Title: PHOTOVOLTAIC MODULES WITH FUNCTIONALLY INTEGRATED METAL BACK SHEETS

Abstract: This disclosure provides a photovoltaic module with an integrated metal back sheet, comprising a glass front sheet, one or more photovoltaic cells adjacent to the glass front sheet, and a metal back sheet adjacent to the one or more photovoltaic cells. A portion of the metal back sheet can extend beyond one or more edges of the glass front sheet and form a frame of the photovoltaic module.
PHOTOVOLTAIC MODULES WITH FUNCTIONALLY INTEGRATED METAL BACK SHEETS

CROSS-REFERENCE
[0001] This application claims priority to U.S. Provisional Patent Application Serial No. 61/654,762, filed June 1, 2012, which is entirely incorporated herein by reference.

BACKGROUND
[0002] Photovoltaic (PV) modules installed on residential roof tops and in utility fields may utilize crystalline or polycrystalline silicon solar cells packaged with a low iron tempered glass front sheet, a flexible TPE (Tedlar®, polyester, EVA) back sheet, an extruded aluminum frame, and a junction box with cables to connect to adjacent modules. A module size may be about 1.6 m², corresponding to a weight of about 20 kg. Larger and heavier modules are unpopular because they are not as easy to handle during installation, thus increasing labor costs. In roofing systems, such modules are mounted to a standoff metal support structure that is secured to the roof. In utility fields, the support structures may be attached to posts anchored in the ground. Some cost reduction may be achieved by replacing the TPE back sheet with a sheet of glass, but the glass-glass modules may be heavier, limiting their practical size to about a square meter or less. For a given system size this results in higher balance of system (BOS) costs because more modules and more electrical connections are required.

[0003] Thin-film modules may consist of cells deposited on a sheet of glass which may be bonded to a glass front sheet in the case of copper indium gallium diselenide (CIGS), or a glass back sheet in the case of cadmium telluride (CdTe). CIGS thin-film solar cells deposited on a thin flexible substrate may be used in either encapsulation format; however, the TPE commonly used with silicon may contain an additional sheet of thin aluminum (TAPE) to provide adequate protection from moisture ingress for the more sensitive thin-film cells.

[0004] Solar modules are rapidly becoming a commodity, with downward pricing pressure coming from both technological improvements and the decreasing cost of silicon worldwide. Still, the total PV system costs are not yet competitive enough with conventional power to cause a large surge in market demand.

SUMMARY
[0005] Recognized herein is the for cost effective solar module that can be made larger for the same weight, and that can provide seamless integration into conventional solar
installations while simultaneously delivering improved mechanical and environmental performance.

[0006] The present disclosure provides solar photovoltaic modules and building integrated applications for the production of electricity. Some embodiments provide a solar module with a functionally integrated metal back sheet that is more economical than the standard construction of crystalline silicon or thin-film modules.

[0007] An aspect of the present disclosure provides a photovoltaic module with an integrated metal back sheet, comprising a front sheet that is transparent to light, at least one photovoltaic cell (PV) adjacent to the front sheet, and a metal back sheet adjacent to the at least one PV cell. The at least one PV cell is configured to generate electricity upon exposure to light. The metal back sheet can be situated along a plane that is parallel to the at least one PV cell. A segment of the metal back sheet can be bent one or more times to form a frame of the photovoltaic module. The segment of the metal back sheet can extend away from the plane.

[0008] Another aspect of the present disclosure provides a method for forming a photovoltaic module, comprising providing a front sheet adjacent to at least one photovoltaic (PV) cell, and a back sheet adjacent to the at least one PV cell. The front sheet is transparent to light. The back sheet can be disposed along a plane that is parallel to the PV cell. A first portion of the back sheet can extend beyond one or more edges of the front sheet. Next, the first portion can be bent along a first direction to form a first segment of the back sheet. The first direction can extend away from the plane. A portion of the first segment can then be bent along a second direction to form a second segment of the back sheet. The second direction can be oriented towards the plane.

[0009] Another aspect of the present disclosure provides a method for forming a photovoltaic system, comprising providing a photovoltaic module comprising a front sheet that is transparent to light, at least one photovoltaic cell (PV) adjacent to the front sheet, and a metal back sheet adjacent to the at least one PV cell. The at least one PV cell is configured to generate electricity upon exposure to light. The metal back sheet can be situated along a plane that is parallel to the at least one PV cell. A segment of the metal back sheet can be bent one or more times to form a frame of the photovoltaic module. The segment of the metal back sheet can extend away from the plane. The method further comprises securing the segment of the metal back sheet to a securing member of a frame of the photovoltaic system.

