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(54) Title: MULTIPLE SEQUENCED DAYLIGHT REDIRECTING LAYERS

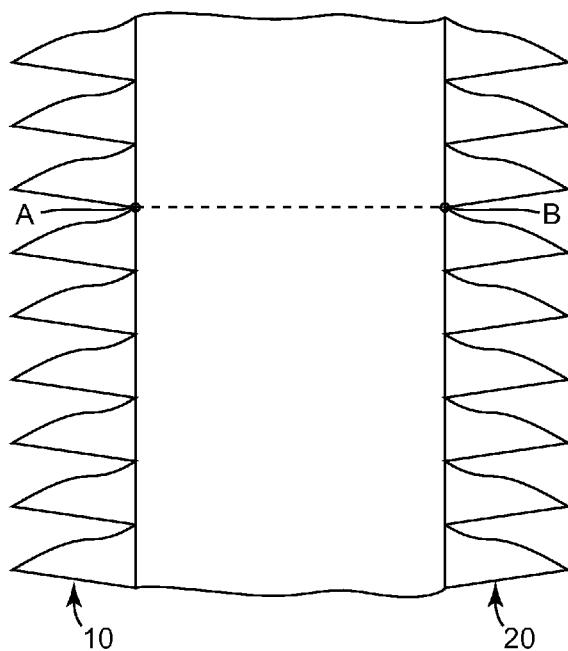


FIG. 1

(57) Abstract: Some solar light redirecting glazing constructions include a glazing substrate and two solar light redirecting layers present on the two major surfaces of the glazing substrate. Other solar light redirecting glazing constructions include two glazing substrates, each glazing substrate having a light redirecting layer present on one of the major surfaces of the glazing substrate. The light redirecting layers are microstructured surfaces forming a plurality of prism structures. At least one of the microstructured surfaces is an ordered arrangement of a plurality of asymmetric refractive prisms, and the two solar light redirecting layers are not identical or mirror images.

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MULTIPLE SEQUENCED DAYLIGHT REDIRECTING LAYERS

Field of the Disclosure

5 This disclosure relates generally to light management constructions, specifically to light redirecting constructions, especially solar light redirecting layers and glazing units.

Background

10 A variety of approaches are used to reduce energy consumption in buildings. Among the approaches being considered and applied is the more efficient use of sunlight to provide lighting inside buildings. One technique for supplying light inside of buildings, such as in offices, etc. is the redirection of incoming sunlight. Because sunlight enters windows at a downward angle, much of this light is not useful in illuminating a room. However, if the incoming downward light rays can be redirected upward such that they
15 strike the ceiling, the light can be more usefully employed in lighting the room.

 A variety of articles have been developed to redirect sunlight to provide illumination within rooms. A light deflecting panel is described in US Patent No. 4,989,952 (Edmonds). These panels are prepared by making a series of parallel cuts in sheets of transparent solid material with a laser cutting tool. Examples of daylighting
20 films include European Patent No. EP 0753121 and US Patent No. 6,616,285 (both to Milner) which describe optical components that include an optically transparent body with a plurality of cavities. Another daylighting film is described in US Patent No. 4,557,565 (Ruck et al.), which describes a light deflecting panel or plate which is formed of a plurality of parallel identically spaced apart triangular ribs on one face. Examples of films
25 that have a plurality of prism structures are described in US Patent Publication No. 2008/0291541 (Padiyath et al.) and pending US Patent Applications: Serial Number 61/287360, titled "Light Redirecting Constructions" filed 12/17/2009 (Padiyath et al.), and Serial Number 61/287354, titled "Light Redirecting Film Laminate" filed 12/17/2009 (Padiyath et al.). Constructions that incorporate both light redirection and light diffusion
30 include the pending US Patent Application Serial Number 61/469147, titled "Hybrid Light Redirecting And Light Diffusing Constructions" filed 3/30/2011 (Padiyath et al.), and Canadian Patent Publication No. 2,598,729 (McIntyre et al.).

Summary

Disclosed herein are solar light redirecting glazing constructions. In some embodiments the solar light redirecting glazing construction comprises a first glazing substrate having a first major surface and a second major surface, a first solar light redirecting layer disposed on the first major surface of the first glazing substrate, and a second solar light redirecting layer disposed on the second major surface of the first glazing substrate. The first solar light redirecting layer comprises a microstructured surface forming a plurality of prism structures. The second solar light redirecting layer comprises a microstructured surface forming a plurality of prism structures. At least one of the first or the second microstructured surface comprises an ordered arrangement of a plurality of asymmetric refractive prisms, such that the first solar light redirecting layer and the second solar light redirecting layer are not identical or mirror images. The first solar light redirecting layer and the second solar light redirecting layer may have different structures or the same structures that are misregistered. The solar light redirecting glazing construction may also comprise additional glazing substrates.

In some embodiments, the solar light redirecting glazing construction comprises a first glazing substrate having a first major surface and a second major surface with a first solar light redirecting layer disposed on either the first major surface or the second major surface of the first glazing substrate, and a second glazing substrate having a first major surface and a second major surface with a second solar light redirecting layer disposed on the first major surface or the second major surface of the second glazing substrate. The first solar light redirecting layer comprises a major surface forming a plurality of prism structures. The second solar light redirecting layer comprises a major surface forming a plurality of prism structures. At least one of the first or the second microstructured surfaces comprises an ordered arrangement of a plurality of asymmetric refractive prisms, such that the first solar light redirecting layer and the second solar light redirecting layer are not identical or mirror images. The first solar light redirecting layer and the second solar light redirecting layer may have different structures or the same structures that are misregistered.

Brief Description of the Drawings

The present application may be more completely understood in consideration of the following detailed description of various embodiments of the disclosure in connection with the accompanying drawings.

5 Figure 1 shows a cross sectional view of a glazing substrate with registered microstructured patterns.

 Figure 2 shows a cross sectional view of a glazing substrate with misregistered microstructured patterns.

10 Figure 3 shows a cross sectional view of a light management construction of this disclosure.

 Figure 4 shows a cross sectional view of a light management construction of this disclosure.

 Figure 5 shows a cross sectional view of a comparative single film light management construction.

15 Figure 6A shows a cross sectional view of a light management construction of this disclosure.

 Figure 6B shows a cross sectional view of a comparative light management construction.

20 Figure 7 shows a cross sectional view of a light management construction of this disclosure.

 Figure 8 shows a cross sectional view of a light management construction of this disclosure.

 Figure 9 shows a cross sectional view of a light management construction of this disclosure.

25 Figure 10A shows a cross sectional view of a light management construction of this disclosure.

 Figure 10B shows a cross sectional view of a comparative light management construction.

30 In the following description of the illustrated embodiments, reference is made to the accompanying drawings, in which is shown by way of illustration, various embodiments in which the disclosure may be practiced. It is to be understood that the embodiments may be utilized and structural changes may be made without departing from

the scope of the present disclosure. The figures are not necessarily to scale. Like numbers used in the figures refer to like components. However, it will be understood that the use of a number to refer to a component in a given figure is not intended to limit the component in another figure labeled with the same number.

5

Detailed Description

Windows and similar constructions are used to provide natural sunlight to rooms, corridors, and the like, in buildings. However, the angle that natural sunlight falls upon windows is such that typically the light may not penetrate far into the room or corridor. Additionally, since the incoming light may be unpleasantly strong near the window, users sitting near the window may be induced to close shutters, blinds or curtains and thus eliminate this potential source of room illumination. Therefore constructions that can redirect sunlight from the normal incident angle to a direction towards the ceiling of a room or corridor would be desirable.

Since there are many windows for which it would be desirable to effect the redirection of sunlight, it is impractical and impossible to replace all the present windows with ones that redirect light. Therefore, the need remains for light management constructions, such as films, that can be attached to existing substrates, such as windows, and redirect light, especially sunlight, in useful directions, such as towards the ceiling of a room to provide illumination for the room.

As discussed in the background section above, a number of films have been developed to redirect sunlight to provide room illumination. In this disclosure, light management constructions are presented that comprise two sequenced daylight redirecting layers that may be films that are able to redirect light, especially sunlight, in a desirable direction, and additionally are able to redirect more light in a desirable direction than a single film construction. The sequenced daylight redirecting film constructions comprise at least one glazing substrate and at least two solar light redirecting layers. Each of the solar light redirecting layers comprises a microstructured surface comprising a plurality of multi-sided refractive prisms. At least one of the solar redirecting layers comprises an ordered arrangement of a plurality of asymmetric refractive prisms. The layers are sequenced in such a way that the microstructured surfaces are not identical or mirror images of each other.

The layers redirect sunlight from the normal incident direction, which is downward and not very useful for room illumination, to an upwards direction towards the ceiling of the room to provide greater illumination for the room. The layers can be applied to substrates, like windows, for example, to provide the light redirection without needing to
5 modify or replace the window itself. It has been discovered, however, that care must be exercised with the two solar redirecting films. If the two solar light redirecting layers are arranged such that their microstructured patterns are not identical or mirror images of each other, the amount of light redirected in the desired direction is increased. However, if the patterns of the two solar light redirecting layers are identical or mirror images of each
10 other, the amount of light redirected in the desired direction may actually be reduced compared to the amount of light redirected by a single solar light redirecting layer.

There are a number of ways of achieving a solar light redirecting construction comprising two sequenced solar light redirecting layers where each of the solar light redirecting layers comprises a microstructured surface comprising a plurality of multi-
15 sided refractive prisms, and at least one of the layers (we will call it the “first layer” for clarity, but this designation is not intended to describe any directionality) has a microstructured surface that is an ordered arrangement of a plurality of asymmetric refractive prisms. In some embodiments, the second layer has a microstructured surface that is a non-ordered arrangement of multi-sided refractive prisms. In other embodiments,
20 the second layer has a microstructured surface that is an ordered arrangement of a plurality of refractive prisms, either symmetric or asymmetric refractive prisms, but the prisms have a different shape than the shape of the asymmetric refractive prisms on the first layer of the solar light redirecting construction. In still other embodiments, both of the solar light redirecting layers comprise a microstructured surface that is an ordered arrangement of a
25 plurality of asymmetric refractive prisms with the same shape, but the periods of the ordered arrangements may be different or the periods of the ordered arrangements may be misregistered. Each of these embodiments is described in greater detail below.

The term “optical film” and “optical substrate” as used herein refers to films and substrates that are at least optically transparent, may be optically clear and may also
30 produce additional optical effects. Examples of additional optical effects include, for example, light diffusion, light polarization or reflection of certain wavelengths of light.

The term “optically transparent” as used herein refers to films or constructions that appear to be transparent to the naked human eye. The term “optically clear” as used herein refers to film or article that has a high light transmittance over at least a portion of the visible light spectrum (about 400 to about 700 nanometers), and that exhibits low haze. An optically clear material often has a luminous transmission of at least about 90 percent and a haze of less than about 2 percent in the 400 to 700 nm wavelength range. Both the luminous transmission and the haze can be determined using, for example, the method of ASTM-D 1003-95.

The term “ordered arrangement” as used herein to describe a plurality of structures, refers to a regular, repeated pattern of structures, or patterns of structures.

The terms “registered” and “misregistered” are used herein to describe ordered arrangements of structures. Two parallel ordered arrangements of structures are said to be registered when there is correspondence between the parallel arrangements such that the valleys between structures at the point where the structure begins for one arrangement corresponds to the valley between structures where the structure begins on the second arrangement. This is illustrated by Figure 1, where **Point A** of ordered arrangement of structures **10** corresponds to **Point B** of ordered arrangement of microstructures **20**. The structures need not have the same or even similar shapes, as long as there is correspondence between the structures. Two parallel ordered arrangements of structures are said to be misregistered when there is no correspondence between the parallel arrangements such that the valleys between structures at the point where the structure begins for one arrangement does not correspond to the valley between structures where the structure begins on the second arrangement. This is illustrated by Figure 2, where **Point C** of ordered arrangement of structures **30** does not correspond to **Point D** of ordered arrangement of microstructures **40**. The structures need not have the same or even similar shapes, as long as there is a lack of correspondence between the structures.

The terms “point”, “side”, and “intersection” as used herein, have their typical geometric meanings.

The term “aspect ratio” as used herein when referring to a structure attached to a film, refers to the ratio of the greatest height of the structure above the film to the base of the structure that is attached to, or part of, the film.

The term “adhesive” as used herein refers to polymeric compositions useful to adhere together two adherends. Examples of adhesives are heat activated adhesives, and pressure sensitive adhesives.

