemplated. Each of the foregoing numbers can be preceded by the word “about,” “at least about,” “less than about,” or “more than about,” and any of the foregoing numbers can be used singly to describe an open-ended range or in combination to describe a close-ended range.

[0083] Illustrative, but non-limiting, examples of dispersants can include Disperbyk-190 (commercially available from BYK-Chemie GmbH).

[0084] Fire resistant compositions can include one or more pigments. In some embodiments, a total amount of pigment(s) in a fire resistant composition can be from about 0 wt% to about 10 wt%, such as from about 0.5 wt% to about 8 wt%, such as from about 1 wt% to about 5 wt%, based on the total weight of the fire resistant composition. In at least one embodiment, the total amount (in wt%) of pigment(s) in a fire resistant composition, based on the total weight of the fire resistant composition, can be 0, 0.25, 0.5, 0.75, 1, 1.5, 2, 2.5, 3, 3.5, 4, 4.5, 5, 5.5, 6, 6.5, 7, 7.5, 8, 8.5, 9, 9.5, or 10, or ranges thereof, though other amounts are contemplated. Each of the foregoing numbers can be preceded by the word “about,” “at least

about,” “less than about,” or “more than about,” and any of the foregoing numbers can be used singly to describe an open-ended range or in combination to describe a close-ended range.

[0085] Illustrative, but non-limiting, examples of pigments can include magnesium oxide (commercially available from Sigma Aldrich), iron oxide (commercially available from Sigma Aldrich), titanium oxide (commercially available from Sigma Aldrich), calcium carbonate (commercially available from Sigma Aldrich), or combinations thereof.

[0086] Materials used for pigments can also be utilized as a fire barrier additive. Fire barrier additives that can be used include, but are not limited to, oxides (for example, magnesium oxide and iron oxide). When a fire barrier additive is used, a total amount of fire barrier additive(s) in a fire resistant composition can be from about 0 wt% to about 10 wt%, such as from about 0.5 wt% to about 8 wt%, such as from about 1 wt% to about 5 wt%, based on the total weight of the fire resistant composition. In at least one embodiment, the total amount (in wt%) of fire barrier additive(s) in a fire resistant composition, based on the total weight of the fire resistant composition, can be 0, 0.25, 0.5, 0.75, 1, 1.5, 2, 2.5, 3, 3.5, 4, 4.5, 5, 5.5, 6, 6.5, 7, 7.5, 8, 8.5, 9, 9.5, or 10, or ranges thereof, though other amounts are contemplated. Each of the foregoing numbers can be preceded by the word “about,” “at least about,” “less than about,” or “more than about,” and any of the foregoing numbers can be used singly to describe an open-ended range or in combination to describe a close-ended range.

[0087] Fire resistant compositions can include one or more coalescing agents. In some embodiments, a total amount of coalescing agent(s) in a fire resistant composition can be from about 0 wt% to about 10 wt%, such as from about 0.5 wt% to about 7.5 wt%, such as from about 1 wt% to about 5 wt%, based on the total weight of the fire resistant composition. In at least one embodiment, the total amount (in wt%) of coalescing agent(s) in a fire resistant composition, based on the total weight of the fire resistant composition, can be 0, 0.25, 0.5, 0.75, 1, 1.5, 2, 2.5, 3, 3.5, 4, 4.5, 5, 5.5, 6, 6.5, 7, 7.5, 8, 8.5, 9, 9.5, or 10, or ranges thereof, though other amounts are contemplated. Each of the foregoing numbers can be preceded by the word “about,” “at least about,” “less than about,” or “more than about,” and any of the foregoing numbers can be used singly to describe an open-ended range or in combination to describe a close-ended range.

[0088] Illustrative, but non-limiting, examples of coalescing agents can include 2,2,4-trimethyl-1,3-pentanediol monoisobutyrate (also known as Texanol commercially available from Sigma Aldrich and NX 795 commercially available from Synthomer PLC).

[0089] In some embodiments, fire resistant compositions can include one or more insulating fillers. In some embodiments, a total amount of insulating filler(s) in a fire resistant composition can be from about 0 wt% to about 10 wt%, such as from about 0.5 wt% to about 7.5 wt%, such as from about 1 wt% to about 5 wt%, based on the total weight of the fire resistant composition. In at least one embodiment, the total amount (in wt%) of coalescing agent(s) in a fire resistant composition, based on the total weight of the fire resistant composition, can be 0, 0.25, 0.5, 0.75, 1, 1.5, 2, 2.5, 3, 3.5, 4, 4.5, 5, 5.5, 6, 6.5, 7, 7.5, 8, 8.5, 9, 9.5, or 10, or ranges thereof, though other amounts are contemplated. Each of the foregoing numbers can be preceded by the word "about," "at least about," "less than about," or "more than about," and any of the foregoing numbers can be used singly to describe an open-ended range or in combination to describe a close-ended range.

