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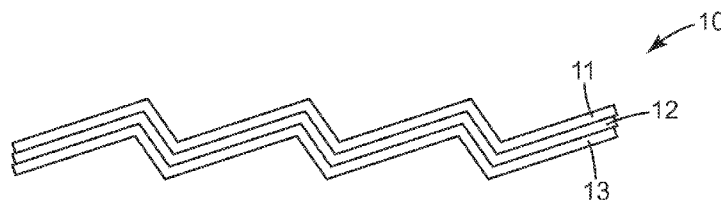


Fig. 1

(57) Abstract: A building construction article includes an infrared (IR) reflective film configured to reflect at least 50 percent of incident IR light over a range of IR wavelengths, an ultraviolet (UV) reflective film configured to reflect at least 50 percent of incident UV light over a range of UV wavelengths, and a first adhesive layer disposed between the IR reflective film and the ultraviolet reflective film. At least one of the IR reflective film, UV reflective film, and first adhesive layer can include an IR transmissive colorant.



REFLECTIVE ARTICLES FOR BUILDING CONSTRUCTION WITH VISIBLE LIGHT ABSORBING COLORANTS

TECHNICAL FIELD

[0001] The present disclosure relates to building materials. More specifically, the present disclosure relates to textured UV-IR reflective panels for building applications with visible light absorbing colorants.

BACKGROUND

[0002] As building energy efficiency has become of increasing importance in the world, the demand for energy efficient roof systems has increased. In certain communities, building codes have been issued to require more energy efficient buildings. Energy-efficient roofing materials can result in cooler roof surfaces and less energy spent to cool a building. As such, energy-efficient roofing materials can reduce building cooling costs. The use of energy efficient roof coatings can also reduce the amount of roof insulation required in a building

SUMMARY

[0003] In one aspect, a building construction article includes an infrared (IR) reflective film configured to reflect at least 50 percent of incident IR light over a range of IR wavelengths, an ultraviolet (UV) reflective film configured to reflect at least 50 percent of incident UV light over a range of UV wavelengths, and a first adhesive layer disposed between the IR reflective film and the ultraviolet reflective film. At least one of the IR reflective film, UV reflective film, and first adhesive layer includes an IR transmissive colorant. In some embodiments, a polymeric support layer is disposed on a side of the IR reflective film opposite the UV reflective film, and a second adhesive layer is provided between the IR reflective film and the polymeric support layer. Optionally, the second adhesive layer includes the IR transmissive colorant. In some embodiments, a porous insulating sheet is coupled to the polymeric support layer on a side opposite the IR reflective film. Optionally, a metallic coating on the porous insulating sheet on a side opposite the polymeric support layer. In some embodiments, a metallic coating (e.g., aluminum, copper, or silver) is provided on a side of the IR reflective film opposite the UV reflective film. In some embodiments, a protective coating is applied on a side of the UV reflective film opposite the IR reflective film. The protective coating may comprise a fluoropolymer, siloxane, acrylate, or urethane cross-linked with the UV reflective film. In some embodiments, a top surface of the building construction article is textured or corrugated, and wherein the building construction article further comprises a visible light absorbing colorant. In

some embodiments, the building construction article is configured to reflect narrow bands of visible light to provide coloring. In some embodiments, the IR reflective film and/or the UV reflective film include embossed sections that are thinner than non-embossed sections of the IR reflective film and/or UV reflective film.

[0004] In another aspect, a building construction article includes a textured or corrugated assembly including an infrared (IR) reflective film configured to reflect at least 50 percent of incident IR light over a range of IR wavelengths, an ultraviolet (UV) reflective film configured to reflect at least 50 percent of incident UV light over a range of UV wavelengths, a polymeric support layer on a side of the IR reflective film opposite the UV reflective film, and a visible light absorbing colorant. A porous insulating sheet can be coupled to the polymeric support layer on a side opposite the IR reflective film. In some embodiments, the textured or corrugated assembly further includes a first adhesive layer between the IR reflective film and the UV reflective film, and/or a second adhesive layer between the IR reflective film and the polymeric support layer. Optionally, at least one of the IR reflective film, UV reflective film, first adhesive layer and second adhesive layer includes an IR transmissive colorant. In some embodiments, a metallic coating (e.g., aluminum, copper, or silver) is provided on the porous insulating sheet on a side opposite the polymeric support layer, and/or a metallic coating (e.g., aluminum, copper, or silver) is provided on a side of the IR reflective film opposite the UV reflective film. In some embodiments, a protective coating is applied on a side of the UV reflective film opposite the IR reflective film. The protective coating may comprise a fluoropolymer, siloxane, acrylate, or urethane cross-linked with the UV reflective film. In some embodiments, the IR reflective film and/or the UV reflective film include embossed sections that are thinner than non-embossed sections of the IR reflective film and/or UV reflective film.

[0005] In a further aspect, a method for manufacturing a building construction article includes adhering an infrared (IR) reflective film to an ultraviolet (UV) reflective film with an adhesive including an IR transmissive colorant to form a UV-IR reflective assembly. In some embodiments, the IR reflective film is configured to reflect at least 50 percent of incident IR light over a range of IR wavelengths and the UV reflective film configured to reflect at least 50 percent of incident UV light over a range of UV wavelengths. The method further comprises applying a visible light absorbing colorant to the UV-IR reflective assembly, and thermoforming the UV-IR reflective assembly to provide a textured or corrugated outer surface on the UV-IR reflective assembly. In some embodiments, the method further includes coating the IR reflective film with a metal on a side opposite the UV reflective film and/or adhering a polymeric support layer to the UV-IR reflective assembly on a side of the IR reflective film opposite the UV reflective film. In some embodiments, the method further includes coupling a porous insulating sheet to the

polymeric support layer on a side opposite the IR reflective film. The method may further include coating the porous insulating sheet with a metal on a side opposite the polymeric support layer. In some embodiments, the method further includes applying a protective coating to a side of the UV reflective film opposite the IR reflective film. The method may further include singulating the UV-IR reflective assembly into a plurality of individual building construction articles. The method may further include embossing the IR reflective film and/or the UV reflective film such that embossed sections are thinner than non-embossed sections of the IR reflective film and/or UV reflective film

[0006] In a still further aspect a building construction article includes an infrared (IR) reflective film configured to reflect at least 50 percent of incident IR light over a range of IR wavelengths, an ultraviolet (UV) reflective film configured to reflect at least 50 percent of incident UV light over a range of UV wavelengths, and a corrugated solar energy absorbing polymeric structural layer disposed between the IR reflective film and UV reflective film. In some embodiments, the building construction article further includes one or more ducts configured for coupling to a collection manifold for solar harvesting of low grade heat. In some embodiments, the one or more ducts are configured for coupling to a solar thermal unit for storage or transfer of the low grade heat. In some embodiments, a low emissivity coating is formed on the UV reflective film and/or corrugated solar energy absorbing polymeric structure. In some embodiments, the IR reflective film and/or the UV reflective film include embossed sections that are thinner than non-embossed sections of the IR reflective film and/or UV reflective film.

[0007] While multiple embodiments are disclosed, still other embodiments of the present invention will become apparent to those skilled in the art from the following detailed description, which shows and describes illustrative embodiments of the invention. Accordingly, the drawings and detailed description are to be regarded as illustrative in nature and not restrictive.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] FIGS. 1-6 are schematic cross-sectional views of embodiments of a reflective textured multilayer building construction article according to the present disclosure.

[0009] FIGS. 7-12 are schematic cross-sectional views of embodiments of a reflective corrugated multilayer building construction article according to the present disclosure.

[0010] FIG. 13 is a schematic view of a system including a building construction article according to the present disclosure for harvesting and storing solar energy.

[0011] FIGS. 14 and 15 are schematic cross-sectional views of embodiments of a reflective textured multilayer building construction article in which thermal embossing thins the optical layers to change the reflection band of the building construction article.

DETAILED DESCRIPTION

[0012] FIG. 1 is a schematic cross-sectional view of a reflective textured multilayer building construction article 10 according to an embodiment of the present disclosure. The building construction article 10 includes an ultraviolet (UV) reflective film 11, an optional adhesive layer 12, and an infrared (IR) reflective film 13. The adhesive layer 12 secures the UV reflective film 11 to the IR reflective film 13. The UV reflective film 11 and IR reflective film 13 are in intimate contact. “Ultraviolet” (also “UV”) as used herein refers to electromagnetic radiation having wavelengths up to 400 nm. “Infrared” (also “IR”) as used herein refers to electromagnetic radiation having wavelengths greater than 750 nm.

[0013] The building construction article 10 illustrated includes a texturing along the upper and lower surfaces of the article 10. In some embodiments, the texturing is provided to resemble conventional building materials and to give the building construction articles an aesthetically pleasing appearance. In FIG. 1, texturing is represented by the zigzagging of each of the layers. For example, the texturing can give the building construction article the appearance of wood grain, roofing shingles, roofing tiles, or building siding. In addition, in some embodiments, the building construction article 10 includes one or more visible light absorbing colorants that further give the appearance of a conventional construction article. Further, the building construction article can be configured such that narrow bands of visible light are reflected to achieve a desired color or aesthetically pleasing color patterns. In alternative embodiments, no visible light colorants are used in the building construction article, and the UV reflective film 11, adhesive layer 12, and IR reflective film 13 are comprised of visible light transmissive material to allow the building construction article 10 to be used to provide interior building day lighting.

[0014] To form the building construction article 10, an assembly of the UV reflective film 11 and IR reflective film 13 may be manufactured by applying an adhesive layer 12 to one of the films 11, 13 and securing the other the films 11, 13 thereto. The assembly may then be thermoformed or otherwise shaped to include texturing (e.g., embossing) or other features to provide the desired appearance. Thermoforming of multilayer optical films is generally described in U.S. Patent No. 6,788,463 B2 (Merrill et al.), which is hereby incorporated by reference in its entirety. Flame embossing is another useful method for texturing films and is described in U.S. Patent No. 6,096,247 (Strobel et al.), which is hereby incorporated by reference in its entirety. Other possible forming techniques include vacuum forming, shaping, rolling, or pressure forming the building construction article into shapes and/or dimensions. In some embodiments, the assembly may then be cut (e.g., singulated) into building construction articles 10 having the desired size and shape.

[0015] The UV reflective film 11 and/or IR reflective film 13 may be configured to reflect at least 50 percent (in some embodiments, at least 55, 60, 65, 70, 75, 80, 85, 90, 95, 96, 97, or 98) percent of incident light over a wavelength range within the UV and IR wavelength spectrum.

[0016] The UV reflective film 11 and/or IR reflective film 13 may comprise a plurality of laminated optical layers. In some embodiments, the UV reflective film 11 and/or IR reflective film 13 includes at least 100 layers (e.g., 100 to greater than 2,000 total layers). For example, the UV reflective film 11 and/or IR reflective film 13 may include a plurality of alternating layers (e.g., first and second optical layers) having different optical and chemical properties. In some embodiments, the alternating first and second layers of the multilayer films 11 and/or 13 have a difference in refractive index of at least 0.04 (in some embodiments in some embodiments, at least 0.05, 0.06, 0.07, 0.08, 0.09, 0.1, 0.125, 0.15, 0.175, 0.2, 0.225, 0.25, 0.275, or 0.3).

[0017] By appropriate selection of the first optical layers and the second optical layers, the UV reflective film 11 and/or IR reflective film 13 can be designed to reflect or transmit a desired bandwidth of light. It will be understood from the foregoing discussion that the choice of a second optical layer is dependent not only on the intended application of the multilayer optical film, but also on the choice made for the first optical layer, as well as the processing conditions.

[0018] As light passes through optical stack 140, the light or some portion of the light will be transmitted through an optical layer, absorbed by an optical layer, or reflected off the interface between the optical layers.

