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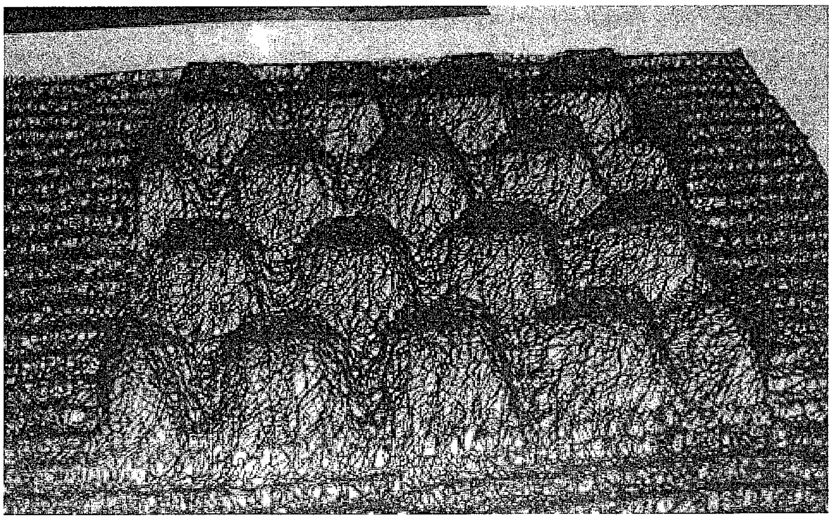

FIG. 4

(57) **Abstract**: A thin, flexible photovoltaic panel is mounted on the horizontal roof of a building by means of an entangled monofilament polymer web. As a result, conductive heating of the roof and the building underneath by the fugitive heat generated by the photovoltaic panel, which would otherwise occur if the photovoltaic panel were directly mounted on the roof, is eliminated.

WO 2011/002667 A1

MOUNTING SYSTEM FOR PHOTOVOLTAIC PANEL

Cross Reference to Related Application

[0001] This application claims the benefit of U.S. Provisional Patent Application Serial No. 61/221,398, entitled "MOUNTING SYSTEM FOR PHOTOVOLTAIC PANEL" and filed June 29, 2009, the disclosure of which is hereby fully incorporated herein by reference.

Background

[0002] This invention relates to mounting systems for mounting solar or photovoltaic panels ("PV" panels), especially flexible PV panels, on roofs and other building structures.

[0003] Using PV panels to convert sunlight directly into electricity is becoming increasingly popular. Most PV panels take the form of flat, rigid, usually-rectangular panels in which a planar central section containing an array of PV elements is surrounded by a rigid frame.

[0004] When a rigid PV panel is mounted on the roof a building, a mounting system is used which typically suspends the panel above the roof by a suitable distance, usually a few inches to a few feet or more. Where the roof is flat, *i.e.*, essentially horizontal, the mounting system desirably mounts the panel at an acute angle with respect to the horizontal, since this allows rain water to wash off dirt and other debris that would otherwise accumulate on the panel and block access to sunlight.

[0005] While such rigid PV panels work well, they are inherently expensive, since they are normally made robust in structure from expensive materials. Moreover, significant labor is required for their installation, not only for assembling their mounting systems but also for securing these mounting systems to the roof and then attaching the panels to these mounting systems.

[0006] Finally, these mounting systems introduce an inherent design flaw into the roofs on which they are mounted in that the nails, screws, lag bolts or other fasteners which secure these mounting systems to the roof penetrate its outermost water-proof layer ("roofing surface") and hence must be specially sealed to prevent future leaks. In an alternative arrangement, ballast (*i.e.*, heavy weights) are used to secure certain types of mounting systems to flat roofs. However, this also requires significant labor and, moreover, imparts a significant weight load to the roof's superstructure.

[0007] In order to avoid these disadvantages, flexible PV panels have been developed. In these panels, the array of PV elements is embedded in a layer of a suitable polymer and a separate rigid frame surrounding the array is eliminated. Moreover, the entire assembly is made thin and flexible enough so that it is rollable, *i.e.*, the entire assembly can be rolled up upon itself in essentially the same way as roofing felt.

[0008] Flexible PV panels are less expensive to manufacture than their rigid counterparts, since they are thin and flexible rather than thick, robust, substantial and rigid. Moreover, flexible PV panels are much less expensive to install, since they are typically mounted in direct contact with the roofs they cover, usually with suitable adhesives.

[0009] However, flexible PV panels have their own disadvantages. For example a desirable application for flexible PV panels is to supply electricity for air conditioning. Unfortunately, most flexible PV panels are dark in color, usually black, dark blue or dark brown. As a result, they generate significant fugitive heat in addition to electricity when exposed to direct sunlight.

[0010] This fugitive heat is not a problem when rigid PV panels are used, since such panels are supported above and out of contact with the roofs on which they are mounted. Flexible PV panels, however, are normally bonded directly to their roofs. As a result, at least some of the fugitive heat they produce transfers to their underlying roofs and then into the buildings underneath by conductive heat transfer. The net result is that the cooling obtained from the electricity they produce is largely cancelled by this conductive heat transfer.

Summary

[0011] In accordance with this invention, this disadvantage of flexible PV panels is eliminated by mounting these panels on their roofing surfaces by means of an open volume web. In accordance with this invention, it has been found that the open space created by this open volume web allows essentially all of the fugitive heat generated by these PV panel to be discharged to the atmosphere by convective heat flow rather than being transferred to these roofing surfaces by conductive heat flow.

[0012] Thus, this invention provides a process for mounting a PV panel on the roofing surface of a building, the process comprising securing the PV panel to the roofing surface by means of a mounting system comprising at least one flexible open volume web, the open volume web having a pair of generally opposed major faces and lateral edges connecting these major faces, a major portion of the volume of the open volume web being open space freely communicating with the atmosphere surrounding the lateral edges of the web, the mounting system having a thickness which is large enough to reduce conductive heat transfer from the PV panel to roofing surface.

[0013] In addition, this invention also provides a combination comprising a flexible PV panel and an attached mounting system for mounting the PV panel on the roofing surface of a building, the flexible PV panel defining a cross-sectional profile in its length and width dimensions, the mounting system comprising at least one open volume web, a major portion of the volume of the open volume web being open space freely communicating with the atmosphere surrounding the lateral edges of the web, the mounting system having a thickness which is large enough to reduce conductive heat transfer from the PV panel to the roofing surface on which it is or may become mounted, the mounting system defining a cross-sectional area which is at least 50% of the cross-sectional area of the PV panel.

[0014] In addition, this invention further provides a mounting system for mounting a flexible PV panel on the roofing surface of a building, the mounting system comprising an open volume web in the form of an entangled monofilament polymer web, the open volume web having an essentially planar profile generally corresponding to the planar profile of the PV panel, a major portion of the volume of the open volume web being open space freely communicating with the atmosphere surrounding the lateral edges of the web, the mounting system having a thickness which is large enough to reduce conductive heat transfer from the PV panel to the roofing surface on which it is or may become mounted, the thickness of the web increasing from one side of the web to an opposite side of the web by an amount sufficient so that when one of the major faces of the web is mounted on a generally horizontal roofing surface, the other major face will support the flexible PV panel at an acute angle with respect to the horizontal, this acute angle being large enough to cause rain water to wash off any dirt or other debris that may accumulated on the panel.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] This invention may be more readily understood by reference to the drawings wherein:

[0016] Fig. 1 is a schematic illustration of one embodiment of this invention in which the inventive mounting system in the form of a fibrous pad is used to mount a flexible PV panel on a roofing surface in accordance with this invention;

[0017] Fig. 2 is a schematic illustration similar to Fig. 1 in which the fibrous pad forming the inventive mounting system has a variable thickness so as to position the flexible PV panel at an acute angle with respect to the horizontal; and

[0018] Fig. 3 is a schematic illustration similar to Fig. 2, Fig. 3 further showing a foam adhesive being used to bond the inventive mounting system to the roofing surface for providing additional resistance to conductive heat flow.