[0090] One or more water softeners can additionally be present in fire resistant compositions. Water softeners can include sodium polyphosphate (commercially available from Sigma Aldrich). In some embodiments, a total amount of water softener(s) in a fire resistant composition can be from about 0 wt% to about 10 wt%, such as from about 0.5 wt% to about 7.5 wt%, such as from about 1 wt% to about 5 wt%, based on the total weight of the fire resistant composition. In at least one embodiment, the total amount (in wt%) of water softener(s) in a fire resistant composition, based on the total weight of the fire resistant composition, can be 0, 0.25, 0.5, 0.75, 1, 1.5, 2, 2.5, 3, 3.5, 4, 4.5, 5, 5.5, 6, 6.5, 7, 7.5, 8, 8.5, 9, 9.5, or 10, or ranges thereof, though other amounts are contemplated. Each of the foregoing numbers can be preceded by the word "about," "at least about," "less than about," or "more than about," and any of the foregoing numbers can be used singly to describe an open-ended range or in combination to describe a close-ended range.

[0091] A total amount of optional additive(s) in fire resistant compositions can be about 40 wt% or less, such as about 30 wt% or less, such as about 20 wt% or less, such as about 15 wt% or less, such as about 10 wt% or less, such as from about 0 wt% to about 10 wt%, such as from about 0.5 wt% to about 8 wt%, such as from about 1 wt% to about 6 wt%, such as from about

2 wt% to about 5 wt%, such as from about 3 wt% to about 4 wt%. In some embodiments, the total amount (in wt%) of optional additive(s) in a fire resistant composition, based on the total weight of the fire resistant composition, can be 0, 0.25, 0.5, 0.75, 1, 1.5, 2, 2.5, 3, 3.5, 4, 4.5, 5, 5.5, 6, 6.5, 7, 7.5, 8, 8.5, 9, 9.5, 10, 10.5, 11, 11.5, 12, 12.5, 13, 13.5, 14, 14.5, 15, 15.5, 16, 16.5, 17, 17.5, 18, 18.5, 19, 19.5, 20, 20.5, 21, 21.5, 22, 22.5, 23, 23.5, 24, 24.5, 25, 25.5, 26, 26.5, 27, 27.5, 28, 28.5, 29, 29.5, 30, or ranges thereof, though higher or lower amounts are contemplated. Each of the foregoing numbers can be preceded by the word “about,” “at least about,” “less than about,” or “more than about,” and any of the foregoing numbers can be used singly to describe an open-ended range or in combination to describe a close-ended range.

[0092] In some embodiments, fire resistant compositions can include water. The water can serve as a diluent, a viscosity reducer, or both. An amount of water in fire resistant compositions can be about 40 wt% or less, such as from about 0 wt% to about 30 wt%, such as from about 5 wt% to about 20 wt%, such as from about 10 wt% to about 18 wt% or from about 5 wt% to about 15 wt%. In at least one embodiment, the total amount (in wt%) of water in a fire resistant composition, based on the total weight of the fire resistant composition, can be 0, 0.25, 0.5, 0.75, 1, 1.5, 2, 2.5, 3, 3.5, 4, 4.5, 5, 5.5, 6, 6.5, 7, 7.5, 8, 8.5, 9, 9.5, 10, 10.5, 11, 11.5, 12, 12.5, 13, 13.5, 14, 14.5, 15, 15.5, 16, 16.5, 17, 17.5, 18, 18.5, 19, 19.5, 20, 20.5, 21, 21.5, 22, 22.5, 23, 23.5, 24, 24.5, 25, 25.5, 26, 26.5, 27, 27.5, 28, 28.5, 29, 29.5, or 30, or ranges thereof, though other amounts are contemplated. Each of the foregoing numbers can be preceded by the word “about,” “at least about,” “less than about,” or “more than about,” and any of the foregoing numbers can be used singly to describe an open-ended range or in combination to describe a close-ended range.

[0093] To prepare a fire resistant composition, the components to be used—for example, the expandable graphite and binder component(s)—are mixed together in any suitable order, combination, or sub-combination. In some embodiments, a fire resistant composition is prepared by mixing the expandable graphite, catalyst, blowing agent, thermoplastic compound, and thermoset compound in any order, combination or sub-combination. The fire resistant composition can be dried or cured to form at least a portion of the coating 102. Optional additives, described above, can also be introduced to the mixture. Water can also be utilized, if desired, to aid in mixing the components.

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[0094] In some embodiments, the fire resistant composition comprises, consists of, or consists essentially of one or more of the following: a) a first expandable graphite compound having a mean particle size in the range of about 300 microns to about 1000 microns; b) a second expandable graphite compound having a mean particle size in the range of about 0.5 microns to about 250 microns with a first expandable graphite compound to second expandable graphite compound weight ratio in the range of about 4:1 to about 1:4; c) a binder comprising: i) a thermoplastic compound; and ii) a thermoset compound with a thermoplastic compound to thermoset compound weight ratio in the range of about 10:1 to about 1:3; d) a catalyst; and e) a blowing agent.