[0010] Another aspect of the present disclosure provides a solar (or photovoltaic) module constructed with an integrated back sheet and support frame.
Another aspect of the present disclosure provides a solar module with improved mechanical and environmental performance.

Another aspect of the present disclosure provides an improved solar module of similar weight but larger size compared to typical modules.

Another aspect of the present disclosure provides a solar module that is less costly to produce than conventional solar modules, including flexible modules without glass.

Additional aspects and advantages of the present disclosure will become readily apparent to those skilled in this art from the following detailed description, wherein only illustrative embodiments of the present disclosure are shown and described. As will be realized, the present disclosure is capable of other and different embodiments, and its several details are capable of modifications in various obvious respects, all without departing from the disclosure. Accordingly, the drawings and description are to be regarded as illustrative in nature, and not as restrictive.

BRIEF DESCRIPTION OF THE DRAWINGS

While the drawings are meant to convey a sense of the scale and relative sizes of the elements of the invention, it should be appreciated that they are not drawn precisely to scale. Those skilled in the art will realize that small changes in scale may not represent a significant deviation from the spirit of the invention.

FIG. 1 is a large scale perspective schematic view of an array of photovoltaic (PV) modules being assembled on multiple glass front sheets which are then covered by back sheets from a roll of precut thin steel.

FIG. 2a is a planar drawing viewed from the thin steel back sheet side of one of the module positions from FIG. 1 showing an example of an embodiment for the shape of the corner cutouts in the thin steel sheet.

FIG. 2b is a planar view from the thin steel side of a single module after it is cut from the larger array of modules of FIG. 1. It is also the view of a single module that can be made from individual precut thin steel back sheets.

FIG. 3 is a cross-sectional schematic diagram showing an example of the construction of a PV module of the present disclosure.

FIG 4 shows a set of sequential steps (a through j) for folding or bending that portion of the thin steel back sheet which extends past the edges of the glass front sheet of the module to form a frame which includes an additional sealing region that extends around and over the edge of the glass front sheet.
[0021] FIG. 5 shows the primary double folding steps (some combined) of an alternative embodiment that uses a thinner and lighter steel back sheet that can yield equivalent frame strength while reducing the overall module weight.

[0022] FIG. 6a shows an embodiment of a square-like cutout shape for a back sheet in the region of the circle of FIG. 2a viewed from the glass front sheet side after the module is laminated.

[0023] FIG. 6b shows the region of the circle of FIG. 2b viewed from the glass front sheet side after the module is laminated and cut out of the large sheet of modules, or as the module can appear when using precut back sheets.

[0024] FIG. 6c shows an expanded detail of a finished corner of a module viewed from the glass front sheet side when the square-like cutout is used.

[0025] FIG. 7a shows a square shaped cutout with V-notches along the sides for a back sheet as viewed from the glass front sheet side after the module is laminated.

[0026] FIG. 7b shows a square shaped cutout with V-notches viewed from the glass front sheet side after the module is laminated and cut out of the large sheet of modules, or as the module can appear when using precut back sheets.

[0027] FIG. 7c shows an expanded detail of a finished corner of a module viewed from the glass front sheet side when the square shaped cutout with V-notches is used.

[0028] FIG. 8a shows the embodiment of FIG. 7a utilizing a variant of the V-notches.

[0029] FIG. 8b shows the embodiment of FIG. 7b utilizing a variant of the V-notches.

[0030] FIG. 8c shows the embodiment of FIG. 7c utilizing a variant of the V-notches.

[0031] FIG. 9 illustrates planar and edge views of three examples (A, B, and C) of mounting clips that can be used to secure the module of the present invention to a field or roof mounting beam member.

[0032] FIG. 10 shows a perspective view of the top corner of a module illustrating two examples of the application of an additional corner brace.

[0033] FIG. 11 is a perspective view of the top corner of a module showing an alternative method of forming the top and side of the frame with an integrated corner brace.

[0034] FIG. 12 is a cross-sectional view of a sequence of folds in the edge of the metal back sheet to produce a standing seam style of building integrated photovoltaic roofing panel.

[0035] FIG. 13 shows planar and cross-sectional views of a metal back sheet building integrated photovoltaic roofing shingle.
FIG. 14 illustrates a large scale shingle-like embodiment of a metal back sheet building integrated photovoltaic roofing panel.

DETAILED DESCRIPTION

While various embodiments of the invention have been shown and described herein, it will be obvious to those skilled in the art that such embodiments are provided by way of example only. Numerous variations, changes, and substitutions may occur to those skilled in the art without departing from the invention. It should be understood that various alternatives to the embodiments of the invention described herein may be employed.

The term "photovoltaic cell" or "solar cell," as used herein, generally refers to a solid state electrical device having an active material (or absorber) that converts the energy of electromagnetic radiation (or light) into electricity by the photovoltaic (PV) effect.

