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(54) Title: DURABLE SOLAR MIRROR FILMS

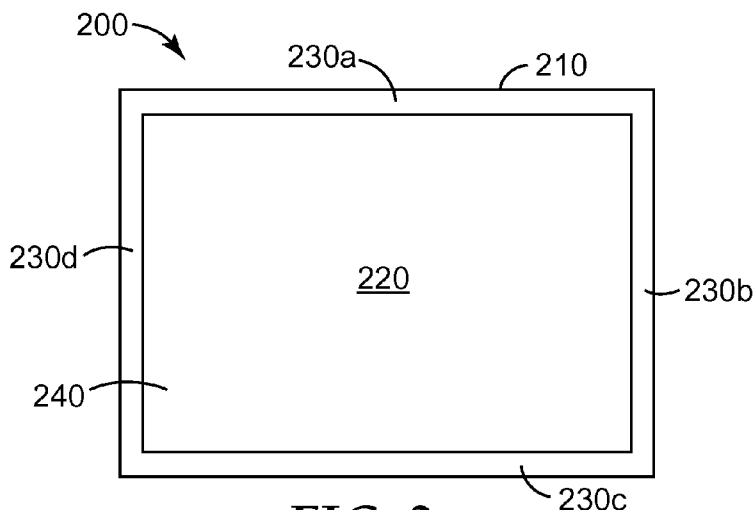


FIG. 2

(57) Abstract: The present disclosure generally relates to durable solar mirror films, methods of making durable solar mirror films, and constructions including durable solar mirror films. In some embodiments, the present disclosure relates to a solar mirror film comprising: a weatherable layer having a first major surface and a second major surface; regions of reflective material adjacent to the first major surface of the weatherable layer; and regions of the first major surface of the weatherable layer substantially lacking reflective material. In some embodiments, the present disclosure relates to a weatherable layer having a first major surface and a second major surface; wherein the first major surface includes a bulk region and an edge region; and a reflective material adjacent to the bulk region of the first major surface of the weatherable layer and substantially absent from the edge region.

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DURABLE SOLAR MIRROR FILMS

Government License Rights

[0001] The Government of the United States of America has rights in at least some of the inventions described in this Patent Application pursuant to DE-AC36-08GO28308 (CRADA No. 08-316) awarded by the U.S. Department of Energy.

Technical Field

[0002] The present disclosure generally relates to durable solar mirror films, methods of making durable solar mirror films, and constructions including durable solar mirror films.

Background

[0003] Renewable energy is energy derived from natural resources that can be replenished, such as sunlight, wind, rain, tides, and geothermal heat. The demand for renewable energy has grown substantially with advances in technology and increases in global population. Although fossil fuels provide for the vast majority of energy consumption today, these fuels are non-renewable. The global dependence on these fossil fuels has not only raised concerns about their depletion but also environmental concerns associated with emissions that result from burning these fuels. As a result of these concerns, countries worldwide have been establishing initiatives to develop both large-scale and small-scale renewable energy resources. One of the promising energy resources today is sunlight. Globally, millions of households currently obtain power from solar photovoltaic systems.

[0004] In general, concentrated solar technology involves the collection of solar radiation in order to directly or indirectly produce electricity. The three main types of concentrated solar technology are concentrated photovoltaic, concentrated solar power, and solar thermal.

[0005] In concentrated photovoltaic (CPV), concentrated sunlight is converted directly to electricity via the photovoltaic effect. Generally, CPV technology uses optics (*e.g.* lenses or mirrors) to concentrate a large amount of sunlight onto a small area of a solar photovoltaic material to generate electricity. CPV systems are often much less expensive to produce than other types of photovoltaic energy generation because the concentration of solar energy permits the use of a much smaller number of the higher cost solar cells.

[0006] In concentrated solar power (CSP), concentrated sunlight is converted to heat, and then the heat is converted to electricity. Generally, CSP technology uses mirrored surfaces in multiple geometries (*e.g.*, flat mirrors, parabolic dishes, and parabolic troughs) to concentrate sunlight onto

a receiver. That, in turn, heats a working fluid (*e.g.* a synthetic oil or a molten salt) or drives a heat engine (*e.g.*, steam turbine). In some cases, the working fluid is what drives the engine that produces electricity. In other cases, the working fluid is passed through a heat exchanger to produce steam, which is used to power a steam turbine to generate electricity.

[0007] Solar thermal systems collect solar radiation to heat water or to heat process streams in industrial plants. Some solar thermal designs make use of reflective mirrors to concentrate sunlight onto receivers that contain water or the feed stream. The principle of operation is very similar to concentrated solar power units, but the concentration of sunlight, and therefore the working temperatures, are not as high.

[0008] The rising demand for solar power has been accompanied by a rising demand for reflective devices and materials capable of fulfilling the requirements for these applications. Some of these solar reflector technologies include glass mirrors, aluminized mirrors, and metalized polymer films. Of these, metalized polymer films are particularly attractive because they are lightweight, offer design flexibility, and potentially enable less expensive installed system designs than conventional glass mirrors. Polymers are lightweight, inexpensive, and easy to manufacture. In order to achieve metal surface properties on a polymer, thin layers of metal (*e.g.* silver) are coated on the polymer surface.

[0009] One exemplary commercially available solar mirror film is shown schematically in Fig. 1. The solar mirror film 100 of Fig. 1 includes a premask layer 110, a weatherable layer 120 (including, for example, a polymer), a thin, sputter-coated tie layer 140, a reflective layer 150 (including, for example, a reflective metal such as silver), a corrosion resistant layer 160 (including, for example, a metal such as copper), an adhesive layer 170, and a liner 180. The film of Fig. 1 is typically applied to a support substrate by removing liner 180 and placing adhesive layer 170 adjacent to the support substrate. Premask layer 110 is then removed to expose weatherable layer 120 to sunlight.

Summary

[0010] The metalized polymer films used in concentrated solar power units and concentrated photovoltaic solar systems are subject to continuous exposure to the elements. Consequently, a technical challenge in designing and manufacturing metalized polymer reflective films is achieving long-term (*e.g.*, 20 years) durability when subjected to harsh environmental conditions. There is a need for metalized polymer films that provide durability and retained optical performance (*e.g.*, reflectivity) once installed in a concentrated solar power unit or a concentrated photovoltaic cell. Mechanical properties, optical clarity, corrosion resistance, ultraviolet light

stability, and resistance to outdoor weather conditions are all factors that can contribute to the gradual degradation of materials over an extended period of operation.

[0011] The inventors of the present disclosure recognized that many of the technical problems in forming a durable metalized polymer film capable of long-term outdoor use that retains its optical performance arise from the fundamental mismatch in the physical and chemical nature and properties of metals and polymers. One particular difficulty relates to ensuring good adhesion between the polymer layer and the metal reflective surface. Without good adhesion between these layers, delamination occurs. Delamination between the polymer layer and the reflective layer is often referred to as “tunneling.”

[0012] The inventors of the present disclosure recognized that the delamination typically results from the decreased adhesion between the polymer layer and the reflective layer. This decreased adhesion can be caused by any of numerous factors - and often a combination of these factors. Some exemplary factors that the inventors of the present disclosure recognized include (1) increased mechanical stress between the polymer layer and the reflective layer; (2) oxidation of the reflective layer; (3) oxidation of an adhesive adjacent to the reflective layer; and (4) degradation of the polymer layer (this can be due to, for example, exposure to sunlight). Each of these factors can be affected by numerous external conditions, such as, for example, environmental temperature (including variations in environmental temperatures), thermal shock, humidity, exposure to moisture, exposure to air impurities such as, for example, salt and sulfur, UV exposure, product handling, and product storage.

[0013] One of the most challenging problems is related to stress at the metal/polymer interface. Once the stress becomes too great, buckling can occur, causing the polymer layer to delaminate from the reflective layer. Further, when metalized polymer films are cut, their edges may be fractured and unprotected. Corrosion of metalized polymers begins at their edges, so this combination of fractured, exposed metal edges with the net interfacial stresses listed above can overcome adhesion strength and cause tunneling. The inventors of the present invention recognized the importance of protecting the interface between the polymer layer and the reflective layer – especially along the edges of this interface.

[0014] Two prior art approaches have been used to address these problems. First, a sealing caulk has been applied around the edges of the metalized film. Second, a tape has been wrapped around the edges of the metalized film. Both approaches are effective at minimizing short-term delamination and/or tunneling, if properly applied. However, both approaches disadvantageously reduce the total available reflective area. Also, both approaches disadvantageously introduce a separate material to the front surface of the metalized film, which results in the creation of a ridge or protrusion above and below the plane of the metalized film. These ridges or protrusions are

areas of potential additional stress when the metalized film is exposed to, for example, wind and hail. The additional stress is increased during routine maintenance processes including, for example, cleaning (*e.g.* pressure washing) and handling during application. Also, in order to be effective over the lifetime of the metalized film (*e.g.*, 20 years), the separate material must adhere to the metalized film for the lifetime of the film. These materials have limited ability to do so.

[0015] The inventors of the present disclosure recognized that the reflective layer in existing solar mirror films extends across the entire weatherable layer. As discussed above, the mismatch in properties of these layers make their interface prone to delamination and tunneling – especially at the edges of the mirror film. Thus, the inventors of the present disclosure recognized that a solar mirror film with less or no reflective material in some regions, areas, or portions of the solar mirror film exhibits increased durability and decreased delamination and/or tunneling.

[0016] One embodiment of the present disclosure relates to a solar mirror film comprising: a weatherable layer having a first major surface and a second major surface; wherein the first major surface includes a bulk region and an edge region; and a reflective material adjacent to the bulk region of the first major surface of the weatherable layer and substantially absent from the edge region.

[0017] Some embodiments of the present disclosure relate to a solar mirror film comprising: a weatherable layer having a first major surface and a second major surface; regions of reflective material adjacent to the first major surface of the weatherable layer; and regions of the first major surface of the weatherable layer substantially lacking reflective material. In some embodiments, the regions of reflective material are directly adjacent to the first major surface of the weatherable layer. In some embodiments, the materials and/or layer are between the regions of reflective material and the first major surface of the weatherable layer. In some embodiments, the materials and/or layers are at least one of a tie layer and a compliant layer.

[0018] In some embodiments, the regions substantially lacking reflective material include less than 50% reflective material over the area of the region substantially lacking reflective material. In some embodiments, the regions substantially lacking reflective material include less than 60% reflective material over the area of the region substantially lacking reflective material. In some embodiments, the regions substantially lacking reflective material include less than 70% reflective material over the area of the region substantially lacking reflective material. In some embodiments, the regions substantially lacking reflective material include less than 75% reflective material over the area of the region substantially lacking reflective material. In some embodiments, the regions substantially lacking reflective material include less than 80% reflective material over the area of the region substantially lacking reflective material. In some embodiments, the regions substantially lacking reflective material include less than 85% reflective

material over the area of the region substantially lacking reflective material. In some embodiments, the regions substantially lacking reflective material include less than 90% reflective material over the area of the region substantially lacking reflective material. In some embodiments, the regions substantially lacking reflective material include less than 95% reflective material over the area of the region substantially lacking reflective material. In some embodiments, the regions substantially lacking reflective material include less than 97% reflective material over the area of the region substantially lacking reflective material. In some embodiments, the regions substantially lacking reflective material include less than 99% reflective material over the area of the region substantially lacking reflective material.