[0095] In at least one embodiment, the first expandable graphite compound and second expandable graphite compound are present in a fire resistant composition in a combined amount in the range of about 1 wt% to about 50 wt%, based on the total weight of the fire resistant composition. In some embodiments, the binder is present in a fire resistant composition in the range of about 10 wt% to about 80 wt%, based on the total weight of the fire resistant composition. In at least one embodiment, the blowing agent is present in a fire resistant composition in the range of about 1 wt% to about 20 wt%, based on the total weight of the fire resistant composition. In some embodiments, the catalyst is present in a fire resistant composition in the range of about 0.5 wt% to about 20 wt%, based on the total weight of the composition.

Example Methods

[0096] Embodiments described herein also relate to methods of making articles, for example laminates, described herein. Methods of making or forming the articles described herein can include applying a material comprising, or consisting of, a fire resistant composition to at least a portion of one or more surfaces of the substrate 101 (which can be a radiant barrier layer). Here, the material comprising, or consisting of, a fire resistant composition can be introduced to, coated on, or otherwise applied to the substrate 101 using any suitable method such as brush coating, spray coating, roller coating, dip coating, curtain coating, and combinations thereof. The substrate 101, having the fire resistant composition disposed thereon, can then be cured or dried by suitable methods to form the coating 102. Curing or drying can be performed using suitable methods such as utilizing curing ovens at elevated

temperatures. Heating is optional. Curing or drying can be performed at ambient conditions. Besides heating, other curing and drying methods include, but are not limited to, light, electromagnetic radiation, hot-melt, styrene-acrylics, epoxies, among others. Optionally, adhesives or binders, described above, can be used to secure or otherwise adhere various layers of the article 100.

[0097] The coating 102 can include raised features 103a, recessed features 103b, or combinations thereof, as described above. The features 103 can be formed by using any suitable method such as pressboard molding, stamping, engraving, among other techniques. In some examples, the features 103 can be formed using a notched trowel. The features 103 can be formed into or onto the fire resistant composition before it cures or dries into the coating 102. Alternatively, the features 103 can be formed after the fire resistant composition cures or dries into the coating 102 on substrate 101.

[0098] In some embodiments, the method can include placing fasteners or clips onto the article to facilitate fastening or mounting to a structure or installation. Additionally, or alternatively, holes can be disposed in the article by suitable methods. The holes can facilitate use of nails or screws to secure the article 100 to a structure or installation.

[0099] In some embodiments, a method for making an article 100 described herein can include forming a layer of an intumescent composition on a surface of the substrate 101. Here the layer of an intumescent composition can be formed by, for example, by coating the substrate 101 using any suitable method such as brush coating, spray coating, roller coating, dip coating, curtain coating, and combinations thereof. Features 103 can then be formed on or in the layer by using any suitable method such as pressboard molding, stamping, engraving, among other techniques. In some examples, the features 103 can be formed using a notched trowel. The features 103 can be formed into or onto the intumescent composition before it cures or dries into the coating 102. The method further include drying or curing the intumescent composition with the substrate to form the article 100. Drying and curing is described above. In some embodiments, the features 103 can be formed into or onto the intumescent composition after it cures or dries into the coating 102. Further operations, such as adding fasteners, forming holes, among other operations can be performed as described above.

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[0100] Articles described herein can be pre-formed or pre-fabricated into a variety of shapes such as those used for wrapping walls and roofs of commercial and residential structures or installations among other applications. The substrate 101 can be cut into specific dimensions prior to performing the methods. Alternatively, the finished article 100 (for example, as a cured composite comprising the substrate 101 and the coating 102) can be cut into specific dimensions. The article 100 can be produced in the form of a wrap, a sleeve, a sheath, a mat, a roll, a wall, a panel, a siding, or the like. After production of the articles at a manufacturing site, the produced articles can be installed at a work site.

[0101] The following examples are put forth so as to provide those of ordinary skill in the art with a complete disclosure and description of how to make and use embodiments of the present disclosure, and are not intended to limit the scope of embodiments of the present disclosure. Efforts have been made to ensure accuracy with respect to numbers used but some experimental errors and deviations should be accounted for.

EXAMPLES

[0102] Non-limiting examples of articles were prepared and evaluated using fire testing, water vapor transmission testing, and permeance testing.

[0103] A fire resistant composition was prepared. The non-limiting formulation of the fire resistant composition is shown in Table 1. The viscosity of the fire resistant composition was determined to be about 30,000 cP using a Brookfield viscometer at 25°C and a spindle speed of 20 rpm.