The term "absorber," as used herein, generally refers to a photoactive material that, upon exposure to electromagnetic radiation, converts the energy of electromagnetic radiation into electricity by the photovoltaic (PV) effect. An absorber can be configured to generate electricity at select wavelengths of light. An absorber layer can be configured to generate electron / hole pairs. Upon exposure to light, an absorber can generate electron / hole pairs. Examples of absorbers include, without limitation, copper indium gallium di-selenide (CIGS) and copper indium selenide (CIS). An absorber layer can be doped n-type or p-type. Some absorbers are n-type or p-type without any additional doping. For example, CIGS, as formed, can be p-type and may not require any additional p-type doping. In some cases, upon formation of the absorber layer (e.g., silicon absorber layer), a precursor of an n-type or p-type dopant is introduced for incorporating the n-type or p-type dopant into the absorber layer. As an alternative, following formation of the absorber layer, the n-type or p-type dopant can be introduced into the absorber layer by ion implantation followed by annealing. In some situations (e.g., CIGS), a sodium precursor is provided to the absorber layer to include sodium in the absorber layer.

The term "photovoltaic module" or "solar module," as used herein, refers to a packaged array of one or more PV cells. The PV module (also "module" herein) can be used as a component of a larger photovoltaic system to generate and supply electricity, such as in commercial and residential applications. A PV module can include a support structure having one or more PV cells. In some embodiments, a PV module includes a plurality of PV cells, which can be interconnected, such as, for example, in series with the aid of interconnects. A PV array can include a plurality of PV modules.
The term "adjacent" or "adjacent to," as used herein, includes 'next to', 'adjoining', 'in contact with', and 'in proximity to'. In some instances, adjacent to components are separated from one another by one or more intervening layers. For example, the one or more intervening layers can have a thickness less than about 10 micrometers ("microns"), 1 micron, 500 nanometers ("nm"), 100 nm, 50 nm, 10 nm, 1 nm, or less. In an example, a first layer is adjacent to a second layer when the first layer is in direct contact with the second layer. In another example, a first layer is adjacent to a second layer when the first layer is separated from the second layer by a third layer.

The present disclosure provides PV modules and methods for forming PV modules. PV modules formed according to methods of the present disclosure can have various uses and applications, such as for use on roof tops.

FIG. 1 shows a perspective view of an array of photovoltaic (PV) modules on an assembly line. A conveyor table (not shown) can support the glass sheets 1 that have been placed in given positions. Upon each of the glass sheets 1 is provided a solar cell and sheets of adhesive and other materials. A roll 1a of relatively thin metallic back sheet material is unrolled to cover the glass sheets. The back sheet material 2 can have appropriate cutouts (or apertures) 3 and 4 that can be pre-punched and supplied in the roll, or they maybe punched as the material is unrolled. Cutout 3 can be located at the corners of the glass sheets 1 as indicated in circle 5, and aperture 4 can be located on the back of the module where the electrical leads from the cells will emerge into a conventional junction box (J-box) that is attached later. The cutouts 3 and 4 can be located at other points of the glass sheets 1. The width "w" of back sheet material between modules is selected based upon the amount of material needed later to finish the module frame. The roll of back sheet material 2 can be cut along dashed line 6, and the array of modules proceeds along the direction indicated by arrow 7 into a conventional laminator where they are all laminated at once. Of course the size of the array of modules and the width of the roll of back sheet material is selected to be compatible with whatever laminator size is used. For purposes of further discussion, galvanized thin gauge steel will be used as an example of back sheet material 2, although other metals and coating can be used.

As another example, the array of PV modules shown in FIG. 1 can have the back sheet material 2 already precut to a given size and pre-punched with the appropriate cutouts, so that instead of coming from roll 1a, they are taken from a stack and placed individually on each module. This has the advantage that all of the cut edges may be galvanized after
cutting, in the case of thin steel, or otherwise coated with various protective layers as, for example, that used for metal roofing materials.

[0045] FIG. 2a shows one of the modules from the array of FIG. 1 after lamination. In this example, cutout 3 is more clearly seen as just a square with only a small notch left in each corner to cover the corners of glass front sheets 1. Cutting back sheet 2 along phantom lines 8 creates the individual module shown in FIG. 2b. The amount of back sheet material that extends beyond the edges of glass front sheet 1 and the module lamination materials is indicated as w/2. FIG. 2b can look the same if the back sheet were first cut to size and placed individually on the module as, discussed above.