[0019] The light transmitted through an optical layer is related to absorbance, thickness, and reflection. Transmission (T) is related to absorbance (A) in that $A = -\log T$, and $\%A + \%T + \% \text{reflection} = 100\%$. Reflection is generated at each interface between the optical layers. As discussed above, the first and second layers of UV reflective film 11 and/or IR reflective film 13 have respective refractive indices that are different, n_1 and n_2 , respectively. Light may be reflected at the interface of adjacent optical layers. Light that is not reflected at the interface of adjacent optical layers typically passes through successive layers and is either absorbed in a subsequent optical layer, reflected at a subsequent interface, or is transmitted through the UV reflective film 11 and/or IR reflective film 13. Typically, the optical layers of a given layer pair are selected such as to be substantially transparent to those light wavelengths at which reflectivity is desired. Light that is not reflected at a layer pair interface passes to the next layer pair interface where a portion of the light is reflected and unreflected light continues on, and so on. In this way, a UV reflective film 11 and/or IR reflective film 13 with many optical layers (e.g., more than 50, more than 100, more than 1000, or even more than 2000 optical layers) is capable of generating a high degree of reflectivity.

[0020] In general, the reflectivity of the interface of adjacent optical layers is proportional to the square of the difference in index of refraction on the first optical layer and the second optical layer at the reflecting wavelength. The absolute difference in refractive index between the layer pair ($n_1 - n_2$) is typically 0.1 or larger. Higher refractive index differences between the first optical layer and the second optical layer are desirable, because more optical power (e.g., reflectivity) can be created, thus enabling more reflective bandwidth. However, the absolute difference between the layer pair may be less than 0.20, less than 0.15, less than 0.10, less than 0.05, or even less than 0.03, depending on the layer pair selected. For example, poly(methyl methacrylate) and DYNEON HTE 1705 have an absolute refractive index difference of 0.12.

[0021] By selecting the appropriate layer pairs, the layer thickness, and/or the number of layer pairs, the optical stack can be designed to transmit or reflect the desired wavelengths. The thickness of each layer may influence the performance of the optical stack by either changing the amount of reflectivity or shifting the reflectivity wavelength range. The optical layers typically have an average individual layer thickness of about one quarter of the wavelength of interest, and a layer pair thickness of about one half of the wavelength of interest. The optical layers can each be a quarter-wavelength thick or the optical layers can have different optical thicknesses, as long as the sum of the optical thicknesses for the layer pair is half of a wavelength (or a multiple thereof). For example, to reflect 400 nanometer (nm) light, the average individual layer thickness would be about 100 nm, and the average layer pair thickness would be about 200 nm. Similarly, to reflect 800 nm light, the average individual layer thickness would be about 200 nm, and the average layer pair thickness would be about 400 nm. The first and second optical layers may have the same thicknesses. Alternatively, the optical stack can include optical layers with different thicknesses to increase the reflective wavelength range. An optical stack having more than two layer pairs can include optical layers with different optical thicknesses to provide reflectivity over a range of wavelengths. For example, an optical stack can include layer pairs that are individually tuned to achieve optimal reflection of normally incident light having particular wavelengths or may include a gradient of layer pair thicknesses to reflect light over a larger bandwidth. The normal reflectivity for a particular layer pair is primarily dependent on the optical thickness of the individual layers, where optical thickness is defined as the product of the actual thickness of the layer times its refractive index. The intensity of light reflected from the optical layer stack is a function of its number of layer pairs and the differences in refractive indices of optical layers in each layer pair. The ratio $n_1 d_1 / (n_1 d_1 + n_2 d_2)$ (commonly termed the “f-ratio”) correlates with reflectivity of a given layer pair at a specified wavelength. In the f-ratio, n_1 and n_2 are the respective refractive indexes at the specified wavelength of the first and second optical layers in a layer pair, and d_1 and d_2 are the respective thicknesses of the first and second optical layers in the layer pair. By proper selection of

the refractive indexes, optical layer thicknesses, and f-ratio, one can exercise some degree of control over the intensity of first order reflection. For example, first order visible reflections of violet (400 nanometers wavelength) to red (700 nanometers wavelength) can be obtained with layer optical thicknesses between about 0.05 and 0.3 nanometers. In general, deviation from an f-ratio of 0.5 results in a lesser degree of reflectivity.

[0022] The equation $\lambda/2 = n_1d_1 + n_2d_2$ can be used to tune the optical layers to reflect light of wavelength λ at a normal angle of incidence. At other angles, the optical thickness of the layer pair depends on the distance traveled through the component optical layers (which is larger than the thickness of the layers) and the indices of refraction for at least two of the three optical axes of the optical layer. The optical layers can each be a quarter-wavelength thick or the optical layers can have different optical thicknesses, as long as the sum of the optical thicknesses is half of a wavelength (or a multiple thereof). An optical stack (e.g., UV reflective film 11 and/or IR reflective film 13) having more than two layer pairs can include optical layers with different optical thicknesses to provide reflectivity over a range of wavelengths. For example, an optical stack can include layer pairs that are individually tuned to achieve optimal reflection of normally incident light having particular wavelengths or may include a gradient of layer pair thicknesses to reflect light over a larger bandwidth. A typical approach is to use all or mostly quarter-wave film stacks. In this case, control of the spectrum requires control of the layer thickness profile in the film stack. A broadband spectrum, such as one required to reflect visible light over a large range of angles in air, still requires a large number of layers if the layers are polymeric, due to the relatively small refractive index differences achievable with polymer films compared to inorganic films. Layer thickness profiles of such optical stacks can be adjusted to provide for improved spectral characteristics using the axial rod apparatus taught in U.S. Patent No. 6,783,349 (Neavin et al.) combined with layer profile information obtained with microscopic techniques.

[0023] One technique for providing a multilayer optical film (e.g., UV reflective film 11 and/or IR reflective film 13) with a controlled spectrum includes:

- 1) The use of an axial rod heater control of the layer thickness values of coextruded polymer layers as taught in U.S. Patent No. 6,783,349 (Neavin et al.).
- 2) Timely layer thickness profile feedback during production from a layer thickness measurement tool such as e.g., an atomic force microscope, a transmission electron microscope, or a scanning electron microscope.
- 3) Optical modeling to generate the desired layer thickness profile.

- 4) Repeating axial rod adjustments based on the difference between the measured layer profile and the desired layer profile.

[0024] The basic process for layer thickness profile control involves adjustment of axial rod zone power settings based on the difference of the target layer thickness profile and the measured layer profile. The axial rod power increase needed to adjust the layer thickness values in a given feedblock zone may first be calibrated in terms of watts of heat input per nanometer of resulting thickness change of the layers generated in that heater zone. Fine control of the spectrum is possible using 24 axial rod zones for 275 layers. Once calibrated, the necessary power adjustments can be calculated once given a target profile and a measured profile. The procedure may be repeated until the two profiles converge.

[0025] Increasing the number of optical layers in the optical stack may also provide more optical power. For example, if the refractive index between the layer pairs is small, the optical stack may not achieve the desired reflectivity, however by increasing the number of layer pairs, sufficient reflectivity may be achieved. In one embodiment of the present disclosure, the optical stack comprises at least 2 first optical layers and at least 2 second optical layers, at least 5 first optical layers and at least 5 second optical layers, at least 50 first optical layers and at least 50 second optical layers, at least 200 first optical layers and at least 200 second optical layers, at least 500 first optical layers and at least 500 second optical layers, or even at least 1000 first optical layers and at least 1000 second optical layers.

[0026] Birefringence (e.g., caused by stretching) of optical layers is another effective method for increasing the difference in refractive index of the optical layers in a layer pair. Optical stacks that include layer pairs, which are oriented in two mutually perpendicular in-plane axes are capable of reflecting an extraordinarily high percentage of incident light depending on, e.g., the number of optical layers, f-ratio, and the indices of refraction, and are highly efficient reflectors.

[0027] Exemplary materials for making the reflective layers for the UV reflective film 11 and/or IR reflective film 13 include polymers (e.g., polyesters, copolyesters, and modified copolyesters). In this context, the term “polymer” will be understood to include homopolymers and copolymers, as well as polymers or copolymers that may be formed in a miscible blend, for example, by co-extrusion or by reaction, including transesterification. The terms “polymer” and “copolymer” include both random and block copolymers. Polyesters suitable for use in some exemplary multilayer optical films constructed according to the present disclosure generally include dicarboxylate ester and glycol subunits and can be generated by reactions of carboxylate monomer molecules with glycol monomer molecules. Each dicarboxylate ester monomer molecule has two or more carboxylic acid or ester functional groups and each glycol monomer molecule has two or more hydroxy functional groups. The dicarboxylate ester monomer molecules may all be

the same or there may be two or more different types of molecules. The same applies to the glycol monomer molecules. Also included within the term “polyester” are polycarbonates derived from the reaction of glycol monomer molecules with esters of carbonic acid.

[0028] Examples of suitable dicarboxylic acid monomer molecules for use in forming the carboxylate subunits of the polyester layers include 2,6-naphthalene dicarboxylic acid and isomers thereof; terephthalic acid; isophthalic acid; phthalic acid; azelaic acid; adipic acid; sebacic acid; norbornenedicarboxylic acid; bi-cyclo-octane dicarboxylic acid; 1,4-cyclohexanedicarboxylic acid and isomers thereof; t-butylisophthalic acid, trimellitic acid, sodium sulfonated isophthalic acid; 4,4'-biphenyl dicarboxylic acid and isomers thereof; and lower alkyl esters of these acids, such as methyl or ethyl esters. The term “lower alkyl” refers, in this context, to C₁-C₁₀ straight-chain or branched alkyl groups.

[0029] Examples of suitable glycol monomer molecules for use in forming glycol subunits of the polyester layers include ethylene glycol; propylene glycol; 1,4-butanediol and isomers thereof; 1,6-hexanediol; neopentyl glycol; polyethylene glycol; diethylene glycol; tricyclodecanediol; 1,4-cyclohexanedimethanol and isomers thereof; norbornanediol; bicyclooctanediol; trimethylolpropane; pentaerythritol; 1,4-benzenedimethanol and isomers thereof; Bisphenol A; 1,8-dihydroxybiphenyl and isomers thereof; and 1,3-bis(2-hydroxyethoxy)benzene.

[0030] Another exemplary birefringence polymer useful for the reflective layer(s) is polyethylene terephthalate (PET), which can be made, for example, by reaction of terephthalic dicarboxylic acid with ethylene glycol. Its refractive index for polarized incident light of 550 nm wavelength increases when the plane of polarization is parallel to the stretch direction from about 1.57 to as high as about 1.69. Increasing molecular orientation increases the birefringence of PET. The molecular orientation may be increased by stretching the material to greater stretch ratios and holding other stretching conditions fixed. Copolymers of PET (CoPET), such as those described in U.S. Patent No. 6,744,561 (Condo et al.) and U.S. Patent No. 6,449,093 (Hebrink et al), the disclosures of which are incorporated herein by reference, are particularly useful for their relatively low temperature (typically less than 250°C) processing capability making them more coextrusion compatible with less thermally stable second polymers. Other semicrystalline polyesters suitable as birefringent polymers include polybutylene terephthalate (PBT), polyethylene terephthalate (PET), and copolymers thereof such as those described in U.S. Patent No. 6,449,093 B2 (Hebrink et al.) or U.S. Patent Application Publication No. 2006/0084780 (Hebrink et al.), the disclosures of which are incorporated herein by reference. Another useful birefringent polymer is syndiotactic polystyrene (sPS).

[0031] Further, for example, the second (layer) polymer of the multilayer optical film can be made from a variety of polymers having glass transition temperatures compatible with that of the first layer and having a refractive index similar to the isotropic refractive index of the birefringent polymer. Examples of other polymers suitable for use in optical films and, particularly, in the second polymer include vinyl polymers and copolymers made from monomers such as vinyl naphthalenes, styrene, maleic anhydride, acrylates, and methacrylates. Examples of such polymers include polyacrylates, polymethacrylates, such as poly (methyl methacrylate) (PMMA), and isotactic or syndiotactic polystyrene. Other polymers include condensation polymers such as polysulfones, polyamides, polyurethanes, polyamic acids, and polyimides. In addition, the second polymer can be formed from homopolymers and copolymers of polyesters, polycarbonates, fluoropolymers, and polydimethylsiloxanes, and blends thereof.