Heat activated adhesives are non-tacky at room temperature but become tacky and capable of bonding to a substrate at elevated temperatures. These adhesives usually have a glass transition temperature (T_g) or melting point (T_m) above room temperature. When the temperature is elevated above the T_g or T_m , the storage modulus usually decreases and the adhesive becomes tacky.

Pressure sensitive adhesive compositions are well known to those of ordinary skill in the art to possess at room temperature properties including the following: (1) aggressive and permanent tack, (2) adherence with no more than finger pressure, (3) sufficient ability to hold onto an adherend, and (4) sufficient cohesive strength to be cleanly removable from the adherend. Materials that have been found to function well as pressure sensitive adhesives are polymers designed and formulated to exhibit the requisite viscoelastic properties resulting in a desired balance of tack, peel adhesion, and shear holding power. Obtaining the proper balance of properties is not a simple process.

Some embodiments of the of the light management constructions of this disclosure comprise a first glazing substrate and two solar light redirecting layers. The first glazing substrate has a first major surface and second major surface. The first solar light redirecting layer is disposed on the first major surface of the first glazing substrate, and the second solar light redirecting layer is disposed on the second major surface of the first glazing substrate. The first solar light redirecting layer comprises a microstructured surface forming a plurality of prism structures and the second solar light redirecting layer comprises a microstructured surface forming a plurality of prism structures. At least one of the first or second light redirecting layer comprises an ordered arrangement of a plurality of asymmetric refractive prisms. The first solar light redirecting layer and the second solar light redirecting layer are sequenced such that the microstructured surfaces of the first and second solar light redirecting layers are not identical or mirror images.

The first and second light redirecting layers comprise an array of protrusions arising from the surface of an optical substrate. This optical substrate may be the glazing substrate itself, but more typically the optical substrate is an optical film. The optical film may be single layer film or it may be a multi-layer film construction. Typically, the

optical film or multi-layer optical film, is prepared from polymeric materials that permit the film to be optically clear. Examples of suitable polymeric materials include, for example, polyolefins such as polyethylene and polypropylene, polyvinyl chloride, polyesters such as polyethylene terephthalate, polyamides, polyurethanes, cellulose acetate, ethyl cellulose, polyacrylates, polycarbonates, silicones, and combinations or blends thereof. The optical film may contain other components besides the polymeric material, such as fillers, stabilizers, antioxidants, plasticizers and the like. In some embodiments, the optical film may comprise a stabilizer such as a UV absorber (UVA) or hindered amine light stabilizer (HALS). Suitable UVAs include, for example, benzotriazole UVAs such as the compounds available from Ciba, Tarrytown, NY as TINUVIN P, 213, 234, 326, 327, 328, 405 and 571. Suitable HALS include compounds available from Ciba, Tarrytown, NY as TINUVIN 123, 144, and 292.

The use of a multi-layer optical film substrate permits the optical substrate to supply additional functional roles to the light management construction besides providing support for the two light redirecting layers. For example, the multi-layer film substrate can provide physical effects, optical effects, or a combination thereof. The multi-layer film substrate may include layers such as a tear resistant layer, a shatter resistant layer, an infrared light reflection layer, an infrared absorbing layer, a light diffusing layer, an ultraviolet light blocking layer, a polarizing layer or a combination thereof. Among the especially suitable multi-layer films are multi-layer film constructions that can reflect infrared light. In this way, the light redirecting laminate can also help to keep the undesirable infrared light (heat) out of the building while allowing the desirable visible light into the building. Examples of suitable multi-layer films useful as the optical film include those disclosed, for example, in US Patent Nos. 6,049,419, 5,223,465, 5,882,774, 6,049,419, RE 34,605, 5,579,162 and 5,360,659. In some embodiments, the optical film is a multilayer film in which the alternating polymeric layers cooperate to reflect infrared light. In some embodiments, at least one of the polymeric layers is a birefringent polymer layer.

The light management constructions of this disclosure comprise at least one glazing substrate. A wide variety of glazing substrates are suitable. A typical example of a glazing substrate is a window. Windows may be made of a variety or different types of glazing materials such as a variety of glasses or from polymeric materials such as

polycarbonate or polymethylmethacrylate. In some embodiments, the glazing substrate may also comprise additional layers or treatments. Examples of additional layers include, for example, additional layers of film designed to provide glare reduction, tinting, shatter resistance and the like. Examples of additional treatments that may be present of windows include, for example, coatings or various types such as hardcoats, and etchings such as decorative etchings.

When the light management construction comprises a first glazing substrate, the first solar light redirecting layer is disposed on the first major surface of the first glazing substrate, and the second solar light redirecting layer is disposed on the second major surface of the first glazing substrate. Each of these solar light redirecting layers comprises a microstructured surface comprising a plurality of multi-sided refractive prisms. The microstructured surfaces may contain a wide range of prism structures. In many embodiments, the prism structures are linear prism structures, or pyramidal prism structures. In some embodiments, the prism structures are pyramidal prism structures. The pyramidal prism structures can have any useful configuration such as, for example, shape tip, rounded tip, and/or truncated tip, as desired. The prism structures can have a varying height, spatially varying pitch, or spatially varying facet angle, as desired. In some embodiments, the prism structures have a pitch and height in a range from 50 to 2000 micrometers, or from 50 to 1000 micrometers. Examples of suitable prism structures include those described in US Patent Publication No. 2008/0291541 (Padiyath et al.). As is known in the microstructure art, the microstructures may be identical or some or all of the microstructures may have variations in structure smaller than the scale of the structures themselves.

At least one of the microstructured surfaces comprises an ordered arrangement of a plurality of asymmetric refractive prisms, and the first solar light redirecting layer and the second solar light redirecting layer are not identical or mirror images.

For purposes of discussion, the at least one microstructured surface that comprises an ordered arrangement of a plurality of asymmetric refractive prisms will be called the "first layer". This designation is merely to assist in the discussion and is not intended to denote any directionality (such as, for example, facing the incoming solar light). It is desirable that the prisms be asymmetrical such that incoming incident solar light (which comes from above and is incident upon the layer at an angle of from 5-80° from the

direction perpendicular to the film) is redirected upwards towards the ceiling of the room, but incoming light from below is not redirected downwards. An artifact of symmetrical structures is that the downward directed light could be visible to the observer, which is undesirable.

5 The plurality of asymmetrical multi-sided refractive prisms on the first layer is designed to effectively redirect incoming solar light towards the ceiling of a room which contains a window or other aperture containing the light directing film. Typically, the asymmetrical multi-sided refractive prisms comprise 3 or greater sides, more typically 4 or greater sides. The prisms may be viewed as an orderly array of protrusions arising from
10 the surface of an optical substrate. This optical substrate may be the glazing substrate itself, but more typically the optical substrate is an optical film. (For purposes of discussion, the light redirecting layer on an optical film may be called a light management film or just a film.) Typically, the aspect ratio of these protrusions is 1 or greater, that is to say that the height of the protrusion is at least as great as the width of the protrusion at
15 the base. In some embodiments, the height of the protrusions is at least 50 micrometers. In some embodiments, the height of the protrusions is no more than 250 micrometers. This means that the asymmetrical structures typically protrude from 50 micrometers to 250 micrometers from the first major surface of the optical substrate.

Examples of suitable asymmetrical multi-sided refractive prisms are described in
20 pending US Patent Applications: Serial Number 61/287360, titled "Light Redirecting Constructions" filed 12/17/2009 (Padiyath et al.), and Serial Number 61/287354, titled "Light Redirecting Film Laminate" filed 12/17/2009 (Padiyath et al.). An example of a 4 sided prism is one that contains sides A, B, C and D. In this prism, side A is adjacent to the optical substrate, side B is joined to side A, side C is joined to side A, and side D
25 which is joined to side B and side C. Side B is angled in such a way that it produces total internal reflection to solar light rays incident upon the second major surface of the optical substrate and passing through side A. Solar light rays are incident from above the second major surface of the optical substrate and typically form an angle of from about 5-80° from perpendicular to the first major surface of the optical substrate depending upon the
30 time of day, time of year, geographical location of the film, etc. The incident light rays that enter the prism are reflected from side B by the phenomenon of total internal reflection. To achieve total internal reflection, it is desirable that side B not be

perpendicular to side A, but be offset from perpendicular by an angle (the angle is arbitrary called θ). The selection of the value for angle θ will depend upon a variety of variable features including, for example, the refractive index of the composition materials used to prepared the light management construction, the proposed geographic location of use for the light management construction, etc, but typically the value for angle θ is in the range 6-14° or even 6-12°.

Side C is joined to side A and connects side A to side D. It is desirable that side C not be perpendicular to side A, but be offset from perpendicular by an angle arbitrarily called α . The offset of angle α , among other features, aids in preventing light which exits the prism through side D from entering an adjacent prism. As with angle θ , the selection of the value for angle α depends upon a variety of variable features, including the closeness of adjacent prisms, the nature and size of side D, etc. Typically, angle α is in the range 5-25° or even 9-25°.

Side D is the side of the prism from which the redirected light rays exit the prism. Side D may comprise a single side or a series of sides. In some embodiments it is desirable that side D be a curved side, but side D need not be curved in all embodiments. Light rays that are reflected from side B are redirected by side D to a direction useful for improving the indirect lighting of a room. By this it is meant that the light rays reflected from side D are redirected either perpendicular to side A or at an angle away from perpendicular and towards the ceiling of the room.

In some embodiments, side C may be curved, side D may be curved, or the combination of sides C and D may form a single continuously curved side. In other embodiments, side C or D or C and D taken together comprises a series of sides, wherein the series of sides comprises a structured surface. The structured surface may be regular or irregular, i.e., the structures may form regular patterns or random patterns and may be uniform or the structures may be different. These structures, since they are substructures on a microstructure, are typically very small. Typically, each dimension of these structures (height, width and length) is smaller than the dimension of side A.

The intersection of side B and side D forms the apex of the prism. This intersection may be a point, or it may be a surface. If the light management film is to be bonded to a substrate at the intersection of sides B and D, it may desirable that this intersection be a flat surface instead of sharp point to permit easier bonding of the

substrate to the prism structure. If, however, the film is not to be bonded to a substrate at the intersection of sides B and D, it may be desirable that this intersection be a point.

The entire first light redirecting layer may contain microstructures, or the microstructures may be present on only a portion of the first surface of the optical substrate. Since the light management film construction may be part of a large glazing article, such as, for example, a window, it may not be necessary or desirable for the entire surface of the glazing article to contain a microstructured surface in order to produce the desirable light redirection effect. It may be desirable for only a portion of the glazing article to contain the light redirection film construction, or alternatively, if the entire glazing article surface is covered by a film construction, it may be desirable that only a portion of the film construction contain the light redirecting microstructures. Similarly, the second light redirecting layer also contains a microstructured surface, and this second microstructured surface may be present on only a portion of the second surface of the optical substrate

The ordered arrangement of a plurality of asymmetrical multi-sided refractive prisms can form an array of microstructures. The array can have a variety of elements. For example, the array can be linear (i.e. a series of parallel lines), sinusoidal (i.e. a series of wavy lines), random, or combinations thereof. While a wide variety of arrays are possible, it is desirable that the array elements are discrete, i.e., that the array elements do not intersect or overlap.

The first microstructure layer may be formed in a variety of ways. Typically, the microstructure layer comprises a thermoplastic or a thermoset material. In some embodiments, the microstructure layer is formed on the glazing substrate. More typically, the microstructure layer is part of microstructured film that is adhered to the glazing substrate.

The microstructured films described above are manufactured using various methods, including embossing, extrusion, casting and curing, compression molding and injection molding. One method of embossing is described in U.S. Patent No. 6,322,236, which includes diamond turning techniques to form a patterned roll which is then used for embossing a microstructured surface onto a film. A similar method may be used to form the films described above having an ordered arrangement of a plurality of asymmetrical structures.

Other approaches may be followed for producing a film having a microstructured surface with a repeating pattern. For example, the film may be injection molded using a mold having a particular pattern thereon. The resulting injection molded film has a surface that is the complement of the pattern in the mold. In another and similar approach, the film may be compression molded.

In some embodiments, the structured films are prepared using an approach called casting and curing. In casting and curing, a curable mixture is coated onto a surface to which a microstructuring tool is applied or the mixture is coated into a microstructuring tool and the coated microstructuring tool is contacted to a surface. The curable mixture is then cured and the tooling is removed to provide a microstructured surface. Examples of suitable microstructuring tools include microstructured molds and microstructured liners. Examples of suitable curable mixtures include thermoset materials such as the curable materials used to prepare polyurethanes, polyepoxides, polyacrylates, silicones, and the like.