[0019] Figs. 4 and 5 illustrate additional embodiments of this invention in which the inventive mounting system is formed from a tangled web of randomly oriented extruded thermoplastic polymer nanofilaments arranged in a system of hills and valleys.

DETAILED DESCRIPTION

The Underlying Roof

[0020] The inventive mounting system is intended for use in mounting PV panels to any type of building structure, *e.g.*, side wall, chimney, etc. Normally, however, the inventive mounting system will be used for mounting PV panels to the of the roof of a building, particularly its outermost waterproof layer ("roofing surface). This can be done with any type of building roof such as, for example, conventional pitched roofs carrying conventional roofing materials such as asphalt shingles, metal sheeting and the like.

[0021] Most commonly, however, the inventive mounting system will be used for mounting PV panels to "flat roofs," *i.e.*, roofs which are arranged in a horizontal configuration or a "low slope" configuration, *i.e.*, substantially horizontal but sloped enough to allow positive drainage. While such roofing systems can be made from a variety of different materials, they are normally made from a bituminous membrane roofing system, *i.e.*, a roofing system composed of one or more layers of a water-proof membrane commonly made for a bituminous material or analog. The roof substrate can be made from any type of material such as wood (*e.g.*, woodfiber board, plywood), concrete, metal or plastic, Normally, it is cleaned of dirt and other impurities and/or pretreated by well-known activation techniques for enhancing its surface adhesion properties before the bituminous roofing system is applied.

[0022] When a new bituminous roofing system is being applied to a roof substrate, the underlayment of the bituminous roofing system is normally formed by applying a liquid bituminous composition, *e.g.*, molten bitumen or solvent based bitumen adhesive, and then applying a pre-formed bituminous membrane over the bituminous composition. This can be done a single time so as to form a "single-ply" underlayment or multiple times to form a "multi-ply" or "built-up" or "BUR" underlayment. The pre-formed bituminous membranes used for this purpose are usually composed of a carrier such as paper, fiberglass, polyester or felt which is impregnated with bitumen or other similar material.

[0023] Once the underlayment is formed, the outermost layer of the bituminous roofing system is then applied to complete the bituminous roofing system. As well known in the art, three different approaches are commonly used to form the outermost surface layer of a bituminous membrane roofing system. In the first, referred to here as the "in-situ aggregate" approach, a layer of bitumen (asphalt) or other adhesive is laid down on the underlayment of the roofing system, *i.e.*, the portion of the roofing system under the outermost layer, and a layer of aggregate typically on the order of about 3/8 inch (~1 cm) in diameter is laid down on and partially embedded in the adhesive.

[0024] In the second, referred to here as the "liquid applied membrane" approach, the outermost surface layer is formed by coating the underlayment with a roof paint or covering which forms a relatively thick (i.e. membrane-like) waterproof coating.

[0025] In the third, referred to here as the "cap-sheet" approach, the outermost surface layer is formed from multiple preformed membranes or sheets (hereinafter "cap-sheets") which are laid up or arranged in an adjacent, overlapping edge fashion (like shingles in a shingle roof) to cover the entire roof surface to be covered. A layer of bitumen (asphalt) or other adhesive, typically applied to one or more lateral edges of each cap-sheet, is used to secure these cap-sheets to one another as well as the underlayment. Typically, these cap-sheets are made from a fibrous web or sheet of fiberglass, polyester fiber or both impregnated with bitumen (asphalt) or other suitable adhesive. Not infrequently, these cap-sheets are also covered with a suitable aggregate during manufacture for adding desired texture and/or color. Because the edges of adjacent cap-sheets are normally adhered atop one another, such aggregate is normally much smaller in size, typically on the order of 1/8 inch (~0.3 cm) in diameter or less.

[0026] The inventive mounting system can be used to mount PV panels on all of these different types of roofing systems.

[0027] In an especially interesting embodiment of this invention, the inventive mounting system is used to mount PV panels, and especially flexible PV panels, on the cool roof coverings described in commonly assigned application Serial No. 11/510,385, filed August 25, 2006 (atty. docket no. 06821/07578), the entire disclosure of which is incorporated herein by reference. These cool roof coverings are made with white and/or light-colored components, which inherently reflect a significant portion of the IR radiation impinging thereon. As a result, absorbance of heat generated from this IR radiation by the building's roof is minimized. Other high solar reflectance roofing systems, in particular roofing systems having a solar reflectance of at least 60% as measured by ASTM E1918-97 and ASTM E903-96 and a thermal emittance of at least 65 as measured by ASTM E-408-71, can also be used. Combining such high solar-reflectance roofing systems with the inventive mounting system minimizes absorbance of heat by the building's roof, thereby enabling air conditioners powered by the PV panels carried by these mounting systems to provide maximum cooling effect.

The PV Panels

[0028] The inventive mounting system can be used for mounting any type of PV panel, both flexible and rigid. Most commonly, however, they will be used for mounting flexible PV panels. In this context, "flexible" means that the center of a section of the PV panel measuring 12 inches x 12 inches (~30 cm x ~30 cm) can be displaced in a direction normal to the plane of the section by at least 1/4 inch (~0.6 cm) without destroying the functionality of the panel. PV panels which are flexible enough so that the center of a 12 inch x 12 inch section of the panel can be displaced by at least 1/2, 1, 2, 3, 4 or even 5 inches (at least ~1.2, ~2.5, ~5, ~8, ~10 or ~13 cm) are more interesting. "Rigid" meanwhile means any PV panel which is not flexible.

[0029] Flexible PV panels are well known in the art. As indicated above, they typically comprise an array of photovoltaic cells embedded in an essentially continuous planar layer of a suitable polymer, the entire assembly being made thin and flexible enough so as to achieve the desired degree of flexibility. They are described, for example, in the following publications, the entire disclosures of which are incorporated herein by reference: U.S. 6,310,281, U.S. 7,323,635, U.S. 7,351,907, WO 2008/051997 and WO/2008/074224. They are available from a wide variety of different sources including Xunlight Corporation of Toledo, Ohio, United Solar Ovonic LLC, a division of Energy Conversion Devices of Rochester Hills, Minnesota, and AltE Corporation of Hudson, Massachusetts.

[0030] Particularly interesting flexible PV panels are those which are "rollable," *i.e.*, that can be rolled up upon themselves without destroying their functionality. Flexible PV panels which can be rolled up upon themselves into rolls having internal diameters of 3 feet (~91 cm), 2 feet (~61 cm), 1 foot (~30 cm), and even less are especially interesting.

[0031] Flexible PV panels are available in a wide variety of different sizes, both in terms of physical size as well as power output. In terms of physical size, they are usually rectangular in configuration with widths ranging from a few inches, to 6 inches (~15 cm), 1 foot (~30 cm), 2 feet (~61 cm) and even 3 feet (~91 cm) and lengths ranging from 3 feet (~91 cm) or more. Lengths of about 1, 2, 3, 4, 5, 6 and more meters are not uncommon.

[0032] Any other type of rigid PV panel can also be mounted with the inventive mounting system.

Inventive Mounting System

[0033] The inventive mounting system comprises a flexible, generally planar web of material which has an open volume construction. In this context, "web" and "web section" in the context of this document mean an intricate three-dimensional network or arrangement of numerous interconnected filaments, fibers, threads, thongs, branches or other similar elongated elements which, in the aggregate, span the entire length, width and thickness of the web (or web section) and which, in addition, resemble or are suggestive of woven or entangled textile fibers. So, for example, an open cell or reticulated foam is a "web" in the context of this document, because the numerous elements which form the foam (the cell walls of the foam), in the aggregate, form an intricate three-dimensional network extending across the entire length, width and thickness of the foam. In addition, these cell walls in the aggregate resemble or at least suggest woven or entangled textile fibers, because adjacent cell walls in combination are thin, curved and intertwined. Similarly, a fibrous mat is a "web" in the context of this document, because the elements forming the mat (the fibers) are also thin, curved, intertwined and, in the aggregate, form an intricate three-dimensional network which extends across the entire length, width and thickness of the mat.