[0046] FIG. 3 schematically illustrates an example of a module construction. The module of FIG. 3 is shown inverted with respect to the module discussed above. Sunlight can be incident on the module from a side of glass sheet (or layer) 1, as indicated by the direction of the arrow. Between glass sheet 1 and back sheet 2 are a number of layers. Layer 9 is an adhesive that can be transparent to allow sunlight to reach the layer of interconnected solar cells 10. Either silicon or thin-film solar cells can be used. Layer 11 is another layer of adhesive which need not be transparent, but it may flow around the edges of the cells to merge with layer 9 during lamination. Layer 12 is an electrical insulating layer, which can be formed of polyethylene terephthalate (PET) a few thousandths of an inch thick and is adhered to back sheet 2 by another adhesive layer 13. Layer 12 can be sufficiently think to enable the module to pass the industry standard wet high electrical potential test so that the module is safe when installed in a 600 to 1000 volt string.

[0047] The module can be sealed against moisture by a special edge seal adhesive 14 that directly bonds the glass front sheet to the metal back sheet. The notches left in the corners of the back sheet cutouts, as previously mentioned, can be made to allow this edge seal to be made continuously around the module, including the corners. The direct sealing of the glass front sheet to the metal back sheet forms a highly desirable and robust environmental seal against moisture ingress into the module over its life time, and the stronger metal back sheet is practically impervious to any shipping and handling damage. Improved economy derives from the elimination of the more expensive TPE or TAPE conventional back sheet.

[0048] FIG. 4 shows a series of cross sectional sketches of the edge of a module constructed as described above. Only glass front sheet 1 and back sheet 2 are explicitly shown. The alphabetical sequence (a thru j) of the sketches represents a series of folds or bends that can be made in the back sheet material to form both a frame and an additional sealed region
around the module. Sketch "a" shows the initial edge of the module after lamination and separation. The length W/2 of the extension of the back sheet material is at least a few inches. Sketch "b" shows the outer edge of the back sheet material bent up at a right angle, and in sketch "c" that bend is folded over. In sketch "d" the folded region is again bent up at a right angle to form a lip 15 that will end up on top of the edge of the glass front sheet. In sketch "e" the back sheet material is bent at a right angle toward the back of the module, the bend being made approximately at the edge of the glass front sheet. Another right angle bend can be made back toward the front of the module as depicted in sketch "f". A bead of edge seal adhesive 16 can be placed along the lip formed in "d" at either of the last two steps. The right angle bend in "f" is made at a location such that the next right angle bend in "g" brings lip 15 just over the edge of the glass front sheet to form both a glass sheet restraint and an additional seal. Excess sealing adhesive may be trimmed or otherwise removed from the edge of the lip with a blade after it sets.

[0049] The thickness "t" of the side wall of the frame can be twice the thickness of the initial back sheet material 2. Additional bends in the frame can increase the strength of the frame. The frame can be further strengthened by another bend along its back edge. Sketches "h", "i", and "j" show examples of possible types of bends. A few small holes, indicated by shaded arrow 17, made along the inside edge of these final bends may be needed to allow condensed water or rain escape. The final height "ht" of the module can be between about an inch and an inch and a half to be compatible with conventional framed silicon modules. The length W/2 of the extension of back sheet 2 is selected to accommodate the bending and folding that produces the desired final frame strength and height. All of the folds and bends just described for making the frame can have "fold lines" embossed in the back sheet material at the beginning in order to make the folding operations more accurate and efficient.

[0050] The module of FIG. 4 is suited for use in at least some PV modules currently available, such as PV modules comprising silicon PV cells. The frame formed from the back sheet 2 can be compatible with PV modules presently available.

[0051] FIG. 5 shows a sequence of sketches for bends and folds that can result in twice as many layers in the frame as those described above. The increase in layers can add increased strength to the resulting frame. The sequence can be similar to that shown in FIG. 4, except that some steps have been combined for simplicity. Although not precisely to scale, sketch "a" indicates an extension length W/2 of back sheet material 2 that is approximately twice that shown in FIG. 4, but it can be about half as thick (i.e., the weights of the extended
sections are approximately equal). The edge is shown already folded over to form a short overlapped region as indicated. In sketch "b" about half of back sheet extension 2 is folded back toward the edge of the module. Sketch "c" shows a right angle bend near the edge the glass front sheet and a right angle bend to form a lip 15 at the bottom edge. A bead of edge seal adhesive 16 can be placed in the lip there or at the next step as explained for FIG. 4. The right angle bend in "d" is made at a location such that the next right angle bend in "e" brings lip 15 just over the edge of the glass front sheet to form both a restraint and an additional moisture seal. At this point the thickness "t" of the side wall of the frame is four times as thick as the back sheet material, but about equal to that of the frame of FIG. 4, so the strength is approximately the same. However, the back sheet material that covers the back of the glass front sheet is only half the weight of that previously described; therefore, the total weight of the module is reduced. Sketches "f", "g", and "h" illustrate three more (of many) possible examples of bends at the back edge of the frame that can increase its strength. The brace-like structures shown as 18a, 18b, and 18c require an extra amount of back sheet material that incurs a small additional weight penalty. More frame strength may be obtained by occasional spot welds through the layers of material or by placing small amounts of epoxy in the folds to bond the layers together. Many folding and bending arrangements are possible which can develop acceptable frames, and other structures will occur to those skilled in the art.