Table 1

	Ingredients	Parts by weight
	Part I	
Water	Water	19.8
Dispersant	DISPERBYK 190	0.84
Pigment	Calcium Carbonate	8.36
Expandable graphite	Nyagraph 251	8.36
	Nyagraph 35	8.36
Blowing agent	Melafine	4.18
Catalyst	Exolit AP 422	8.36
Defoamer	BYK037	0.21
Thickener	Natrosol 250 HR , 2 %	0.2
	Part II	
Water	Water	3.40
Binders	Multibond IP2	28.96
	XB-91MO	7.27
Coalescing agent	NX 795	1.09
Water softener	Sodium Polyphosphate , 10%	0.63
Thickener	Thixol 53L	1.00

[0104] The fire resistant composition was prepared by the following non-limiting procedure. The materials from Part I were charged to a vessel while mixing. The mixture was covered with plastic or wax paper and was allowed to stand for one hour for the mixture to reach equilibrium. The mixture was then gently mixed to form a suspension. The suspension was then ground using a Dispermat at about 3500 rpm for about 20 minutes. After the grinding was completed, the materials from Part II were then charged to the vessel while mixing. The

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pH and viscosity were then measured. If necessary, the pH was adjusted to above 8.5. The mixture was then thickened with Rheotech 3800 rheology improver to achieve the desired thickness.

Fire Testing of Example Article

[0105] An example article (Example 1) for the fire test was made according to the following non-limiting procedure. Fiberglass non-woven scrim weighing about 0.75 ounce/yard (~25 grams per square meter) was placed on a Teflon covered pallet. A layer (or coating) of a fire resistant composition was rolled into the scrim to saturate the scrim. The scrim was flipped onto a second pallet, and a layer of FG was troweled evenly on the surface to a wet weight target of about 1 g/in^2 (~0.16 g/cm^2). A notched trowel was then used to form the water channel peaks and valleys (features). The composition was allowed to dry or cure on the scrim to form the example article.

[0106] The example article (Example 1) demonstrated excellent fire performance. The 20-minute duration of the fire testing, which is twice the industry standard, resulted in temperatures at interface of the example article and the mounting panel below 300°C , when wood begins to char. In addition, visual analysis found excellent char density and height.

Water Vapor Transmission

[0107] Example articles that were subjected to water vapor transmission and permeance testing were made by the same procedure described above for the fire testing. However, the example articles were prepared with different coating weights of the fire resistant composition. Example 2-1 and Example 2-2 had a coating weight of about 0.3 g/in^2 (~0.05 g/cm^2) and about 0.5 g/in^2 (~0.08 g/cm^2), respectively. Example 2-3 and Example 2-4 had a coating weight of about 0.7 g/in^2 (~0.11 g/cm^2) and about 0.9 g/in^2 (~0.14 g/cm^2), respectively.

[0108] After curing the substrate with the fire resistant composition, each example article was cut into sample dimensions of about 2.5 inch diameter (~6.4 cm diameter) for water vapor transmission and water vapor permeance testing. Water vapor transmission and water vapor permeance was determined according to ASTM E96-16, Standard Test Methods for Water Vapor Transmission of Materials (Procedure B). Each sample was tested in triplicate. Each

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sample was attached to an aluminum test cup filled with distilled water to within 0.5 inch of the sample. The sample was then sealed to the test cup using neoprene gaskets. The samples for Example 2-1 and Example 2-2 were tested for 97 hours, while the samples for Example 2-3 and Example 2-4 were tested for 161 hours. All samples were placed in an environmental chamber (ICN: 784) at $23 \pm 2^\circ\text{C}$ and a relative humidity of $50 \pm 2\%$. Periodic measurements (ICN: 1084) were taken to determine the weight change over the course of the testing to determine the rate of water vapor transmission.

[0109] Table 2 shows the results of water vapor transmission and water vapor permeance. In Table 2, water vapor transmission (in standard units and US units) are shown. Also, water vapor permeance is shown in both units of the U.S. perm and the equivalent SI (International System of Units) measure. The SI measure is the nanogram per second per square meter per pascal ($\text{ng}\cdot\text{s}^{-1}\cdot\text{m}^{-2}\cdot\text{Pa}^{-1}$), and $1 \text{ ng}\cdot\text{s}^{-1}\cdot\text{m}^{-2}\cdot\text{Pa}^{-1} \approx 0.0174784 \text{ U.S. perms}$.

Table 2

Example No.	Water Vapor Transmission		Water Vapor Permeance	
	$\text{g}\cdot\text{h}^{-1}\cdot\text{m}^{-2}$	$\text{grains}\cdot\text{h}^{-1}\cdot\text{ft}^2$	$\text{ng}\cdot\text{s}^{-1}\cdot\text{m}^{-2}\cdot\text{Pa}^{-1}$	U.S. perm
Example 2-1	5.32	7.60	1190	20.9
Example 2-2	5.49	7.86	1230	21.6
Example 2-3	4.97	7.10	1060	18.6
Example 2-4	4.95	7.07	1060	18.5