[0034] In contrast, the mounting hardware used, for example, to mount the Solyndra™ PV panels available from Solyndra, Inc. of Fremont, California, as shown on Solyndra's website at www.solyndra.com., do not constitute a "web" within the meaning of this document. This is because the individual mounting "stands" which constitute this mounting hardware are each formed from only four long, straight, rigid, metal rods which are rigidly secured at their tops to a mounting pad for attaching to the frame of the Solyndra PV panel and at their bottoms to respective long, straight, rigid metal "feet." These relatively few, large, straight, rigid, metal rods, pads and feet do not constitute "numerous" interconnected "filaments, fibers, threads, thongs, branches or other similar elongated elements" within the meaning of this disclosure. Nor can the generally-trapezoidal arrangement of these relatively few, large, straight, rigid, metal rods, pads and feet be regarded as "intricate" within the meaning of this disclosure. Nor do these relatively few, large, straight, rigid, metal rods, pads and feet resemble or suggest woven or entangled textile fibers, because they are too large, too rigid, too straight, and further because they are rigidly secured to one another in an essentially-trapezoidal arrangement.

[0035] Similarly, "flexible" in this context means that the web is not rigid, *i.e.*, that the web is sufficiently pliable so that it can conform to the roofing surface on which it is mounted, especially when such roofing surfaces are not completely planar. Mounting systems which are flexible enough so that the center of a 12 inch x 12 inch section of the mounting system can be displaced by ≥ ~1/4 inch (≥ ~0.6 cm) are more interesting. Mounting systems which are flexible enough so that the center of a 12 inch x 12 inch section can be displaced by ≥ 1/2, ≥ 1, ≥ 2, ≥ 3, ≥ 4, ≥ 5 or even 6 inches are even more interesting.

[0036] In addition, "generally planar" in this context means that the web defines two major faces, one for mating with the roofing surface and the other for carrying the PV panel to be mounted, which major faces are arranged generally opposite one another and which are spaced apart by a distance (thickness) which is less than the length or width of either major face. Normally, the length and width of the web will be greater than the thickness of the web by a factor of 2, 3, 4 or more. As further discussed below in connection with Figs. 4 and 5, one or both of these major faces can be formed by multiple "peaks" of multiple "hills" formed by the interconnected filaments, fibers, threads, thongs, branches or other similar elongated elements forming the web, which multiple peaks span the area of the major face or faces.

[0037] Finally, an "open volume construction" in the context of this document means that a major portion of the volume of the web forming the inventive mounting system is open space, with this open space freely communicating with the atmosphere surrounding the lateral edges of the web. And by "freely communicating" is meant that a fluid such as air can freely flow into and out of this open space through these lateral edges, from one lateral side of the web to the other. Open volume webs in which the open space comprises ≥ 50%, ≥ 75%, ≥ 90%, ≥ 93%, ≥ 95%, ≥ 97%, ≥ 98% and ≥ 99%, of the total volume of the web are more interesting.

[0038] Normally, the web forming the inventive mounting system also has a cross-sectional size and shape ("profile") generally corresponding to the cross-sectional size and shape ("footprint") of the particular PV panel being mounted. In this context, "cross-sectional size and shape" refers to the size and shape of the web in its length and width dimensions, not its thickness dimension. Moreover, a "generally corresponding size and shape" means that the lateral edges of the web forming the inventive mounting system are at least coterminous, or at least essentially coterminous, with the lateral edges of the PV panel which it mounts over a majority of the periphery of the web. In this context, "coterminous" means that the lateral edge of the mounting system extends to and is generally parallel with the corresponding lateral edge of the PV panel. Usually, the web will be at least coterminous, or at least essentially coterminous, with the lateral edges of the PV panel which it mounts over ≥ ~75%, ≥ ~85%, ≥ ~90%, ≥ ~95%, or even ≥ ~98%, of the periphery of the web.

[0039] In this regard, the inventive mounting system can also have a planar profile which is larger than the corresponding planar profile of the PV panel it supports, *i.e.*, greater than coterminous in the sense that the lateral edges of the inventive mounting system extend beyond the planar profile of the PV panel. This arrangement may make it possible to lower installation costs in some instances such as, for example, where the inventive mounting system as supplied from the manufacturer is larger than the PV panel being mounted. Using a larger mounting system may avoid the additional labor costs associated with trimming the edges of the mounting system to fit the profile of the panel. Since using a larger mounting system does not adversely affect its function and/or operation, such larger mounting systems can be used, if desired.

[0040] Also, in certain embodiments of the invention as further discussed below, adjacent PV panels may be arranged in abutting and/or slightly overlapping relationships with respect to one another. If so, it may be necessary to remove a portion of the generally planar web forming the inventive mounting system along its abutting and/or overlapping lateral edges. It will be understood that such a mounting system will still be understood as "generally corresponding in size and shape" to the PV panel it mounts, notwithstanding the fact that, at these abutting and/or overlapping locations, its lateral edge does not extend all the way, or essentially all the way, to the lateral edge of the PV panel. Similarly, the lateral edges of such a mounting system will still be understood to be "at least coterminous, or at least essentially coterminous," with the corresponding lateral edges of this PV panel, notwithstanding the fact that the portions of the lateral edges of the mounting system at these abutting and/or overlapping locations do not extend all the way, or essentially all the way, to the corresponding lateral edge of the PV panel.

[0041] In terms of thickness, the open volume webs forming the inventive mounting system normally require a certain minimum thickness to exert a noticeable decrease in conductive heat transfer from PV panel to roofing surface. For webs in which the open volume represents about ~97% of the web's total volume, this minimum thickness is on the order of ~ 1 cm. Greater thickness lead to greater decreases in conductive heat flow, with minimum thicknesses on the order of ~ 2 cm, ~ 3 cm, ~ 4 cm, ~ 5 cm, ~ 6 cm, ~ 7 cm, ~ 8 cm, ~ 9 cm, ~ 10 cm, and sometimes more being especially interesting. For webs with smaller or larger ratios of open space to total volume, correspondingly greater or lesser minimum thicknesses may be possible.

[0042] In terms of maximum thickness, there is no particular restriction on maximum web thickness, and hence any thickness can be used, as desired. On the other hand, there is usually a practical limit (*i.e.*, a maximum practical thickness) beyond which no particular advantage is realized by making the web any thicker. For webs in which the open volume represents about 95% of the web's total volume, this maximum practical thickness is on the order of ~5 to ~ 11 cm. For webs with smaller or larger ratios of open space to total volume, correspondingly greater or lesser maximum practical thicknesses may be possible. In any event, the minimum necessary thickness, the maximum practical thickness, and the preferred thickness to use for a particular application of this invention can be easily determined by routine experimentation.

[0043] In this regard, a particular advantage of the inventive mounting system is that it is inexpensive to manufacture and install. For this reason, it is desirable to make the open volume webs of this invention with a thickness which accomplishes the goal of eliminating, minimizing or at least reducing convective heat transfer to the desired degree but is not so thick that it needlessly increases manufacturing and/or installation costs.

[0044] The open volume webs of this invention can be made from essentially any physical structure. For example, they can be formed from fibrous mats, open cell foams, reticulated foams, wire meshes, fiberglass meshes, woven and unwoven fabrics, and so forth. In addition, they can also be made from extruded and/or injected molded plastics. For example, injection molding or extrusion can be used to form an open volume web in the form of a sheet or frame carrying a system of hills, bumps and/or protrusions extending from the sheet, these hills, bumps and/or protrusions defining therebetween the open volume and thickness of the web and being formed from interconnected filaments, fibers, threads, thongs, branches or other similar elongated elements.

[0045] In terms of materials of construction, the open volume webs of this invention can be made from any material which is strong enough to support the PV panels being mounted in an essentially stationary position and, in addition, which is strong enough to hold these PV panels in place when subjected to the atmospheric conditions that will be encountered in use (*e.g.*, rain, snow, hail, wind storms, etc.). For example, the open volume webs can be made from metals, fiberglass, plastics and other suitable materials. For this purpose, exemplary plastics include nylon, polypropylene, polyethylene, polyester, polyurethane, etc.