[0052] An estimate of the necessary thickness of back sheet material 2 can be made by considering the following. If the back sheet material is made from steel, it can have a density of nearly three times that of the aluminum used for the frames of conventional modules. However, since steel has more than three times the strength of aluminum, adequately strong frames made from steel may not be significantly different in total weight. An important additional feature of the present disclosure is that the frame is not bonded only to the edge of the glass front sheet as in conventional modules. Rather, the frame is contiguous with the rest of the sheet of high strength steel, which both covers and is bonded to the entire back of the glass front sheet. This feature adds significant strength to both the glass sheet and the module, and allows the total amount of steel to be reduced for similar frame geometries. Consider the following examples.

[0053] Example 1: Typical silicon modules with aluminum frames weigh about 20 kg and usually are 1.0 meter by 1.6 meters in size. The web thickness of the aluminum commonly used in extruded frames is about 3/32nds (0.093") of an inch. For equivalent strength, the
steel may need to be about 1/32 of an inch thick or about 0.031". Steel sheet metal of 27
gauge has a thickness of 0.0164". If the back sheet and frame were made from this material
and folded as described in FIG. 4, the frame can have a wall thickness of .0328" and the total
weight of steel can be about 6.8 kg. Standard size glass for the front sheet is 3.2 mm thick
and weights about 12.7 kg. Even though the glass may be thinner because of the stronger
back sheet, the module weight is still around 20 kg as expected from the previous
considerations. The solar cells and lamination materials can add a small amount of additional
weight, but the total is within the accepted average range. Because of the strength of the
integrated back sheet and frame, the modules can be made lighter in weight by using thinner
glass, an option not possible with conventional modules because the TPE back sheet provides
little to no additional strength.

[0054] Example 2: If thinner back sheet material is used to save weight, the extension around
the module can be increased to allow the double folding described in FIG. 5 to keep the
frame the same thickness and strength as that described in Example 1. Intermediate
combinations and tradeoffs between back sheet thickness, frame thickness, and weight can be
employed, but for this example consider that sheet steel of 34 gauge has a thickness of
0.0082", which is just half of the 27 gauge of Example 1. The extension of the back sheet
material 2 can be doubled to result in the same frame thickness, but this represents only a
small fraction of the total weight of the sheet. The total weight of the back sheet and frame is
about 4.2 kg compared to the 6.8 kg obtained from using the 27 gauge material in the
previous example; however, the frames are essentially equivalent. Using standard glass, the
module weight is about 18 kg, so the size of the module can be increased somewhat without
exceeding the 20 kg standard, thus creating some savings in the balance of systems (BOS)
costs.

[0055] Example 3: This example takes into consideration what may be required to make a
two square meter module and keep the weight in line with the specifications for silicon
modules. This can create a 20% saving in BOS costs compared to standard modules for J-
boxes, wiring interconnects, mounting hardware, and associated labor. The larger area of
back sheet material made from 34 gauge steel can add 0.9 kg to the 4.2 kg (e.g., 5.1 kg)
described in Example 2 for a standard sized module. The larger glass sheet can now weigh
15.9 kg for a total of a little over 20.9 kg. Adding a kilogram or so for cells and adhesives
can bring the total weight to a little over 22 kg - not far from the standard. Because of the
added strength of the bonded back sheet of steel, the glass can be made thinner. Reducing the
glass thickness to 2.75 mm instead of the standard 3.2 mm can lower the module weight to less than 20 kg. Such thinner glass is within the capabilities of modern float glass and glass tempering technologies.

[0056] Examples of the manner in which modules of the present disclosure can be secured to mounting frames are shown in the examples of FIG. 6. Conventional screws and brackets can also be used. FIG. 6 shows three sketches A, B, and C, each illustrating a type of mounting clip used for securing a module to a support rail. Each sketch first shows a cross-sectional edge view of the module resting on a support rail and then a side view of the module. Depicted in sketch A is a module with a frame like that shown in sketch "h" of FIG. 4 with a mounting clip 19 that hooks into a hole 20 made in the side of the module frame. A similar clip can be used for the frame structure off and "g" in FIG. 5. The clip can then be snapped around support rail 21 as shown in the side view of sketch A. The clip can be made of spring quality heavy wire, or similar material. In like manner, sketches B and C illustrate securing members 22 and 23 (e.g., clips) appropriate for securing modules with frames like those shown in sketches "i" and "j" of FIG. 4. These clips can be made from tempered strapping steel ribbon similar to that used for crating. Since the clips in these last two cases are positioned entirely under the edges of the modules, the modules may be placed very close together on the support rails.