[0110] Overall, the data in Table 2 shows excellent water vapor transmission and water vapor permeance, with water vapor transmission rates of about $4.95 \text{ g}\cdot\text{h}^{-1}\cdot\text{m}^{-2}$ to about $5.49 \text{ g}\cdot\text{h}^{-1}\cdot\text{m}^{-2}$, and water vapor permeance of about $1,060 \text{ ng}\cdot\text{s}^{-1}\cdot\text{m}^{-2}\cdot\text{Pa}^{-1}$ to about $1230 \text{ ng}\cdot\text{s}^{-1}\cdot\text{m}^{-2}\cdot\text{Pa}^{-1}$. The results show that the example articles are permeable to water vapor but resistant

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to bulk water. The results also indicate that, at least under the coating weights tested (0.3, 0.5, 0.7, and 0.9 g/in²) and the conditions tested, the articles have excellent permeability.

[0111] Embodiments of the present disclosure generally relate to vapor permeable, water resistive, and fire resistive articles for residential and commercial structures and installations. Unlike conventional technologies, embodiments of articles described herein can provide moisture permeability, water resistance, and fire resistance in a single article. Further, articles described herein can also serve as an air barrier and can reflect radiant heat.

EMBODIMENTS LISTING

[0112] The present disclosure provides, among others, the following embodiments, each of which can be considered as optionally including any alternate embodiments:

[0113] Clause A1. A vapor permeable laminate, comprising:

a substrate having a first surface and a second surface opposite the first surface, the second surface for facing an interior of a structure; and

an intumescent coating disposed over at least a portion of the first surface of the substrate, the intumescent coating having raised features disposed thereon, recessed features formed therein, or combinations thereof, the features for providing a water drainage path.

[0114] Clause A2. The vapor permeable laminate of Clause A1, wherein the vapor permeable laminate has a water vapor permeance (ASTM E96-16) of at least about 500 ng·s⁻¹·m⁻²·Pa⁻¹.

[0115] Clause A3. The vapor permeable laminate of Clause A2, wherein the water vapor permeance is from about 1,000 ng·s⁻¹·m⁻²·Pa⁻¹ to about 2,000 ng·s⁻¹·m⁻²·Pa⁻¹.

[0116] Clause A4. The vapor permeable laminate of any one of Clauses A1-A3, wherein the substrate is selected from the group consisting of fiberglass, glass, metal, foam, polymer, plastic, elastomer, rubber, cellular solids, or combinations thereof.

[0117] Clause A5. The vapor permeable laminate of any one of Clauses A1-A4, wherein the substrate comprises a material for reflecting radiant heat.

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[0118] Clause A6. The vapor permeable laminate of Clause A5, wherein the material for reflecting radiant heat comprises a metal, a metalloid, an oxide thereof, a salt thereof, an alloy thereof, or combinations thereof.

[0119] Clause A7. The vapor permeable laminate of Clause A5 or Clause A6, wherein the material for reflecting radiant heat comprises aluminum, titanium, iron, barium, silicon, or combinations thereof.

[0120] Clause A8. The vapor permeable laminate of any one of Clauses A1-A7, wherein the substrate is in the form of an open mesh.

[0121] Clause A9. The vapor permeable laminate any one of Clauses A1-A8, wherein the intumescent coating has a coating weight of about 0.015 g/cm^2 to about 0.17 g/cm^2 .

[0122] Clause A10. The vapor permeable laminate any one of Clauses A1-A9, wherein the substrate has a thickness of about 0.05 g/cm^2 to about 0.15 g/cm^2 .

[0123] Clause A11. The vapor permeable laminate any one of Clauses A1-A10, wherein:
the raised features, when present, have a height of about 1 mm to about 5 mm; and
the recessed features, when present, have a depth of about 1 mm to about 5 mm.

[0124] Clause A12. The vapor permeable laminate any one of Clauses A1-A11, wherein the intumescent coating comprises a composition, the composition comprising or being derived from:

an intumescent compound;

a binder comprising a thermoplastic compound and a thermoset compound;

a catalyst; and

a blowing agent.

[0125] Clause A13. The vapor permeable laminate of Clause A12, wherein the intumescent compound comprises:

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a first expandable graphite compound having a mean particle size in a range of about 300 microns to about 1000 microns; and

a second expandable graphite compound having a mean particle size in a range of about 0.5 microns to about 250 microns, wherein a weight ratio of the first expandable graphite compound to the second expandable graphite compound is in a range of about 4:1 to about 1:4.

[0126] Clause A14. The vapor permeable laminate of Clause A12, wherein a weight ratio of the thermoplastic compound to the thermoset compound in the binder is in a range of about 10:1 to about 1:3.

[0127] Clause A15. A building structure, comprising the vapor permeable laminate of any one of Clauses A1-A14 affixed to a wall structure.