[0046] To make the inventive mounting system as inexpensive as possible, it is also desirable that its design be such that it can be produced in the form of a continuous web or sheet (or at least a large area web or sheet) by an automatic manufacturing operation which automatically provides and interconnects the various different elements forming the web into their final form and arrangement. For example, automatic manufacturing processes such as forming an open cell or reticulated foam, weaving and then bunching a fabric, assembling a fibrous mat, injection molding and extrusion are examples of automatic manufacturing operations with can manufacture a product to a desired final thickness, cross-sectional shape and open volume structure without manually assembling the different elements forming the product.

[0047] In accordance with another embodiment of this invention, the inventive mounting system is made from multiple sections of flexible open volume webs which are assembled together by the installer to provide a completed mounting system of this invention. For example, two continuous webs each having a desired final thickness, cross-sectional shape and open volume structure can be placed one atop the other, or side by side, to form a completed mounting system of this invention. In this embodiment, the total number of web sections needed to form the inventive mounting system will normally be no more than 8, more typically no more than 7, 6, 5, 4, 3 or 2. Of course, when PV panels extremely large in size are used, more web sections may be required.

[0048] In this embodiment, the multiple web sections will normally be assembled in a closely packed arrangement in the sense that when aggregated together they form an essentially continuous web of material spanning essentially the entire cross-sectional size and shape of the PV panel being mounted. However, it is also contemplated that, at least in some embodiments of this invention, multiple web sections of will be used which, in the aggregate, extend over less than the entire cross-sectional area ("footprint") of the PV panel being mounted. If so, these web sections in the aggregate desirably extend over a cross-sectional area representing ≥~50%, ≥~60%, ≥~70%, ≥~80%, or even ≥~90% of the cross-sectional area of the "footprint" of the PV panel being mounted.

[0049] As indicated above, the inventive mounting system at least in some embodiments is structured to have a cross-sectional profile which has essentially the same cross-sectional size and shape as the "footprint" as the PV panel to be mounted. In other words, the cross-sectional profile of the inventive mounting system and cross-sectional profile of the PV panel being mounts are essentially congruent with one another. In one embodiment of this invention, this is done by manufacturing the open volume web to have this desired profile. In another embodiment of the invention, this is done by manufacturing open volume web sections with "regular" profiles (*e.g.*, profiles of standard dimensions such as a rectangle 1 cm thick, 10 cm wide and 100 cm long) and combining multiple web sections in a side-by-side and/or one atop the other relationship to build a mounting system of a desired cross-sectional profile and thickness. Depending on the material from which the open volume web is made, it may also be necessary to subdivide such web section into suitable lengths and/or shapes such as by cutting, sawing or the like to achieve the desired profile. Using web sections of predetermined regular profiles in this way further reduces costs, since it reduces the number and types of different open volume webs that must manufactured, stored, shipped and supplied.

[0050] A particularly interesting material for use in making the inventive open volume webs of this invention are the Driwall™ line of drainage and ventilation mats available from Keene Building Products of Mayfield Heights, Ohio. These products, which can be described as "entangled monofilament polymer webs," take the form of a tangled web of randomly oriented extruded thermoplastic polymer monofilaments which are bonded to one another at their respective junctions, preferably by heat welding, thereby forming a resilient, structural mat of predetermined thickness. *See*, the website of Keene Building Products at http://keenebuilding.com. *See, also,* U.S. 7,096,630 and U.S. 4,315,392, the entire disclosures of which are incorporated herein by reference.

[0051] In an especially interesting embodiment of this invention, these entangled monofilament polymer webs are made with a thicknesses that varies from side to side, as shown in Fig. 2 discussed below, instead of a uniform thickness, in order to facilitate drainage of rain water. In another especially interesting embodiment of this invention, these entangled monofilament polymer webs are made with geometric patterns of hills, valleys, protrusions, etc., much like the bottom of an egg carton such as shown, for example, in Figs.

4 and 5 also discussed below. If desired, these hills, valleys, protrusions, etc. can be made to vary from region to region and/or to vary in thickness from one to the other in order to provide particular combinations of flexibility and open volume design. *See*, Fig. 5.

[0052] In still another embodiment of this invention, a metalized layer or sheet can be interposed between the inventive mounting system and the PV panel, or between the inventive mounting system and the roofing surface, or both, for providing still additional reflectance of infrared radiation. Metal foils such as aluminum foil can be used for this purpose, as can metalized plastic sheets and metalized plastic fabrics. Additionally or alternatively, one or more layers of other materials, *e.g.*, closed cell polymer foams, can also be interposed between the inventive mounting system and the PV panel, or between the inventive mounting system and the roofing surface, or both, for providing still additional reflectance of infrared radiation.

[0053] In still another embodiment of this invention, one or both of the major faces of the open volume web forming the inventive mounting system are bonded to a continuous sheet of material, thereby forming a two or three layered laminated web. Woven and unwoven fabrics made from plastic, glass or metal fibers can be used for this purpose, as can extruded and/or blown polymer films, as can metal films and metalized plastic films. Using this laminated web approach allows the bond strength of the open volume web to its adjacent adherents to be controlled at the factory, which in turn avoids installation problems which might be attributable to the open character of this open volume web. In addition, this approach also facilitates installation in that it avoids dripping and/or gravity-induced flow of adhesive applied to the upper surface of an open volume web into the web's interior before the adhesive sets up (*i.e.*, before the adhesive becomes immobile). This approach finds particular application when the open volume web forming the inventive mounting system is an entangled monofilament polymer web, as described above. However, this approach can also be used with any of the other open volume webs described above, as well.

Adhesives

[0054] The inventive mounting system is secured to the PV panel being mounted, as well as to the roof on which it is mounted, by a suitable adhesive.

[0055] Generally speaking, any adhesive exhibiting the desired combination of adhesive strength and weather resistance can be used for this purpose. For example, the same adhesives currently used for bonding flexible PV panels to new and existing roofing surfaces can be used for this purpose. Other specific examples include hot asphalt, other hot melt adhesives, aqueous asphalt emulsions, and solvent-based adhesives comprising a mixture of one or more organic resins and an organic solvent system capable of dissolving the organic resin. Butyl tape adhesives, *i.e.*, the adhesives used to bond commercially-available butyl tape and other similar non-metal "counterflashing" materials to roofing surfaces, window openings, etc., are particularly interesting.

[0056] Adhesives which are also storage stable, fire retardant or both are also of interest, especially if they are VOC compliant and non-tacky to reduce dirt pick-up. In this context, "storage stable" means that the adhesive composition can be stored in containers for at least six months without substantial separation of its ingredients whereby only minor mixing is necessary to provide a homogenous composition. In addition, "fire retardant" means that the adhesive composition in its final form, *i.e.*, after being applied and dried, will not support combustion. Similarly, "VOC-compliant" means that the adhesive composition contains no more than 250 grams of non-exempt volatile organic compounds per liter of composition.

[0057] It will also be appreciated that "adhesive" is used in this document in accordance with its normal meaning. Solvent-based adhesives work through evaporation of the organic solvent from the composition. Nonetheless, "adhesive" is commonly used to refer to adhesive compositions both before they are applied as after they have been applied and allowed to dry. That same conventional usage is followed in this document as well.

[0058] The adhesive can be applied to the roofing surface, to the underside of the PV panel whether flexible or rigid, to the inventive mounting system itself, or to any combination thereof. However, care should be taken to avoid allowing excessive amounts of adhesive to drip or otherwise flow by gravity into the interior of the open volume web forming the inventive mounting system, since this would adversely affect its open-volume design.

[0059] So, for example, in one embodiment of this invention, the adhesives are applied to the roofing surface and to the underside of the PV panel whether flexible or rigid or both. The inventive mounting system can then be placed into position on the adhesive-coated roofing surface immediately, or anytime thereafter so long as the adhesive is still pliable and/or tacky enough so that it securely bonds the inventive mounting system that it receives. However, the PV panel is not mounted on the inventive mounting system until the adhesive applied to its underside has thickened to the point where it is no longer capable of dripping or flowing by gravity to any significant degree. Hot melt adhesives and butyl tape adhesives work well in this approach.