[0019] In some embodiments, the regions substantially lacking reflective material comprise less than 30% of the total area of the solar mirror film. In some embodiments, the regions substantially lacking reflective material comprise less than 40% of the total area of the solar mirror film. In some embodiments, the regions substantially lacking reflective material comprise less than 50% of the total area of the solar mirror film. In some embodiments, the regions substantially lacking reflective material comprise less than 60% of the total area of the solar mirror film. In some embodiments, the regions substantially lacking reflective material comprise less than 70% of the total area of the solar mirror film. In some embodiments, the regions substantially lacking reflective material comprise less than 80% of the total area of the solar mirror film. In some embodiments, the regions substantially lacking reflective material comprise less than 90% of the total area of the solar mirror film. In some embodiments, the regions substantially lacking reflective material comprise less than 95% of the total area of the solar mirror film. In some embodiments, the regions substantially lacking reflective material comprise less than 97% of the total area of the solar mirror film. In some embodiments, the regions substantially lacking reflective material comprise less than 98% of the total area of the solar mirror film. In some embodiments, the regions substantially lacking reflective material comprise less than 99% of the total area of the solar mirror film.

[0020] Some embodiments of the present disclosure relate to a weatherable layer having a first major surface and a second major surface; wherein the first major surface includes a bulk region and an edge region; and a reflective material adjacent to the bulk region of the first major surface of the weatherable layer and substantially absent from the edge region.

[0021] Some embodiments of the present disclosure relate to a weatherable layer having a first major surface and a second major surface; wherein the first major surface includes a bulk region and an edge region; a reflective material adjacent to the bulk region of the first major surface of the weatherable layer; and a tie material in direct contact with the edge region of the first major surface of the weatherable layer.

[0022] In some embodiments of the solar mirror film, the edge region extends from the terminal edge of the weatherable layer to 2 mm onto the first major surface. In some embodiments, the edge region extends from the terminal edge of the weatherable layer to between about 2 mm and about 20 mm onto the first major surface. In some embodiments, the weatherable layer includes at least one of PMMA, polycarbonate, polyester, multilayer optical film, fluoropolymer, and a blend of an acrylate and a fluoropolymer. In some embodiments, the reflective material includes at least one of silver, gold, aluminum, copper, nickel, and titanium. In some embodiments, the solar mirror film further comprises a tie layer between the weatherable layer and the reflective material. In some embodiments, the tie layer includes an adhesive. In some embodiments, the bond strength between the tie layer and the weatherable layer is greater than the bond strength between the weatherable layer and the reflective material. In some embodiments, the bond strength between the reflective layer and the tie layer is greater than the bond strength between the weatherable layer and the reflective material. In some embodiments, the solar mirror film further comprises a polymeric material between the weatherable layer and the reflective material. In some embodiment, the solar mirror film further comprises a corrosion protective layer adjacent to the reflective layer. In some embodiments, the corrosion protective layer comprises at least one of copper and an inert metal alloy. In some embodiments, the solar mirror film further comprises an adhesive layer adjacent to the reflective layer. In some embodiments, the adhesive layer comprises a pressure sensitive adhesive. In some embodiments, the adhesive layer is between the reflective layer and a substrate. In some embodiments, the substrate is part of one of a photovoltaic solar panel system and a concentrated solar power system. In some embodiments, one of a polymeric material and an adhesive material is adjacent to the edge regions of the weatherable layer from which reflective material is substantially absent.

[0023] Another embodiment of the present disclosure relates to a concentrated solar power system including a solar mirror film as described herein, including, but not limited to, any of the embodiments described above.

[0024] Another embodiment of the present disclosure relates to a concentrated photovoltaic power system including a solar mirror film as described herein, including, but not limited to, any of the embodiments described above.

[0025] Another embodiment of the present disclosure relates to a window film including a solar mirror film as described herein.

[0026] Various aspects and advantages of exemplary embodiments of the disclosure have been summarized. The above summary is not intended to describe each illustrated embodiment or every implementation of the present disclosure. The Drawings and the Detailed Description that follow

more particularly exemplify the various embodiments disclosed herein. These and various other features and advantages will be apparent from a reading of the following detailed description.

Brief Description of Drawings

[0027] Fig. 1 is a schematic view of a prior art solar mirror film.

[0028] Fig. 2 is a schematic top view of one exemplary embodiment of a solar mirror film in accordance with the present disclosure.

[0029] Fig. 3 is a schematic top view of another exemplary embodiment of a solar mirror film in accordance with the present disclosure.

[0030] Fig. 4 is a schematic top view of another exemplary embodiment of a solar mirror film in accordance with the present disclosure.

[0031] Fig. 5 is a schematic top view of another exemplary embodiment of a solar mirror film in accordance with the present disclosure.

[0032] Fig. 6 is a schematic top view of another exemplary embodiment of a solar mirror film in accordance with the present disclosure.

[0033] Fig. 7 is a schematic top view of another exemplary embodiment of a solar mirror film in accordance with the present disclosure.

[0034] Fig. 8 is a schematic top view of another exemplary embodiment of a solar mirror film in accordance with the present disclosure.

[0035] Fig. 9 is a schematic top view of another exemplary embodiment of a solar mirror film in accordance with the present disclosure.

Detailed Description

[0036] Some embodiments of the present application relate to solar mirror films that substantially lack reflective layer material on one or more of the edge portions of a solar mirror film. In some embodiments, only two of the edges substantially lack the reflective material.

[0037] Some embodiments of the present application relate to solar mirror films having a reflective layer with discontinuities in the edge portion of the solar mirror film. In some embodiments, the solar mirror films include areas in the edge regions substantially free of reflective material and areas including reflective material. In some embodiments, the edge regions have strips or dots of reflective material and strips or dots of areas substantially free of reflective material.

[0038] Some embodiments of the present application relate to solar mirror films that have regions, areas, or portions that substantially lack reflective layer material, including, for example, the bulk

region or one or more of the edge regions. These regions, areas, or portions can be on any portion of the solar mirror film. These regions, areas, or portions can be any shape or size, and can be random or patterned. Any pattern can be used. Some exemplary regions, areas, or portions are rectangular areas or dots scattered randomly or in a desired pattern or frequency (*e.g.*, some defined number of dots per square inch of solar mirror film).

[0039] The embodiments described herein all provide a more durable solar mirror film because the areas lacking reflective material have a better adhesion than the areas including reflective material. Because the bond strength in the areas lacking reflective material is increased (compared to the bond strength in the areas including reflective material), the overall construction has an increased bond strength. Consequently, the incidence of delamination or tunneling is minimized.

[0040] In some embodiments, the adhesion is enhanced for at least the reason that the weatherable layer bonds directly to a layer other than the reflective layer (for example, a tie layer). The weatherable layer and the layer to which it adheres have a bond strength that is greater than the bond strength of the weatherable layer and reflective layer.

[0041] Typically, areas from which reflective material has been removed are non-reflective. Because the efficiency of a power-generating system including the solar mirror films described herein is dependent on the amount of incident light, which is dependent on the amount of light reflected by the solar mirror films, it may be preferable in some embodiments to minimize the size of the areas substantially lacking reflective material in order to minimize the total area of non-reflectivity of the solar mirror film. In some embodiments, it may be preferable to tailor the size, shape, and position of the regions substantially lacking reflective material to maximize the benefits of the increased bond strength while minimizing the total non-reflective area of the solar mirror film.

[0042] Some exemplary solar mirror film patterns and constructions are described below and shown in the accompanying figures.

[0043] One exemplary embodiment is shown as a schematic top view in Fig. 2. Solar mirror film 200 of Fig. 2 includes a weatherable layer 210 including a bulk region 220 and four edge regions 230a, 230b, 230c, and 230d. A reflective material 240 is adjacent to bulk region 220 of weatherable layer 210. In this embodiment, reflective material 240 is largely (or substantially) absent from edge regions 230a, 230b, 230c, and 230d. Those of skill in the art will appreciate that the specific embodiment shown in Fig. 2 has reflective material 240 substantially absent from all four edge regions 230, but it is within the scope of the present disclosure to have reflective material 240 absent from only one or more of the edge regions. As used herein, the term “substantially absent” or “substantially free” or “substantially lacking” with respect to the reflective material being substantially absent from a region of the solar mirror film refers to at least

about 70% of the specific region lacking reflective material (in other words, about 70% of the region is free of reflective material or about 30% or less of the total area of that region includes reflective material). In some embodiments, at least about 75% of the specific region lacks reflective material. In some embodiments, at least about 80% of the specific region lacks reflective material. In some embodiments, at least about 85% of the specific region lacks reflective material. In some embodiments, at least about 90% of the specific region lacks reflective material. In some embodiments, at least about 95% of the specific region lacks reflective material. In some embodiments, at least about 97% of the specific region lacks reflective material. In some embodiments, at least about 98% of the specific region lacks reflective material.

[0044] As used herein, the term “edge region” refers to the area between one edge of a sheeting and the bulk region. The edge region can, but does not have to, run the entire length or width of the sheeting. The size of edge region may vary based on specific applications. However, the edge area may be of any size that is large enough to form a bond strength between the adhesive layer and the weatherable layer that exceeds the bond strength between the weatherable layer and the reflective layer.

[0045] Fig. 3 shows an embodiment in which not all four edge regions of a rectangular sheet are free of reflective material. Specifically, the schematic top view of Fig. 3 shows a solar mirror film 300 including a weatherable layer 210 including a bulk region 320 and edge regions 330a and 330b. A reflective material 240 is adjacent to bulk region 320 of weatherable layer 210. Reflective material 240 is largely (or substantially) absent from edge regions 330a and 330b.

[0046] The inventors of the present application recognized that there are typically two types of tunneling. The first type extends along the longitudinal direction of a parabolic shaped solar panel. The second type is perpendicular to the first type. The inventors of the present application found that typically, the first type of tunneling develops before the second type of tunneling. Thus, in some embodiments where only two of the edge regions substantially lack reflective material, those two edges extend along the longitudinal direction of the solar mirror film.