[0128] Clause B1. A wrap for a structure or an installation, comprising:

a substrate having a first substrate surface and a second substrate surface opposite the first substrate surface, the second substrate surface for facing an interior of the structure or the installation; and

an intumescent coating having a first coating surface and a second coating surface opposite the first coating surface, the second coating surface adjacent to the first substrate surface, the intumescent coating comprising a composition, the composition comprising or being derived from:

an intumescent compound;

a binder comprising a thermoplastic compound and a thermoset compound;

a catalyst; and

a blowing agent,

the wrap having a water vapor permeance (ASTM E96-16) of at least about $500 \text{ ng} \cdot \text{s}^{-1} \cdot \text{m}^{-2} \cdot \text{Pa}^{-1}$.

[0129] Clause B2. The wrap of Clause B1, further comprising:

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a plurality of raised features disposed on the first coating surface of the intumescent coating;

a plurality of recessed features formed in the first coating surface of the intumescent coating; or

combinations thereof, the features configured to provide a path for water drainage.

[0130] Clause B3. The wrap of Clause B1 or Clause B2, wherein the substrate is selected from the group consisting of fiberglass, glass, metal, foam, polymer, plastic, elastomer, rubber, cellular solids, or combinations thereof.

[0131] Clause B4. The wrap of any one of Clauses B1-B3, wherein the substrate comprises a material for reflecting radiant heat, the material for reflecting radiant heat selected from the group consisting of a metal, a metalloid, an oxide thereof, a salt thereof, an alloy thereof, or combinations thereof.

[0132] Clause C1. A method for making a vapor permeable laminate, the method comprising:

forming a layer comprising an intumescent composition on a surface of a substrate, the intumescent composition configured to expand in the presence of heat;

forming features on or in the layer, the features for providing a water drainage path; and

drying or curing the intumescent composition with the substrate to form the vapor permeable laminate.

[0133] As is apparent from the foregoing general description and the specific embodiments, while forms of the embodiments have been illustrated and described, various modifications can be made without departing from the spirit and scope of the present disclosure. Accordingly, it is not intended that the present disclosure be limited thereby. Likewise, the term “comprising” is considered synonymous with the term “including.” Likewise whenever a composition, an element or a group of elements is preceded with the transitional phrase “comprising,” it is understood that we also contemplate the same

composition or group of elements with transitional phrases “consisting essentially of,” “consisting of,” “selected from the group of consisting of,” or “Is” preceding the recitation of the composition, element, or elements and vice versa, such as the terms “comprising,” “consisting essentially of,” “consisting of” also include the product of the combinations of elements listed after the term.

[0134] For purposes of this present disclosure, and unless otherwise specified, all numerical values within the detailed description and the claims herein are modified by “about” or “approximately” the indicated value, and consider experimental error and variations that would be expected by a person having ordinary skill in the art. For the sake of brevity, only certain ranges are explicitly disclosed herein. However, ranges from any lower limit may be combined with any upper limit to recite a range not explicitly recited, as well as, ranges from any lower limit may be combined with any other lower limit to recite a range not explicitly recited, in the same way, ranges from any upper limit may be combined with any other upper limit to recite a range not explicitly recited. Additionally, within a range includes every point or individual value between its end points even though not explicitly recited. Thus, every point or individual value may serve as its own lower or upper limit combined with any other point or individual value or any other lower or upper limit, to recite a range not explicitly recited.

[0135] The use of headings is for purposes of convenience only and does not limit the scope of the present disclosure.

[0136] Where isomers of a named molecule group exist (for example, n-butyl, iso-butyl, sec-butyl, and tert-butyl), reference to one member of the group (for example, n-butyl) shall expressly disclose the remaining isomers (for example, iso-butyl, sec-butyl, and tert-butyl) in the family. Likewise, reference to a named molecule without specifying a particular isomer (for example, butyl) expressly discloses all isomers (for example, n-butyl, iso-butyl, sec-butyl, and tert-butyl).

[0137] As used herein, the term “about” when referring to a measurable value such as an amount, a temporal duration, and the like, is meant to encompass variations of $\pm 20\%$, $\pm 15\%$, $\pm 10\%$, $\pm 5\%$, $\pm 1\%$, or $\pm 0.1\%$ from the specified value, as such variations are appropriate.

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[0138] As used herein, the indefinite article “a” or “an” shall mean “at least one” unless specified to the contrary or the context clearly indicates otherwise. For example, embodiments comprising “a layer” include embodiments comprising one, two, or more layers, unless specified to the contrary or the context clearly indicates only one layer is included.

[0139] While the foregoing is directed to embodiments of the present disclosure, other and further embodiments of the disclosure may be devised without departing from the basic scope thereof, and the scope thereof is determined by the claims that follow.