[0032] Other exemplary polymers, for the optical layers include homopolymers of polymethylmethacrylate (PMMA), such as those available from Ineos Acrylics, Inc., Wilmington, DE, under the trade designations “CP71” and “CP80;” and polyethyl methacrylate (PEMA), which has a lower glass transition temperature than PMMA. Additional useful polymers include copolymers of PMMA (CoPMMA), such as a CoPMMA made from 75 wt% methylmethacrylate (MMA) monomers and 25 wt% ethyl acrylate (EA) monomers, (available from Ineos Acrylics, Inc., under the trade designation “PERSPEX CP63” or Arkema, Philadelphia, PA, under the trade designation “ATOGLAS 510”), a CoPMMA formed with MMA comonomer units and n-butyl methacrylate (nBMA) comonomer units, or a blend of PMMA and poly(vinylidene fluoride) (PVDF), for example as described in U.S. Patent No. 7,141,297 (Condo et al.), which is hereby incorporated by reference in its entirety.

[0033] Additional suitable polymers for the optical layers include polyolefin copolymers such as poly (ethylene-co-octene) (PE-PO) available from Dow Elastomers, Midland, MI, under the trade designation “ENGAGE 8200,” poly (propylene-co-ethylene) (PPPE) available from Atofma Petrochemicals, Inc., Houston, TX, under the trade designation “Z9470,” and a copolymer of atactic polypropylene (aPP) and isotactic polypropylene (iPP). The multilayer optical films can also include, for example, in the second layers, a functionalized polyolefin, such as linear low density polyethylene-graft-maleic anhydride (LLDPE-g-MA) such as that available from E.I. duPont de Nemours & Co., Inc., Wilmington, DE, under the trade designation “BYNEL 4105.”

[0034] Preferred polymer compositions in alternating layers with the at least one birefringent polymer include PMMA, CoPMMA, poly(dimethylsiloxane oxamide) based segmented copolymer (SPOX), fluoropolymers including homopolymers such as PVDF and copolymers such as those derived from tetrafluoroethylene, hexafluoropropylene, and vinylidene fluoride (THV), blends of PVDF/PMMA, acrylate copolymers, styrene, styrene copolymers,

silicone copolymers, polycarbonate, polycarbonate copolymers, polycarbonate blends, blends of polycarbonate and styrene maleic anhydride, and cyclic-olefin copolymers.

[0035] The selection of the polymer combinations used in creating the UV reflective film 11 and/or IR reflective film 13 depends, for example, upon the desired bandwidth that will be reflected. Higher refractive index differences between the birefringent polymer and the second polymer create more optical power thus enabling more reflective bandwidth.

[0036] Alternatively, additional layers may be employed to provide more optical power. Preferred combinations of birefringent layers and second polymer layers may include, for example, the following: PET/THV, PET/SPOX, PEN/THV, PEN/SPOX, PEN/PMMA, PET/CoPMMA, PEN/CoPMMA, CoPEN/PMMA, CoPEN/SPOX, sPS/SPOX, sPS/THV, CoPEN/THV, PET/fluoroelastomers, sPS/fluoroelastomers and CoPEN/ fluoroelastomers.

[0037] In one embodiment, two or more multilayer optical mirrors with different reflection bands are laminated together to broaden the reflection band. For example, a PET/CoPMMA multilayer reflective mirror which reflects 98% of the light from 350 nm to 500 nm would be laminated to a PET/CoPMMA multilayer reflective mirror which reflects 90% of the light from 650 nm to 1350 nm to create a UV stabilized IR colored mirror reflecting light from 650 nm to 1350 nm. In another example, a PET/CoPMMA multilayer reflective mirror that reflects 96.8% of the light from 370 nm to 800 nm could be laminated to a multilayer reflective mirror which reflects 96.8% of the light from 700 nm to 1300 nm to create a broader band mirror reflecting light from 400 nm to 1300 nm.

[0038] Preferred material combinations for making the optical layers that reflect UV and/or IR light (e.g., the first and second optical layers) include PMMA/THV, PC/THV, PC (polycarbonate)/PMMA, PC(polycarbonate)/(PVDF/PMMA blend), (80:20 PMMA/PVDF blend first optical layers)/(20:80 PVDF/PMMA second optical layers), and PET/CoPMMA.

[0039] The UV reflective film 11 and/or IR reflective film 13 can be fabricated by methods well-known to those of skill in the art by techniques such as e.g., co-extruding, laminating, coating, vapor deposition, or combinations thereof. In co-extrusion, the polymeric materials are co-extruded into a web. In co-extrusion, it is preferred that the two polymeric materials have similar rheological properties (e.g., melt viscosities) to prevent layer instability or non-uniformity. In lamination, sheets of polymeric materials are layered together and then laminated using either heat, pressure, and/or an adhesive. In coating, a solution of one polymeric material is applied to another polymeric material. In vapor deposition, one polymeric material is vapor deposited onto another polymeric material. Additionally, functional additives may be added to the first optical layer, the second optical layer, and/or the optional additional layers to improve

processing. Examples of functional additives include processing additives, which may e.g., enhance flow and/or reduce melt fracture.

[0040] Other examples of suitable configurations and materials for the UV reflective film 11, adhesive layer 12, IR reflective film 13, and additional optional layers are described in PCT Publication No. WO2011/062836, entitled “Multi-Layer Optical Films,” and U.S. Patent Application Publication No. 2011/0255155, entitled “Fluoropolymeric Multilayer Optical Film and Methods of Making and Using the Same,” each of which is incorporated by reference in its entirety for all purposes.

[0041] The optional adhesive layer 12 may be any adhesive suitable for intimately coupling the UV reflective film 11 to the IR reflective film 13. In one embodiment, the adhesive layer 12 is an optically clear adhesive (available from 3M Company, St. Paul, MN, under the trade designation “OPTICALLY CLEAR LAMINATING ADHESIVE PSA 8171”). In another embodiment, the adhesive layer 12 is an extrudable thermoplastic adhesive. In yet another embodiment, the adhesive layer 12 is a cross-linkable silicone or cross-linkable urethane polymer. An exemplary adhesive layer 12 is an acrylic foam tape (available from 3M Company, St. Paul, MN under the trade designation VHB). In alternative embodiments, the UV reflective film 11 is coupled to the IR reflective film 13 by other means, such as co-extruding, laminating, coating, vapor deposition, or combinations thereof.

[0042] In some embodiments, at least one of the UV reflective film 11, adhesive layer 12, and IR reflective film 13 includes an IR transmissive colorant or pigment. For example, the IR transmissive colorant may be blended into the polymeric layers of the UV reflective film 11 and/or IR reflective film 13, or into an extrudable thermoplastic of the adhesive layer 12. The IR transmissive colorant may be substantially transmissive of both near-IR radiation and IR radiation. Suitable infrared-transmissive colorant can be inorganic or organic. Examples of IR transmissive colorants that can be employed in the UV reflective film 11, adhesive layer 12, and/or IR reflective film 13 include zinc sulfide, zinc oxide, nanoparticle titanium dioxide and other nanopigments, Color Index (CI) Pigment Black 31, CI Pigment Black 32, CI Pigment Red 122, CI Pigment Yellow 13, perylene pigments, ultramarine blue pigments, quinacrodone pigments, azo pigments, and pearlescent pigments. The IR transmissive colorants can be used to provide visible color to the film 11, 13 and/or adhesive 12 containing the IR-transmissive colorants. Other examples of IR transmissive colorants suitable for use with the building construction articles of the present disclosure are described in U.S. Patent Application Publication No. 2008/0006323, entitled “Photovoltaic Module,” and U.S. Patent Application Publication No. 2009/0098477, entitled “Black Toners Containing Infrared Transmissive and Reflecting Colorants,” each of which is incorporated by reference in its entirety for all purposes. Still other IR transmissive colorants

suitable for use with the building construction articles of the present disclosure are available from Epolin, Inc., Newark, Nj, (e.g., products sold under the trade designation “SpectreTM”) and from BASF, Inc., Florham Park, N.J. (e.g., products sold under the trade designation “Lumogen®.”)

[0043] FIG. 2 is a schematic cross-sectional view of a building construction article 20 according to another embodiment of the present disclosure. The building construction article 20 includes a UV reflective film 21, an optional first adhesive layer 22, an IR reflective film 23, an optional second adhesive layer 24, and a polymeric support layer 25. The adhesive layer 22 secures the UV reflective film 21 to the IR reflective film 23 such that the UV reflective film 11 and IR reflective film 13 are in intimate contact. The adhesive layer 24 secures the IR reflective film 23 to the polymer support layer 25. The UV reflective film 21, adhesive layer 22, and IR reflective film 23 can have characteristics and configurations similar to the UV reflective film 11, adhesive layer 12, and IR reflective film 13, respectively, as described herein with regard to FIG. 1. In addition, the building construction article 20 can include the texturing or other contouring similar to the building construction article 10 to resemble conventional building materials, and the building construction article 20 can be manufactured via methods similar to those described herein.

[0044] In the embodiment illustrated in FIG. 2, a polymeric support layer 25 is secured to a side of the IR reflective layer 23 with the adhesive layer 24 opposite the UV reflective layer 21 to enhance the durability of the building construction article 20. The polymeric support layer 25 may alternatively be secured to the IR reflective film 23 with any known means. In some embodiments, the polymeric support layer 25 is a thick sheet having suitable durability for the application in which the building construction article 20 is used. The polymeric support layer 25 may be thermoformable to allow the polymeric support layer 25 to be textured or otherwise formed into the desired configuration for the building construction article 20. One example material suitable for the polymeric support layer 25 is polycarbonate. One exemplary reinforcing material suitable for the polymeric support layer 25 is twin wall polycarbonate sheeting, e.g., as available as SUNLITE MULTIWALL POLYCARBONATE SHEET from Palram Americas, Inc. of Kutztown, Pa.

[0045] In some embodiments, at least one of the UV reflective film 21, adhesive layer 22, IR reflective film 23, and adhesive layer 24 includes an IR transmissive colorant or pigment. For example, the IR transmissive colorant may be blended into the polymeric layers of the UV reflective film 21 and/or IR reflective film 23, or into an extrudable thermoplastic of the adhesive layers 22 and/or 24. The IR transmissive colorant may be substantially transmissive of both near-IR radiation and IR radiation. The IR transmissive colorant may be any suitable IR transmissive colorant, such as those discussed above with regard to FIG. 1.

[0046] FIG. 3 is a schematic cross-sectional view of a building construction article 30 according to another embodiment of the present disclosure. The building construction article 30 includes a UV reflective film 31, an optional first adhesive layer 32, an optional second adhesive layer 34, and a polymeric support layer 35, having characteristics and configurations similar to the UV reflective film 11, optional first adhesive layer 12, optional second adhesive layer 24, and polymeric support layer 25, respectively, as described herein. In addition, the building construction article 30 can include the texturing or other contouring similar to the building construction article 10 to resemble conventional building materials, and the building construction article 30 can be manufactured via methods similar to those described herein.

[0047] In the embodiment illustrated in FIG. 3, the building construction article 30 includes a coated IR reflective film 36 disposed between the UV reflective film 31 and the polymeric support layer 35. The coated IR reflective film 36 includes a coating of IR reflective metal to enhance the solar reflectivity of the building construction article 30. In some embodiments, the coating of IR reflective metal is formed on the side of the IR reflective film 36 facing the polymeric support layer 35. In some embodiments, the IR reflective metal coating comprises aluminum, copper, silver, and/or gold.

[0048] The UV reflective film 31, adhesive layer 32, and/or IR reflective film 36 may include an IR transmissive colorant or pigment as described herein. In that the IR reflective film 36 includes a coating of IR reflective metal on the surface above the adhesive layer 34, the adhesive layer 34 may or may not include the IR transmissive colorant.