[0047] Fig. 4 shows an embodiment in which the edge regions that include less reflective material than prior art solar mirror films do not run the entire length of the solar mirror film. Specifically, the schematic top view of Fig. 4 shows a solar mirror film 400 including a weatherable layer 210 including a bulk region 420 and numerous edge regions 430. A reflective material 240 is adjacent to bulk region 420 of weatherable layer 210. Reflective material 240 is largely (or substantially) absent from edge regions 430. As such, the reflective material is discontinuous along the edges of the sheet. The edge regions where the reflective material is substantially absent can be randomly sized (as shown, for example, in Fig. 4) or sized to form a pattern (as shown, for example, in Fig.

5). As such, the discontinuity can be patterned (for example, as shown in Fig. 4) or random (for example, as shown in Fig. 5). While the specific embodiments shown in Figs. 4 and 5 have discontinuous reflective material along all four of the edges of the weatherable layer, in some embodiments, discontinuous regions are formed along at least one edge region. In some embodiments, discontinuous regions are formed along at least two edge regions. In some embodiments, discontinuous regions are formed along at least three edge regions.

[0048] Fig. 5 shows an embodiment in which the edge regions do not run the entire length of the solar mirror film. Specifically, the schematic top view of Fig. 5 shows a solar mirror film 500 including a weatherable layer 210 including a bulk region 520 and numerous edge regions 530. A reflective material 240 is adjacent to bulk region 520 of weatherable layer 210. Reflective material 240 is largely (or substantially) absent from edge regions 530. As such, the reflective material is discontinuous along the edges of the sheet.

[0049] Fig. 6 shows an embodiment in which the solar mirror film includes regions with reflective material and regions without reflective material. Specifically, the schematic top view of solar mirror film 600 shows a weatherable layer 210 adjacent to which are numerous regions including reflective material 630 and regions substantially lacking reflective material 620. The regions substantially lacking reflective material 620 are generally rectangular and form a pattern across the entire solar mirror film 600. Those of skill in the art will appreciate that the regions including reflective material and regions substantially lacking reflective material shown in the specific exemplary embodiment of Fig. 6 can be reversed in an alternative embodiment covered by the present disclosure. Specifically, in an alternative embodiment, regions 630 lack reflective material and regions 620 include reflective material.

[0050] As is discussed above, the regions lacking reflective material are non-reflective. Consequently, it is desirable in some embodiments to minimize the size of the regions lacking reflective material. Fig. 7 is one exemplary embodiment that includes smaller regions lacking reflective material (smaller than the exemplary embodiment shown in Fig. 6). Specifically, the schematic top view of solar mirror film 700 shows a weatherable layer 210 adjacent to numerous regions 730 substantially lacking reflective material. The areas or regions of the first major surface of weatherable layer 210 that do not lack reflective material include reflective material. As shown in Fig. 7, the regions 730 substantially lacking reflective material are dots that are relatively evenly spaced from adjacent dots and are spread across the majority (in some embodiments, entire) first major surface of weatherable layer 210. In alternative embodiments, the dot size or shape can vary, the dots can be randomly spaced from adjacent dots, and/or the dots can be on one or more portions of the weatherable layer instead of across all or a majority of the weatherable layer as shown in the specific exemplary embodiment of Fig. 7.

[0051] Fig. 8 is an exemplary embodiment in which a dot pattern similar to the one shown in Fig. 7 (except randomly spaced) is on only the edge regions of a solar mirror film. Specifically, the schematic top view of Fig. 8 show solar mirror film 800 including a weatherable layer 210 adjacent to numerous regions 830 substantially lacking reflective material. Regions 830 are shown in this specific exemplary embodiment as randomly spaced dots that are in all four edge regions 840 of solar mirror film 800. In alternative embodiments, the dot size or shape can vary, the dots can be randomly spaced from adjacent dots, and/or the dots can be on one or more portions of the weatherable layer instead of only in the edge regions as shown in the specific exemplary embodiment of Fig. 8. Further, in alternative embodiments, only one or more edge regions may include regions 830 substantially lacking reflective material.

[0052] As mentioned above, the inventors of the present disclosure recognized that the first type of tunneling to develop in solar mirror film material typically extends along the longitudinal direction of a parabolic shaped solar panel. As such, in some embodiments, the areas or regions that are substantially free of reflective material extend along the longitudinal direction of the solar mirror film or the solar mirror film when installed in a parabolic shaped solar panel. One exemplary embodiment is shown schematically in Fig. 9. Fig. 9 shows a solar mirror film 900 including a weatherable film 210 adjacent to which are linear regions 910 that substantially lack reflective material. The areas of the first major surface of weatherable layer 210 that are not adjacent to regions 910 are adjacent to reflective material.

[0053] In some embodiments, these linear regions extend along the longitudinal direction of the solar mirror film. In alternative embodiments, these regions do not extend along the longitudinal direction of the solar mirror film. In alternative embodiments, these regions run perpendicular to the longitudinal direction of the solar mirror film. In alternative embodiments, the line length and/or thickness varies, the lines can be randomly spaced from adjacent lines, and/or the lines can be adjacent to different portions of the first major surface of weatherable layer 210 instead of the regions shown in the specific exemplary embodiment of Fig. 9.

[0054] Additionally or alternatively, the inventors of the present disclosure have recognized that in some instances, tunneling occurs mostly perpendicular to the bending direction of the parabolic trough. Consequently, some embodiments include vertical linear regions lacking reflective material along the machine direction of the solar mirror film.

[0055] For purposes of simplicity, the schematic views shown in Figs. 2-9 only show the first major surface of the weatherable layer and the areas including reflective material and areas substantially free of reflective material. These embodiments and this disclosure, however, are meant to include other layers in the solar mirror film, including, for example, layers between the weatherable layer and the reflective layer (*e.g.*, a tie layer) and layers on top of or below the

weatherable layer and/or the reflective layer. Each of the potential layers is described in greater detail below.

[0056] In some embodiments, the edge regions lacking reflective material are adjacent to (and in some cases, directly adjacent to) a tie layer or adhesive. In some embodiments, the edge regions lacking reflective material are adjacent to (and in some cases, directly adjacent to) a polymeric layer. Some exemplary polymeric layers include, for example, PMMA layer, PVDF layers, and blends thereof.

[0057] Premask Layer

[0058] The premask layer is optional. Where present, the premask protects the weatherable layer during handling, lamination, and installation. Such a configuration can then be conveniently packaged for transport, storage, and consumer use. In some embodiments, the premask is opaque to protect operators during outdoor installations. In some embodiments, the premask is transparent to allow for inspection for defects. Any known premask can be used. One exemplary commercially available premask is ForceField® 1035 sold by Tredegar of Richmond, Virginia. Premask layer can be positioned, for example, as shown in Fig. 1.

[0059] Weatherable Layer

[0060] In some embodiments, the weatherable layer or sheet is flexible and transmissive to visible and infrared light. In some embodiments, the weatherable layer or sheet is resistant to degradation by ultraviolet (UV) light. In some embodiments, the phrase "resistant to degradation by ultraviolet light" means that the weatherable sheet at least one of reflects or absorbs at least 50 percent of incident ultraviolet light over at least a 30 nanometer range in a wavelength range from at least 300 nanometers to 400 nanometers. Photo-oxidative degradation caused by UV light (*e.g.*, in a range from 280 to 400 nm) may result in color change and deterioration of optical and mechanical properties of polymeric films. In some embodiments, the weatherable sheet or layer is generally abrasion and impact resistant and can prevent degradation of, for example, solar assemblies when they are exposed to outdoor elements.

[0061] In some embodiments, the weatherable layer includes one or more organic film-forming polymers. Some exemplary polymers include, for examples, polyesters, polycarbonates, polyethers, polyimides, polyolefins, fluoropolymers, and combinations thereof. Assemblies according to the present disclosure include a weatherable sheet or layer, which can be a single layer (monolayered embodiments) or can include more than one layer (multilayered embodiments).

[0062] A variety of stabilizers may be added to the weatherable sheet to improve its resistance to UV light. Examples of such stabilizers include at least one of ultraviolet absorbers (UVA) (*e.g.*, red shifted UV absorbers), hindered amine light stabilizers (HALS), or anti-oxidants. These additives are described in further detail below. In some of these embodiments, the weatherable sheet need not include UVA or HALS.

[0063] The UV resistance of the weatherable sheet can be evaluated, for example, using accelerated weathering studies. Accelerated weathering studies are generally performed on films using techniques similar to those described in ASTM G-155, "Standard practice for exposing non-metallic materials in accelerated test devices that use laboratory light sources." One mechanism for detecting the change in physical characteristics is the use of the weathering cycle described in ASTM G155 and a D65 light source operated in the reflected mode. Under the noted test, and when the UV protective layer is applied to the article, the article should withstand an exposure of at least 18,700 kJ/m² at 340 nm before the b* value obtained using the CIE L*a*b* space increases by 5 or less, 4 or less, 3 or less, or 2 or less before the onset of significant cracking, peeling, delamination, or haze.

[0064] In some embodiments, the weatherable sheet includes a fluoropolymer. Fluoropolymers are typically resistant to UV degradation even in the absence of stabilizers such as UVA, HALS, and anti-oxidants. Some exemplary fluoropolymers include ethylene-tetrafluoroethylene copolymers (ETFE), ethylene-chloro-trifluoroethylene copolymers (ECTFE), tetrafluoroethylene-hexafluoropropylene copolymers (FEP), tetrafluoroethylene-perfluorovinylether copolymers (PFA, MFA) tetrafluoroethylene-hexafluoropropylene-vinylidene fluoride copolymers (THV), polyvinylidene fluoride homo and copolymers (PVDF), blends thereof, and blends of these and other fluoropolymers. Fluoropolymers typically comprise homo or copolymers of TFE, CTFE, VDF, HFP or other fully fluorinated, partially fluorinated or hydrogenated monomers such as vinyl ethers and alpha-olefins or other halogen containing monomers. The CTE of fluoropolymer films is typically high relative to films made from hydrocarbon polymers. For example, the CTE of a fluoropolymer film may be at least 75, 80, 90, 100, 110, 120, or 130 ppm/K. For example, the CTE of ETFE may be in a range from 90 to 140 ppm/K.

[0065] Weatherable films including fluoropolymer can also include non-fluorinated materials. For example, a blend of polyvinylidene fluoride and polymethyl methacrylate can be used. Useful flexible, visible and infrared light-transmissive substrates also include multilayer film substrates. Multilayer film substrates may have different fluoropolymers in different layers or may include at least one layer of fluoropolymer and at least one layer of a non-fluorinated polymer. Multilayer films can comprise a few layers (*e.g.*, at least 2 or 3 layers) or can comprise at least 100 layers (*e.g.*, in a range from 100 to 2000 total layers or more). The different polymers in the different

multilayer film substrates can be selected, for example, to reflect a significant portion (*e.g.*, at least 30, 40, or 50%) of UV light in a wavelength range from 300 to 400 nm as described, for example, in U.S. Patent No. 5,540,978 (Schrenk). Such blends and multilayer film substrates may be useful for providing UV resistant substrates that have lower CTEs than the fluoropolymers described above.