[0057] FIGS. 7-9, as viewed from the glass front sheet side, show examples of alternative cutouts that can be used for the back sheets of the modules. These cutouts represent a sample of some of the geometries that will permit the folded material to meet at the module corners without an overlap. It should be appreciated that these figures are not exactly to scale.

FIGS. 7a, 8a, and 9a show glass side views of the corners of modules for arrays of laminated modules with different shapes for cutouts 3. Each view is similar to that shown in circle 5 of FIG. 2a. Rectangular and V-shaped notches are provided along the sides of the cutouts.

FIGS. 7b, 8b, and 9b illustrate the corners of modules either cut from an array or laminated using pre-punched back sheets. The extension region of the back sheet 2 material is in each case shown with a couple of dashed lines 24 and 25 shown in relation to the positions of the nearby notches. These lines represent the first and second folds in the sequence shown in FIG. 4, which eventually forms lip 15 and an additional seal around the edges of the glass front sheet. Notch 26 in each case allows the bottom folded edge of the module frame to meet in a similar geometry (i.e., no overlap) as lip 15 on the top of the module. FIGS. 7c, 8c, and 9c are enlarged views of the finished corner detail of lip 15 which results from the folds.
at the notches in the initial cutout patterns 3. In FIG. 7c the lips join at a 90 degree angle. In both FIGs. 8c and 9c the lips join at a 45 degree angle as is common in ordinary picture frames; however, in FIG. 9c only one fold of material makes the 45 degree angle. In all the cases the sides of the resulting frame meet at a 90 degree angle at each corner of the module. The modules in these examples may be further strengthened at their corners. This may be because the back sheet material that forms the sides of the frame meets at a corner at a 90 degree angle after the appropriate bends and folds are made. In an example, an additional tab is provided in cutouts 3 that is folded 90 degrees and welded at each corner of the frame after it is formed.

Examples of PV modules that do not use preformed tabs are illustrated in FIG. 10. This figure shows an isometric view of a top corner of a PV module with an edge cross-section A-A, where lip 15 is made as shown in FIG. 8c or 9c, with a 45 degree intercept at the corner. Various methods are available for joining a frame at the corners. In an example, a series of spot welds or a continuous laser weld can join edges 26 including the 45 degree angle where lip 15 meets and the similar feature (not seen in this view) at the bottom of the frame. Alternatively, a 90 degree interior (or exterior) angle brace like 27 can be welded in place, or conventional fasteners like screws also can be used. In practice corner brace 27 can fill the height of the frame, but is shown shorter for improved visibility in the figure. Instead of, or in addition to, angle brace 27 a corner cap 28 can be spot or laser welded on the corner as shown in view 29. Both the right angle brace and the corner cap can be fashioned from materials similar to the back sheet material.

Those skilled in the art may readily envision other methods to make the braces at the corners of the modules. As another example, FIG. 11 shows an alternative to the individual corner bracing methods discussed above. Here cross-section A-A illustrates that the back sheet material can be readily folded in a way which initially eliminates lip 15. A corner "picture frame" brace 30 can be formed from a long strip of back sheet like material which includes lip 15. The 45 degree corners on lip 15 can be welded before the picture frame brace is placed on the module. Lip 15 can be made with a double fold, as was indicated in previous figures, so that the edge of the lip can form a smooth edge at the transition to the glass. A bead of sealing material can be added around and under the lip 15 (see, e.g., bead 16 of FIG. 4). Picture frame brace 30 can be joined at a position away from a corner, like indicated by lines 31, so that all of the corner braces can include only of right angle bent material without the need for welding along the edges of each corner. The weld or other
joining of the picture frame brace can be made along 31, with picture frame 30 being joined to the sides of the initially folded frame at numerous positions around the periphery of the module. When finished the cross-section at the edge of the module can look like that shown in B-B.