[0049] FIG. 4 is a schematic cross-sectional view of a building construction article 40 according to another embodiment of the present disclosure. The building construction article 40 includes a UV reflective film 41, an optional first adhesive layer 42, an optional second adhesive layer 44, a polymeric support layer 45, and a coated IR reflective film 46 having characteristics and configurations similar to the UV reflective film 11, optional first adhesive layer 12, optional second adhesive layer 24, polymeric support layer 25, and coated IR reflective film 36, respectively, described herein. Alternatively, the building construction article 40 can include an IR reflective film that is not coated with a metal, similar to IR reflective film 13 described herein. In addition, the building construction article 40 can include the texturing or other contouring similar to the building construction article 10 to resemble conventional building materials, and the building construction article 40 can be manufactured via methods similar to those discussed above.

[0050] In the embodiment illustrated in FIG. 4, a protective coating 47 is formed on the UV reflective film 41 on a side opposite the IR reflective mirror 46. The protective coating 47 may be formed on a top surface of the building construction article 40. The protective coating 47 is a durable coating that can be configured to provide scratch resistance and flame resistance. In

some embodiments, the protective coating 47 includes roofing granules or other elements to resemble conventional building construction articles. For example, the protective coating 47 may comprise a fluoropolymer or siloxane that is cross-linked with the UV reflective film 41. Other example materials suitable for the protective coating 47 include acrylates and urethanes that are loaded with flame retardant material and cross-linked with the UV reflective film 41. Examples of scratch resistant coatings include: a cross-linked fluoropolymer sold under the trade designation "Lumiflon" by AGC Chemicals; a thermoplastic urethane sold under the trade designation "TECOFLEX" by Lubrizol Advanced Materials, Inc., Cleveland, Ohio containing 5 weight percent of a UV-absorber sold under the trade designation "TINUVIN 405" by Ciba Specialty Chemicals Corp., 2 weight percent of a hindered amine light stabilizer sold under the trade designation "TINUVIN 123", and 3 weight percent of a UV-absorber sold under the trade designation "TINUVIN 1577" by Ciba Specialty Chemicals Corp.; and a scratch resistant coating consisting of a thermally cured nano-silica siloxane filled polymer sold under the trade designation "PERMA-NEW 6000 CLEAR HARD COATING SOLUTION" by California Hardcoating Co., Chula Vista, Calif.

[0051] The protective coating 47 may optionally include at least one antisoiling component. Examples of antisoiling components include fluoropolymers, silicone polymers, titanium dioxide particles, polyhedral oligomeric silsesquioxanes (e.g., as sold under the trade designation "POSS" by Hybrid Plastics of Hattiesburg, Miss.), or combinations thereof. Additional anti-soiling coatings include acid sintered nano-silica coatings as described in PCT Publication No. WO2012/047422 (Hebrink et al.), and PCT Publication No. WO2012/047872 (Brown et al.), each of which is hereby incorporated by reference in its entirety.

[0052] The UV reflective film 41, adhesive layer 42, IR reflective film 46, and/or protective coating 47 may include an IR transmissive colorant or pigment as described herein. In embodiments in which the IR reflective film 46 includes a coating of IR reflective metal on the surface above the adhesive layer 44, the adhesive layer 44 may or may not include the IR transmissive colorant.

[0053] FIG. 5 is a schematic cross-sectional view of a building construction article 50 according to another embodiment of the present disclosure. The building construction article 50 includes a UV reflective film 51, an optional first adhesive layer 52, an optional second adhesive layer 54, a polymeric support layer 55, a coated IR reflective film 56 (or, alternatively, an uncoated IR reflective film), and a protective coating 57, having characteristics and configurations similar to the UV reflective film 11, optional first adhesive layer 12, optional second adhesive layer 24, polymeric support layer 25, coated IR reflective film 36, and protective coating 47, respectively, as described herein. In addition, the building construction article 50 can include the texturing or

other contouring similar to the building construction article 10 to resemble conventional building materials, and the building construction article 50 can be manufactured via methods similar to those discussed above.

[0054] In the embodiment illustrated in FIG. 5, a sheet or layer of insulating material 58 is applied to the bottom of the building construction article 50 on a side of the polymeric support layer 55 opposite the coated IR reflective film 56. The polymeric support layer 55 may be secured to the insulating sheet 58 using conventional lamination methods, such as heat, pressure, and/or an adhesive. In some embodiments, the insulating sheet 58 comprises a porous polymer. Examples of materials suitable for the insulating sheet include, but are not limited to, acrylic, silicone, polyurethane, polyethylene, neoprene rubber, and polypropylene, which may be filled or unfilled. In one exemplary implementation, the porous insulating sheet 58 is an acrylic foam tape, which can also function as an adhesive layer.

[0055] The UV reflective film 51, adhesive layer 52, IR reflective film 56, and/or protective coating 57 may include an IR transmissive colorant or pigment as described herein. In embodiments in which the IR reflective film 56 includes a coating of IR reflective metal on the surface above the adhesive layer 54, the adhesive layer 54 may or may not include the IR transmissive colorant.

[0056] FIG. 6 is a schematic cross-sectional view of a building construction article 60 according to another embodiment of the present disclosure. The building construction article 60 includes a UV reflective film 61, an optional first adhesive layer 62, an optional second adhesive layer 64, a polymeric support layer 65, a coated IR reflective film 66 (or, alternatively, an uncoated IR reflective film), a protective coating 67, and an insulating sheet 68 having characteristics and configurations similar to the UV reflective film 11, optional first adhesive layer 12, optional second adhesive layer 24, polymeric support layer 25, coated IR reflective film 36, protective coating 47, and insulating sheet 58, respectively, as described herein. In addition, the building construction article 60 can include the texturing or other contouring similar to the building construction article 10 to resemble conventional building materials, and the building construction article 60 can be manufactured via methods similar to those discussed above.

[0057] In the embodiment illustrated in FIG. 6, the insulating sheet 68 is coated on a bottom surface with a metal coating 69 to provide an additional radiant barrier for the building construction article. In some embodiments, the metal coating 69 comprises an IR reflective metal. For example, in some embodiments, the metal coating 69 comprises aluminum, copper, stainless steel, silver, and/or gold.

[0058] The UV reflective film 61, adhesive layer 62, IR reflective film 66, and/or protective coating 67 may include an IR transmissive colorant or pigment as described herein. In

embodiments in which the IR reflective film 66 includes a coating of IR reflective metal on the surface above the adhesive layer 54, the adhesive layer 54 may or may not include the IR transmissive colorant.

[0059] While the building construction articles described have included texturing, the building construction articles may include any other type of contouring to resemble conventional building construction articles. For example, FIGS. 7-11 illustrate building construction articles that are formed into corrugated configurations including a plurality of parallel ridges and furrows. In some embodiments, the corrugations give the building construction articles the appearance of standing seam steel roofing panels or building siding. The open areas under the ridges of the corrugations can provide natural convection cooling under the upper surface of the building construction article.

[0060] In some embodiments, the corrugated building constructions articles are contoured by thermoforming, although other methods are also possible, including, but not limited to, vacuum forming, shaping, rolling, or pressure forming. In addition, in some embodiments, the corrugated building construction articles include one or more visible light absorbing colorants that further give the appearance of a conventional construction article. In alternative embodiments, no visible light colorants are used in the building construction article, and the layers of the building construction articles are comprised of visible light transmissive material to allow the building construction articles to be used to provide interior building day lighting.

[0061] For example, FIG. 7 is a schematic cross-sectional view of a building construction article 70 including corrugations according to an embodiment of the present disclosure. The building construction article 70 includes a UV reflective film 71, an IR reflective film 73, and a polymeric support layer 75. The UV reflective film 71, IR reflective film 73, and polymeric support layer 25 can have characteristics and configurations similar to the UV reflective film 11, IR reflective film 13, and polymeric support layer 25, respectively, as described herein.

[0062] The UV reflective film 71, IR reflective film 73, and polymeric support layer 75 are coupled together such that the films 71, 73 and layer 75 are in intimate contact with each other. The building construction article 70 may be contoured to include corrugations before or after coupling the films 71, 73 and layer 75 to each other. The UV reflective film 71, IR reflective film 73, and polymeric support layer 75 may be coupled to each other by various means, including, but not limited to, adhering, co-extruding, laminating, coating, vapor deposition, or combinations thereof. For example, while not illustrated in FIG. 7, the building construction article 70 may include adhesive layers between the UV reflective film 71 and IR reflective film, and between the IR reflective film 73 and polymeric support layer 75. The adhesive layers may have characteristics similar to adhesive layer 11 discussed herein.

[0063] In some embodiments, at least one of the UV reflective film 71, IR reflective film 73, and/or adhesive layers optionally between the layers of the building construction article 70 includes an IR transmissive colorant or pigment. For example, the IR transmissive colorant may be blended into the polymeric layers of the UV reflective film 71 and/or IR reflective film 73, or into an extrudable thermoplastic of the adhesive layers. The IR transmissive colorant may be substantially transmissive of both near-IR radiation and IR radiation. The IR transmissive colorant may be any suitable IR transmissive colorant, such as those discussed above with regard to FIG. 1.

[0064] The IR reflective film 73 may include a coating of IR reflective metal to enhance the solar reflectivity of the building construction article 70. In some embodiments, the coating of IR reflective metal is formed on the side of the IR reflective film 73 facing the polymeric support layer 75. In some embodiments, the IR reflective metal coating comprises aluminum, copper, silver, and/or gold.

[0065] FIG. 8 is a schematic cross-sectional view of a building construction article 80 according to another embodiment of the present disclosure. The building construction article 80 includes a UV reflective film 81, an IR reflective film 83, and a polymeric support layer 85. The UV reflective film 81, IR reflective film 83, and polymeric support layer 85 can have characteristics and configurations similar to the UV reflective film 11, IR reflective film 13, and polymeric support layer 25, respectively, as described herein. The IR reflective film 83 may also include a coating of IR reflective metal to enhance the solar reflectivity of the building construction article 80. In addition, the layers of the building construction article 80 may be secured to each other using any of the methods described herein.

[0066] In the embodiment illustrated in FIG. 8, a protective coating 87 is formed on the UV reflective film 81 on a side opposite the IR reflective mirror 83. The protective coating 87 may be formed on a top surface of the building construction article 80. The protective coating 87 is a durable coating that can be configured to provide scratch resistance and flame resistance. In some embodiments, the protective coating 87 includes roofing granules or other elements to resemble conventional building construction articles. For example, the protective coating 87 may comprise a fluoropolymer or siloxane that is cross-linked with the UV reflective film 81. Other example materials suitable for the protective coating 87 include acrylates and urethanes that are loaded with flame retardant material and cross-linked with the UV reflective film 81. Other examples and variations on the protective coating 87 are described above with regard to the protective coating 47 illustrated in FIG. 4.

[0067] The UV reflective film 81, IR reflective film 83, protective coating 87, and/or optional adhesive layers in the building construction article 80 may include an IR transmissive colorant or pigment as described herein.

[0068] FIG. 9 is a schematic cross-sectional view of a building construction article 90 according to another embodiment of the present disclosure. The building construction article 90 includes a UV reflective film 91, an IR reflective film 93, and a protective coating 97. The can have characteristics and configurations similar to the UV reflective film 11, IR reflective film 13, and protective coating 47, respectively, as described herein. In addition, the building construction article 90 includes a polymeric support layer 95a, which can have characteristics and configurations similar to the polymeric support layer 25 described herein. The IR reflective film 93 may also include a coating of IR reflective metal to enhance the solar reflectivity of the building construction article 90. In addition, the layers of the building construction article 90 may be secured to each other using any of the methods described herein.

[0069] In the embodiment illustrated in FIG. 9, the building construction article 90 further includes an additional polymeric support layer 95b secured to the bottom of the corrugation furrows of the polymeric support layer 95a. In some embodiments, the additional polymeric support layer 95b is substantially planar. The additional polymeric support layer 95b provides additional strength and rigidity to the building construction article 90. The additional polymeric support layer 95b may be comprised of materials similar to those discussed above with regard to polymeric support layer 25. For example, in some embodiments, the additional polymeric support layer 95b is comprised of polycarbonate.