When a microstructured film is used as the microstructure layer, the microstructured film is typically adhered to the glazing substrate by an adhesive layer. Examples of suitable adhesives include, for example, heat activated adhesives, pressure sensitive adhesives or curable adhesives. Examples of suitable optically clear curable adhesives include those described in US Patent No. 6,887,917 (Yang et al.). Depending upon the nature of the adhesive, the adhesive coating may have a release liner attached to it to protect the adhesive coating from premature adhesion to surfaces and from dirt and other debris which can adhere to the adhesive surface. The release liner typically remains in place until the light redirecting laminate is to be attached to the substrate. Typically, a pressure sensitive adhesive is used.

A wide variety of pressure sensitive adhesive compositions are suitable. Typically, the pressure sensitive adhesive is optically clear. The pressure sensitive adhesive component can be any material that has pressure sensitive adhesive properties. Additionally, the pressure sensitive adhesive component can be a single pressure sensitive adhesive or the pressure sensitive adhesive can be a combination of two or more pressure sensitive adhesives.

Suitable pressure sensitive adhesives include, for example, those based on natural rubbers, synthetic rubbers, styrene block copolymers, polyvinyl ethers, poly(meth)acrylates (including both acrylates and methacrylates), polyolefins, silicones, or polyvinyl butyral.

5 The optically clear pressure sensitive adhesives may be (meth)acrylate-based pressure sensitive adhesives. Useful alkyl (meth)acrylates (i.e., acrylic acid alkyl ester monomers) include linear or branched monofunctional unsaturated acrylates or methacrylates of non-tertiary alkyl alcohols, the alkyl groups of which have from 4 to 14 and, in particular, from 4 to 12 carbon atoms. Poly(meth)acrylic pressure sensitive
10 adhesives are derived from, for example, at least one alkyl (meth)acrylate ester monomer such as, for example, isooctyl acrylate, isononyl acrylate, 2-methyl-butyl acrylate, 2-ethyl-n-hexyl acrylate and n-butyl acrylate, isobutyl acrylate, hexyl acrylate, n-octyl acrylate, n-octyl methacrylate, n-nonyl acrylate, isoamyl acrylate, n-decyl acrylate, isodecyl acrylate, isodecyl methacrylate, isobornyl acrylate, 4-methyl-2-pentyl acrylate and dodecyl
15 acrylate; and at least one optional co-monomer component such as, for example, (meth)acrylic acid, vinyl acetate, N-vinyl pyrrolidone, (meth)acrylamide, a vinyl ester, a fumarate, a styrene macromer, alkyl maleates and alkyl fumarates (based, respectively, on maleic and fumaric acid), or combinations thereof.

20 In certain embodiments, the poly(meth)acrylic pressure sensitive adhesive is derived from between about 0 and about 20 weight percent of acrylic acid and between about 100 and about 80 weight percent of at least one of isooctyl acrylate, 2-ethyl-hexyl acrylate or n-butyl acrylate composition.

25 In some embodiments, the adhesive layer is at least partially formed of polyvinyl butyral. The polyvinyl butyral layer may be formed via known aqueous or solvent-based acetalization process in which polyvinyl alcohol is reacted with butyraldehyde in the presence of an acidic catalyst. In some instances, the polyvinyl butyral layer may include or be formed from polyvinyl butyral that is commercially available from Solutia Incorporated, of St. Louis, MO, under the trade name "BUTVAR" resin.

30 In some instances, the polyvinyl butyral layer may be produced by mixing resin and (optionally) plasticizer and extruding the mixed formulation through a sheet die. If a plasticizer is included, the polyvinyl butyral resin may include about 20 to 80 or perhaps about 25 to 60 parts of plasticizer per hundred parts of resin. Examples of suitable

plasticizers include esters of a polybasic acid or a polyhydric alcohol. Suitable plasticizers are triethylene glycol bis(2-ethylbutyrate), triethylene glycol di-(2-ethylhexanoate), triethylene glycol diheptanoate, tetraethylene glycol diheptanoate, dihexyl adipate, dioctyl adipate, hexyl cyclohexyl adipate, mixtures of heptyl and nonyl adipates, diisononyl
5 adipate, heptylnonyl adipate, dibutyl sebacate, polymeric plasticizers such as the oil-modified sebacic alkyds, and mixtures of phosphates and adipates such as disclosed in U.S. Pat. No. 3,841,890 and adipates such as disclosed in U.S. Pat. No. 4,144,217.

The adhesive layer may be crosslinked. The adhesives can be crosslinked by heat, moisture or radiation, forming covalently crosslinked networks which modify the
10 adhesive's flowing capabilities. Crosslinking agents can be added to all types of adhesive formulations but, depending on the coating and processing conditions, curing can be activated by thermal or radiation energy, or by moisture. In cases in which crosslinker addition is undesirable one can crosslink the adhesive if desired by exposure to an electron beam.

The degree of crosslinking can be controlled to meet specific performance requirements. The adhesive can optionally further comprise one or more additives. Depending on the method of polymerization, the coating method, the end use, etc., additives selected from the group consisting of initiators, fillers, plasticizers, tackifiers, chain transfer agents, fibrous reinforcing agents, woven and non-woven fabrics, foaming
15 agents, antioxidants, stabilizers, fire retardants, viscosity enhancing agents, and mixtures thereof can be used.

In addition to being optically clear, the pressure sensitive adhesive may have additional features that make it suitable for lamination to large substrates such as windows. Among these additional features is temporary removability. Temporarily
25 removable adhesives are those with relatively low initial adhesion, permitting temporary removability from, and repositionability on, a substrate, with a building of adhesion over time to form a sufficiently strong bond. Examples of temporarily removable adhesives are described, for example in US Patent No. 4,693,935 (Mazurek). Alternatively, or in addition, to being temporarily removable, the pressure sensitive adhesive layer may
30 contain a microstructured surface. This microstructured surface permits air egress as the adhesive is laminated to a substrate. For optical applications, typically, the adhesive will wet out the surface of the substrate and flow to a sufficient extent that the microstructures

disappear over time and therefore do not affect the optical properties of the adhesive layer. A microstructured adhesive surface may be obtained by contacting the adhesive surface to a microstructuring tool, such as a release liner with a microstructured surface.

The pressure sensitive adhesive may be inherently tacky. If desired, tackifiers may be added to a base material to form the pressure sensitive adhesive. Useful tackifiers include, for example, rosin ester resins, aromatic hydrocarbon resins, aliphatic hydrocarbon resins, and terpene resins. Other materials can be added for special purposes, including, for example, oils, plasticizers, antioxidants, ultraviolet ("UV") stabilizers, hydrogenated butyl rubber, pigments, curing agents, polymer additives, thickening agents, chain transfer agents and other additives provided that they do not reduce the optical clarity of the pressure sensitive adhesive. In some embodiments, the pressure sensitive adhesive may contain a UV absorber (UVA) or hindered amine light stabilizer (HALS). Suitable UVAs include, for example, benzotriazole UVAs such as the compounds available from Ciba, Tarrytown, NY as TINUVIN P, 213, 234, 326, 327, 328, 405 and 571. Suitable HALS include compounds available from Ciba, Tarrytown, NY as TINUVIN 123, 144, and 292.

The pressure sensitive adhesive of the present disclosure exhibits desirable optical properties, such as, for example, controlled luminous transmission and haze. In some embodiments, substrates coated with the pressure sensitive adhesive may have substantially the same luminous transmission as the substrate alone.

The light management constructions of this disclosure also have a second solar light redirecting layer disposed on the second major surface of the glazing substrate, wherein the second solar light redirecting layer comprises a second microstructured surface comprising a plurality of multi-sided refractive prisms. This second solar light redirecting layer is sequenced on the second major surface of the glazing substrate such that the microstructured surface is not identical to or the mirror image of the first solar light redirecting layer.

In some embodiments, the second light redirecting layer, while a plurality of multi-sided refractive prisms, is not a an ordered arrangement of a plurality of refractive prisms. In other words, the plurality of refractive prisms may be arranged such that they are randomly arranged or arranged such that there is no repeating pattern.

In other embodiments, the second light redirecting layer forms an ordered arrangement of a plurality of refractive prisms. The prisms may be symmetrical or asymmetrical. If symmetrical, the prisms may be in any arrangement desired. If the prisms are asymmetrical, the prisms must be either a different shape from the prisms of the first light redirecting layer, or if the prisms are the same shape, the period of the ordered arrangement of a plurality of asymmetrical refractive prisms must be different from the period of the prisms of the first light redirecting layer, or if the prisms are the same shape and the periods are the same or whole number integers of each other, the periods of the first light redirecting layer and the second light redirecting layer must be misregistered. Each of the embodiments where the second light redirecting layer comprises asymmetrical refracting prisms is described in greater detail below.

In some embodiments, the prisms of the second solar light redirecting layer are asymmetrical, and the prisms are different shape from the prisms of the first light redirecting layer. Figure 3 is a cross sectional view of such a light management construction of this disclosure. In Figure 3, light management construction **100**, comprises glazing substrate **110**. To the first side (again first side is arbitrarily assigned) of glazing substrate **110** is attached solar light redirecting layer **150**. Solar light redirecting layer **150** comprises a film with projecting asymmetrical prism structures **170**. Solar light redirecting layer **150** is adhered to the first major surface of glazing substrate **110** by adhesive layer **130**. Similarly, second solar light redirecting layer **140** with projecting asymmetrical prism structures **160** is adhered to the second major surface of glazing substrate **110** by adhesive layer **120**. In Figure 3, the period of the prism structures **160** on solar light redirecting layer **140** and the period of the prism structures **170** on solar light redirecting layer **150** are registered. Registration is shown by the correspondence of **points A** and **B**, similar to the **points A** and **B** of Figure 1. It should be noted that even though the periods of the prism structures **170** on solar light redirecting layer **150** are registered, the first and second solar light redirecting layers **140** and **150** are not identical or mirror images of each other, and therefore the layers are properly sequenced.

In other embodiments (not shown), the periods of the ordered arrangements of prism structures are whole number integers of one another. In these embodiments, there is

not a one to one correspondence of prism structures, but the periods correspond in a regular whole number pattern.

Figure 4 is a cross sectional view of another exemplary light management construction of this disclosure, in which the prisms of the second light redirecting layer are asymmetrical and the prisms are a different shape from the prisms of the first light redirecting layer. In Figure 4, light management construction **200**, comprises glazing substrate **210**. To the first side (again first side is arbitrarily assigned) of glazing substrate **210** is attached solar light redirecting layer **250**. Solar light redirecting layer **250** comprises a film with projecting asymmetrical prism structures **270**. Solar light redirecting layer **250** is adhered to the first major surface of glazing substrate **210** by adhesive layer **230**. Similarly, second solar light redirecting layer **240** with projecting asymmetrical prism structures **260** is adhered to the second major surface of glazing substrate **210** by adhesive layer **220**. In Figure 4, the period of the prism structures **260** on solar light redirecting layer **240** and the period of the prism structures **270** on solar light redirecting layer **250** are misregistered. Misregistration is shown by the lack of correspondence of **points C** and **D**, similar to the **points C** and **D** of Figure 2.

In some embodiments, the prism structures of the first and second light redirecting layers are the same, and the period of the ordered arrangement of a plurality of asymmetrical refractive prisms of the second light redirecting layer is different from the period of the prisms of the first light redirecting layer. The period of the second light redirecting layer may be shorter or longer than the period of the first light redirecting layer. Typically, it is desirable that there be no point of correspondence between the two arrangements of prisms, but if coincident correspondence occurs it is desirable that there be no more than one point of correspondence per 100 prism units.

In some embodiments, the prism structures of the first and second light redirecting layers are the same asymmetrical shape, and the periods of the first light redirecting layer and the second light redirecting layer are the same and are misregistered. Figure 6A is a cross sectional view of such a light management construction of this disclosure. In Figure 6A, light management construction **400**, comprises glazing substrate **410**. To the first side (again first side is arbitrarily assigned) of glazing substrate **410** is attached solar light redirecting layer **450**. Solar light redirecting layer **450** comprises a film with projecting asymmetrical prism structures **470**. Solar light redirecting layer **450** is adhered to the first

major surface of glazing substrate **410** by adhesive layer **430**. Similarly, second solar light redirecting layer **440** with projecting asymmetrical prism structures **460** is adhered to the second major surface of glazing substrate **410** by adhesive layer **420**. In Figure 6A, prism structures **460** and **470** are the same shape and the periods are the same. The period of the prism structures **460** on solar light redirecting layer **440** and the period of the prism structures **470** on solar light redirecting layer **450** are misregistered. Misregistration is shown by the lack of correspondence of **points E** and **F**, similar to the **points C** and **D** of Figure 2.