CLAIMS

What is claimed is:

1. A vapor permeable laminate, comprising:
a substrate having a first surface and a second surface opposite the first surface, the second surface for facing an interior of a structure; and
an intumescent coating disposed over at least a portion of the first surface of the substrate, the intumescent coating having raised features disposed thereon, recessed features formed therein, or combinations thereof, the features for providing a water drainage path.
2. The vapor permeable laminate of claim 1, wherein the vapor permeable laminate has a water vapor permeance (ASTM E96-16) of at least about $500 \text{ ng} \cdot \text{s}^{-1} \cdot \text{m}^{-2} \cdot \text{Pa}^{-1}$.
3. The vapor permeable laminate of claim 2, wherein the water vapor permeance is from about $1,000 \text{ ng} \cdot \text{s}^{-1} \cdot \text{m}^{-2} \cdot \text{Pa}^{-1}$ to about $2,000 \text{ ng} \cdot \text{s}^{-1} \cdot \text{m}^{-2} \cdot \text{Pa}^{-1}$.
4. The vapor permeable laminate of claim 1, wherein the substrate is selected from the group consisting of fiberglass, glass, metal, foam, polymer, plastic, elastomer, rubber, cellular solids, or combinations thereof.
5. The vapor permeable laminate of claim 1, wherein the substrate comprises a material for reflecting radiant heat.
6. The vapor permeable laminate of claim 5, wherein the material for reflecting radiant heat comprises a metal, a metalloid, an oxide thereof, a salt thereof, an alloy thereof, or combinations thereof.
7. The vapor permeable laminate of claim 5, wherein the material for reflecting radiant heat comprises aluminum, titanium, iron, barium, silicon, or combinations thereof.

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8. The vapor permeable laminate of claim 1, wherein the substrate is in the form of an open mesh.
9. The vapor permeable laminate of claim 1, wherein the intumescent coating has a coating weight of about 0.015 g/cm^2 to about 0.17 g/cm^2 .
10. The vapor permeable laminate of claim 1, wherein the substrate has a thickness of about 0.05 g/cm^2 to about 0.15 g/cm^2 .
11. The vapor permeable laminate of claim 1, wherein:
 - the raised features, when present, have a height of about 1 mm to about 5 mm; and
 - the recessed features, when present, have a depth of about 1 mm to about 5 mm.
12. The vapor permeable laminate of claim 1, wherein the intumescent coating comprises a composition, the composition comprising or being derived from:
 - an intumescent compound;
 - a binder comprising a thermoplastic compound and a thermoset compound;
 - a catalyst; and
 - a blowing agent.
13. The vapor permeable laminate of claim 12, wherein the intumescent compound comprises:
 - a first expandable graphite compound having a mean particle size in a range of about 300 microns to about 1000 microns; and
 - a second expandable graphite compound having a mean particle size in a range of about 0.5 microns to about 250 microns, wherein a weight ratio of the first expandable graphite compound to the second expandable graphite compound is in a range of about 4:1 to about 1:4.
14. The vapor permeable laminate of claim 12, wherein a weight ratio of the thermoplastic compound to the thermoset compound in the binder is in a range of about 10:1 to about 1:3.

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15. A building structure, comprising the vapor permeable laminate of claim 1 affixed to a wall structure.

16. A wrap for a structure or an installation, comprising:

a substrate having a first substrate surface and a second substrate surface opposite the first substrate surface, the second substrate surface for facing an interior of the structure or the installation; and

an intumescent coating having a first coating surface and a second coating surface opposite the first coating surface, the second coating surface adjacent to the first substrate surface, the intumescent coating comprising a composition, the composition comprising or being derived from:

an intumescent compound;

a binder comprising a thermoplastic compound and a thermoset compound;

a catalyst; and

a blowing agent,

the wrap having a water vapor permeance (ASTM E96-16) of at least about $500 \text{ ng} \cdot \text{s}^{-1} \cdot \text{m}^{-2} \cdot \text{Pa}^{-1}$.

17. The wrap of claim 16, further comprising:

a plurality of raised features disposed on the first coating surface of the intumescent coating;

a plurality of recessed features formed in the first coating surface of the intumescent coating; or

combinations thereof, the features configured to provide a path for water drainage.

18. The wrap of claim 16, wherein the substrate is selected from the group consisting of fiberglass, glass, metal, foam, polymer, plastic, elastomer, rubber, cellular solids, or combinations thereof.

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19. The wrap of claim 16, wherein the substrate comprises a material for reflecting radiant heat, the material for reflecting radiant heat selected from the group consisting of a metal, a metalloid, an oxide thereof, a salt thereof, an alloy thereof, or combinations thereof.

20. A method for making a vapor permeable laminate, the method comprising:
forming a layer comprising an intumescent composition on a surface of a substrate, the intumescent composition configured to expand in the presence of heat;
forming features on or in the layer, the features for providing a water drainage path; and
drying or curing the intumescent composition with the substrate to form the vapor permeable laminate.