[0066] Some exemplary weatherable sheets comprising a fluoropolymer can be commercially obtained, for example, from E.I. duPont De Nemours and Co., Wilmington, DE, under the trade designation "TEFZEL ETFE" and "TEDLAR," and films made from resins available from Dyneon LLC, Oakdale, MN, under the trade designations "DYNEON ETFE", "DYNEON THV", "DYNEON FEP", and "DYNEON PVDF", from St. Gobain Performance Plastics, Wayne, NJ, under the trade designation "NORTON ETFE", from Asahi Glass under the trade designation "CYTOPS", and from Denka Kagaku Kogyo KK, Tokyo, Japan under the trade designation "DENKA DX FILM."

[0067] Some useful weatherable sheets are reported to be resistant to degradation by UV light in the absence of UVA, HALS, and anti-oxidants. For example, certain resorcinol isophthalate/terephthalate copolyarylates, for example, those described in U. S. Patent Nos. 3,444,129; 3,460,961; 3,492,261; and 3,503,779 are reported to be weatherable. Certain weatherable multilayer articles containing layers comprising structural units derived from a 1,3-dihydroxybenzene organodicarboxylate are reported in Int. Pat. App. Pub. No. WO 2000/061664, and certain polymers containing resorcinol arylate polyester chain members are reported in U. S. Pat. No. 6,306,507. Block copolyestercarbonates comprising structural units derived from at least one 1,3-dihydroxybenzene and at least one aromatic dicarboxylic acid formed into a layer and layered with another polymer comprising carbonate structural units are reported in US Publication No. 2004/0253428. Weatherable sheets containing polycarbonate may have relatively high CTEs in comparison to polyesters, for example. The CTE of a weatherable sheet containing a polycarbonate may be, for example, about 70 ppm/K.

[0068] For some or all of the embodiments of the weatherable sheet or layer described above, the major surface of the weatherable sheet (*e.g.*, fluoropolymer) can be treated to improve adhesion to a pressure sensitive adhesive. Useful surface treatments include, for example, electrical discharge in the presence of a suitable reactive or non-reactive atmosphere (*e.g.*, plasma, glow discharge, corona discharge, dielectric barrier discharge or atmospheric pressure discharge); chemical pretreatment (*e.g.*, using alkali solution and/or liquid ammonia); flame pretreatment; or electron beam treatment. A separate adhesion promotion layer may also be formed between the major surface of the weatherable sheet and the PSA. In some embodiments, the weatherable sheet may be a fluoropolymer that has been coated with a PSA and subsequently irradiated with an electron

beam to form a chemical bond between the substrate and the pressure sensitive adhesive; (*see, e.g.*, U. S. Pat. No. 6,878,400 (Yamanaka et al.)). Some useful weatherable sheets that are surface treated are commercially available, for example, from St. Gobain Performance Plastics under the trade designation "NORTON ETFE".

[0069] In some embodiments, the weatherable sheet has a thickness from about 0.01 mm to about 1 mm. In some embodiments, the weatherable sheet has a thickness from about 0.05 mm to about 0.25 mm. In some embodiments, the weatherable sheet has a thickness from about 0.05 mm to about 0.15 mm.

[0070] Tie Layer

[0071] In some embodiments, the tie layer includes a metal oxide such as aluminum oxide, copper oxide, titanium dioxide, silicon dioxide, or combinations thereof. As a tie layer, titanium dioxide was found to provide surprisingly high resistance to delamination in dry peel testing. Further options and advantages of metal oxide tie layers are described in U.S. Patent No. 5,361,172 (Schissel et al.), incorporated by reference herein.

In any of the foregoing exemplary embodiments, the tie layer has a thickness of equal to or less than 500 micrometers. In some embodiments, the tie layer has a thickness of between about 0.1 micrometer and about 5 micrometers. In some embodiments, it is preferable that the tie layer have an overall thickness of at least 0.1 nanometers, at least 0.25 nanometers, at least 0.5 nanometers, or at least 1 nanometer. In some embodiments, it is preferable that the tie layer have an overall thickness no greater than 2 nanometers, no greater than 5 nanometers, no greater than 7 nanometers, or no greater than 10 nanometers.

[0072] Reflective Layer / Reflective Material

[0073] The solar mirror films described herein include one or more reflective including one or more reflective materials. The reflective layer(s) (including reflective material) provide reflectivity. In some embodiments, the reflective layer(s) have smooth, reflective metal surfaces that are specular. As used herein, the term "specular surfaces" refer to surfaces that induce a mirror-like reflection of light in which the direction of incoming light and the direction of outgoing light form the same angle with respect to the surface normal. Any reflective metal may be used for this purpose, although preferred metals include silver, gold, aluminum, copper, nickel, and titanium. In some embodiments, the reflective layer includes silver.

[0074] Prior art reflective layers extend across the entire major surface of the weatherable layer. In the present application, the reflective layer(s) do not extend across the entire major surface of

the weatherable layer. Any method can be used to create a reflective layer that does not extend across the entire major surface of the weatherable layer.

[0075] In some embodiments, the reflective layer is deposited onto or otherwise positioned adjacent to the weatherable layer such that the reflective material does not extend across the entire major surface of the weatherable layer. In some embodiments, portions of the weatherable layer are masked during the deposition process such that the reflective layer is applied onto only a pre-determined portion of the compliant layer. U.S. Patent Application Matter No. 69866US002 (assigned to the assignee of the present application) provides more detail on these methods and is incorporated herein by reference.

[0076] Alternatively or additionally, the reflective material may be deposited or positioned adjacent to the weatherable layer such that the reflective material extends across all or substantially all of the major surface of the weatherable layer and then portions of the reflective material are removed to form a reflective layer that does not extend across the entire major surface.

[0077] Application of the reflective layer / the reflective material can be achieved using numerous coating methods including, for example, physical vapor deposition via sputter coating, evaporation via e-beam or thermal methods, ion-assisted e-beam evaporation, electro-plating, spray painting, vacuum deposition, and combinations thereof. The metallization process is chosen based on the polymer and metal used, the cost, and many other technical and practical factors. Physical vapor deposition (PVD) of metals is very popular for some applications because it provides the purest metal on a clean interface. In this technique, atoms of the target are ejected by high-energy particle bombardment so that they can impinge onto a substrate to form a thin film. The high-energy particles used in sputter-deposition are generated by a glow discharge, or a self-sustaining plasma created by applying, for example, an electromagnetic field to argon gas. In some embodiments, the reflective layer and/or reflective material is applied to a weatherable layer. In some embodiments (not shown in the figures), the reflective layer of reflective material is applied onto a tie layer. Exemplary methods of applying the reflective material onto limited portions of a weatherable layer are described, for example, in Patent Application Matter No. 69866US002, assigned to the present assignee and incorporated in its entirety herein.

[0078] Removal of reflective material (including, for example, portions of reflective material) can be effected in numerous ways including, for example, ultrasonically, using mechanical removal methods (including, for example, physical removal and laser removal), and using thermal removal methods. U.S. Patent Application Matter Nos. 69677US002 and 69865US002 (assigned to the assignee of the present application) provide more detail on these methods and are incorporated herein in their entirety.

[0079] The reflective material or layer(s) is preferably thick enough to reflect the desired amount of the solar spectrum of light. The preferred thickness can vary depending on the composition of the reflective layer and the specific use of the solar mirror film. In some exemplary embodiments, the reflective layer is between about 75 nanometers to about 100 nanometers thick for metals such as silver, aluminum, copper, and gold. In some embodiments, the reflective layer has a thickness no greater than 500 nanometers. In some embodiments, the reflective layer has a thickness of from 80 nm to 250 nm. In some embodiments, the reflective layer has a thickness of at least 25 nanometers, at least 50 nanometers, at least 75 nanometers, at least 90 nanometers, or at least 100 nanometers. Additionally, in some embodiments, the reflective layer has a thickness no greater than 100 nanometers, no greater than 110 nanometers, no greater than 125 nanometers, no greater than 150 nanometers, no greater than 200 nanometers, no greater than 300 nanometers, no greater than 400 nanometers, or no greater than 500 nanometers. Although not shown in the figures, two or more reflective layers may be used.

[0080] Corrosion Resistant Layer

[0081] The corrosion resistant layer is optional. Where included, the corrosion resistant layer may include, for example, elemental copper. Use of a copper layer that acts as a sacrificial anode can provide a reflective article with enhanced corrosion-resistance and outdoor weatherability. As another approach, a relatively inert metal alloy such as Inconel (an iron-nickel alloy) can also be used.

[0082] The corrosion resistant layer is preferably thick enough to provide the desired amount of corrosion resistance. The preferred thickness can vary depending on the composition of the corrosion resistant layer. In some exemplary embodiments, the corrosion resistant layer is between about 75 nanometers to about 100 nanometers thick. In other embodiments, the corrosion resistant layer is between about 20 nanometers and about 30 nanometers thick. Although not shown in the figures, two or more corrosion resistant layers may be used.

[0083] In some embodiments, the corrosion resistant layer has a thickness no greater than 500 nanometers. In some embodiments, the corrosion resistant layer has a thickness of from 80 nm to 250 nm. In some embodiments, the corrosion resistant layer has a thickness of at least 25 nanometers, at least 50 nanometers, at least 75 nanometers, at least 90 nanometers, or at least 100 nanometers. Additionally, in some embodiments, the corrosion resistant layer has a thickness no greater than 100 nanometers, no greater than 110 nanometers, no greater than 125 nanometers, no

greater than 150 nanometers, no greater than 200 nanometers, no greater than 300 nanometers, no greater than 400 nanometers, or no greater than 500 nanometers.

[0084] Adhesive Layer

[0085] The adhesive layer is optional. Where present, the adhesive layer adheres the multilayer construction to a substrate (not shown in the figures). In some embodiments, the adhesive is a pressure sensitive adhesive. As used herein, the term “pressure sensitive adhesive” refers to an adhesive that exhibits aggressive and persistent tack, adhesion to a substrate with no more than finger pressure, and sufficient cohesive strength to be removable from the substrate. Exemplary pressure sensitive adhesives include those described in PCT Publication No. WO 2009/146227 (Joseph, et al.), incorporated herein by reference.

[0086] Liner

[0087] The liner is optional. Where present, the liner protects the adhesive and allows the solar mirror film to be transferred onto another substrate. Such a configuration can then be conveniently packaged for transport, storage, and consumer use. In some embodiments, the liner is a release liner. In some embodiments, the liner is a silicone-coated release liner.

[0088] Additional or alternative layers can be included in the solar mirror films described herein. Some exemplary additional or alternative layers include those described in U.S. Patent Application Matter Nos. 69679US002, 69680US002, 69682US002, and 69681US002, all of which are assigned to the present assignee and all of which are incorporated in their entirety herein.