Figure 6B is a cross sectional view of a comparative light management construction where the microstructured layers are registered. In Figure 6B, light management construction **400'**, comprises glazing substrate **410**. To the first side (again first side is arbitrarily assigned) of glazing substrate **410** is attached solar light redirecting layer **450**. Solar light redirecting layer **450** comprises a film with projecting asymmetrical prism structures **470**. Solar light redirecting layer **450** is adhered to the first major surface of glazing substrate **410** by adhesive layer **430**. Similarly, second solar light redirecting layer **440** with projecting asymmetrical prism structures **460** is adhered to the second major surface of glazing substrate **410** by adhesive layer **420**. In Figure 6B, prism structures **460** and **470** are the same shape and the periods are the same. The period of the prism structures **460** on solar light redirecting layer **440** and the period of the prism structures **470** on solar light redirecting layer **450** are registered. Registration is shown by the correspondence of **points E'** and **F'**, similar to the **points A** and **B** of Figure 1.

Some embodiments of the light management constructions of this disclosure comprise two glazing substrates and two solar light redirecting layers. These constructions are very similar to the constructions described above, except that the two solar light redirecting layers are on different glazing substrates. The two glazing substrates can be adjacent to each other or they can be parallel to each other and be separated by a void space. Regardless of the configuration of glazing substrates and solar light redirecting layers, the solar light redirecting layers are sequenced as described above such that the microstructured patterns of the two solar light redirecting layers are not identical or mirror images of each other.

Embodiments of light management constructions of this disclosure that contain two glazing substrates are shown in Figures 7, 8, 9 and 10A. Figure 7 describes light

management construction **500** and includes first glazing substrate **510** and second glazing substrate **520**. To the first side (again first side is arbitrarily assigned) of first glazing substrate **510** is attached solar light redirecting layer **550**. Solar light redirecting layer **550** comprises a film with projecting asymmetrical prism structures **570**. Solar light redirecting layer **550** is adhered to the first major surface of the first glazing substrate **510** by adhesive layer **530**. To the first side (again first side is arbitrarily assigned) of second glazing substrate **520** is attached solar light redirecting layer **560**. Solar light redirecting layer **560** comprises a film with projecting asymmetrical prism structures **580**. Projecting asymmetrical prism structures **580** are different in shape than projecting asymmetrical prism structures **570**. Solar light redirecting layer **560** is adhered to the first major surface of the second glazing substrate **520** by adhesive layer **540**. Void space **590** is present between the glazing substrates. The void space may be a vacuum or it may contain air or other gases such as nitrogen.

Figure 8 describes light management construction **600**, and includes first glazing substrate **610** and second glazing substrate **620**. To the second side (again second side is arbitrarily assigned) of first glazing substrate **610** is attached solar light redirecting layer **650**. Solar light redirecting layer **650** comprises a film with projecting asymmetrical prism structures **670**. Solar light redirecting layer **650** is adhered to the second major surface of the first glazing substrate **610** by adhesive layer **630**. To the second side (again second side is arbitrarily assigned) of second glazing substrate **620** is attached solar light redirecting layer **660**. Solar light redirecting layer **660** comprises a film with projecting asymmetrical prism structures **680**. Projecting asymmetrical prism structures **680** are different in shape than projecting asymmetrical prism structures **670**. Solar light redirecting layer **660** is adhered to the second major surface of the second glazing substrate **620** by adhesive layer **640**. Void space **690** is present between the glazing substrates. The void space may be a vacuum or it may contain air or other gases such as nitrogen.

Figure 9 describes light management construction **700**, and includes first glazing substrate **710** and second glazing substrate **720**. To the second side (again second side is arbitrarily assigned) of first glazing substrate **710** is attached solar light redirecting layer **750**. Solar light redirecting layer **750** comprises a film with projecting asymmetrical

prism structures **770**. Solar light redirecting layer **750** is adhered to the second major surface of the first glazing substrate **710** by adhesive layer **730**. To the first side (again first side is arbitrarily assigned) of second glazing substrate **720** is attached solar light redirecting layer **760**. Solar light redirecting layer **760** comprises a film with projecting asymmetrical prism structures **780**. Projecting asymmetrical prism structures **780** are different in shape than projecting asymmetrical prism structures **770**. Solar light redirecting layer **760** is adhered to the first major surface of the second glazing substrate **720** by adhesive layer **740**. Void space **790** is present between the glazing substrates. The void space may be a vacuum or it may contain air or other gases such as nitrogen.

Figure 10A describes light management construction **800** and includes first glazing substrate **810** and second glazing substrate **820**. To the first side (again first side is arbitrarily assigned) of first glazing substrate **810** is attached solar light redirecting layer **850**. Solar light redirecting layer **850** comprises a film with projecting asymmetrical prism structures **870**. Solar light redirecting layer **850** is adhered to the first major surface of the first glazing substrate **810** by adhesive layer **830**. To the first side (again first side is arbitrarily assigned) of second glazing substrate **820** is attached solar light redirecting layer **860**. Solar light redirecting layer **860** comprises a film with projecting asymmetrical prism structures **880**. Projecting asymmetrical prism structures **880** are identical in shape to projecting asymmetrical prism structures **870**. Solar light redirecting layer **860** is adhered to the first major surface of the second glazing substrate **820** by adhesive layer **840**. Void space **890** is present between the glazing substrates. The void space may be a vacuum or it may contain air or other gases such as nitrogen. In Figure 10A, the period of the prism structures **880** on solar light redirecting layer **840** and the period of the prism structures **870** on solar light redirecting layer **850** are misregistered. Misregistration is shown by the lack of correspondence of **points G** and **H**, similar to the **points C** and **D** of Figure 2.

Figure 10B is a cross sectional view of a comparative light management construction where the microstructured layers are registered. In Figure 10B, light management construction **800'** includes first glazing substrate **810** and second glazing substrate **820**. To the inner side of first glazing substrate **810** is attached solar light redirecting layer **850**. Solar light redirecting layer **850** comprises a film with projecting

asymmetrical prism structures **870**. Solar light redirecting layer **850** is adhered to the inner surface of the first glazing substrate **810** by adhesive layer **830**. To the inner side of second glazing substrate **820** is attached solar light redirecting layer **860**. Solar light redirecting layer **860** comprises a film with projecting asymmetrical prism structures **880**.
5 Projecting asymmetrical prism structures **880** are identical in shape to projecting asymmetrical prism structures **870**. Solar light redirecting layer **860** is adhered to the inner surface of the second glazing substrate **820** by adhesive layer **840**. Void space **890** is present between the glazing substrates. The void space may be a vacuum or it may contain air or other gases such as nitrogen. In Figure 10B, the period of the prism
10 structures **880** on solar light redirecting layer **840** and the period of the prism structures **870** on solar light redirecting layer **850** are registered. Registration is shown by the correspondence of **points G'** and **H'**, similar to the **points A** and **B** of Figure 1.

The light management constructions of this disclosure and exemplified in Figures 3, 4, 6A, 7, 8, 9 and 10A can be contrasted with a single sided solar light redirecting film
15 such as shown in Figure 5 and described in pending US Patent Applications: Serial Number 61/287360, titled "Light Redirecting Constructions" filed 12/17/2009 (Padiyath et al.), and Serial Number 61/287354, titled "Light Redirecting Film Laminate" filed 12/17/2009 (Padiyath et al.). It has been found that the light management constructions of this disclosure are able to redirect more incident solar light upwards towards the ceiling of
20 a room, than a corresponding single sided film. Thus, single-sided film construction **300** of Figure 5 which includes glazing substrate **310**, light redirecting layer **350** with projecting asymmetrical prisms **370**, which is adhered to optical substrate **310** by adhesive layer **330** is directly comparable to the light management constructions of this disclosure and exemplified in Figures 3, 4, 6A, 7, 8, 9 and 10A. It has been discovered that these
25 sequenced constructions are able to redirect more incident solar light than films like **300**. However, this has only been found to be true when the first solar light redirecting layer and the second solar light redirecting layer are not identical or mirror images.

Measurements of the ability of the film constructions to redirect light can be determined by laboratory testing, precluding the need to test the constructions by
30 installing them into windows for testing. An example of such a test involves the shining of a beam of light with a controlled intensity onto the film construction and measuring the amount of light that is redirected upwards. The input beam of light may be set at a given

angle or may be varied over a range of angles. The amount of light redirected upwards can be measured, for example, with a photodetector. It may be desirable to measure the distribution of light at all directions. This type of measurement is commonly referred to as bi-directional transmission distribution function (BTDF). An instrument available from
5 Radiant Imaging, WA, under trade name IMAGING SPHERE may be used to perform such measurements.

Besides the layers described above, the light management constructions of this disclosure may include additional optional layers such as optical substrate layers. The optical substrates typically are optical films. Optical films may be used to cover and
10 protect exposed microstructured surfaces when these surfaces are exposed to the outside environment or are exposed to the interior room environment. The optical film may be single layer film or it may be a multi-layer film construction. Typically, the optical film or multi-layer optical film, is prepared from polymeric materials that permit the film to be optically clear. Examples of suitable polymeric materials include, for example,
15 polyolefins such as polyethylene and polypropylene, polyvinyl chloride, polyesters such as polyethylene terephthalate, polyamides, polyurethanes, cellulose acetate, ethyl cellulose, polyacrylates, polycarbonates, silicones, and combinations or blends thereof. The optical film may contain other components besides the polymeric material, such as fillers, stabilizers, antioxidants, plasticizers and the like. In some embodiments, the
20 optical film may comprise a stabilizer such as a UV absorber (UVA) or hindered amine light stabilizer (HALS). Suitable UVAs include, for example, benzotriazole UVAs such as the compounds available from Ciba, Tarrytown, NY as TINUVIN P, 213, 234, 326, 327, 328, 405 and 571. Suitable HALS include compounds available from Ciba, Tarrytown, NY as TINUVIN 123, 144, and 292.

The use of a multi-layer optical film substrate permits the optical substrate to supply additional functional roles to the light management construction besides providing support for the two light redirecting layers. For example, the multi-layer film substrate can provide physical effects, optical effects, or a combination thereof. The multi-layer film substrate may include layers such as a tear resistant layer, a shatter resistant layer, an
30 infrared light reflection layer, an infrared absorbing layer, a light diffusing layer, an ultraviolet light blocking layer, a polarizing layer or a combination thereof. Among the especially suitable multi-layer films are multi-layer film constructions that can reflect

infrared light. In this way, the light redirecting laminate can also help to keep the undesirable infrared light (heat) out of the building while allowing the desirable visible light into the building. Examples of suitable multi-layer films useful as the optical film include those disclosed, for example, in US Patent Nos. 6,049,419, 5,223,465, 5,882,774, 6,049,419, RE 34,605, 5,579,162 and 5,360,659. In some embodiments, the optical film is a multilayer film in which the alternating polymeric layers cooperate to reflect infrared light. In some embodiments, at least one of the polymeric layers is a birefringent polymer layer.

When used, the optional optical film has a first major surface and a second major surface. The second major surface of the optional optical film makes contact with and is bonded to substantially all of the microstructures on the surface of one of the light redirecting layers. The optional optical film protects the microstructured surface and prevents the structures from becoming damaged, dirty or otherwise rendered incapable of redirecting light.

The second major surface of the optional optical film contacts the tops of the refractive prisms of the microstructured surface which it is covering. At the areas of contact between the optional optical film and the tops of the refractive prisms, these elements are bonded. This bonding may take a variety of forms useful for laminating together two polymeric units, including adhesive bonding, heat lamination, ultrasonic welding and the like. For example, the optional optical film could be heated to soften the film and the film contacted to the microstructured surface of the light redirecting layer. The heated film, upon cooling, forms bonds to the contacted portions of the microstructured layer. Similarly, the optional optical film could be dry laminated to the microstructured surface and then heat, either directly or indirectly, could be applied to produce the laminated article. Alternatively, an ultrasonic welder could be applied to the dry laminate construction. More typically, adhesive bonding is used. When adhesive bonding is used, either a heat activated adhesive or a pressure sensitive adhesive can be used. Generally, pressure sensitive adhesives are used, especially the optically clear pressure sensitive adhesives described above.

To effect the adhesive bonding, the adhesive may be applied either to the microstructured surface, or to the second major surface of the optional optical film. Typically, the adhesive is applied to the second major surface of the optional optical film.