[0061] The principles of the integrated metal back sheet of the present disclosure have been described with respect to modules with a glass top sheet, but they can be readily extended to include building integrated photovoltaic (BIPV) modules and materials. For many BIPV modules, the glass top sheet can be replaced with a flexible transparent moisture barrier sheet. Some of these barrier sheets are now becoming commercially available, although at relatively high cost, but work is ongoing both to improve the availability and to lower the cost. These barrier sheets can comprise an outer (i.e., sunward) layer of weather resistant material like a fluoropolymer with coatings on the inside that are barriers to moisture penetration. Since silicon solar cells are too fragile for use in a flexible embodiment, thin-film cells (CIGS in particular) deposited on flexible substrates can be employed. An example of a BIPV application of the present disclosure can be to use a flexible barrier top sheet in place of the glass and form the extended edges of the steel back sheet material into standing seam roofing panels instead of into a frame. Without the glass top sheet, the module can be light and can be incorporated into practically any size roofing panels.

[0062] FIG. 12 shows an edge view of a PV module that can be implemented for a standing seam roofing application. FIG. 12 shows a sequence of sketches (a thru c) that can be used to form the edge of a standing seam roofing panel. In sketch "a", the glass top sheet used in a conventional module is replaced by a much thinner and lighter flexible barrier sheet 32. The barrier (or top) sheet 32 is shown to be adjacent to a back sheet 2. The PV module of FIG. 12 can include a PV cell and adhesives between the top sheet 32 and back sheet 2 (see, e.g., FIG. 3). Sketch "b" shows the extension region w/2 of back sheet 2 folded into one of the patterns of semi-V ridges that can be used in a standing seam roofing panel. These ridges are formed on each side of an elongated panel and are mounted in the direction that water can flow off of the roof. Sketch "c" shows how the ridges along the sides of two PV panels overlap to form a standing seam. In such a case, the junction box on the back of the PV panel can be eliminated with the sealed electrical leads from the panel going through a small hole in the roof structure where the connections between panels can be made in the dry attic space. If a small junction box is employed, the opening in the roofing structure can be sized to accommodate it.
Other variations and alternatives are possible. As an example, a standing seam roofing panel can be used as a roofing shingle. In some cases, the back sheet extension material can be left flat instead of being folded into the grooves, and the panel can be made smaller. The gauge of the sheet metal can be selected appropriate for a shingle application, and the solar cell "mini-module" can be mounted directly on it in the way previously described for a standing seam roofing panel. The size of the extension region can be adjusted for conventional shingle overlap, and it can be colored or coated consistent with existing metal shingles, and installed in a similar way.

**FIG. 13** illustrates a planar view A and a cross-sectional view B of an example of a PV module configured for use as a shingle. In planar view A, metal back sheet 2 is left flat with moisture barrier sheet 32 and the solar cell array and its associated adhesives 33 mounted on it. They are not centered on the back sheet but are arranged appropriately for a shingle application. Along the top edge (higher on a sloped roof) of the shingle are positions 34 for nails or screws to secure the shingle to the roof deck. Cross-sectional view B shows the way the shingles overlap on the roof when installed. The thicknesses of the elements in the shingle are greatly exaggerated for better clarity. The total thickness of the metal back sheet and all of the module layers can be thinner than an ordinary asphalt composite shingle, so they can lay very flat even when overlapped, and can blend in seamlessly with an ordinary shingled roof.

On the roof side of back sheet 2 is a band of roofing adhesive 35 that extends along the bottom edge of the shingle and up along both short sides. This adhesive is covered by a protective film that is pulled off just before the shingle is installed, as is the case for ordinary shingles. The adhesive bonds the bottom edge of the shingle to the next one below, but may not cover any of the solar cell array. The overlapped regions of back sheet 2 along the sides of the shingles can also be sealed by this band of adhesive 35. The electrical leads can pass through a small hole in the roof and be interconnected in the attic space as with the standing seam panel.

There are various potential uses and implementations of a PV module with a functional metal back sheet as opposed to a very thin metal foil like that used in TAPE as a moisture barrier. **FIG. 14** shows a portion of a large sheet 2. This sheet or panel may have, for example, the dimensions of an ordinary sheet of plywood roof sheathing which is 4 feet by 8 feet. The back sheet is embossed with a series of small parallel ridges 36 which run perpendicular to the downward slope of roof line 37. These ridges are only a fraction of an
inch high and are meant to give the appearance of the overlap seen in ordinary shingled roofing installations. Between the ridges are mounted a rows of shingle size modules 32 with spaces between, or the modules can extend across the width of the embossed sheet as indicated by 38 depending on the desired appearance of the panel. A shingle-like overlapped mounting area can be left at the top of the sheet for nailing (holes 34) the top of the sheet to the roof sheathing. Adhesive strips (not shown) can hold the sheet at the bottom and sides or other regions where nailing can cause a potential leak. Wiring of the modules can run along the panel underneath the ridge areas and pass through an aperture in the roof at selected locations for final wiring in the attic space.