[0070] The UV reflective film 91, IR reflective film 93, protective coating 97, and/or optional adhesive layers in the building construction article 90 may include an IR transmissive colorant or pigment as described herein.

[0071] FIG. 10 is a schematic cross-sectional view of a building construction article 100 according to another embodiment of the present disclosure. The building construction article 100 includes a UV reflective film 101, an IR reflective film 103, polymeric support layers 105, and a protective coating 107, which can have characteristics and configurations similar to the UV reflective film 11, IR reflective film 13, polymeric support layer 25, and protective coating 47, respectively, as described herein. The IR reflective film 103 may also include a coating of IR reflective metal to enhance the solar reflectivity of the building construction article 100. In addition, the layers of the building construction article 100 may be secured to each other using any of the methods described herein.

[0072] In the embodiment illustrated in FIG. 10, a sheet or layer of insulating material 108 is applied to the bottom of the building construction article 100 on a side of the polymeric support layer 105b opposite the polymeric support layer 105a. The polymeric support layer 105b may be secured to the insulating sheet 108 using conventional lamination methods, such as heat, pressure, and/or an adhesive. In some embodiments, the insulating sheet 108 comprises a porous

polymer. Examples of materials suitable for the insulating sheet include, but are not limited to, but are not limited to, acrylic, silicone, polyurethane, polyethylene, neoprene rubber, and polypropylene, which may be filled or unfilled.

[0073] The UV reflective film 101, IR reflective film 103, protective coating 107, and/or optional adhesive layers in the building construction article 100 may include an IR transmissive colorant or pigment as described herein.

[0074] FIG. 11 is a schematic cross-sectional view of a building construction article 110 according to another embodiment of the present disclosure. The building construction article 110 includes a UV reflective film 111, an IR reflective film 113, polymeric support layers 115, a protective coating 117, and an insulating sheet 118, which can have characteristics and configurations similar to the UV reflective film 11, IR reflective film 13, polymeric support layer 25, protective coating 47, and insulating sheet 58, respectively, as described herein. The IR reflective film 113 may also include a coating of IR reflective metal to enhance the solar reflectivity of the building construction article 110. In addition, the layers of the building construction article 110 may be secured to each other using any of the methods described herein.

[0075] In the embodiment illustrated in FIG. 10, the insulating sheet 118 is coated on a bottom surface with a metal coating 119 to provide an additional radiant barrier for the building construction article. In some embodiments, the metal coating 119 comprises an IR reflective metal. For example, in some embodiments, the metal coating 119 comprises aluminum, copper, stainless steel, silver, and/or gold.

[0076] The UV reflective film 111, IR reflective film 113, protective coating 117, and/or optional adhesive layers in the building construction article 110 may include an IR transmissive colorant or pigment as described herein.

[0077] FIG. 12 is a schematic cross-sectional view of a building construction article 120 including polymer sheet corrugations for creating a building construction polymer composite article with air channels, or ducts, for solar harvesting of low grade heat according to an embodiment of the present disclosure. The building construction article 120 includes a UV reflective film 121, an IR reflective film 123, and a corrugated polymeric structural layer 125. The UV reflective film 121 and/or IR reflective film 123 can be laminated to the corrugated polymeric structural layer 125 with an optional adhesive layers 122. The corrugated polymer structural layer 125 can be visible light transparent to allow day lighting, or it can be loaded with solar absorbing pigments (i.e., carbon black, antimony trioxide, etc.) to harvest solar energy. Channels formed by the corrugated polymer structural layer 125 create hot air ducts for transporting hot air for use as indoor heating or drying. Building construction article 120 can be used as building construction articles such as roofing, vertical walls, and sloped walls.

[0078] An optional low-emissivity metallic coating 126 can be applied to the UV reflective film 121 or, optionally, to the corrugated polymer structural layer 125. The low-emissivity metallic coating 126 may be applied by sputtering as described by U.S. Patent Application Publication No. 2008/0160321 (Padiyath et al.), and protected by another coating as described by U.S. Patent No. 4,769,291 (Belkind et al.), and U.S. Patent No. 6,030,671 (Yang et al.), each of which is incorporated by reference in its entirety. An optional foam or foam adhesive layer 127 can be applied to IR reflective film 123, such as acrylic foam tape (available from 3M Company under the trade name VHB). The UV reflective film 121, IR reflective film 123, and polymeric structural layer 125 can have characteristics and configurations similar to the UV reflective film 11, IR reflective film 13, and polymeric support layer 25, respectively, as described herein.

[0079] FIG. 13 is a schematic view of a system 130 including a building construction corrugated polymer composite article 131 with air channels 132, or ducts, for solar harvesting of low grade heat according to an embodiment of the present disclosure. One or more additional air channels 133 supply heated air from the building construction article 130 for building heating, or drying, or other uses. An optional thermal storage unit 134 can store harvested solar energy for later use (e.g., heating of an associated building or structure at night). For example, the one or more air channels 135 connected to the thermal storage unit 134 can return the harvested solar energy to the building construction article 130. The building construction corrugated polymer composite article 131 can be used, for example, as building construction articles such as roofing, vertical walls, and sloped walls.

[0080] FIG. 14 is a schematic cross-section of a view of a building construction article 140 according to another embodiment of the present disclosure. The building construction article 140 includes a UV reflective film 141, an optional adhesive layer 142, an IR reflective film 143, a UV reflective film embossed section 144 that is thinner than other portions of the UV reflective film 141, an adhesive layer embossed section 145 that is thinner than other portions of the adhesive layer 142, and an IR reflective film embossed section 146 that is thinner than other portions of the IR reflective film 143. The adhesive layer 142 secures the UV reflective film 141 to the IR reflective film 143 such that the UV reflective film 141 and IR reflective film 143 are in intimate contact. The UV reflective film 141, adhesive layer 142, and IR reflective film 143 can have characteristics and configurations similar to the UV reflective film 11, adhesive layer 12, and IR reflective film 13, respectively, as described herein with regard to FIG. 1. The thinner embossed sections 144 and 146 of the UV reflective film and IR reflective film, respectively, are transparent allowing any visible colorants to become more visible. In addition, the building construction article 140 can include the texturing or other contouring similar to the building

construction article 10 to resemble conventional building materials, and the building construction article 140 can be manufactured via methods similar to those described herein.

[0081] FIG. 15 is a schematic cross-section of a view of a building construction article 150 according to another embodiment of the present disclosure. The building construction article 150 includes a UV reflective film 151, an optional first adhesive layer 152, an IR reflective film 153, a UV reflective film embossed section 154 that is thinner than other portions of the UV reflective film 151, an adhesive layer embossed section 155 that is thinner than other portions of the adhesive layer 152, and an IR reflective film embossed section 156 that is thinner than other portions of the IR reflective film 153. In the embodiment illustrated in FIG. 15, the building construction article further includes an optional second adhesive layer 157 (which may include embossed sections similar to the embossed section 155 of the first adhesive layer 152). The adhesive layer 152 secures the UV reflective film 151 to the IR reflective film 153 such that the UV reflective film 151 and IR reflective film 153 are in intimate contact. The adhesive layer 157 can secure the IR reflective film 153 to a polymer support layer or other substrate. The thinner embossed sections of the UV reflective film 154 and IR reflective film 156 are transparent, allowing any visible colorants to become more visible. The UV reflective film 151, adhesive layer 152, and IR reflective film 153 can have characteristics and configurations similar to the UV reflective film 11, adhesive layer 12, and IR reflective film 13, respectively, as described herein with regard to FIG. 1. In addition, the building construction article 150 can include the texturing or other contouring similar to the building construction article 10 to resemble conventional building materials, and the building construction article 150 can be manufactured via methods similar to those described herein.

[0082] The building construction articles described herein are useful, for example, as roofing panels, siding, or other building materials. The building construction articles can be textured, corrugated, or otherwise shaped, and/or colored with visible light absorbing colorants to resemble conventional building materials and to give the building construction articles an aesthetically pleasing appearance. For example, the texturing or corrugation and coloring can give the building construction article the appearance of wood grain, roofing shingles, roofing tiles, or building siding. The building construction articles provide exceptional strength to weight ratios and, in corrugated embodiments, the ability to provide natural convection cooling under the upper surface of the article. Additionally, the use of UV mirrors provides UV protection to underlying materials, prolonging the useful life of the underlying materials and potentially allowing the use of less expensive underlying materials. The building construction articles described also have a lower weight than corresponding conventional building materials, thereby reducing shipping costs for the articles. In embodiments in which visible light transmissive materials are used without the

use of visible light absorbing colorants, the building construction articles described can be used to provide interior building day lighting.

EXAMPLES

[0083] The following specific, but non-limiting examples will serve to illustrate the disclosure.

[0084] A first UV reflective multilayer optical film having a reflection band of 350nm-400nm was made with first optical layers of PET (available from Eastman Chemical under the trade designation Eastapak 7452) and second optical layers of coPMMA (available from Plaskolite under the trade designation PERSPEX CP63). The PET and coPMMA were coextruded through a multilayer polymer melt manifold to form a stack of 550 optical layers. The layer thickness profile (layer thickness values) of this UV reflector was adjusted to be approximately a linear profile with the first (thinnest) optical layers adjusted to have about a $\frac{1}{4}$ wave optical thickness (index times physical thickness) for 300 nm light and progressing to the thickest layers which were adjusted to be about $\frac{1}{4}$ wave thick optical thickness for 400 nm light. Layer thickness profiles of such films were adjusted to provide for improved spectral characteristics using the axial rod apparatus taught in U.S. Patent No. 6,783,349 (Neavin et al.), the disclosure of which is incorporated herein by reference in its entirety, combined with layer profile information obtained with atomic force microscopic techniques.

[0085] In addition to these optical layers, non-optical protective skin layers comprising a blend of 62 wt% PMMA (CP82 from Plaskolite), 35wt% PVDF (Dyneon 6008), and 3wt% of UV absorber (obtained from Ciba Specialty Chemicals Corporation, Tarryton, NY, under the trade designation "TINUVIN 1577 UVA") was compounded into these protective skin layers. This multilayer coextruded melt stream was cast onto a chilled roll at 5.4 meters per minute creating a multilayer cast web approximately 500 micrometers (20 mils) thick. The multilayer cast web was then preheated for about 10 seconds at 95 °C and biaxially oriented at draw ratios of 3.5x3.7. The oriented multilayer film was further heated at 225°C for 10 seconds to increase crystallinity of the PET layers.

[0086] The UV-reflective multilayer optical film (Film 1) was measured with the spectrophotometer ("LAMBDA 950") to transmit less than 2 percent of the UV light over a bandwidth of 350-400 nm.

[0087] A second UV reflective multilayer optical film having a reflection band of 350nm-500nm was made with first optical layers of PET (available from Eastman Chemical under the trade designation EASTAPAK 7452) and second optical layers of coPMMA (available from Plaskolite under the trade designation PERSPEX CP63). The PET and coPMMA were coextruded

through a multilayer polymer melt manifold to form a stack of 550 optical layers. The layer thickness profile (layer thickness values) of this UV reflector was adjusted to be approximately a linear profile with the first (thinnest) optical layers adjusted to have about a $\frac{1}{4}$ wave optical thickness (index times physical thickness) for 350 nm light and progressing to the thickest layers which were adjusted to be about $\frac{1}{4}$ wave thick optical thickness for 500 nm light. Layer thickness profiles of such films were adjusted to provide for improved spectral characteristics using the axial rod apparatus taught in U.S. Patent No. 6,783,349 (Neavin et al.), combined with layer profile information obtained with atomic force microscopic techniques.

[0088] In addition to these optical layers, non-optical protective skin layers comprising a blend of 62 wt% PMMA (CP82 from Plaskolite), 35wt% PVDF (Dyneon 6008), and 3wt% of UV absorber (obtained from Ciba Specialty Chemicals Corporation, Tarryton, NY, under the trade designation "TINUVIN 1577 UVA") was compounded into these protective skin layers. This multilayer coextruded melt stream was cast onto a chilled roll at 4.3 meters per minute creating a multilayer cast web approximately 625 micrometers (25 mils) thick. The multilayer cast web was then preheated for about 10 seconds at 95 °C and biaxially oriented at draw ratios of 3.5x3.7. The oriented multilayer film was further heated at 225°C for 10 seconds to increase crystallinity of the PET layers.