[0060] In another approach, the adhesive is applied to the inventive mounting system itself, either to one major face or to both major faces. However, in this embodiment the adhesive-coated web is not oriented so that an adhesive-coated major face is above the remainder of the web until the adhesive has thickened to the point where it is no longer capable of dripping or flowing by gravity to any significant degree. Hot melt adhesives and butyl tape adhesives also work well in this approach.

[0061] Combinations of the above approaches can also be used.

[0062] In those instances where the adhesive is not intended to be applied directly to an "open" major surface of the inventive mounting system, the adhesive may also be sprayable, if desired. "Sprayable" in this context means that the adhesive can be applied to a roof substrate by means of commercially-available spraying equipment, for example, a double ball displacement pump with a pressure range of 500 to 700 psi such as Hennis-Johnson HJ4518X, HJ5318, or a Garlock 120 Sprayer. As appreciated by those skilled in the art, sprayable mixtures have viscosities and other properties which allow them to be atomized into droplets by the shear forces created when the composition is forced through a nozzle at high pressure while simultaneously allowing the droplets so-created to recombine into a coherent mass in layer form when deposited on a substrate.

[0063] In those instances in which the adhesives used in this invention are formulated from organic resins or resin combinations, these resins desirably are both flexible and weather-resistant. In this context, "weather-resistant" means that the resin or resin combination in its final form, *i.e.*, after being formulated into an adhesive and applied to a substrate and dried, will not significantly degrade when exposed to ambient outdoor conditions including sunlight, rain, snow and the like over extended periods of time.

[0064] In a particularly interesting embodiment of this invention, a foamed adhesive is used for bonding the inventive mounting system to the roofing surface, to the PV panel, or both, as this provides an additional barrier to conductive heat flow.

[0065] In still another interesting embodiment of this invention, different adhesives with different bond strengths are used for bonding the PV panel to the inventive bonding system and the inventive bonding system to the roof. In some instances, it may be desirable to remove a PV panel after it is installed. Using adhesives with different bond strengths allows the manner in which the PV panel/mounting system detaches from the roof to be controlled. For example, using a stronger adhesive to bond the PV panel to the inventive mounting system allows both to be drawn off together as a unit when removal is desired.

Pre-attachment

[0066] In still another embodiment of this invention, the inventive mounting system and associated PV panel are bonded to one another at the factory or other remote location before delivery to the building site where they are to be installed. This approach not only reduces installation costs but, in addition, also allows the bond formed between these two products to be precisely controlled.

Exemplary Embodiments

[0067] Fig. 1 illustrates one embodiment of the inventive mounting system and associated PV panel. As shown in this figure, thin film flexible PV panel 12 is mounted on outer roofing surface 14 of a building (not shown) by means of mounting system 16 of this invention. In the particular embodiment shown, mounting system 16 is an open volume web in the form of a mat of fibrous padding having a pair of generally opposed major faces and lateral edges connecting these major faces. PV panel 12 is bonded to the upper major face of mounting system 16 by means of adhesive layer 18, while mounting system 16 is bonded by its lower major face to outer roofing surface 14 by means of adhesive layer 20.

[0068] Fig. 2 illustrates a similar system except that, in the system of Fig. 2, the thickness of mounting system 22 increases essentially continuously from one side of the system to an opposite side of the system. With this feature, PV panel 12 is arranged at an acute angle with respect to the horizontal, which enables rain water 21 to wash off any dirt or other debris that may have accumulated on the panel.

[0069] Although Fig. 2 illustrates only one PV panel 12, it will be appreciate that multiple PV panels mounted at an acute angle with respect to the horizontal can be arranged in rows, with the PV panels in adjacent rows being in an abutting or slightly overlapping relationship with one another. With this approach, "troughs" or passageways are formed by the edges of adjacent rows of PV panels for facilitating transfer of rain water to an appropriately located drain. When PV panels are arranged in an overlapping and/or abutting relationship in accordance with this aspect of the invention, it may be necessary to remove a portion of the open volume web forming the inventive mounting system.

[0070] The embodiment illustrated in Fig. 3 is essentially the same as that of Fig. 2 except that, in the embodiment of Fig. 3, adhesive layer 20 is made from a foamed adhesive to provide further resistance to conductive heat flow between PV panel 12 and outer roofing surface 14.

[0071] Fig. 4 illustrates another embodiment of the inventive mounting system in which the entangled polymer monofilaments forming the inventive mounting system are arranged in a geometric pattern of hills and valleys, such that one major face of the web is formed by multiple, spaced, truncated peaks of these hills while the other major face of the web is formed by the valleys between these hills.

[0072] Finally, Fig. 5 illustrates an inventive mounting system similar to that of Fig. 4 except that, in the inventive mounting system of Fig. 5, the height of the truncated peaks varies from one side of the web to the other. With this design, the thickness of the inventive mounting system varies from one side to the in the same way as the mounting system of Fig. 2 so that a PV panel mounted with this system can also be arranged at an acute angle with respect to the horizontal.

WORKING EXAMPLES

[0073] In order to more thoroughly illustrate this invention, the following working examples are provided. In these examples, PV panels (both simulated and real) were mounted on single ply membrane test roofing surfaces (both white and black) and then irradiated with simulated sunlight produced by a single 120 watt GE Miser flood light spaced from the PV panel by a distance of about 20 inches (~51 cm). The temperature of the test roofing surface was continuously monitored by a thermocouple secured thereto until a steady state temperature was reached, which typically occurred in about 2 to 3.5 hours after irradiation began.

[0074] In each example representing this invention, the PV panel was mounted on the test roofing surface by means of a nylon entangled monofilament polymer web, in particular, a Driwall™ brand mortar deflection panel available from Keene Building Products of Mayfield Heights, Ohio. Mounting systems of different uniform thicknesses were compared to one another as well as to control experiments in which the PV panel was mounted directly on the test roofing surface or no PV panel at all was used.

Example 1

[0075] In this example, the test roofing surface was made from a white single ply membrane, the PV panel was simulated by an aluminum sheet painted black, and mounting systems 1 inch (~2.5 cm) and 2 inches (~5.0 cm) thick were compared to one another as well as to a direct mounted PV panel and no PV panel at all (*i.e.*, bare roof testing surface). The results are reported in the following Table 1:

Table 1

Example 1—Steady State Temperatures vs. Mounting System Thickness

Mounting System Thickness, inches	Steady State Temperature, °F
No Panel	91.9
Direct Mount	107.4
1	98.7
2	90.6

[0076] As can be seen from this table, the temperature of the white test roofing surface of this example rose to a steady state value of about 91.9° F (~33° C) when no PV panel was present. However, when a dark-colored simulated PV panel was directly mounted on this white test roofing surface, the steady state temperature rose to approximately 107.4° F (~42° C). This shows that mounting a flexible PV panel directly on a roofing surface in accordance with traditional practice causes a substantial increase in the temperature of this roofing surface. This in turn suggests that using a flexible PV panel mounted directly on the roof of a building to power an air conditioner used to cool the building's inside is largely self-defeating, because the benefit obtained through the air conditioning is effectively cancelled by the extra heat duty generated by the panel.

[0077] As further shown in Table 1, when the simulated PV panel was mounted on the same white test roofing surface using a 1 inch thick mounting system in accordance with this invention, the steady state temperature dropped to 98.7° F (37° C). This shows that, by using this inventive mounting system in this thickness, the amount of fugitive heat generated by the PV panel and transferred to the test roofing surface by conductive heat flow was reduced by more than half relative to conventional practice in which the flexible PV panel was mounted directly on the test roofing surface.

[0078] As still further shown in Table 1, when the simulated PV panel was mounted on the same white test roofing surface using a 2 inch thick mounting system in accordance with this invention, the steady state temperature dropped to 90.6° F (~33° C). This shows that using this mounting system in a thickness of 2 inches not only eliminated all conductive heating from the fugitive heat generated by the PV panel but also provided a beneficial shading effect, thereby reducing temperatures even further.