[0089] Substrate

[0090] The films described herein can be applied to a substrate by removing liner 180 (where present) and placing adhesive layer 170 (where present) adjacent to the substrate. Premask layer 110 (where present) is then removed to expose weatherable layer 120 to sunlight. Suitable substrates generally share certain characteristics. Most importantly, the substrate should be sufficiently rigid. Second, the substrate should be sufficiently smooth that texture in the substrate is not transmitted through the adhesive/metal/polymer stack. This, in turn, is advantageous because it: (1) allows for an optically accurate mirror, (2) maintains physical integrity of the metal reflective layer by eliminating channels for ingress of reactive species that might corrode the metal reflective layer or degrade the adhesive, and (3) provides controlled and defined stress concentrations within the reflective film-substrate stack. Third, the substrate is preferably

nonreactive with the reflective mirror stack to prevent corrosion. Fourth, the substrate preferably has a surface to which the adhesive durably adheres.

[0091] Exemplary substrates for reflective films, along with associated options and advantages, are described in PCT Publication Nos. WO04114419 (Schripsema), and WO03022578 (Johnston et al.); U.S. Publication Nos. 2010/0186336 (Valente, et al.) and 2009/0101195 (Reynolds, et al.); and U.S. Patent No. 7,343,913 (Neidermeyer), all of which are incorporated in their entirety herein. For example, the article can be included in one of the many mirror panel assemblies as described in co-pending and co-owned provisional U.S. Patent Application No. 13/393,879 (Cosgrove, et al.), incorporated herein in its entirety. Other exemplary substrates include metals, such as, for example, aluminum, steel, glass, or composite materials.

[0092] Advantages and embodiments of this disclosure are further illustrated by the following examples, but the particular materials and amounts thereof recited in these examples, as well as other conditions and details, should not be construed to unduly limit this disclosure. These examples are merely for illustrative purposes and are not meant to be limiting on the scope of the appended claims. Notwithstanding that the numerical ranges and parameters setting forth the broad scope of the disclosure are approximations, the numerical values set forth in the specific examples are reported as precisely as possible. Any numerical value, however, inherently contains certain errors necessarily resulting from the standard deviation found in their respective testing measurements. At the very least, and not as an attempt to limit the application of the doctrine of equivalents to the scope of the claims, each numerical parameter should at least be construed in light of the number of reported significant digits and by applying ordinary rounding techniques. Also, in these examples, all percentages, proportions and ratios are by weight unless otherwise indicated.

[0093] Examples

[0094] TEST METHODS

[0095] Neutral Salt Spray Test

[0096] Corrosion of the comparative examples and examples was evaluated following the procedure outlined on ISO 9227:2006, "Corrosion tests in artificial atmospheres -- Salt spray tests" with the exception that results are reported as either % reflective area after various times in the salt spray or simply as visual observation failure while in the salt spray. Visual observation failure means the first visual sign of corrosion while the sample is in the salt spray.

[0097] Percent Reflective Area

[0098] The reflective area for each sample was taken as the surface area of the laminated samples that did not show any signs of discoloration due to corrosion or delamination. This area was then reported as a percent of the initial reflective surface area of the sample. The initial reflective area of the samples was taken as the full surface area of the control samples, and as the area within the ultrasonic seals for the ultrasonically edge treated samples. This was determined by making a photocopy of the laminates after testing and cutting out and weighing the black portions of the photocopy. The corroded areas appear non-black in the photocopy.

[0099] Comparative Example 1

[00100] A reflective mirror film comprising a polymer layer and a metallized layer (obtained under the trade designation "SOLAR MIRROR FILM SMF-1100" from 3M Company, St. Paul, MN) was laminated onto a painted aluminum substrate having a thickness of approximately 0.02 in (0.05 cm) after removing the pressure sensitive adhesive liner on the metallized side. The aluminum substrate was then cut into 10.2 cm x 10.2 cm (4 in x 4 in) samples using a shear cutter. The premask was removed. The three samples were tested according to the "Neutral Salt Spray Test" described above. Test results are provided in Table 1.

[00101] Comparative Example 2

[00102] A reflective mirror film comprising a polymer layer and a metallized layer (obtained under the trade designation "SOLAR MIRROR FILM SMF-1100" from 3M Company, St. Paul, MN) was laminated onto a painted aluminum substrate having a thickness of approximately 0.02 in (0.05 cm) after removing the pressure sensitive adhesive liner on the metallized side. The aluminum substrate was then cut into 10.2 cm x 10.2 cm (4 in x 4 in) samples using a shear cutter. The premask was removed. All four edges of the sample were taped with 12.7 mm (0.5 in) wide "3M Weather Resistant Film Tape 838" (commercially available from 3M Company, St. Paul, MN) by adhering 6.4 mm (0.25 in) of the tape to the front side of the sample and around the edge face and tightly folding the remaining edge tape over the sample. The sample was tested according to the "Neutral Salt Spray Test" described above and showed signs of corrosion after two weeks.

[00103] Example 1

[00104] A reflective mirror film comprising a polymer layer and a metallized layer (obtained under the trade designation "SOLAR MIRROR FILM SMF-1100" from 3M

Company, St. Paul, MN) was laminated onto a painted aluminum substrate having a thickness of approximately 0.02 in (0.05 cm) after removing the pressure sensitive adhesive liner on the metallized side. The aluminum substrate was then cut into 10.2 cm x 10.2 cm (4 in x 4 in) samples using a shear cutter. The premask was removed.

[00105] Ultrasonic energy was used to weld the reflective mirror film along its edges as follows. An ultrasonic welder with a frequency of 20 kHz, power output of 4kW, having a 3 in (7.62 cm) air cylinder (BRANSON model “2000X” commercially available from Emerson Industrial Automation, St. Louis, MO), a commercially available 1.5 gain titanium booster manufactured by Branson Company, and a titanium bar horn with 3.0 gain was used. This ultrasonic energy output corresponds to an amplitude of 89 -99 micrometers (3.5-3.9 mils) peak to peak. The horn had a weld face of 15 cm x 1.3 cm (6 in x 0.5 in). The laminated aluminum samples were plunge welded using a pressure of 140 kPa (20 psi), a trigger force of 222 N (50 lbf), and a welding residence time of 0.15 sec on each of their four sides.

[00106] The sample was tested according to the “Neutral Salt Spray Test” described above and results are provided in Table 1.

[00107] Example 2

[00108] A welded sample was prepared as described in Example 1, except that a pressure of 178 N (40 lbf) was used. The sample was tested according to the “Neutral Salt Spray Test” described above and results are provided in Table 1.

[00109] Example 3

[00110] A welded sample was prepared as described in Example 1, except the polyolefin premask was not removed. All four sides of the 10.2 cm x 10.2 cm (4 in x 4 in) sample were welded at a distance of about 0.125 in (0.318 cm) from each edge at a pressure of 140 kPa (20 psi), trigger force of 222 N (50 lbf) and time duration of 0.15 sec on each side. The sample was tested according to the “Neutral Salt Spray Test” described above and results are provided in Table 1.

[00111] Example 4

[00112] A laminated aluminum substrate was prepared as described in Example 3, except that a pressure of 240 kPa (35 psi) was used and the trigger force applied for

0.10 sec on each side of the sample. The sample was tested according to the “Neutral Salt Spray Test” described above and results are provided in Table 1.

[00113] Example 5

[00114] A 254 micrometer (10 mil) thick polyvinylidene fluoride (PVDF) homopolymer film (obtained under the trade designation “SOLEF 1010” from Solvay Solexis, West Deptford, NJ) was provided. The PVDF film cut to a width of about 0.1 cm was placed over the mirror film about 3.18 mm (0.125 in) from the edge. All four edges of the 10.2 cm x 10.2 cm construction were welded using the ultrasonic welder described in Example 1 at a distance of about 3.18 mm (0.125 in) from each edge at a pressure of 480 kPa (70 psi) for all sides, a trigger force of 1334 N (300 lbf) for all sides and a time of 0.09 sec for all sides. Thus, a strip of PVDF film was aligned below the horn of the ultrasonic welder using this method and “melted” into the PMMA layer.

[00115] The sample was tested according to the “Neutral Salt Spray Test” described above and results are provided in Table 1.

[00116] Example 6

[00117] A 254 micrometer (10 mil) cast film of an impact modified PMMA based resin was obtained by recommended industry extrusion conditions for such resins. The resin was obtained from Plaskolite, Columbus, OH (OPTIX CA-923 UVA2) and contained 15% of a 2-layer type impact modifier, 1.5% of a UV absorber, and had a melt flow rate of 2.0 - 3.0 (g/10 min, as per ASTM D 1238, (3.8/230)). The film was cut to a width of 0.1 cm and placed over the reflective mirror film side of the 10.2 cm x 10.2 cm (4 in x 4 in) laminated aluminum substrate and welded at a distance of about 3.18 mm (0.125 in) from each edge, using a pressure of 480 kPa (70 psi), trigger force of 1334 N (300 lbf) for, respectively, 0.09, 0.13, 0.10, 0.10 seconds for the first, second, third, and fourth sides. Two additional replicate samples (total of 3) were made and tested with the same salt spray test results as the first sample as reported for Example 6 in Table 1. The narrow impact modified PMMA strips were intended to fill in possible welding holes and protect against impacts and abuse although the examples tested were not submitted to abuse or impact.

[00118] The sample was tested as described in the “Neutral Salt Spray Test” and results are shown in Table 1.

[00119] Example 7

[00120] A sample of the 10.2 cm x 10.2 cm (4 in x 4 in) laminate as described in Example 1 was made. The sample without the PSA and liner had all four metal edges manually mechanically scraped from the metal side of the laminate with a silicon carbide hand tool (12.7 mm (0.5 in) wide blade with square edge). The tool was used to remove 3.18 mm (0.125 in) of the silver from all 4 edges. Following this mechanical removal, an equivalent PSA was coated onto the scraped metal side of the laminate and the laminate was then adhered to the aluminum substrate as described under “Aluminum Substrate Preparation.”

[00121] The sample was tested as described in the “Neutral Salt Spray Test” and showed no signs of corrosion after 67 days.

[00122] Example 8

[00123] A sample of the 10.2 cm x 10.2 cm (4 in x 4 in) laminate was made as described in Example 1. The sample was then laser ablated to create a 15 mm x 15 mm square nominally centered in the middle of the laminate (in range of 25-50 mm (1-2 in) from each side of the laminate). The A SP-40P-HL laser from SPI Lasers was used in conjunction with a “hurrySCAN 20” scanner (commercially available from Scanlab AG, Munich, Germany) with telecentric F-Theta Objective (f=100mm focal length). The scanner and laser were controlled by a computer. Settings included wavelength 1070 nm, pulse length 250 ns, speed 500 mm/sec and repetition rate 30kHz. The laser maximum power was 40W although the actual power used in the example was 50% or 20 W. The laser orientation was through the PMMA side of the laminate. Single or triple width lines were produced by single or triple scans.