[0089] The UV-reflective multilayer optical film (Film 2) was measured with the spectrophotometer ("LAMBDA 950") to transmit less than 3 percent of the light over a bandwidth of 350-500 nm.

[0090] A first IR reflective multilayer optical film having a reflection band of 650nm-1350nm was made with first optical layers of polyethylene terephthalate (under the trade designation EASTAPAK 7452 available from Eastman Chemicals, Kingsport, Tenn.) and second polymer layers created from a poly(methylmethacrylate) copolymer (CoPMMA) made from 75% by weight methylmethacrylate and 25% by weight of ethyl acrylate (obtained from Plaskolite under the trade designation "PERSPEX CP63"). PET and CoPMMA were coextruded thru a multilayer polymer melt manifold to create a multilayer melt stream having 550 alternating birefringent layers and second polymer layers. A masterbatch of PET and ultraviolet light absorber (UVA) commercially available under the trade designation "TA07-07 MB02" from Sukano, Duncan, SC was compounded into the PET optical layers at 10 wt%. In addition, a pair of non-optical polymer blend layers was coextruded as protective skin layers on either side of the optical layer stack. The skin layers were a blend of 35 wt % PVDF (poly(vinylidene difluoride), commercially available from 3M Company, St. Paul, MN under the trade designation "3M DYNEON PVDF 6008/0001", 45 wt % of poly(methylmethacrylate) (PMMA, commercially available under the trade designation "PERSPEX CP82" from Plaskolite, Campton, CA) and 20 wt

% of a masterbatch PMMA and UVA commercially available under the trade designation “TA11-10 MB01” from Sukano. This multilayer coextruded melt stream was cast onto a chilled roll at 22 meters per minute creating a multilayer cast web with optical layers approximately 725 microns (29 mils) thick and a total thickness of 1400 microns. The multilayer cast web was then heated in a tenter oven at 105°C for 10 seconds before being biaxially oriented to a draw ratio of 3.8 by 3.8. The oriented multilayer film was further heated to 225°C for 10 seconds to increase crystallinity of the PET layers. Reflectivity of this multilayer near infrared mirror film was measured with a Lambda 950 spectrophotometer resulting in an average reflectivity of 94.5% over a bandwidth of 650 to 1350 nm at normal angles to the film.

[0091] A second IR reflective multilayer optical film having a reflection band of 650nm-1550nm was made with birefringent layers created from polyethylene terephthalate (under the trade designation EASTAPAK 7452 available Eastman Chemicals, Kingsport, Tenn.) and second polymer layers created from a blend of 50wt% PMMA(available under the trade designation “PERSPEX CP82” from Plaskolite) and 50 wt% by weight of PVDF (available from 3M Company, St. Paul, MN under the trade designation “3M DYNEON PVDF 6008/0001). PET and the PVDF/PMMA polymer blend were coextruded thru a multilayer polymer melt manifold to create a multilayer melt stream having 550 alternating birefringent layers and second polymer layers. A masterbatch of PET and ultraviolet light absorber (UVA) commercially available under the trade designation “TA07-07 MB02” from Sukano, Duncan, SC was compounded into the PET optical layers at 10 wt%. In addition, a pair of non-optical polymer blend layers were coextruded as protective skin layers on either side of the optical layer stack. The skin layers were a blend of 35 wt % PVDF (poly(vinylidene difluoride), commercially available from 3M Company, St. Paul, MN under the trade designation “3M DYNEON PVDF 6008/0001”, 45 wt % of poly(methylmethacrylate) (PMMA, commercially available under the trade designation “PERSPEX CP82” from Plaskolite, Campton, CA) and 20 wt % of a masterbatch PMMA and UVA commercially available under the trade designation “TA11-10 MB01” from Sukano. This multilayer coextruded melt stream was cast onto a chilled roll at 22 meters per minute creating a multilayer cast web with optical layers approximately 932 microns (37 mils) thick and a total thickness of 1600 microns. The multilayer cast web was then heated in a tenter oven at 105°C for 10 seconds before being biaxially oriented to a draw ratio of 3.8 by 3.8. The oriented multilayer film was further heated to 225°C for 10 seconds to increase crystallinity of the PET layers. Reflectivity of this multilayer near infrared mirror film was measured with a Lambda 950 spectrophotometer resulting in an average reflectivity of 95.5% over a bandwidth of 650 to 1550 nm at normal angles to the film.

[0092] In Examples 1-21, IR and UV-IR reflective assemblies were fabricated by laminating varying combinations of the UV and IR reflective films made as described above with 8171 Optically Clear Adhesive (available from 3M Company, St. Paul, MN), coatings on the bottom side of the assemblies, and materials positioned under the assemblies. The percent reflection was measured three times for each of the assemblies using a spectrophotometer (Solar Spectrum Reflectometer, Model SSR-ER, from Device and Services (D&S) Company, Dallas, TX) per ASTM-C-1549-04 (March, 2005). Table 1 shows the percent reflection for each of the tested assemblies, as well as the average reflection for each of the assemblies across the three measurements.

TABLE 1

Example	UV Reflection Band	IR Mirror Reflection Band	Bottom Side Coating	Material Under Sample	%R1	%R2	%R3	Average %Reflection
Example 1	N/A	650-1350nm	Metallic Paint	white paper	73.2	73.9	74.1	73.7
Example 2	350-500nm	650-1350nm	Metallic Paint	white paper	79.4	79.7	80.4	79.8
Example 3	N/A	650-1350nm	White Paint	white paper	80.8	81.4	81.4	81.2
Example 4	350-400nm	650-1550nm	White Paint	white paper	88	87	85	86.7
Example 5	350-400nm	650-1550nm	Black Paint	white paper	75.6	76.9	76	76.2
Example 6	N/A	650-1350nm	Black Paint	white paper	49.2	49.7	49.8	49.6
Example 7	N/A	650-1550nm	Black Paint	white paper	77	76	75.9	76.3
Example 8	N/A	650-1550nm	White Paint	white paper	88.6	88.7	88.1	88.5
Example 9	350-500nm	650-1550nm	White Paint	white paper	88.9	89	89	89.0
Example 10	350-500nm	650-1550nm	Black Paint	white paper	79.5	79.1	79.2	79.3
Example 11	350-500nm	650-1350nm	N/A	white paper	85	84.6	84.6	84.7
Example 12	350-500nm	650-1350nm	N/A	black bench top	67.6	67.6	66.8	67.3
Example 13	350-500nm	650-1350nm	White Paint	white paper	82.7	82.5	82.4	82.5
Example 14	350-500nm	650-1350nm	Black Paint	white paper	62.3	62.2	62.6	62.4
Example 15	350-400nm	650-1550nm	N/A	white paper	88.5	88.6	88.6	88.6
Example 16	350-400nm	650-1550nm	N/A	black bench top	76.3	76.7	76.9	76.6
Example 17	350-500nm	650-1550nm	N/A	white paper	89.5	89.4	89	89.3
Example 18	350-500nm	650-1550nm	N/A	black bench top	80.4	80.5	79.7	80.2
Example 19	N/A	650-1550nm	N/A	white paper	87.8	87.7	87.8	87.8
Example 20	N/A	650-1350nm	N/A	white paper	81.7	82	81.5	81.7
Example 21	N/A	650-1350nm	N/A	black bench top	54.1	53.8	55.4	54.4

[0093] Example 22: A UV mirror film having a reflection band of 350nm-500nm was laminated to an IR mirror film having a reflection band of 650nm-1350nm with 8171 optically

clear adhesive (available from 3M Company, St. Paul, MN) to which 1.8 grams/ft² of Lumogen-Black-FK-4280 (available from BASF, Newport, DE) was added. The cool roof rating percent reflection was measured to be 53% using a spectrophotometer (Solar Spectrum Reflectometer, Model SSR-ER, from D&S Company, Dallas, TX) per ASTM-C-1549-04 (March, 2005).

[0094] Example 23: A UV mirror film having a reflection band of 350nm-500nm was laminated to a first side (top) of a corrugated black polycarbonate sheet (available from Amerilux International under the trade name Coverlite) using VHB tape (available from 3M Company, St. Paul, MN) and an IR mirror film having a reflection band of 650nm-1350nm was laminated to the second side (bottom) of the same corrugated black polycarbonate sheet also using VHB tape to form a UV-IR reflective composite panel capable of withstanding a load of 200 lbs/sq ft without damage.

[0095] Example 24: A UV mirror film having a reflection band of 350nm-500nm was laminated to a first side (top) of a corrugated black polycarbonate sheet (available from Amerilux International under the trade name Coverlite) using 8172P optically clear adhesive (available from 3M Company, St. Paul, MN) and an IR mirror film having a reflection band of 650nm-1350nm was laminated to the second side (bottom) of the same corrugated black polycarbonate sheet with 8172 optically clear adhesive (available from 3M Company, St. Paul, MN) to form a UV-IR reflective composite panel capable of withstanding a load of 200 lbs/sq ft without damage.

[0096] Various modifications and additions can be made to the exemplary embodiments discussed without departing from the scope of the present invention. For example, while the embodiments described above refer to particular features, the scope of this invention also includes embodiments having different combinations of features and embodiments that do not include all of the above described features.

CLAIMS

1. A building construction article comprising:
 - an infrared (IR) reflective film configured to reflect at least 50 percent of incident IR light over a range of IR wavelengths;
 - an ultraviolet (UV) reflective film configured to reflect at least 50 percent of incident UV light over a range of UV wavelengths; and
 - a first adhesive layer disposed between the IR reflective film and the ultraviolet reflective film,wherein at least one of the IR reflective film, UV reflective film, and first adhesive layer includes an IR transmissive colorant.
2. The building construction article of claim 1, and further comprising:
 - a polymeric support layer on a side of the IR reflective film opposite the UV reflective film; and
 - a second adhesive layer between the IR reflective film and the polymeric support layer.
3. The building construction article of claim 2, wherein the second adhesive layer includes the IR transmissive colorant.
4. The building construction article of claim 2, and further comprising:
 - a porous insulating sheet coupled to the polymeric support layer on a side opposite the IR reflective film.
5. The building construction article of claim 4, and further comprising:
 - a metallic coating on the porous insulating sheet on a side opposite the polymeric support layer.
6. The building construction article of claim 1, and further comprising:
 - a metallic coating on a side of the IR reflective film opposite the UV reflective film.
7. The building construction article of claim 6, wherein the metallic coating comprises aluminum, copper, or silver.

8. The building construction article of claim 1, and further comprising:
a protective coating on a side of the UV reflective film opposite the IR reflective film.
9. The building construction article of claim 8, wherein the protective coating comprises a fluoropolymer, siloxane, acrylate, or urethane cross-linked with the UV reflective film.
10. The building construction article of claim 1, wherein a top surface of the building construction article is textured or corrugated, and wherein the building construction article further comprises a visible light absorbing colorant.
11. The building construction article of claim 1, wherein the building construction article is configured to reflect narrow bands of visible light to provide coloring.
12. The building construction article of claim 1, wherein the IR reflective film and/or the UV reflective film include embossed sections that are thinner than non-embossed sections of the IR reflective film and/or UV reflective film.
13. A building construction article comprising:
a textured or corrugated assembly including an infrared (IR) reflective film configured to reflect at least 50 percent of incident IR light over a range of IR wavelengths, an ultraviolet (UV) reflective film configured to reflect at least 50 percent of incident UV light over a range of UV wavelengths, a polymeric support layer on a side of the IR reflective film opposite the UV reflective film, and a visible light absorbing colorant; and
a porous insulating sheet coupled to the polymeric support layer on a side opposite the IR reflective film.
14. The building construction article of claim 13, and further comprising:
a first adhesive layer between the IR reflective film and the UV reflective film;
and
a second adhesive layer between the IR reflective film and the polymeric support layer,

wherein at least one of the IR reflective film, UV reflective film, first adhesive layer and second adhesive layer includes an IR transmissive colorant.