The applied adhesive coating may be continuous or discontinuous. The adhesive coating may be applied through any of a variety of coating techniques including knife coating, roll coating, gravure coating, rod coating, curtain coating, air knife coating, or a printing technique such as screen printing or inkjet printing. The adhesive may be applied as a solvent-based (i.e. solution, dispersion, suspension) or 100% solids composition. If solvent-based adhesive compositions are used, typically, the coating is dried prior to lamination by air drying or at elevated temperatures using, for example, an oven such as a forced air oven. The adhesive coated optional optical film can then be laminated to the microstructured surface. The lamination process should be well controlled to provide uniform and even contact on the tips of the microstructured prisms described above.

Examples

These examples are merely for illustrative purposes only and are not meant to be limiting on the scope of the appended claims.

Modeling Procedural Description

A series of light redirecting films were modeled using the general procedural descriptions below to determine the ability of the films to redirect light in a desirable direction. This redirection is described as the "up:down ratio" which describes the ratio of light redirected upwards (which is the desired direction) to the light that is directed downwards.

For the modeling, the films are supported by an optical substrate, like a window. The window is assumed vertically situated and faces directly south at 45 degrees north latitude on about the autumnal equinox of 9/21/2010. The effects of the sun transiting the sky over the course of daylight hours on that date are approximated by computing the transmitted flux directed upwards and downwards at half hour intervals from when the sun rises 15 degrees elevation above the horizon to when it again sets past 15 degrees elevation. An "up:down ratio" is formed from the sum of these total transmitted light fluxes through the double pane window plus films construction.

Sunrise and sunset for any day of any year at any latitude and longitude were computed using Muneer's PROG1-7, obtained from the National Renewable Energy Lab (NREL). Solar azimuth and elevation at any time of any day of any year at any latitude

and longitude were computed using Muncer's PROG1-6, obtained from NREL. Solar irradiance on the window surface at any time of any day of any year at any latitude and longitude were computed using the SMARTS Code, Version 2.9.5, obtained from NREL.

Optical modeling and raytracing were done for each configuration with optical modeling software ASAP 2010V1R1SP2 from Breault Research Organization.

An executive program to alter run parameters and control the execution of the solar and optical modeling codes was created and run with Mathematica 8.0.0 from Wolfram Research.

Comparative Example C1

The film modeled is illustrated in Figure 5 and was prepared in the following manner. A master tool having the negative of the desired linear grooves and prismatic elements was obtained using a diamond turning process. A UV curable resin composition was prepared by blending 74 parts by weight of an aliphatic urethane acrylate oligomer, commercially available under the trade designation "PHOTOMER 6010" from Cognis, Monheim, Germany, 25 parts 1,6-hexanediol diacrylate, commercially available under the trade designation "SARTOMER SR 238" from Sartomer, Exton, PA, and an alpha-hydroxy ketone UV photoinitiator (2-hydroxy-2-methyl-1-phenyl-1--18-propanone), commercially available under the trade designation "DAROCUR 1173" from Ciba, Basel, Switzerland. A 76 micrometer (3 mil) thick PET (polyethylene terephthalate) film, commercially available from DuPont Teijin Films, Hopewell, VA under the trade designation "MELINEX 453", was coated with the UV curable resin to an approximate thickness of 85 micrometers. The coated film was placed in physical communication with the master tool such that the grooves were void of any air. The resin was cured while in physical communication with the master tool with a microwave powered UV curing system available from Fusion UV systems, Gaithersburg, MD. The cured resin on the web was removed from the master tool resulting in a microstructured film. One liner of a 25 micrometer (1 mil) thick 10 optically clear adhesive transfer tape, commercially available from 3M Company, St. Paul, MN under the trade designation "3M OPTICALLY CLEAR ADHESIVE 8171", was removed and the exposed adhesive surface was laminated to the non-structured side of the microstructured film in a roll-to-roll laminator available from Protech Engineering, Wilmington, Delaware.

The remaining liner of the construction can then be removed and the laminate can then be applied to one of the inner glass surfaces of a double pane window as illustrated in Figure 5. In Figure 5, the window is **310**, the adhesive is **330**, and the light redirecting layer **350** has microstructures **370**. The second pane of the double pane window is not shown in Figure 5. For modeling purposes the distance between microstructures was 3 micrometers, the width of the microstructures as measured parallel to the glass surface was 50 micrometers resulting in a pitch of 53 micrometers. Modeled up:down ratio is presented in Table 1.

Comparative Example C2

The double pane window of Comparative Example C1 with the exact same structured film of Comparative Example C1 applied to one of the inner glass surfaces may be further modified by attaching a second structured film to the other opposing inner glass surface of the double pane window. For modeling purposes this second structured film was considered identical to the first film and microstructure teeth were registered between the 2 films as illustrated in Figure 10B. Figure 10B includes first glazing substrate **810** and second glazing substrate **820**. To the inner side of first glazing substrate **810** is attached solar light redirecting layer **850**. Solar light redirecting layer **850** comprises a film with projecting asymmetrical prism structures **870**. Solar light redirecting layer **850** is adhered to the inner surface of the first glazing substrate **810** by adhesive layer **830**. To the inner side of second glazing substrate **820** is attached solar light redirecting layer **860**. Solar light redirecting layer **860** comprises a film with projecting asymmetrical prism structures **880**. Projecting asymmetrical prism structures **880** are identical in shape to projecting asymmetrical prism structures **870**. Solar light redirecting layer **860** is adhered to the inner surface of the second glazing substrate **820** by adhesive layer **840**. Void space **890** is present between the glazing substrates. The void space may be a vacuum or it may contain air or other gases such as nitrogen. In Figure 10B, the period of the prism structures **880** on solar light redirecting layer **840** and the period of the prism structures **870** on solar light redirecting layer **850** are registered. Registration is shown by the correspondence of points G' and H', similar to the points A and B of Figure 1. Modeled up:down ratio is presented in Table 1.

Example 1

The double pane window of Comparative Example C2 with the exact same first structured film as in Comparative Example C2 applied to one of the inner glass surfaces may be further modified by attaching a second structured film to the other opposing inner glass surface of the double pane window. This second structured film is different than the first film as illustrated in Figure 7. Figure 7 includes first glazing substrate **510** and second glazing substrate **520**. To the inner side of first glazing substrate **510** is attached solar light redirecting layer **550**. Solar light redirecting layer **550** comprises a film with projecting asymmetrical prism structures **570**. Solar light redirecting layer **550** is adhered to the inner surface of the first glazing substrate **510** by adhesive layer **530**. To the inner side of second glazing substrate **520** is attached solar light redirecting layer **560**. Solar light redirecting layer **560** comprises a film with projecting asymmetrical prism structures **580**. Projecting asymmetrical prism structures **580** are different in shape to projecting asymmetrical prism structures **570**. Solar light redirecting layer **560** is adhered to the inner surface of the second glazing substrate **520** by adhesive layer **540**. Void space **590** is present between the glazing substrates. The void space may be a vacuum or it may contain air or other gases such as nitrogen. For modeling purposes the distance between all microstructures was 3 micrometers, the width of the microstructures as measured parallel to the glass surface was 50 micrometers resulting in a pitch of 53 micrometers. Modeled up:down ratio is presented in Table 1.

The light redirecting construction prepared above can be prepared on a glass substrate. A similar master tool obtained using a diamond turning process could be used. A similar UV curable resin composition containing 74 parts by weight of an aliphatic urethane acrylate oligomer, commercially available under the trade designation "PHOTOMER 6010" from Cognis, Monheim, Germany, 25 parts 1,6-hexanediol diacrylate, commercially available under the trade designation "SARTOMER SR 238" from Sartomer, Exton, PA, and an alpha-hydroxy ketone UV photoinitiator (2-hydroxy-2-methyl-1-phenyl-1-propanone), commercially available under the trade designation "DAROCUR 1173" from Ciba, Basel, Switzerland could be prepared. A glass plate could be coated with the UV curable resin to an approximate thickness of 85 micrometers. The coated film could be placed in physical communication with the master tool such that the grooves are void of any air. The resin could be cured while in physical communication

with the master tool with a microwave powered UV curing system available from Fusion UV systems, Gaithersburg, MD. The cured resin on the web could be removed from the master tool resulting in a microstructured film.

5 **Example 2**

The double pane window of Comparative Example C2 with the exact same structured films of Comparative Example C2 applied to the inner glass surfaces except that the microstructure teeth are misregistered by being offset $0.75 \times (\text{tooth pitch})$ up with respect to the left as illustrated in Figure 10A. Figure 10A includes first glazing substrate **810** and second glazing substrate **820**. To the inner side of first glazing substrate **810** is attached solar light redirecting layer **850**. Solar light redirecting layer **850** comprises a film with projecting asymmetrical prism structures **870**. Solar light redirecting layer **850** is adhered to the inner surface of the first glazing substrate **810** by adhesive layer **830**. To the inner side of second glazing substrate **820** is attached solar light redirecting layer **860**. Solar light redirecting layer **860** comprises a film with projecting asymmetrical prism structures **880**. Projecting asymmetrical prism structures **880** are identical in shape to projecting asymmetrical prism structures **870**. Solar light redirecting layer **860** is adhered to the inner surface of the second glazing substrate **820** by adhesive layer **840**. Void space **890** is present between the glazing substrates. The void space may be a vacuum or it may contain air or other gases such as nitrogen. In Figure 10A, the period of the prism structures **880** on solar light redirecting layer **840** and the period of the prism structures **870** on solar light redirecting layer **850** are misregistered. Registration is shown by the correspondence of points G and H, similar to the points C and D of Figure 2. For modeling purposes the distance between all microstructures was 3 micrometers, the width of the microstructures as measured parallel to the glass surface was 50 micrometers resulting in a pitch of 53 micrometers. Modeled up:down ratio is presented in Table 1.

Table 1

Example	Description	Light Redirecting Up:Down Ratio
Comparative	One film with structures on one side	3.22

Example C1	of glass substrate.	
Comparative Example C2	Two Films on two glass surfaces, identical structures, registered.	0.82
Example 1	Two Films on two glass surfaces, different structures.	4.63
Example 2	Same as CE C2, but misregistered.	4.85

What is claimed is:

1. A solar light redirecting glazing construction comprising:

a first glazing substrate having a first major surface and a second major surface;
a first solar light redirecting layer disposed on the first major surface of the first
5 glazing substrate, the first solar light redirecting layer comprising a
microstructured surface forming a plurality of prism structures; and
a second solar light redirecting layer disposed on the second major surface of the
first glazing substrate, the second solar light redirecting layer comprising a
microstructured surface forming a plurality of prism structures, wherein at least
10 one of the first or the second microstructured surface comprises an ordered
arrangement of a plurality of asymmetric refractive prisms,
such that the first solar light redirecting layer and the second solar light
redirecting layer are not identical or mirror images.

15 2. The solar light redirecting glazing construction of claim 1, wherein both the first solar
light redirecting layer and the second solar light redirecting layer comprise a
microstructured surface forming an ordered arrangement of a plurality of asymmetrical
prism structures.

20 3. The solar light redirecting glazing construction of claim 2, wherein the first solar light
redirecting layer and the second solar light redirecting layer are misregistered.

25 4. The solar light redirecting glazing construction of claim 1, wherein the solar light
redirecting layer that comprises the ordered arrangement of a plurality of asymmetrical
prism structures comprises an optical substrate having a first major surface and a second
major surface opposite the first major surface, wherein the first major surface comprises a
microstructured surface comprising asymmetrical structures, wherein the asymmetrical
structures comprise an ordered arrangement of a plurality of multi-sided refractive prisms,
wherein a cross section of each of the multi-sided refractive prisms comprise at least 4
30 sides (sides A, B, C, and D) such that: side A of each of the multi-sided refractive prisms
is parallel to and adjacent to the first major surface of the optical substrate; side B of each
of the multi-sided refractive prisms is joined to side A and is designed to produce total

internal reflection of light rays incident upon the second major surface of the optical substrate at an angle of from 5-80° above the horizontal of normal to side A; side C of each of the multi-sided refractive prisms is joined to side A; and side D of each of the multi-sided refractive prisms is connected to side C and side B, and is designed to substantially redirect light rays reflected from side B in a direction away from side B and towards the side C and/or D, and wherein the second major surface of the first optical film is adhered to the first glazing substrate.

5. The solar light redirecting glazing construction of claim 4, wherein the asymmetrical structures protrude 50 micrometers to 250 micrometers from the first major surface of the optical substrate.

6. The solar light redirecting glazing construction of claim 4, wherein the asymmetrical structures comprise a thermoplastic or a thermoset material.