[00124] The sample was tested as described in the “Neutral Salt Spray Test” and showed signs of corrosion after 7 days.

[00125] Example 9

[00126] A sample was made as described in Example 8 but was laser ablated at 60% power. The sample was tested as described in the “Neutral Salt Spray Test” and showed signs of corrosion after 21 days.

[00127] Example 10

[00128] A sample was made as described in Example 8 but was laser ablated before lamination to the aluminum substrate. The sample was tested as described in the “Neutral

Salt Spray Test” and showed no signs of corrosion after 9 days, at which point the test was stopped.

[00129] Example 11

[00130] A sample was made as described in Example 10 but with 60% power. The samples were tested as described in the “Neutral Salt Spray Test” and showed no signs of corrosion after 9 days.

[00131] Example 12

[00132] In addition to the ultrasonic examples 1-6, ultrasonic welding was also demonstrated using a knurled anvil. A few knurl patterns were tried and an optimized knurl pattern was determined to be one with a repeat pitch of 0.020 inch, an included angle of 90 degrees and a width of 0.64 cm (0.25 in). “SOLAR MIRROR FILM SMF-1100” film (not laminated to aluminum substrate) with the adhesive premask side facing the knurl patterned anvil was passed under a bar horn. The horn was vibrating at a frequency of 20 kHz. The weld face of the horn was 15 cm x 2.5 cm (6 in x 1 in). The horn has a radius of 6.22 cm (2.45 in) continuous across the 2.5 cm (1 in) weld face. Amplitude as measured at the weld face was 44.7 micrometers (1.76 mils) peak to peak which is 75% of the total output, speed of the film was 10.7 m/min (35 feet/min) and force was 667 N (150 lbf).

[00133] The samples were tested as described in the “Neutral Salt Spray Test” and showed less than 5% corrosion after 16 days.

[00134] Example 13

[00135] A sample was made as described in Example 12 except the amplitude was 87.5% of the total output, the speed was 15 m/min (50 feet/min), and the force was 500 N (112.5 lbf). The samples were tested according to the “Neutral Salt Spray Test” and showed no signs of corrosion after 16 days.

[00136] Example 14

[00137] A sample was made as described in Example 12 except the amplitude was 100% of the total output, the speed was 11 m/min (35 feet/min), and the force was 334 N (75 lbf). The samples were tested according to the “Neutral Salt Spray Test” and showed less than 5% corrosion after 16 days.

[00138] Example 15

[00139] Two 10.2cm x 10.2cm (4 in x 4 in) pieces of polymethylmethacrylate film (PMMA, same source and thickness as in “SOLAR MIRROR FILM SMF-1100”) were masked a distance of 12.7 mm (0.5 in) from the perimeter edges of the sample using a tape. The samples were then vapor coated with silver in a homemade desktop evaporative vapor coater. Samples of PMMA were placed into the load-lock chamber of the evaporator, which was pumped down to a vacuum level of 53 mPa (4.0×10^{-4} torr) (each run). The samples were then loaded into the main vacuum chamber, which reaches pressures ranging from 1.1 mPa (8.0×10^{-6}) to 6.7 mPa (5.0×10^{-5} torr). The heating of a crucible filled with 99.995% pure silver pellets was then heated up via thermal conductivity at a power setting of 5V. Silver deposition occurred at a rate of 8.0 angstroms per second, using an resistive (thermal) heat source, for a total of 1000 angstroms of metal deposited.

[00140] After vapor coating, the tape was removed leaving 13 mm (0.5 in) of bare PMMA exposed around the perimeter of the sample. The sample then had a PSA adhesive coated onto the metal side (PSA same as that used in “SOLAR MIRROR FILM SMF-1100”) and was then laminated as described under “Aluminum Substrate Preparation.” The samples were then tested according to the “Neutral Salt Spray Test” and the results are shown in Table 1.

[00141] Example 16

[00142] Two 10.2cm x 10.2cm (4 in x 4 in) pieces of polymethylmethacrylate film (PMMA, same source and thickness as in “SOLAR MIRROR FILM SMF-1100”) were masked a distance of 13 mm (0.5 in) from the perimeter edges of the sample using a tape. The samples were then vapor coated with silver in a homemade desktop evaporative vapor coater. Samples of PMMA were placed into the load-lock chamber of the evaporator, which was pumped down to a vacuum level of 53 mPa (4.0×10^{-4} torr) (each run). The samples were then loaded into the main vacuum chamber, which reaches pressures ranging from 1.1 mPa (8.0×10^{-6}) to 6.7 mPa (5.0×10^{-5} torr). The heating of a crucible filled with 99.995% pure silver pellets was then heated up via thermal conductivity at a power setting of 5V. Silver deposition occurred at a rate of 8.0 angstroms per second, using an resistive (thermal) heat source, for a total of 1000 angstroms of metal deposited. After vapor coating, the tape was removed leaving 13 mm (0.5 in) of bare PMMA exposed around the perimeter of the sample. The samples were then vapor coated with aluminum metal using the vapor coater. Aluminum deposition occurred at a rate of 8.0 angstroms per second using an e-beam heat source, for a total of 1000 angstroms of metal deposited. The final product consisted of a silver square 7.6 cm x 7.6 cm (3 in x 3 in) which was surrounded by and backed up with aluminum metal.

[00143] The sample then had a PSA adhesive coated onto the metal side (PSA same as that used in “SOLAR MIRROR FILM SMF-1100”) and was then laminated as described under “Aluminum Substrate Preparation.” The samples were then tested according to the “Neutral Salt Spray Test” and the results are shown in Table 1.

Table 1. Reflective Area and Visual Time to Failure Results

Examples	Percent Reflective Area	Visual Time to Failure
Comparative Example 1	Sample 1: 5% after 11 days Sample 2: 5% after 11 days Sample 3: 20% after 11 days	Failed within 1 day
Comparative Example 2	Not measured	Failed at 14 days
Example 1	100% after 31 days	Not measured
Example 2	100 after 31 days	Not measured
Example 3	95 after 11 days 60 after 31 days	Not measured
Example 4	100 after 31 days	Not measured
Example 5	100 after 31 days	Not measured
Example 6	100 after 31 days	Not measured
Example 7	Not measured	No sign of corrosion after 67 days
Example 8	Not measured	Failed at 7 days
Example 9	Not measured	No sign of corrosion after 21 days
Example 10	Not measured	No sign of corrosion after 9 days
Example 11	Not measured	No sign of corrosion after 9 days
Example 12	Not measured	<5% corrosion after 16 days
Example 13	Not measured	No signs of corrosion after 16 days
Example 14	Not measured	<5% corrosion after 16 days
Example 15	100% after 10 days	Has not failed after 10 days
Example 16	100% after 10 days	Has not failed after 10 days

[00144] All references mentioned herein are incorporated by reference.

[00145] Unless otherwise indicated, all numbers expressing feature sizes, amounts, and physical properties used in the present disclosure and claims are to be understood as being modified in all instances by the term “about.” Accordingly, unless indicated to the contrary, the numerical

parameters set forth in the foregoing specification and attached claims are approximations that can vary depending upon the desired properties sought to be obtained by those skilled in the art utilizing the teachings disclosed herein.

[00146] As used in this specification and the appended claims, the singular forms “a”, “an”, and “the” encompass embodiments having plural referents, unless the content clearly dictates otherwise. As used in this disclosure and the appended claims, the term “or” is generally employed in its sense including “and/or” unless the content clearly dictates otherwise.

[00147] Various embodiments and implementation of the present disclosure are disclosed. The disclosed embodiments are presented for purposes of illustration and not limitation. The implementations described above and other implementations are within the scope of the following claims. One skilled in the art will appreciate that the present disclosure can be practiced with embodiments and implementations other than those disclosed. Those having skill in the art will appreciate that many changes may be made to the details of the above-described embodiments and implementations without departing from the underlying principles thereof. It should be understood that this invention is not intended to be unduly limited by the illustrative embodiments and examples set forth herein and that such examples and embodiments are presented by way of example only with the scope of the invention intended to be limited only by the claims set forth herein as follows. Further, various modifications and alterations of the present invention will become apparent to those skilled in the art without departing from the spirit and scope of the present disclosure. The scope of the present application should, therefore, be determined only by the following claims.

What is claimed is:

1. A solar mirror film comprising:
a weatherable layer having a first major surface and a second major surface; wherein the first major surface includes a bulk region and an edge region; and
a reflective material adjacent to the bulk region of the first major surface of the weatherable layer and substantially absent from the edge region.
2. The solar mirror film of claim 1, wherein the edge region extends from the terminal edge of the weatherable layer to 2 mm onto the first major surface.
3. The solar mirror film of either claim 1 or claim 2, wherein the edge region extends from the terminal edge of the weatherable layer to between about 2 mm and about 20 mm onto the first major surface.
4. The solar mirror film of any of the preceding claims, wherein the weatherable layer includes at least one of PMMA, polycarbonate, polyester, multilayer optical film, fluoropolymer, and a blend of an acrylate and a fluoropolymer.
5. The solar mirror film of any of the preceding claims, wherein the reflective material includes at least one of silver, gold, aluminum, copper, nickel, and titanium.
6. The solar mirror film of any of the preceding claims, further comprising:
a tie layer between the weatherable layer and the reflective material.
7. The solar mirror film of claim 5, wherein the tie layer includes an adhesive.
8. The solar mirror film of either of claims 6 or 7, wherein the bond strength between the tie layer and the weatherable layer is greater than the bond strength between the weatherable layer and the reflective material.
9. The solar mirror film of any of the preceding claims, further comprising:
a polymeric material between the weatherable layer and the reflective material.
10. The solar mirror film of any of the preceding claims, further comprising:

a corrosion protective layer adjacent to the reflective layer.

11. The solar mirror film of claim 8, wherein the corrosion protective layer comprises at least one of copper and an inert metal alloy.

12. The solar mirror film of any of the preceding claims, further including an adhesive layer adjacent to the reflective layer.

13. The solar mirror film of claim 10, wherein the adhesive layer comprises a pressure sensitive adhesive.

14. The solar mirror film of claim 10 or claim 11, wherein the adhesive layer is between the reflective layer and a substrate.

15. The solar mirror film of any of the preceding claims, wherein the substrate is part of one of a photovoltaic solar panel system and a concentrated solar power system.

16. The solar mirror film of any of the preceding claims, wherein one of a polymeric material and an adhesive material is adjacent to the edge regions of the weatherable layer from which reflective material is substantially absent.

17. A solar mirror film comprising:
a weatherable layer having a first major surface and a second major surface; wherein the first major surface includes a bulk region and an edge region;
a reflective material adjacent to the bulk region of the first major surface of the weatherable layer; and
a tie material in direct contact with the edge region of the first major surface of the weatherable layer.

18. The solar mirror film of claim 17, wherein the edge region extends from the terminal edge of the weatherable layer to about 2 mm onto the first major surface.