15. The building construction article of claim 13, and further comprising:
a metallic coating on the porous insulating sheet on a side opposite the polymeric support layer.
16. The building construction article of claim 13, and further comprising:
a metallic coating on a side of the IR reflective film opposite the UV reflective film.
17. The building construction article of claim 16, wherein the metallic coating comprises aluminum, copper, or silver.
18. The building construction article of claim 13, and further comprising:
a protective coating on a side of the UV reflective film opposite the IR reflective film.
19. The building construction article of claim 18, wherein the protective coating comprises a fluoropolymer, siloxane, acrylate, or urethane cross-linked with the UV reflective film.
20. The building construction article of claim 13, wherein the IR reflective film and/or the UV reflective film include embossed sections that are thinner than non-embossed sections of the IR reflective film and/or UV reflective film.
21. A method for manufacturing a building construction article, the method comprising:
adhering an infrared (IR) reflective film to an ultraviolet (UV) reflective film with an adhesive including an IR transmissive colorant to form a UV-IR reflective assembly, the IR reflective film configured to reflect at least 50 percent of incident IR light over a range of IR wavelengths and the UV reflective film configured to reflect at least 50 percent of incident UV light over a range of UV wavelengths;
applying a visible light absorbing colorant to the UV-IR reflective assembly; and
thermoforming the UV-IR reflective assembly to provide a textured or corrugated outer surface on the UV-IR reflective assembly.

22. The method of claim 21, and further comprising:
adhering a polymeric support layer to the UV-IR reflective assembly on a side of the IR reflective film opposite the UV reflective film.
23. The method of claim 22, wherein prior to adhering the polymeric support layer to the UV-IR reflective assembly, the method further comprises:
coating the IR reflective film with a metal on a side opposite the UV reflective film.
24. The method of claim 22, and further comprising:
coupling a porous insulating sheet to the polymeric support layer on a side opposite the IR reflective film.
25. The method of claim 24, and further comprising:
coating the porous insulating sheet with a metal on a side opposite the polymeric support layer.
26. The method of claim 21, and further comprising:
applying a protective coating to a side of the UV reflective film opposite the IR reflective film.
27. The method of claim 21, and further comprising:
singulating the UV-IR reflective assembly into a plurality of individual building construction articles.
28. The method of claim 21, and further comprising:
embossing the IR reflective film and/or the UV reflective film include embossed sections that are thinner than non-embossed sections of the IR reflective film and/or UV reflective film.
29. A building construction article comprising:
an infrared (IR) reflective film configured to reflect at least 50 percent of incident IR light over a range of IR wavelengths;

an ultraviolet (UV) reflective film configured to reflect at least 50 percent of incident UV light over a range of UV wavelengths; and
a corrugated solar energy absorbing polymeric structural layer disposed between the IR reflective film and UV reflective film.

30. The building construction article of claim 29, and further comprising one or more ducts configured for coupling to a collection manifold for solar harvesting of low grade heat.

31. The building construction article of claim 30, wherein the one or more ducts are configured for coupling to a solar thermal unit for storage or transfer of the low grade heat.

32. The building construction article of claim 29, and further comprising a low emissivity coating on the UV reflective film and/or corrugated solar energy absorbing polymeric structure.

33. The building construction article of claim 29, wherein the IR reflective film and/or the UV reflective film include embossed sections that are thinner than non-embossed sections of the IR reflective film and/or UV reflective film.

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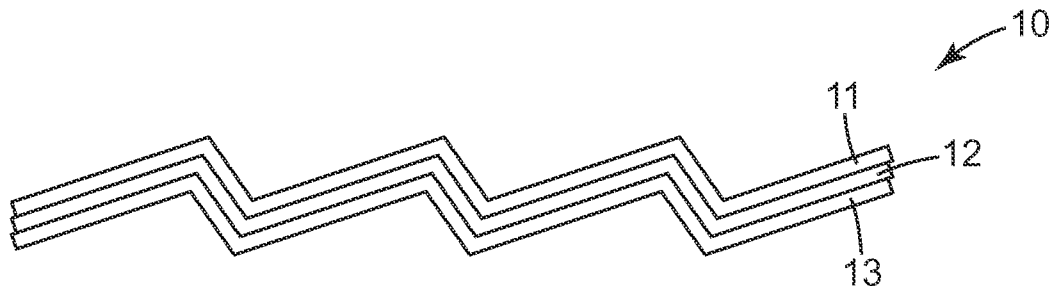


Fig. 1

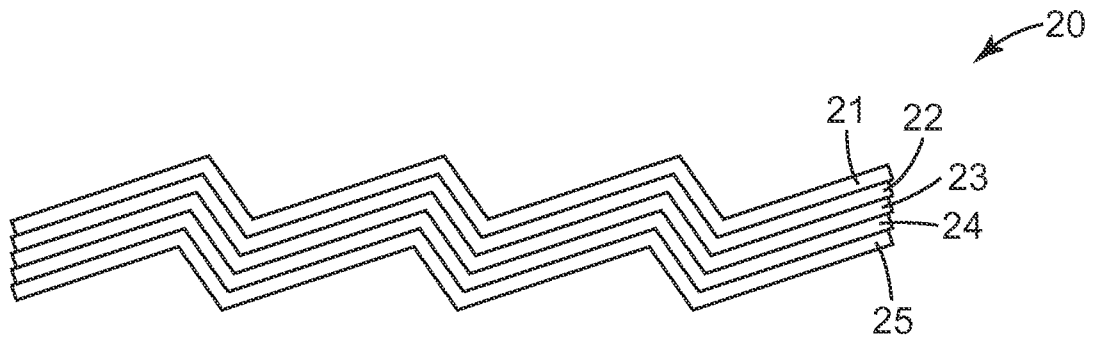


Fig. 2

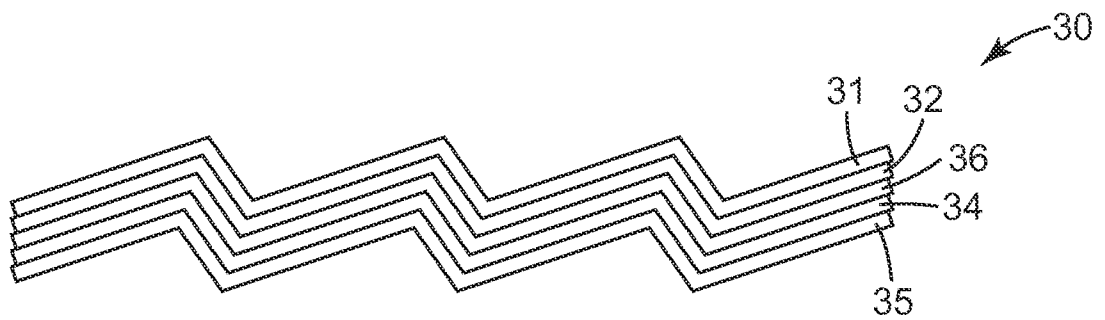


Fig. 3

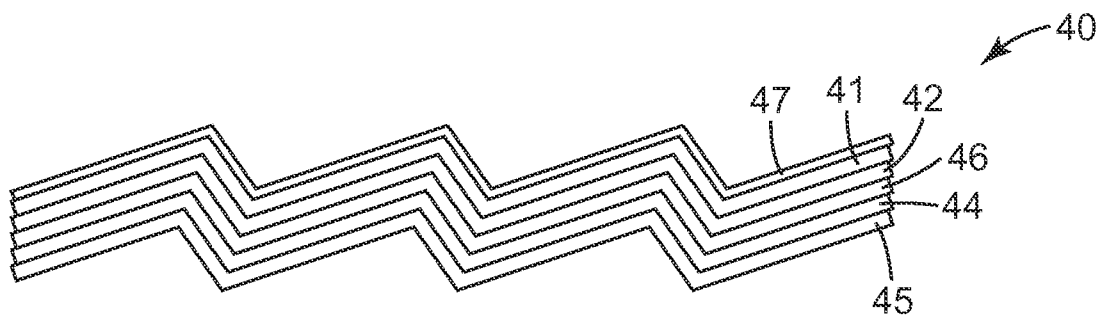


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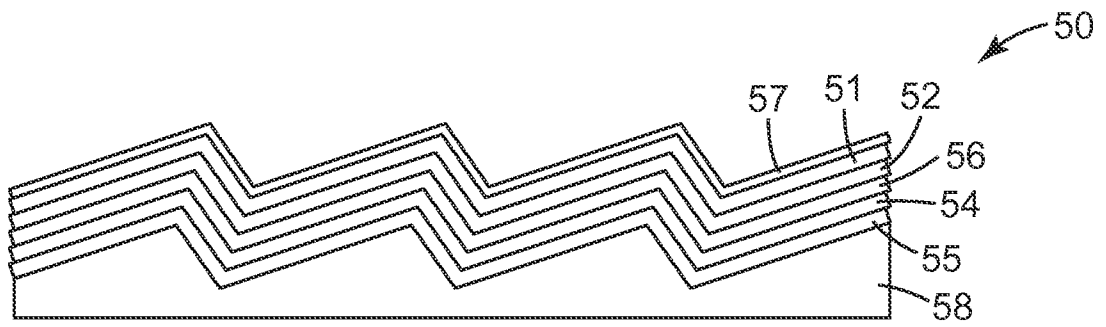


Fig. 5

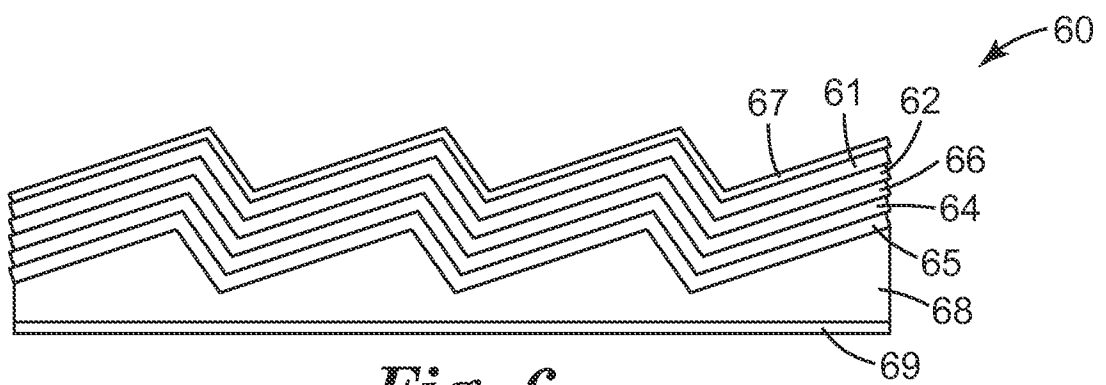
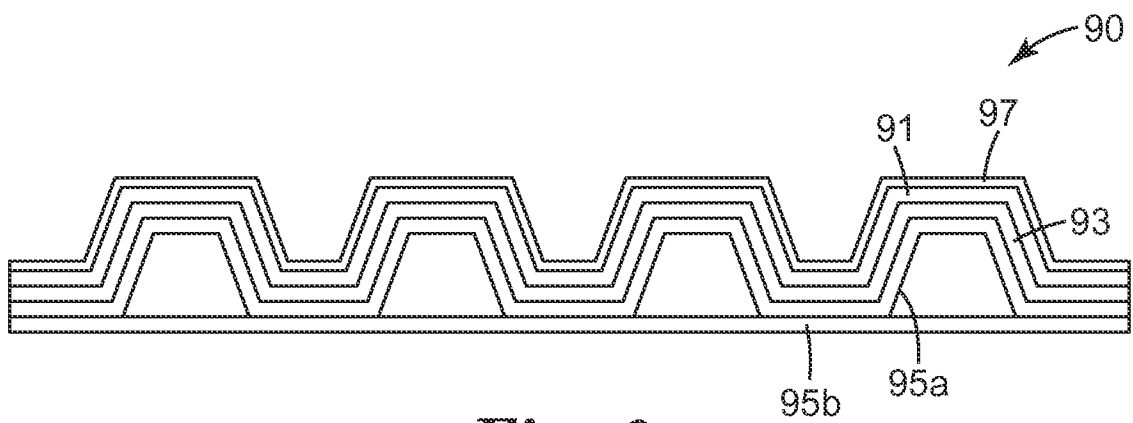