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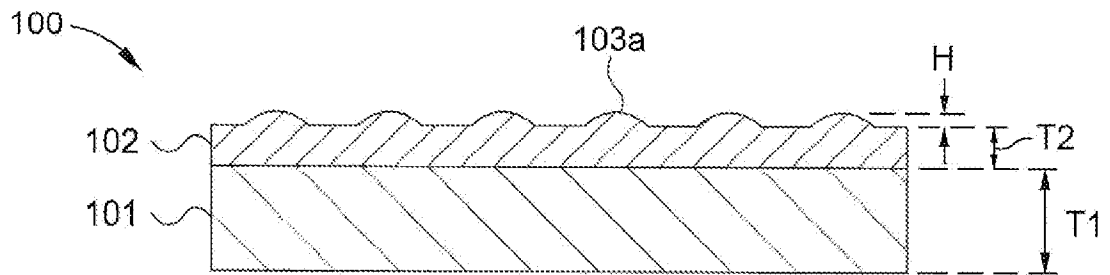


FIG. 1A

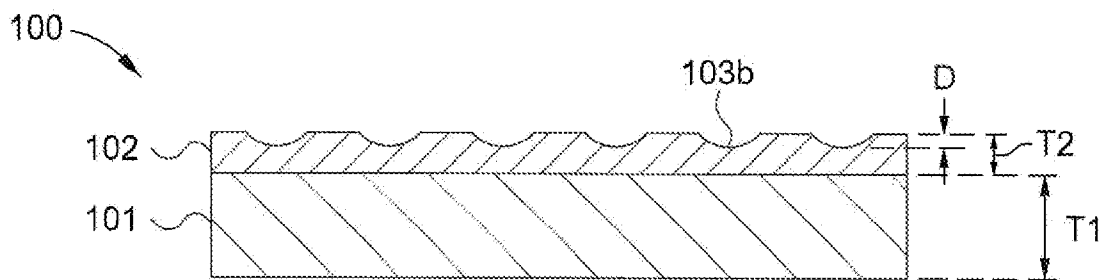


FIG. 1B

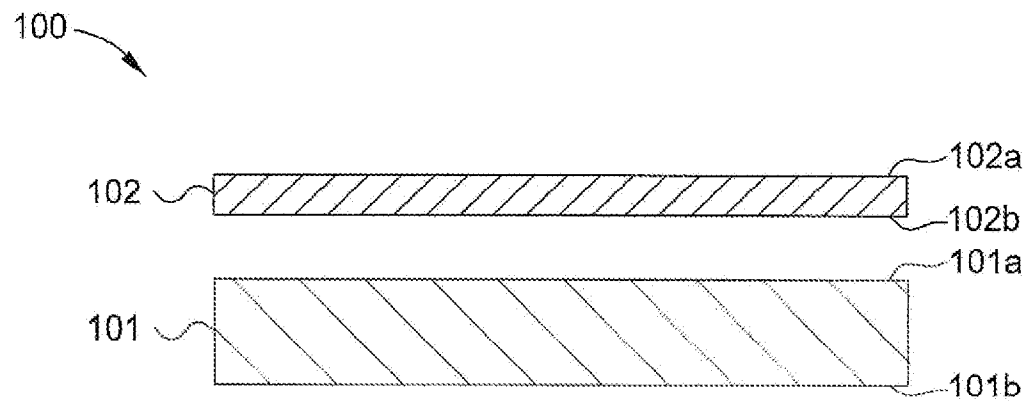


FIG. 1C

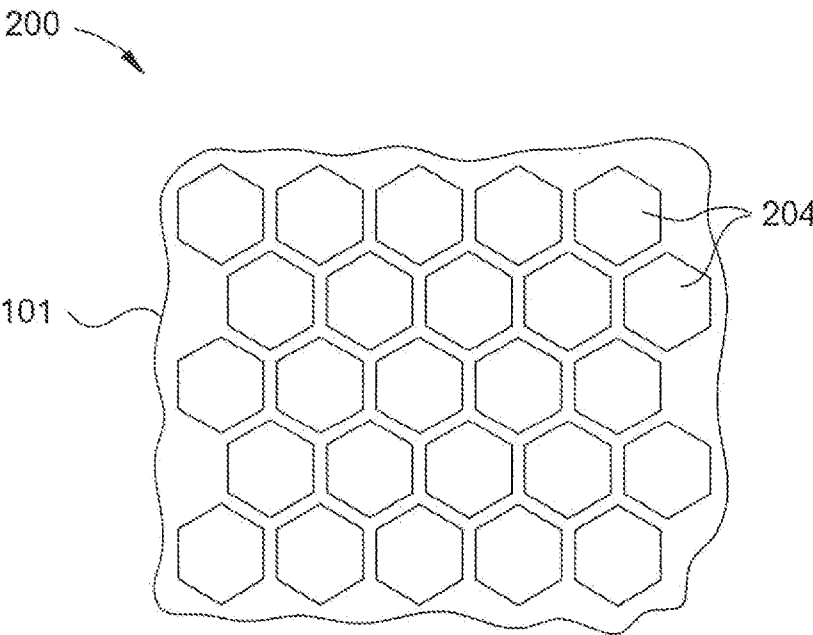


FIG. 2