19. The solar mirror film of claims 17 or 18, wherein the edge region extends from the terminal edge of the weatherable layer to between about 2 mm and 20 mm onto the first major surface.

20. The solar mirror film of any of claims 17-19, further comprising:
tie material between the bulk region of the first major surface of the weatherable layer and the reflective layer.

21. The solar mirror film of any of claims 17-20, wherein the tie material is an adhesive material.

22. The solar mirror film of either of claims 20 or 21, wherein the bond strength between the tie layer and the reflective material is greater than the bond strength between the weatherable layer and the reflective material.

23. The solar mirror film of any of claims 17-22, wherein the reflective material is substantially absent from the edge region.

24. The solar mirror film of any of claims 17-23, further comprising:
a corrosion protective layer adjacent to the reflective material.

25. The solar mirror film of claim 24, wherein the corrosion protective layer comprises at least one of copper and an inert metal alloy.

26. The solar mirror film of any of claims 17-25, further including an adhesive layer adjacent to the reflective layer.

27. The solar mirror film of claim 26, wherein the adhesive layer comprises a pressure sensitive adhesive.

28. The solar mirror film of claim 26 or claim 27, wherein the adhesive layer is between the reflective layer and a substrate.

29. The solar mirror film of claim 27, wherein the substrate is part of one of a photovoltaic solar panel system and a concentrated solar power system.

30. The solar mirror film of any of claims 17-29, wherein the solar mirror film is a window film.

31. The solar mirror film of any of claims 17-30, wherein one of a polymeric material and an adhesive material is adjacent to the edge regions of the weatherable layer from which reflective material is substantially absent.

32. A solar mirror film comprising:
a weatherable layer having a first major surface and a second major surface;
regions of reflective material adjacent to the first major surface of the weatherable layer;
and
regions of the first major surface of the weatherable layer substantially lacking reflective material.

33. The solar mirror film of claim 32, wherein the regions of reflective material are directly adjacent to the first major surface of the weatherable layer.

34. The solar mirror film of claim 32, wherein materials and/or layer are between the regions of reflective material and the first major surface of the weatherable layer.

35. The solar mirror film of claim 34, wherein the materials and/or layers are at least one of a tie layer and a compliant layer.

36. The solar mirror film of any of claims 32-35, wherein the regions substantially lacking reflective material include less than 50% reflective material over the area of the region substantially lacking reflective material.

37. The solar mirror film of any of claims 32-35, wherein the regions substantially lacking reflective material include less than 60% reflective material over the area of the region substantially lacking reflective material.

38. The solar mirror film of any of claims 32-35, wherein the regions substantially lacking reflective material include less than 70% reflective material over the area of the region substantially lacking reflective material.

39. The solar mirror film of any of claims 32-35, wherein the regions substantially lacking reflective material include less than 75% reflective material over the area of the region substantially lacking reflective material.

40. The solar mirror film of any of claims 32-35, wherein the regions substantially lacking reflective material include less than 80% reflective material over the area of the region substantially lacking reflective material.

41. The solar mirror film of any of claims 32-35, wherein the regions substantially lacking reflective material include less than 85% reflective material over the area of the region substantially lacking reflective material.

42. The solar mirror film of any of claims 32-35, wherein the regions substantially lacking reflective material include less than 90% reflective material over the area of the region substantially lacking reflective material.

43. The solar mirror film of any of claims 32-35, wherein the regions substantially lacking reflective material include less than 95% reflective material over the area of the region substantially lacking reflective material.

44. The solar mirror film of any of claims 32-35, wherein the regions substantially lacking reflective material include less than 97% reflective material over the area of the region substantially lacking reflective material.

45. The solar mirror film of any of claims 32-35, wherein the regions substantially lacking reflective material include less than 99% reflective material over the area of the region substantially lacking reflective material.

46. The solar mirror film of any of claims 32-45, wherein the regions substantially lacking reflective material comprise less than 30% of the total area of the solar mirror film.

47. The solar mirror film of any of claims 32-45, wherein the regions substantially lacking reflective material comprise less than 40% of the total area of the solar mirror film.

48. The solar mirror film of any of claims 32-45, wherein the regions substantially lacking reflective material comprise less than 50% of the total area of the solar mirror film.

49. The solar mirror film of any of claims 32-45, wherein the regions substantially lacking reflective material comprise less than 60% of the total area of the solar mirror film.

50. The solar mirror film of any of claims 32-45, wherein the regions substantially lacking reflective material comprise less than 70% of the total area of the solar mirror film.

51. The solar mirror film of any of claims 32-45, wherein the regions substantially lacking reflective material comprise less than 80% of the total area of the solar mirror film.

52. The solar mirror film of any of claims 32-45, wherein the regions substantially lacking reflective material comprise less than 90% of the total area of the solar mirror film.

53. The solar mirror film of any of claims 32-45, wherein the regions substantially lacking reflective material comprise less than 95% of the total area of the solar mirror film.

54. The solar mirror film of any of claims 32-45, wherein the regions substantially lacking reflective material comprise less than 97% of the total area of the solar mirror film.