Example 2

[0079] Example 1 was repeated except that the test roofing surface was made from a black bitumen membrane. The results are reported in the following Table 2:

Table 2

Example 2—Steady State Temperatures vs. Mounting System Thickness

Mounting System Thickness, inches	Steady State Temperature, °F
Direct Mount	117
0.5	109
1.0	103
1.5	94.5

[0080] Table 2 shows essentially the same results as Table 1, *i.e.*, that lower steady state temperatures were reached when the simulated PV panel was mounted using the inventive mounting system rather than the control in which the PV panel was mounted directly on the test roofing surface and further that the magnitude of temperature lowering increased as the thickness of the inventive mounting system increased.

Example 3

[0081] Example 2 was repeated, except that the PV panel used was a section cut from a commercially available Unisolar brand flexible Solar panel available from United Solar Ovonic LLC, a division of Energy Conversion Devices of Rochester Hills, Minnesota. The results are reported in the following Table 3:

Table 3

Example 3—Steady State Temperatures vs. Mounting System Thickness

Mounting System Thickness, inches	Steady State Temperature, °F
No Panel	110.1
Direct Mount	103.9
0.5	101.9
1.0	95.7
1.5	92.2
2.0	88.5

[0082] Table 3 shows that, while direct mount of this flexible solar panel will actually reduce the amount of heat transferred to the test roofing surface somewhat, a still greater amount of heat reduction is achieved if this flexible solar panel is mounted to this test roofing surface by the inventive mounting system. In addition, Table 3 further shows that the magnitude of this additional heat reduction increases as the thickness of the inventive mounting system increases.

Example 4

[0083] Example 3 was repeated, except that the test roofing surface used was the same a white test roofing surface used in Example 1. The results are reported in the following Table 4:

Table 4

Example 4—Steady State Temperatures vs. Mounting System Thickness

Mounting System Thickness, inches	Steady State Temperature, °F
No Panel	89.2
Direct Mount	104.6
0.5	100.3
1.0	97.5
1.5	928
2.0	87.1

[0084] Table 4 shows essentially the same results as in Table 1. In particular, this table shows that directly mounting a flexible solar panel onto a white test roofing surface significantly increases the amount of heat transferred to the surface, but that this unwanted heat transfer can be reduced and even eliminated entirely if the inventive mounting system is used.

[0085] Although only a few embodiments of the inventive mounting system are described above, it should be appreciated that many modifications can be made without departing from the spirit and scope of the invention. For example, although Figs. 2 and 3 show that PV panel 12 is arranged at an acute angle with respect to the horizontal by using an open volume web 16 of increasing thickness from side to side, it should be appreciated that another element, *e.g.*, a closed cell polymer foam, can be used for this purpose for providing this acute angle. If so, open volume web 16 can have a uniform thickness from side to side, or a different varying thickness, all as desired. All such modifications are intended to be included within the scope of the present invention, which is to limited only by the following claims.

Claims:

1. A process for mounting a PV panel on the roofing surface of a building, the process comprising securing the PV panel to the roofing surface by means of a mounting system comprising at least one flexible open volume web, the open volume web having a pair of generally opposed major faces and lateral edges connecting these major faces, a major portion of the volume of the open volume web being open space freely communicating with the atmosphere surrounding the lateral edges of the web, the mounting system having a thickness which is large enough to reduce conductive heat transfer from the PV panel to roofing surface.

2. The process of claim 1, wherein the PV panel is flexible and defines a planar profile in its length and width dimensions, and further wherein the inventive mounting system has an essentially planar profile generally corresponding in size and shape to the planar profile of the PV panel.

3. The process of claim 1, wherein the mounting system has a thickness of at least ~1 cm.

4. The process of claim 3, wherein the mounting system has a thickness of ~2 cm to ~5 cm, and further wherein the open space defined by the open volume web represent at least ~97% of its total volume.

5. The process of claim 1, wherein the PV panel is flexible and defines a planar profile in its length and width dimensions, wherein the mounting system defines a cross-sectional area in its length and width dimensions, and further wherein the mounting system cross-sectional area is at least about 50% of the cross-sectional area of the PV panel.

6. The process of claim 5, wherein the open volume web is formed from multiple flexible open volume web sections.

7. The process of claim 6, wherein the multiple flexible open volume web sections are closely packed with one another.

8. The process of claim 5, wherein the open volume web is formed from a single flexible open volume web.

9. The process of claim 1, wherein the open volume web is an open cell foam, a reticulated foam, a fabric, a fibrous mat, an injection molding or an extrusion.

10. The process of claim 9, wherein the open volume web is an entangled monofilament polymer web.

11. The process of claim 9, wherein the mounting system further comprises a continuous sheet of material bonded to a major face of the open volume web.

12. The process of claim 1, wherein the thickness of the web increases from one side of the web to an opposite side of the web by an amount sufficient so that when one of the major faces of the web is mounted on a generally horizontal roofing surface, the other major face will support the flexible PV panel at an acute angle with respect to the horizontal, this acute angle being large enough to cause rain water to wash off any dirt or other debris that may accumulated on the panel.

13. The process of claim 1, wherein the PV panel is secured to the mounting system before the mounting system is secured to the roofing surface.

14. The process of claim 13, wherein the PV panel is secured to the mounting system before the combination of the PV panel and mounting system are delivered to the site of the building.

15. A combination comprising a flexible PV panel and an attached mounting system for mounting the PV panel on the roofing surface of a building, the flexible PV panel defining a cross-sectional profile in its length and width dimensions, the mounting system comprising at least one open volume web, a major portion of the volume of the open volume web being open space freely communicating with the atmosphere surrounding the lateral edges of the web, the mounting system having a thickness which is large enough to reduce conductive heat transfer from the PV panel to the roofing surface on which it is or may become mounted, the mounting system defining a cross-sectional area which is at least 50% of the cross-sectional area of the PV panel.

16. The combination of claim 15, wherein the thickness of the mounting system is at least ~1 cm.

17. The combination of claim 16, wherein the mounting system has a thickness of ~2 cm to ~5 cm, and further wherein the open space defined by the open volume web represent at least ~97% of its total volume.

18. The combination of claim 15, wherein the open volume web is formed from multiple flexible open volume web sections.

19. The combination of claim 18, wherein the multiple flexible open volume web sections are closely packed with one another.

20. The process of claim 15, wherein the open volume web is formed from a single flexible open volume web.

21. The combination of claim 15, wherein the open volume web is selected from an open cell foam, a reticulated foam, a fabric, a fibrous mat, an injection molding or an extrusion.

22. The combination of claim 21, wherein the open volume web is an entangled monofilament polymer web.

23. The combination of claim 21, wherein the mounting system further comprises a continuous sheet of material bonded to a major face of the open volume web.

24. The combination of claim 15, wherein the thickness of the web increases from one side of the web to an opposite side of the web by an amount sufficient so that when one of the major faces of the web is mounted on a generally horizontal roofing surface, the other major face will support the flexible PV panel at an acute angle with respect to the horizontal, this acute angle being large enough to cause rain water to wash off any dirt or other debris that may accumulated on the panel.

25. A mounting system for mounting a flexible PV panel on the roofing surface of a building, the mounting system comprising an open volume web in the form of an entangled monofilament polymer web, the open volume web having an essentially planar profile generally corresponding to the planar profile of the PV panel, a major portion of the volume of the open volume web being open space freely communicating with the atmosphere surrounding the lateral edges of the web, the mounting system having a thickness which is

large enough to reduce conductive heat transfer from the PV panel to the roofing surface on which it is or may become mounted, the thickness of the web increasing from one side of the web to an opposite side of the web by an amount sufficient so that when one of the major faces of the web is mounted on a generally horizontal roofing surface, the other major face will support the flexible PV panel at an acute angle with respect to the horizontal, this acute angle being large enough to cause rain water to wash off any dirt or other debris that may accumulated on the panel.