Fig. 6

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*Fig. 7**Fig. 8**Fig. 9*

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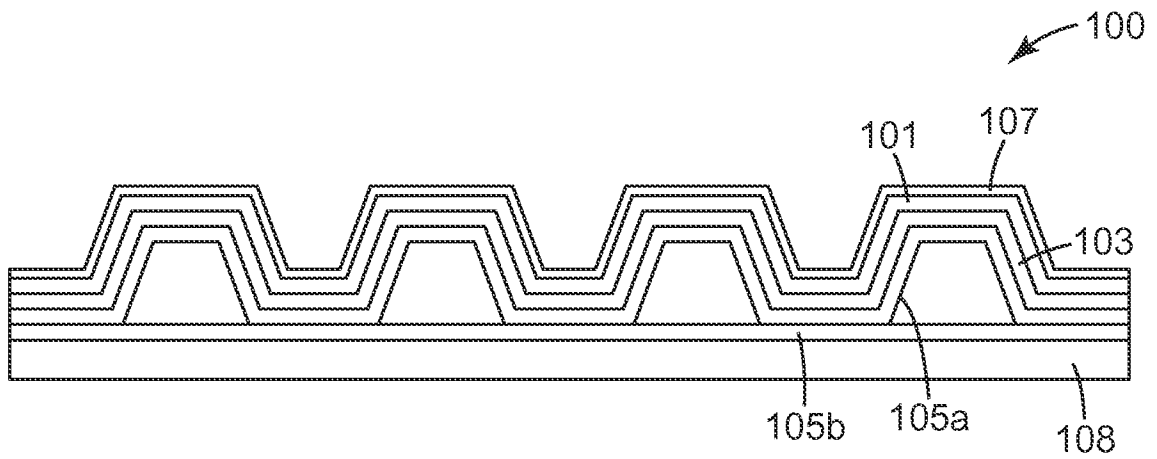


Fig. 10

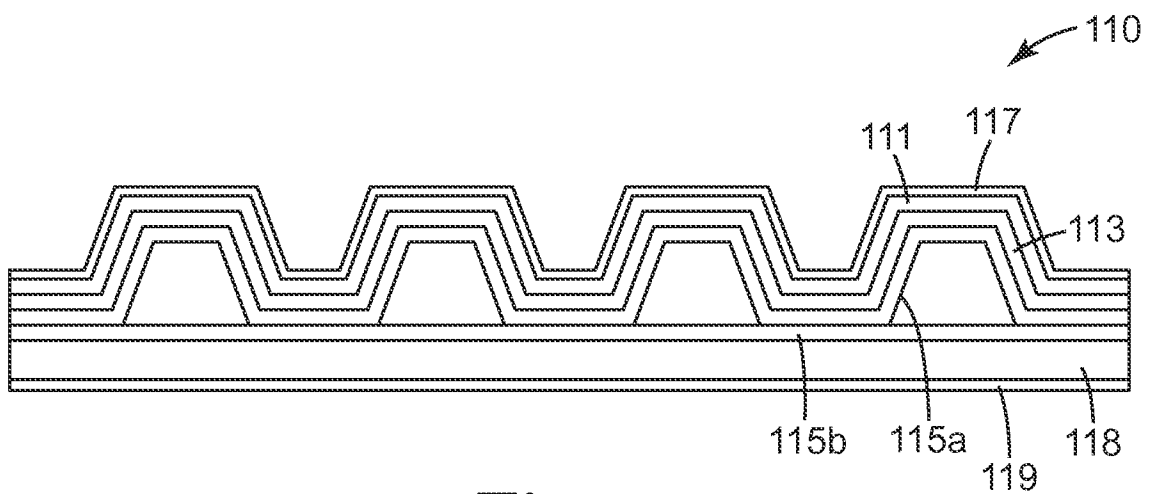


Fig. 11

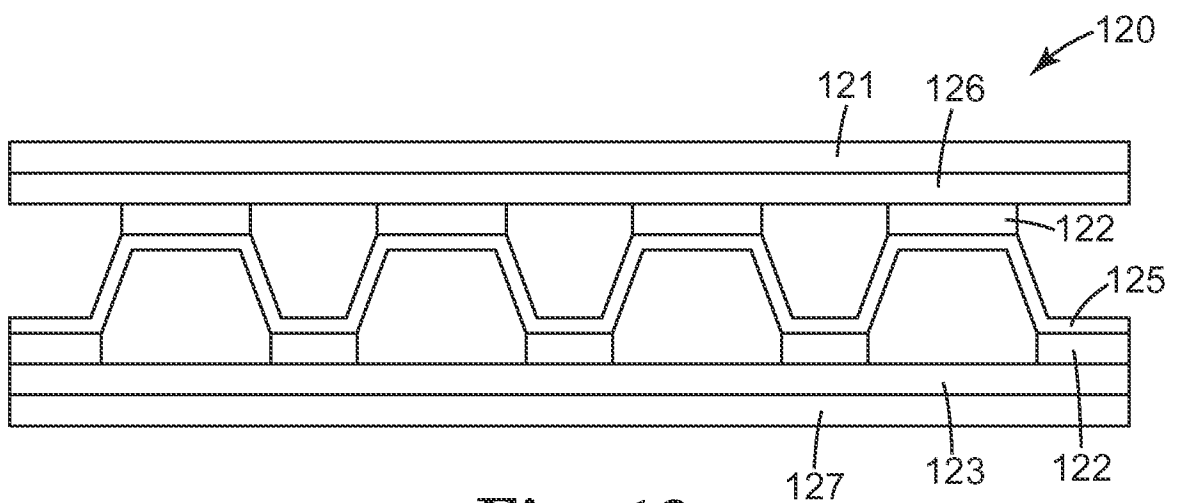
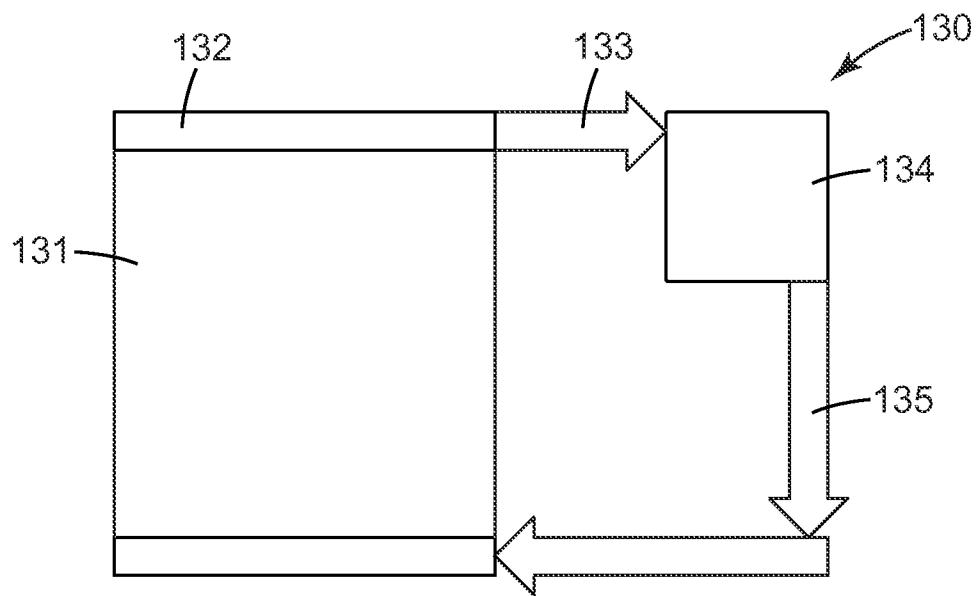
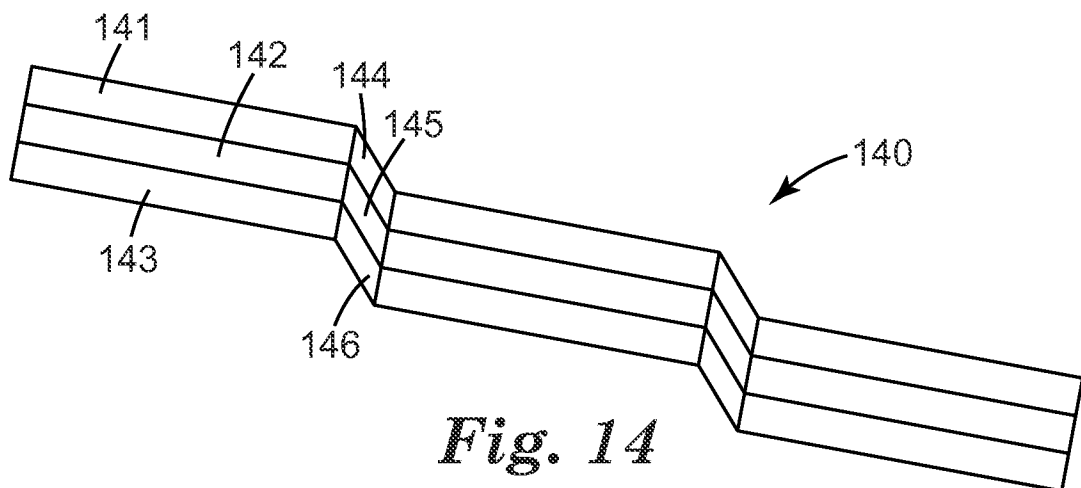
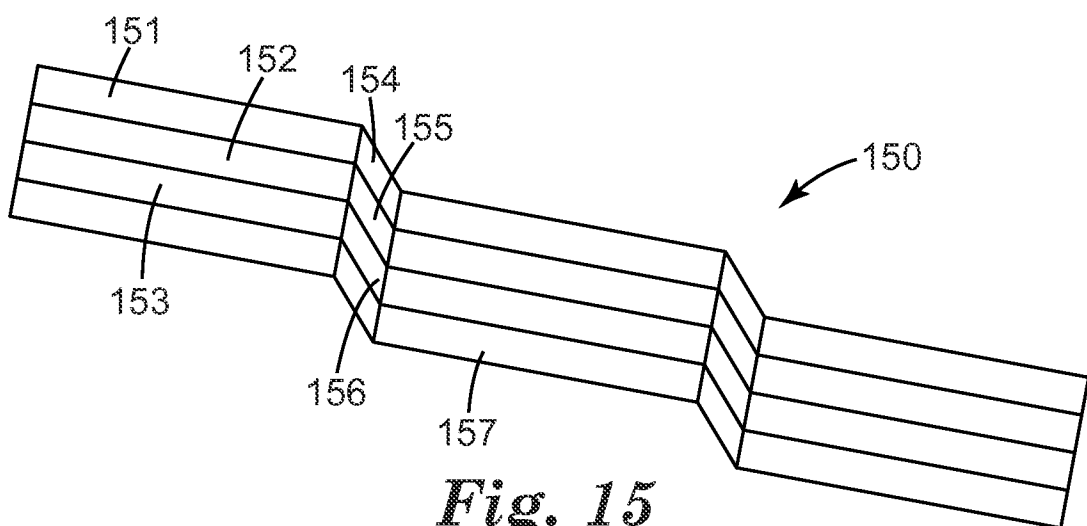


Fig. 12

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*Fig. 13**Fig. 14**Fig. 15*

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2013/056100A. CLASSIFICATION OF SUBJECT MATTER
INV. B32B27/00 G02B5/08
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B32B G02B

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

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

EPO-Internal, COMPENDEX, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 2006/132875 A1 (3M INNOVATIVE PROPERTIES CO [US]) 14 December 2006 (2006-12-14) claim 1 -----	1



Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

20 November 2013

Date of mailing of the international search report

27/11/2013

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Authorized officer

Hillebrand, Gerhard

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2013/056100

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