7. A solar light redirecting glazing construction comprising:

a first glazing substrate having a first major surface and a second major surface;
a first solar light redirecting layer disposed on either the first major surface or the second major surface of the first glazing substrate, the first solar light redirecting layer comprising a major surface forming a plurality of prism structures;
a second glazing substrate having a first major surface and a second major surface; and
a second solar light redirecting layer disposed on the first major surface or the second major surface of the second glazing substrate, the second solar light redirecting layer comprising a major surface forming a plurality of prism structures, wherein at least one of the first or the second microstructured surface comprises an ordered arrangement of a plurality of asymmetric refractive prisms, such that the first solar light redirecting layer and the second solar light redirecting layer are not identical or mirror images.

8. The solar light redirecting glazing construction of claim 7, wherein the first solar light redirecting layer comprising a major surface forming a plurality of prism structures is

disposed on the first major surface of the first glazing substrate, and wherein the first major surface of the first glazing substrate comprises an exterior surface of the glazing construction.

5 9. The solar light redirecting glazing construction of claim 8, wherein the second solar light redirecting layer is disposed on the first major surface of the second glazing substrate, and wherein the first major surface of the second glazing substrate is an interior surface of the glazing construction.

10 10. The solar light redirecting glazing construction of claim 8, wherein the second solar light redirecting layer is disposed on the second major surface of the second glazing substrate, and wherein the first major surface of the second glazing substrate is an interior surface of the glazing construction.

15 11. The solar light redirecting glazing construction of claim 7, wherein the first solar light redirecting layer comprising a major surface forming a plurality of prism structures is disposed on the second major surface of the first glazing substrate, and wherein the first major surface of the first glazing substrate comprises an exterior surface of the glazing construction.

20 12. The solar light redirecting glazing construction of claim 11, wherein the second solar light redirecting layer is disposed on the first major surface of the second glazing substrate, and wherein the first major surface of the second glazing substrate is an interior surface of the glazing construction.

25 13. The solar light redirecting glazing construction of claim 11, wherein the second solar light redirecting layer is disposed on the second major surface of the second glazing substrate, and wherein the first major surface of the second glazing substrate is an interior surface of the glazing construction.

30 14. The solar light redirecting glazing construction of claim 7, wherein a void space is present between the first glazing substrate and the second glazing substrate.

15. The solar light redirecting glazing construction of claim 7, wherein both the first solar light redirecting layer and the second solar light redirecting layer comprise a major surface forming an ordered arrangement of a plurality of asymmetrical prism structures.

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16. The solar light redirecting glazing construction of claim 15, wherein the first solar light redirecting layer and the second solar light redirecting layer are misregistered.

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17. The solar light redirecting glazing construction of claim 7, wherein the solar light redirecting layer that comprises the ordered arrangement of a plurality of asymmetrical prism structures comprises an optical substrate having a first major surface and a second major surface opposite the first major surface, wherein the first major surface comprises a microstructured surface comprising asymmetrical structures, wherein the asymmetrical structures comprise an ordered arrangement of a plurality of multi-sided refractive prisms, wherein a cross section of each of the multi-sided refractive prisms comprise at least 4 sides (sides A, B, C, and D) such that: side A of each of the multi-sided refractive prisms is parallel to and adjacent to the first major surface of the optical substrate; side B of each of the multi-sided refractive prisms is joined to side A and is designed to produce total internal reflection of light rays incident upon the second major surface of the optical substrate at an angle of from 5-80° above the horizontal of normal to side A; side C of each of the multi-sided refractive prisms is joined to side A; and side D of each of the multi-sided refractive prisms is connected to side C and side B, and is designed to substantially redirect light rays reflected from side B in a direction away from side B and towards the side C and/or D, and wherein the second major surface of the first optical film is adhered to a glazing substrate.

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18. The solar light redirecting glazing construction of claim 17, wherein the asymmetrical structures protrude 50 micrometers to 250 micrometers from the first major surface of the optical substrate.

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19. The solar light redirecting glazing construction of claim 18, wherein the asymmetrical structures comprise a thermoplastic or a thermoset material.

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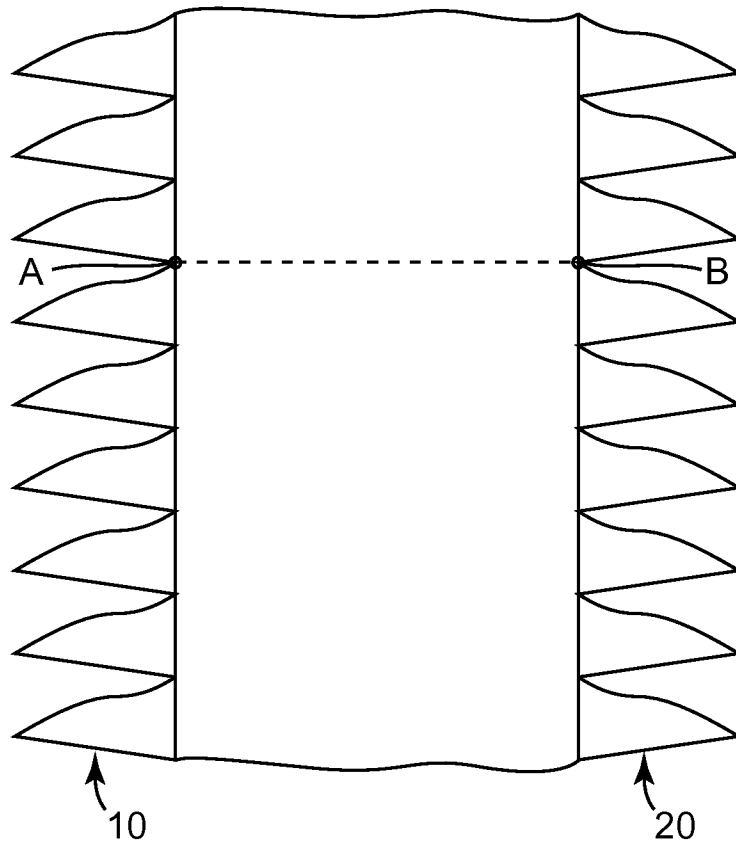


FIG. 1

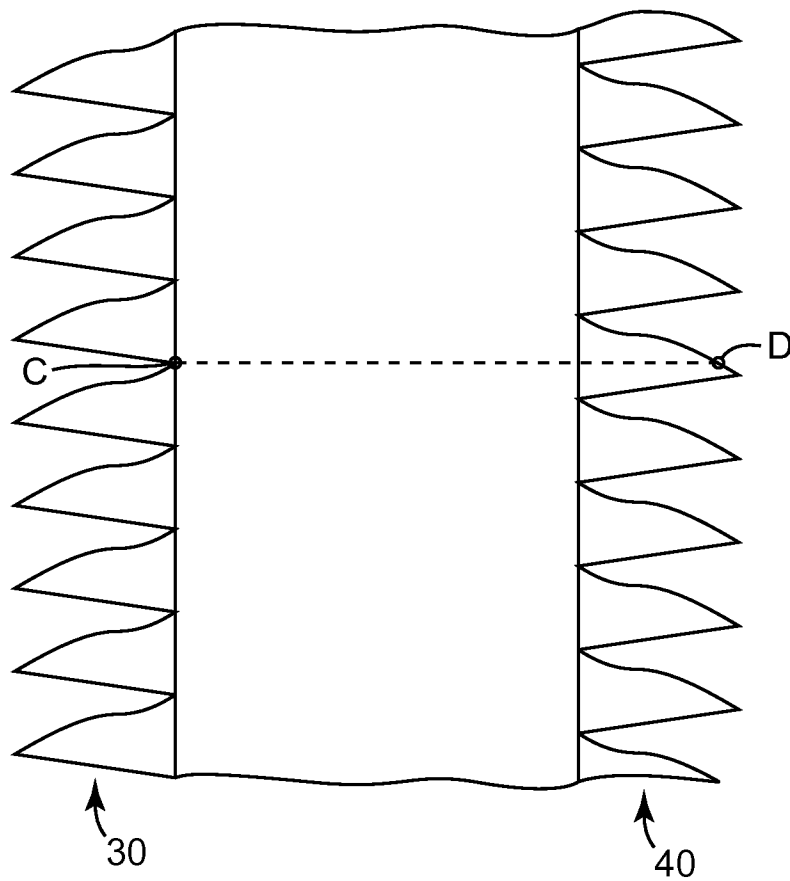
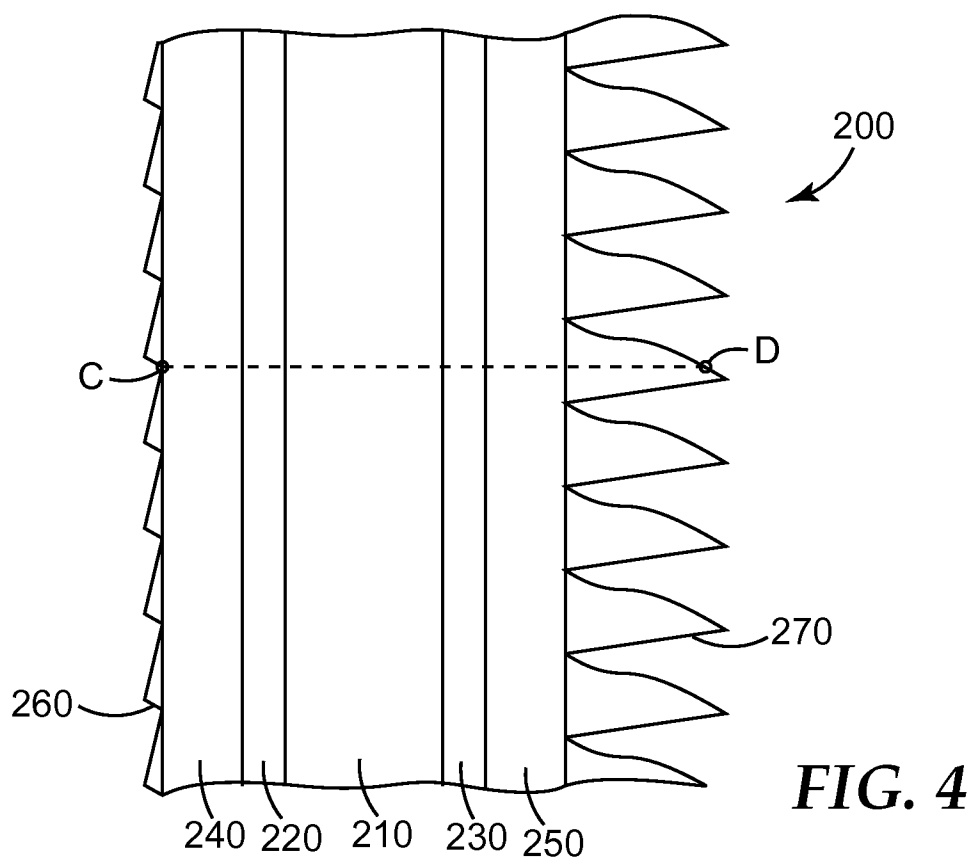
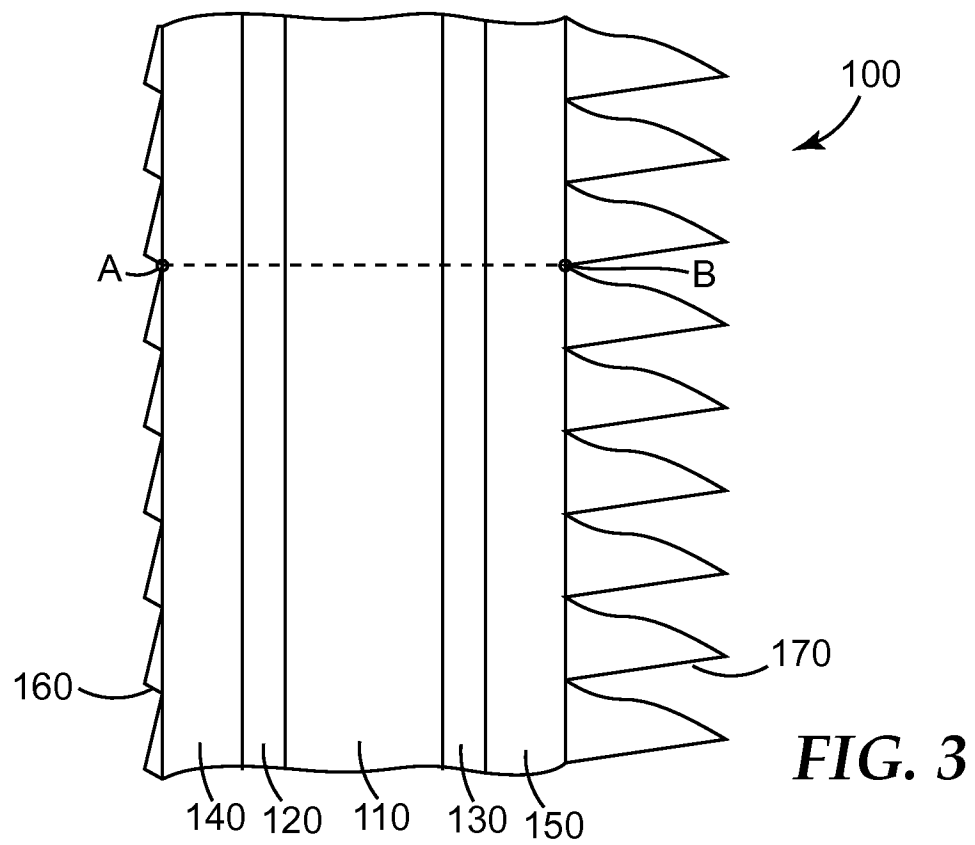