26. The combination of claim 25, wherein the smallest thickness of the mounting system is at least ~1 cm.

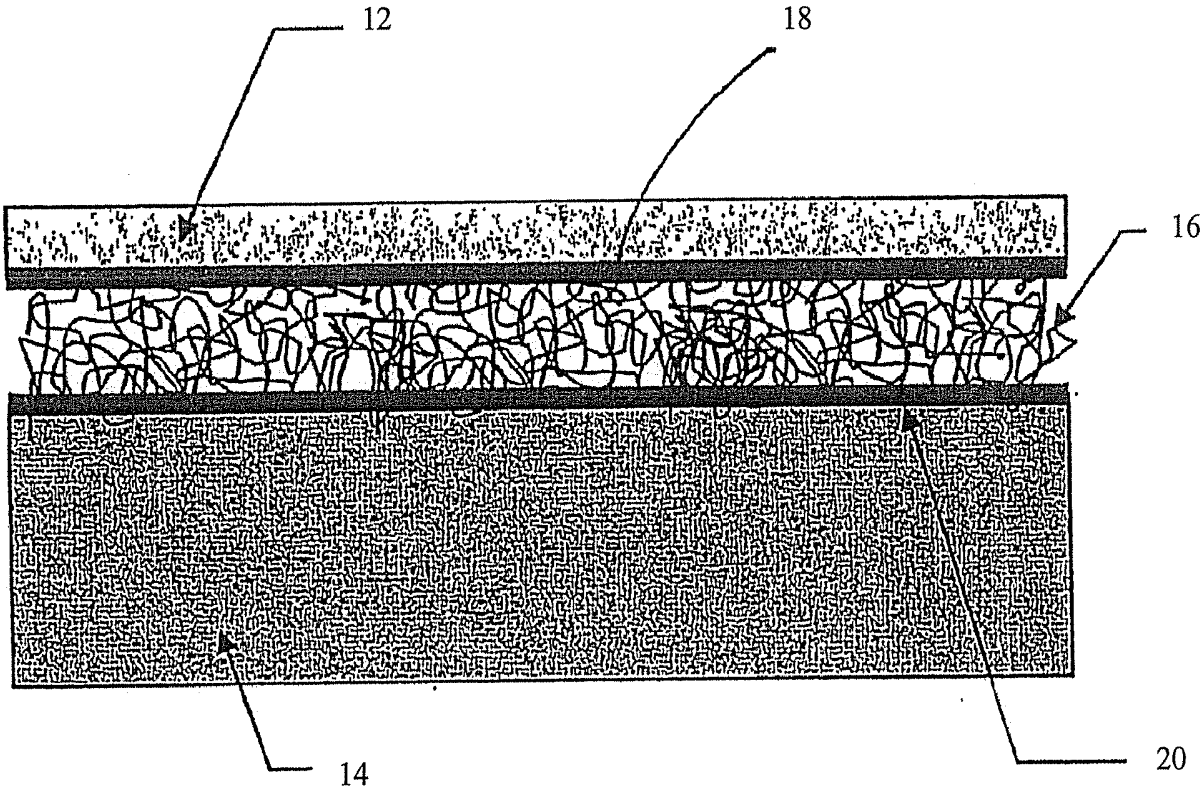

FIG. 1

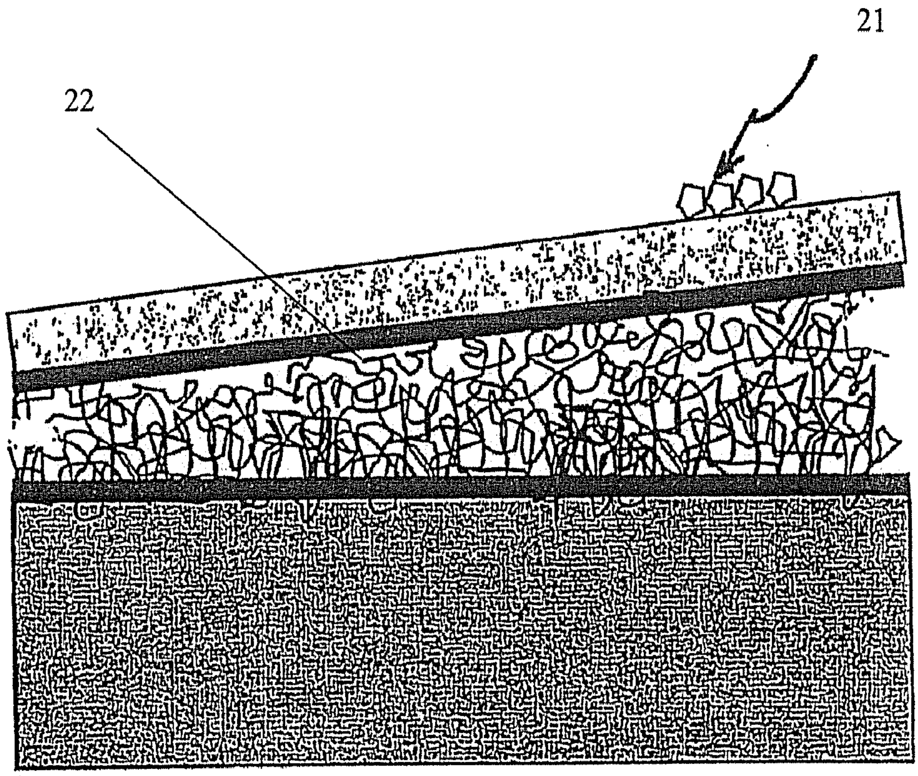

FIG. 2

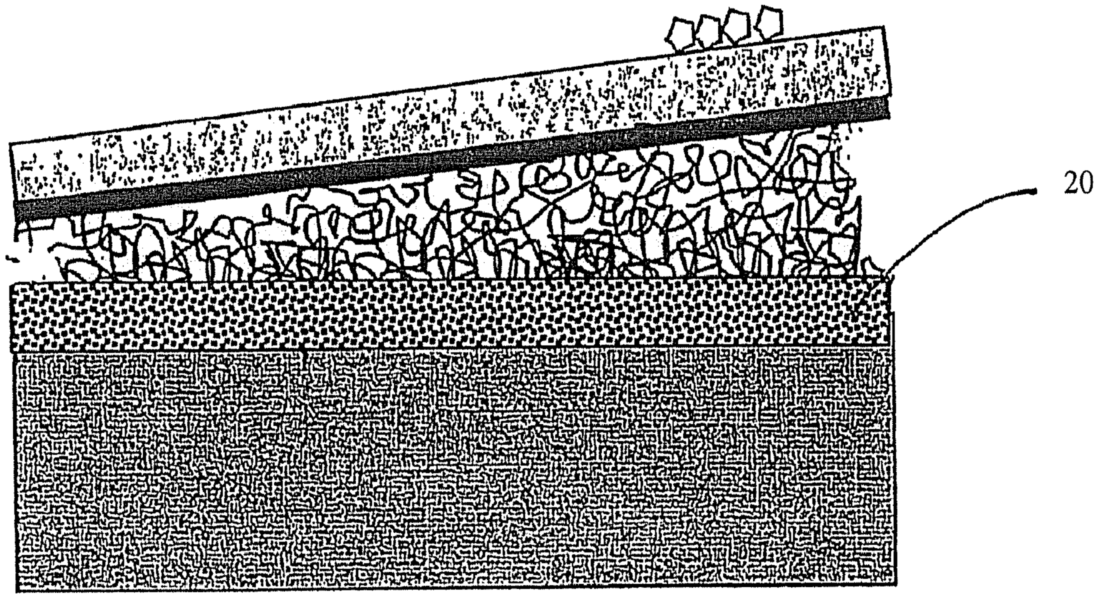

FIG. 3

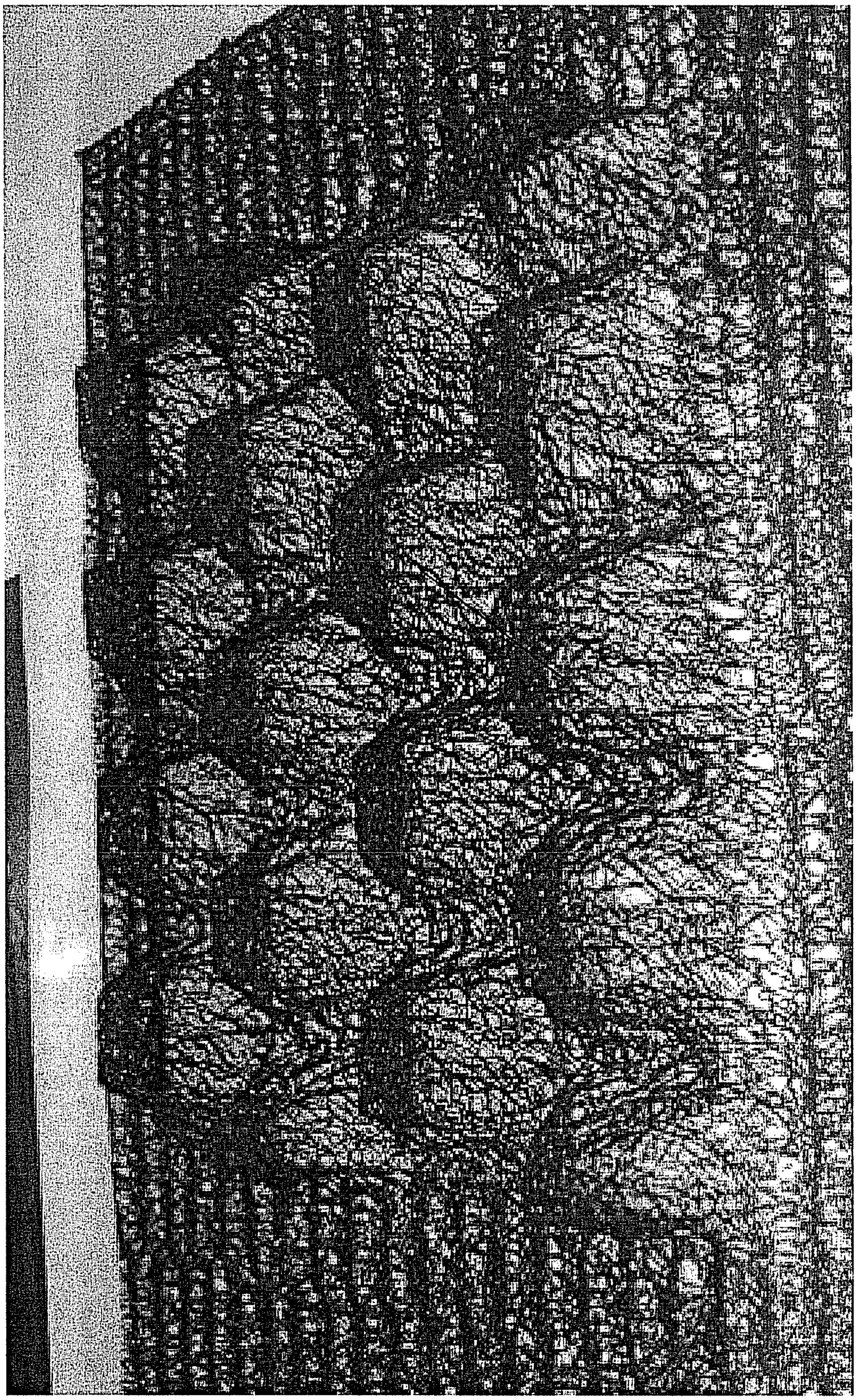

FIG. 4

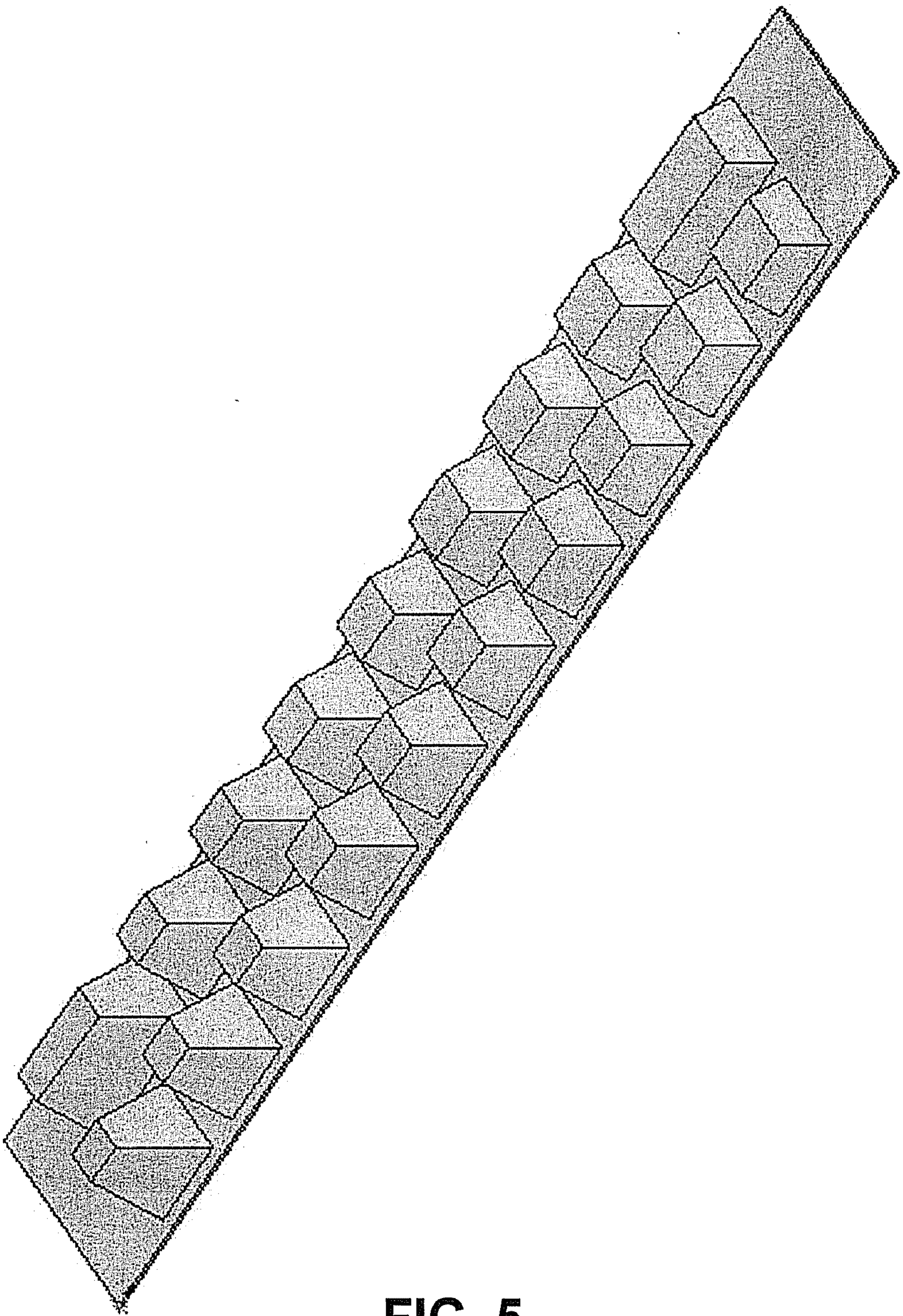

FIG. 5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2010/039896

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - H01L 31/048 (2010.01)
USPC - 136/244
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) - H01L 31/048, 042 (2010.01)
USPC - 136/244, 251; 52/408

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, Google Patent

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y	US 4,677,248 A (LACEY et al) 30 June 1987 (30.06.1987) entire document	1, 3-4, 12-14 ----- 2, 5-11, 15-26
Y	US 5,298,085 A (HARVEY et al) 29 March 1994 (29.03.1994) entire document	9-11, 21-23
Y	US 6,930,238 B2 (MAKITA et al) 16 August 2005 (16.08.2005) entire document	15-24
Y	US 6,495,750 B1 (DINWOODIE) 17 December 2002 (17.12.2002) entire document	2, 5-8, 25, 26

☐ Further documents are listed in the continuation of Box C. ☐

* 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
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"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	Date of mailing of the international search report
08 August 2010	27 AUG 2010

Name and mailing address of the ISA/US	Authorized officer:
Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-3201	Blaine R. Copenheaver PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774