55. A concentrated photovoltaic system, comprising the solar mirror film of any of claims 1-54.

56. A concentrated solar power system, comprising the solar mirror film of any of claims 1-54.

1/4

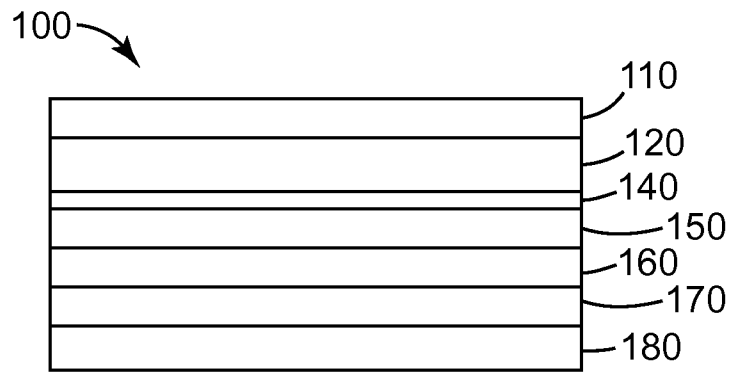


FIG. 1
PRIOR ART

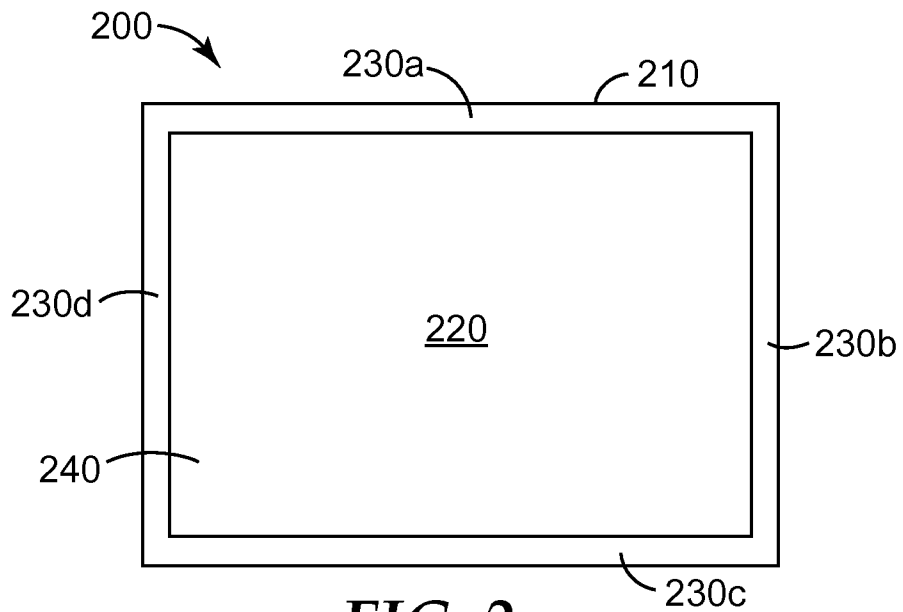


FIG. 2

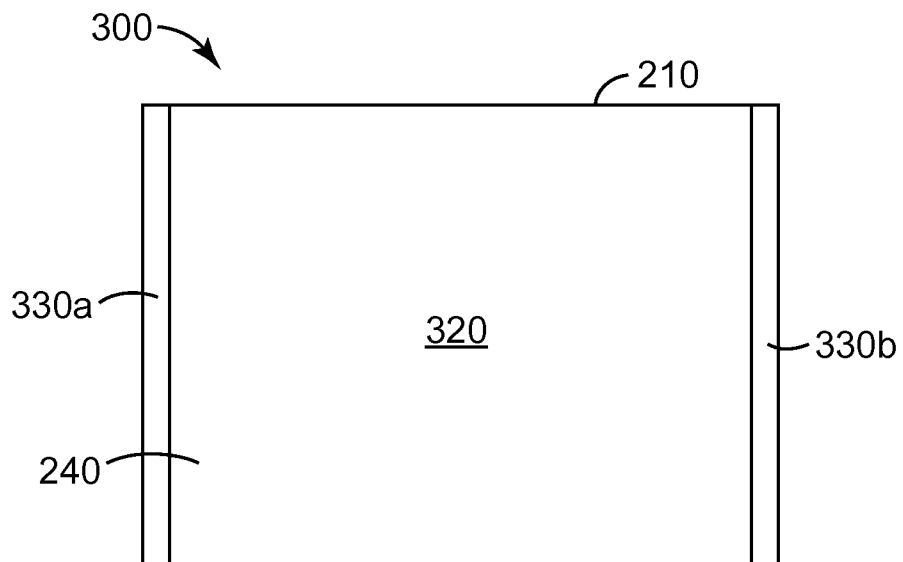


FIG. 3

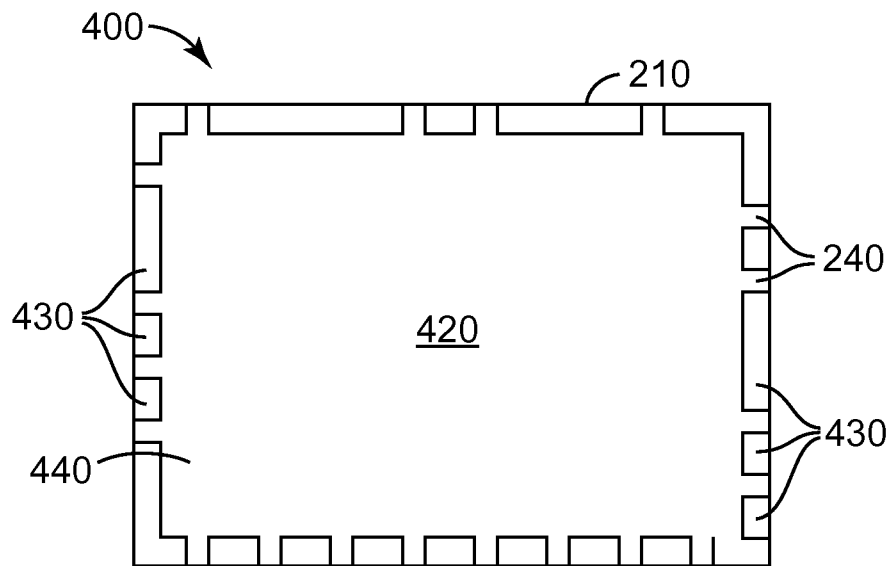


FIG. 4

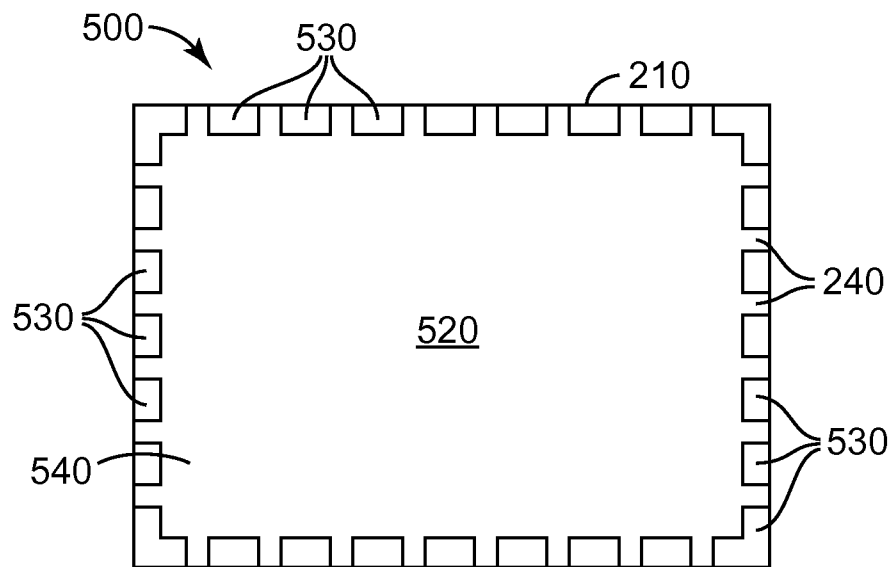


FIG. 5

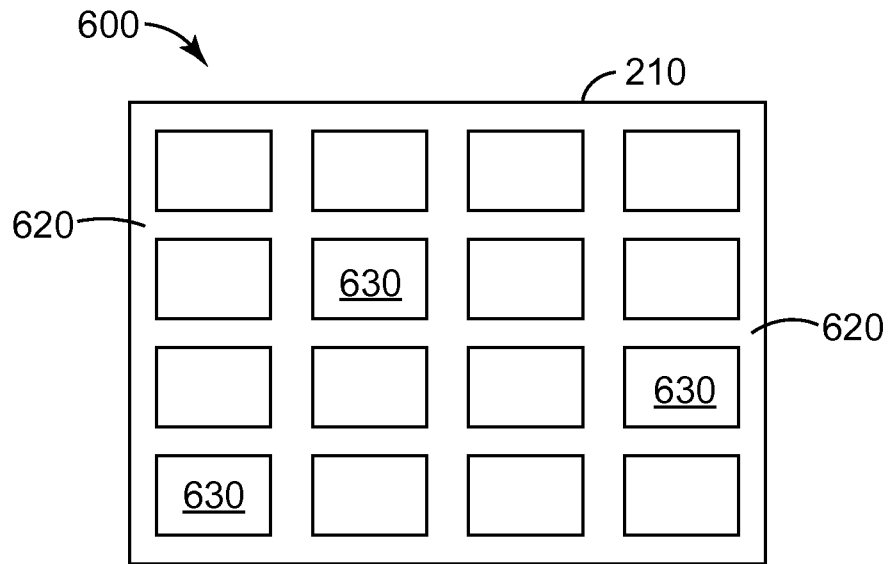


FIG. 6

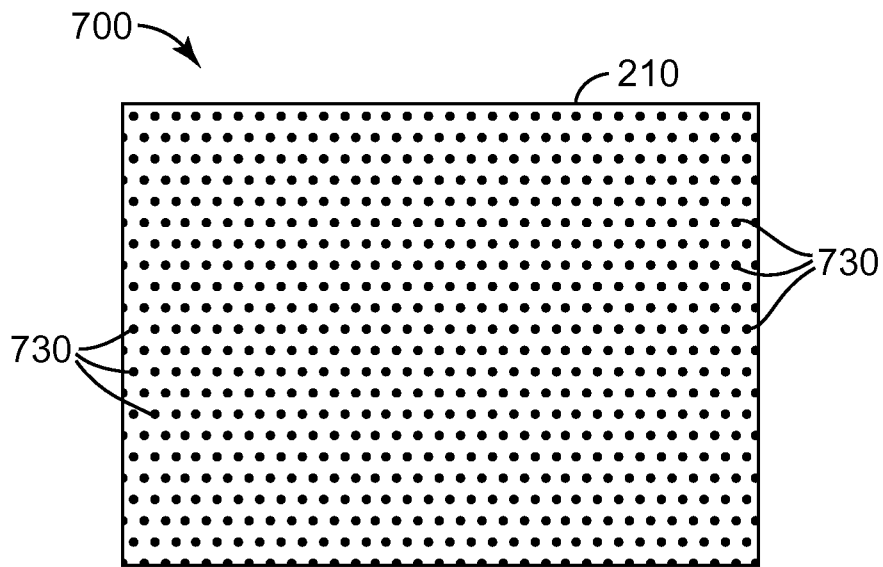


FIG. 7

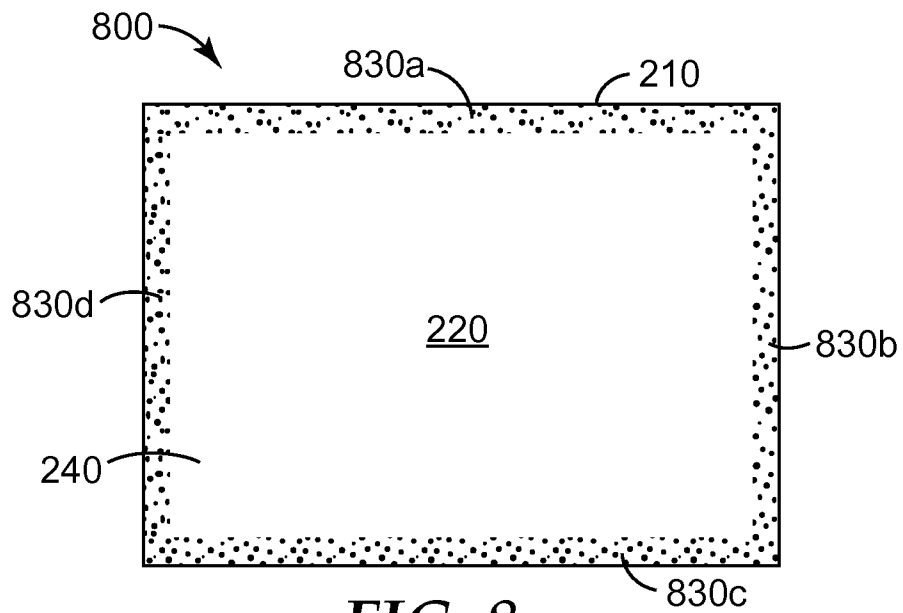


FIG. 8

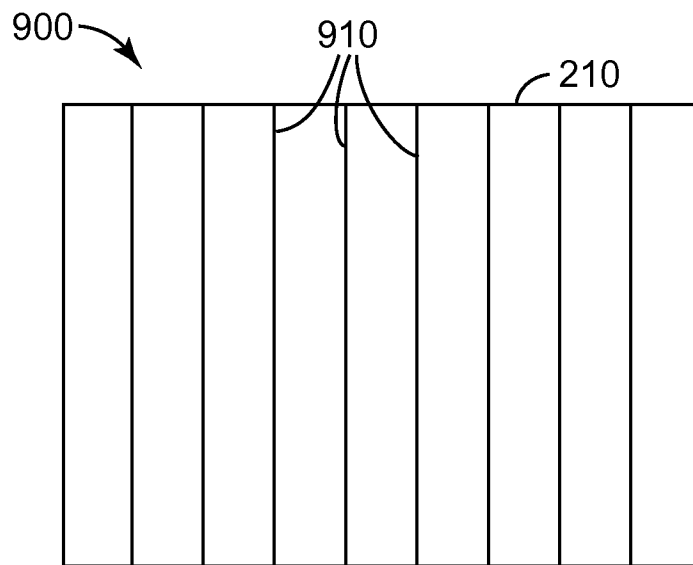


FIG. 9

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US13/38740

A. CLASSIFICATION OF SUBJECT MATTER IPC(8) - H02N 6/00; H01L 31/00 (2013.01) USPC - 136/251, 259 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) IPC(8): H02N 6/00; H01L 31/00, 31/042 (2013.01) USPC: 136/244, 251, 259; 428/212, 220, 45 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) MicroPatent (US-G, US-A, EP-A, EP-B, WO, JP-bib, DE-C,B, DE-A, DE-T, DE-U, GB-A, FR-A); DialogPro (Derwent, INSPEC, NTIS, PASCAL, Current Contents Search, Dissertation Abstracts Online, Inside Conferences); IP.com; Google; Search terms: weather, solar, photovoltaic, edge, border, encapsulate				
C. DOCUMENTS CONSIDERED TO BE RELEVANT				
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.		
X ----- Y Y A	US 6,204,443 B1 (KISO, S. et al.) March 20, 2001, Figure 1, column 4, lines 35-60, column 7, lines 40-45, column 8, lines 20-35 WO 2009/070361 A1 (LIU, P. C. et al.) June 4, 2009, Abstract, page 7, third paragraph, Figures 1-3 US 2011/0297313 A1 (SAMUELS, S) December 8, 2011, entire document	1, 17, 32-45 ----- 2, 3, 18-19 2, 3, 18, 19 1-3, 17-19, 32-45		
<input type="checkbox"/> Further documents are listed in the continuation of Box C. <input type="checkbox"/>				
<table style="width: 100%; border: none;"> <tr> <td style="width: 50%; border: none;"> * Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed </td> <td style="width: 50%; border: none;"> "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family </td> </tr> </table>			* Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family
* Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family			
Date of the actual completion of the international search 28 August 2013 (28.08.2013)	Date of mailing of the international search report <h2 style="text-align: center; margin: 0;">18 SEP 2013</h2>			
Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-3201	Authorized officer: <h3 style="text-align: center; margin: 0;">Shane Thomas</h3> PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774			

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US13/38740

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

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

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

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

3. Claims Nos.: 4-16, 20-31, 46-56
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

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

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

1. As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3. As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

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