FIG. 2

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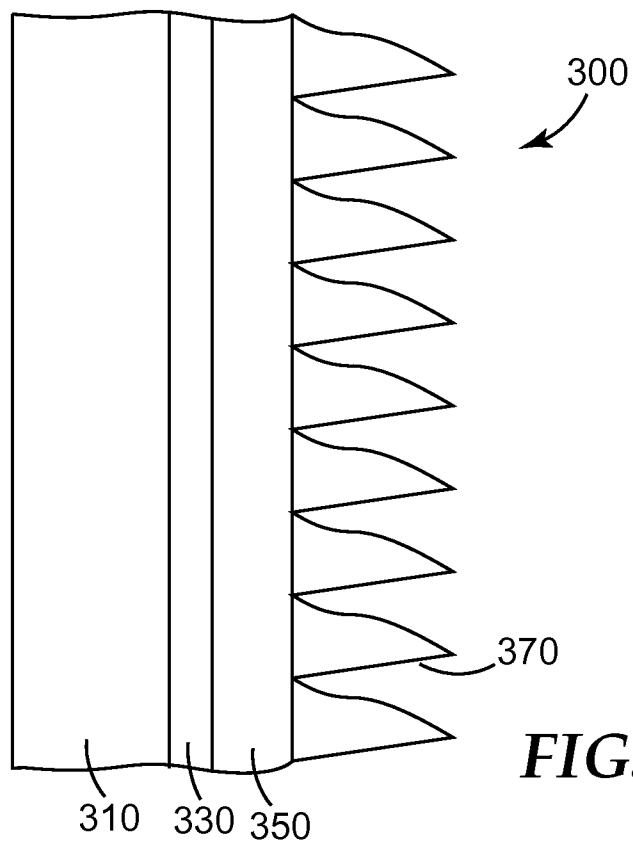


FIG. 5

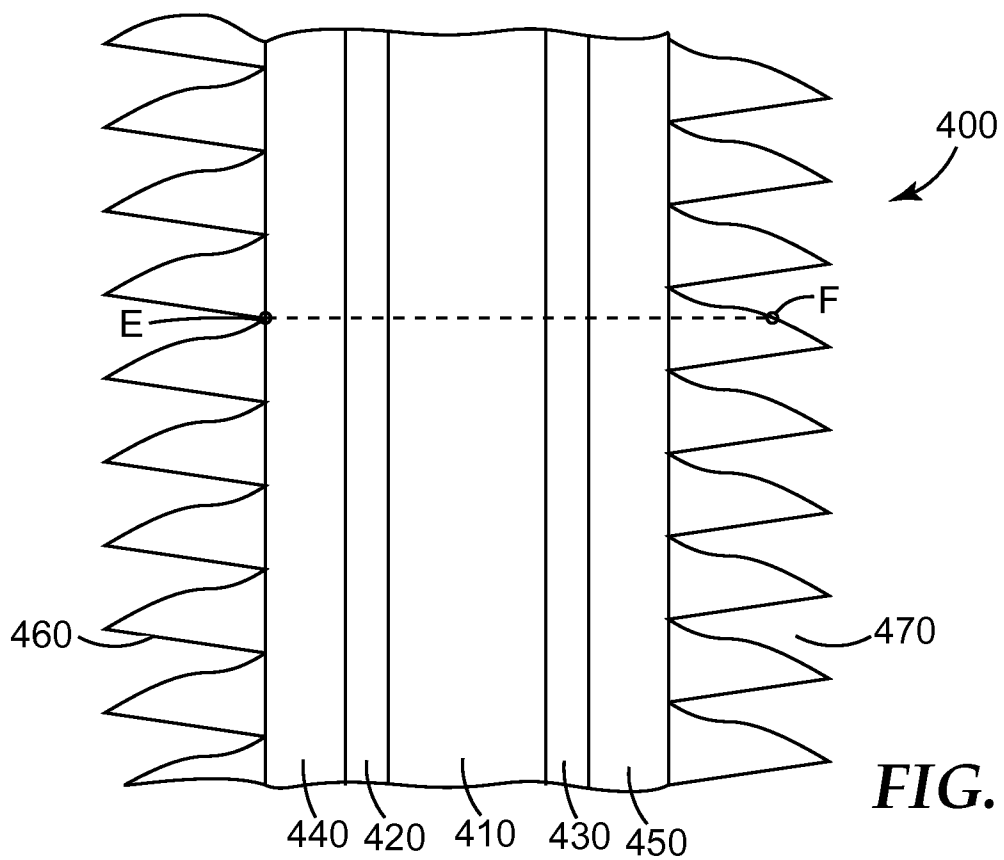
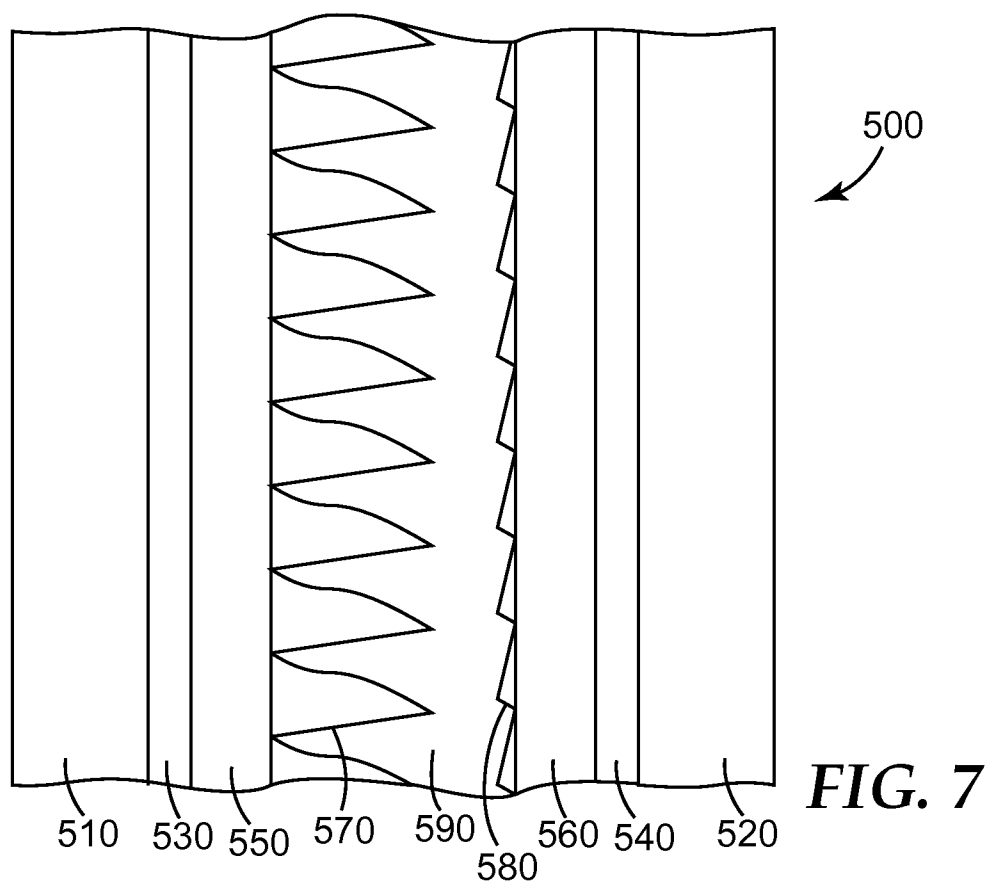
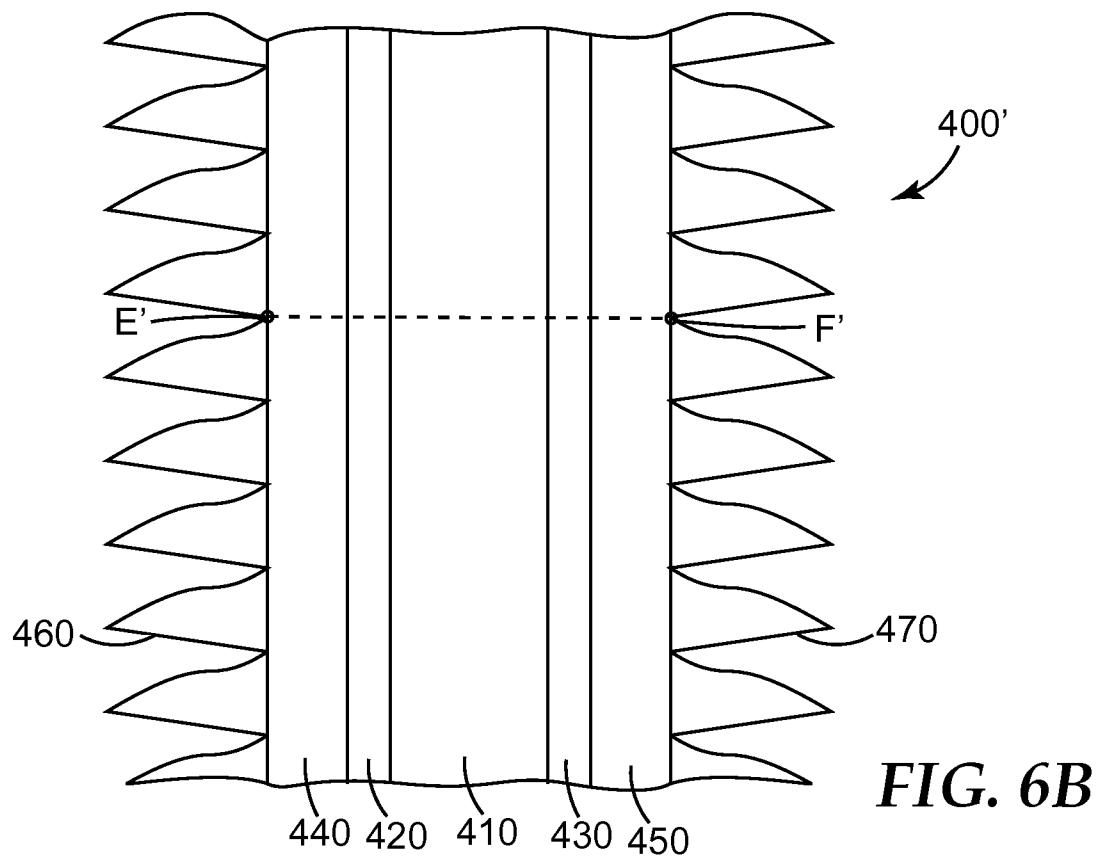
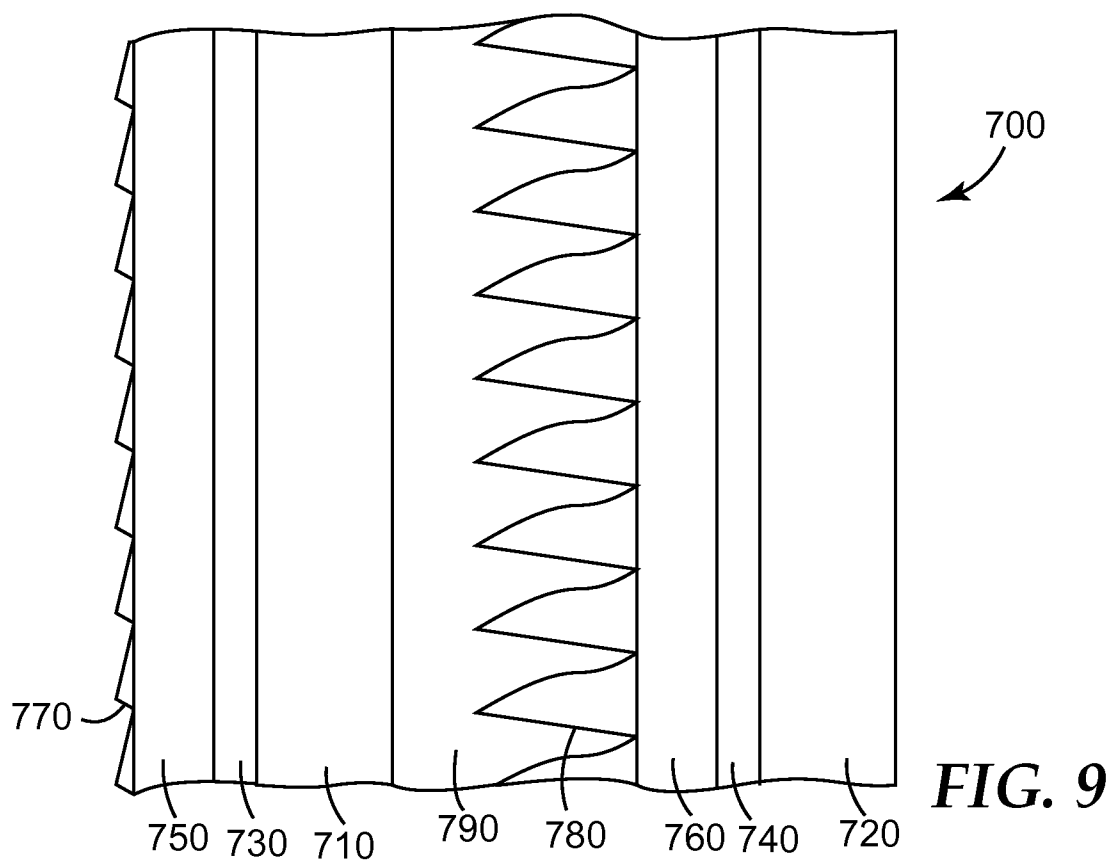
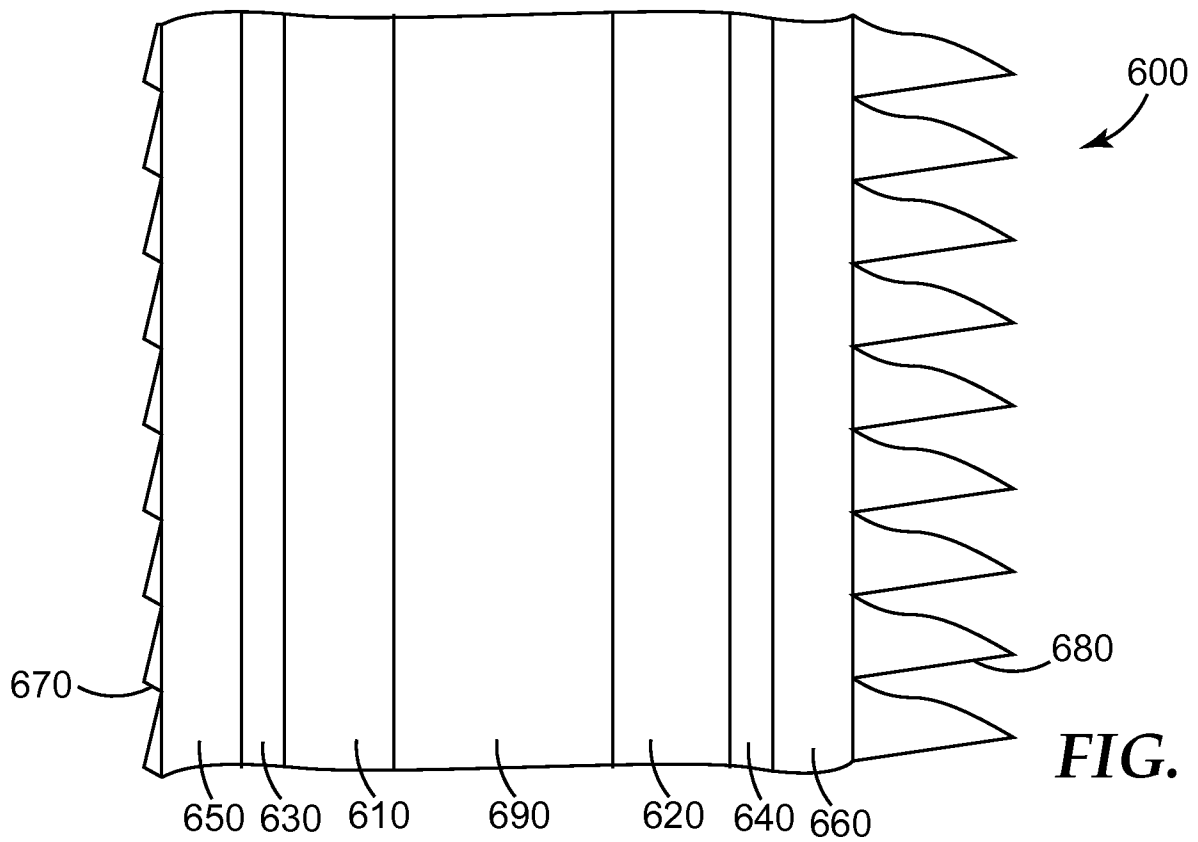


FIG. 6A

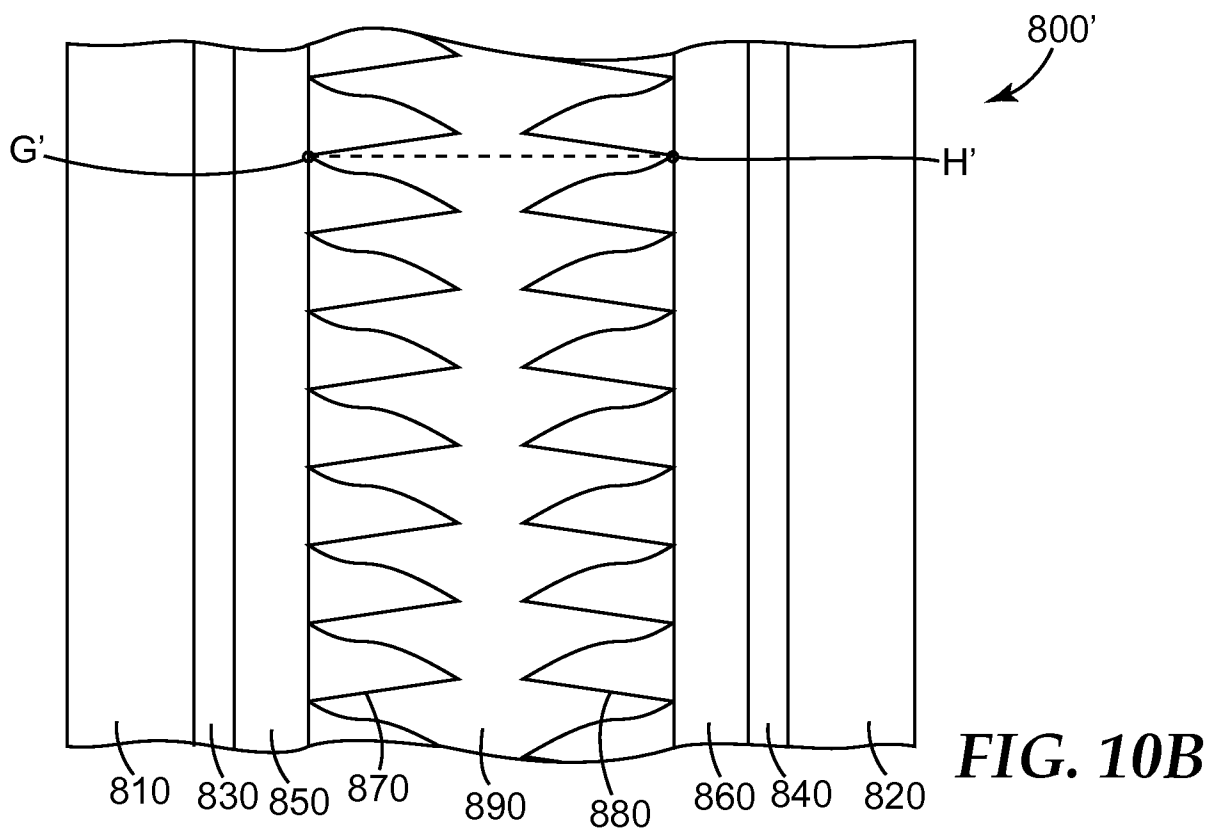
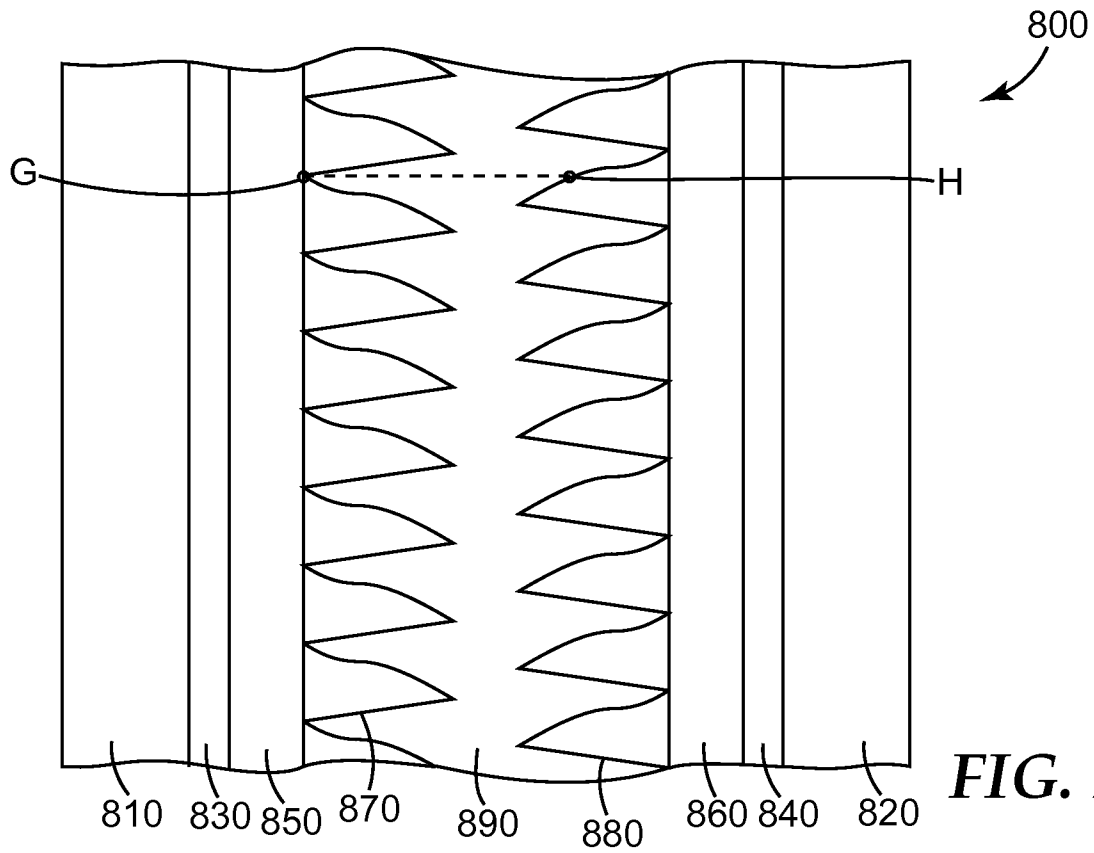
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A. CLASSIFICATION OF SUBJECT MATTER**G02B 5/04(2006.01)i, G02B 5/20(2006.01)i, A47H 23/00(2006.01)i, E06B 9/26(2006.01)i**

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

G02B 5/04; G02B 3/08; G02B 9/04; G02B 27/00; G02F 1/1335; G02B 5/02

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

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

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

eKOMPASS(KIPO internal) & Keywords: solar, redirecting, glazing, dual-sided, prism, asymmetric, optical, substrate

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y A	WO 2011-084303 A2 (3M INNOVATIVE PROPERTIES COMPANY et al.) 14 July 2011 See abstract; claims 1, 9, 10 and 21; figure 1.	1,2,4-7,15,17-19 3,8-14,16
Y A	US 05940149A A (DENNIS F. VANDERWERF) 17 August 1999 See abstract; column 4, lines 13 - 63; figure 2.	1,2,4-7,15,17-19 3,8-14,16
A	US 2011-0043919 A1 (CHUN-YU KO et al.) 24 February 2011 See abstract and figures 4C-6.	1-19
A	US 6377406 B1 (WERNER HOFMANN) 23 April 2002 See abstract, figures 2 and 3.	1-19



Further documents are listed in the continuation of Box C.



See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search

17 JANUARY 2013 (17.01.2013)

Date of mailing of the international search report

21 JANUARY 2013 (21.01.2013)

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2012/047067

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