[0067] The integrated metal back sheet can provide extra strength to a standard glass module while reducing both its weight and cost. In addition, the metal back sheet is impervious to moisture ingress, and is more robust against handling damage than the TPE or TAPE in current use with silicon and some thin-film modules. It is not easy accidentally to punch a hole or to cut a sheet of thin steel. The integrated metal back sheet enables many flexible embodiments for BIPV applications.

[0068] It should be understood from the foregoing that, while particular implementations have been illustrated and described, various modifications can be made thereto and are contemplated herein. It is also not intended that the invention be limited by the specific examples provided within the specification. While the invention has been described with reference to the aforementioned specification, the descriptions and illustrations of the preferable embodiments herein are not meant to be construed in a limiting sense. Furthermore, it shall be understood that all aspects of the invention are not limited to the specific depictions, configurations or relative proportions set forth herein which depend upon a variety of conditions and variables. Various modifications in form and detail of the embodiments of the invention will be apparent to a person skilled in the art. It is therefore contemplated that the invention shall also cover any such modifications, variations and equivalents. It is intended that the following claims define the scope of the invention and that methods and structures within the scope of these claims and their equivalents be covered thereby.
CLAIMS

WHAT I CLAIMED IS:

1. A photovoltaic module with an integrated metal back sheet, comprising;
   a front sheet that is transparent to light;
   at least one photovoltaic cell (PV) adjacent to said front sheet, wherein said at least one PV cell is configured to generate electricity upon exposure to light; and
   a metal back sheet adjacent to said at least one PV cell, wherein said metal back sheet is situated along a plane that is parallel to said at least one PV cell, wherein a segment of said metal back sheet is bent one or more times to form a frame of said photovoltaic module, and wherein said segment of said metal back sheet extends away from said plane.

2. The photovoltaic module of claim 1, wherein said front sheet is formed of glass.

3. The photovoltaic module of claim 1, wherein said front sheet is formed of a flexible moisture barrier material.

4. The photovoltaic module of claim 1, wherein a portion of said segment of said metal back sheet is in proximity to said front sheet.

5. The photovoltaic module of claim 4, further comprising an adhesive between said front sheet and said portion of said segment.

6. The photovoltaic module of claim 1, wherein said metal back sheet is a galvanized steel sheet.

7. The photovoltaic module of claim 1, wherein said metal back sheet is a coated metal sheet.

8. The photovoltaic module of claim 1, wherein said PV cell comprises an absorber comprising silicon, copper indium gallium di-selenide (CIGS) or copper indium selenide (CIS).

9. The photovoltaic module of claim 1, wherein said PV cell is a thin-film PV cell.

10. The photovoltaic module of claim 1, wherein said glass front sheet comprises glass with a thickness of less than about 2.75 millimeters.

11. The photovoltaic module of claim 10, wherein an area of the photovoltaic module is at least two square meters.

12. The photovoltaic module of claim 1, wherein said segment of said metal back sheet extends away from said plane along a direction that is at an angle greater than 0° with respect to said plane.
13. The photovoltaic module of claim 1, wherein said back sheet further comprises another segment that extends towards said plane along a direction that is at an angle greater than 180° with respect to said plane.

14. The photovoltaic module of claim 1, wherein said segment of said metal back sheet is adapted to provide structural support for building integrated photovoltaic applications.

15. The photovoltaic module of claim 1, wherein said segment of said metal back sheet is formed into ridges for use as a standing seam roof panel.

16. The photovoltaic module of claim 1, wherein said metal back sheet comprises a panel including embossed ridges.

17. The photovoltaic module of claim 1, wherein said at least one PV cell comprises a plurality of PV cells, and wherein individual PV cells of said plurality are interconnected.

18. A method for forming a photovoltaic module, comprising:
   (a) providing a front sheet adjacent to at least one photovoltaic (PV) cell, and a back sheet adjacent to said at least one PV cell, wherein said front sheet is transparent to light, wherein said back sheet is disposed along a plane that is parallel to said PV cell, wherein a first portion of said back sheet extends beyond one or more edges of said front sheet;
   (b) bending said first portion along a first direction to form a first segment of said back sheet, wherein said first direction extends away from said plane; and
   (c) bending a portion of said first segment along a second direction to form a second segment of said back sheet, wherein said second direction is oriented towards said plane.

19. The method of claim 18, further comprising bringing a portion of said second segment in proximity to said front sheet.

20. The method of claim 19, further comprising providing an adhesive between said portion of said second segment and said front sheet.

21. The method of claim 18, wherein said back sheet has a width that is larger than a width of said front sheet.

22. The method of claim 18, wherein (a) further comprises providing a roll of a metallic material, providing said at least one PV cell adjacent to said roll, and cutting said roll into segments comprising said back sheet.

23. The method of claim 18, further comprising bending an outer portion of said second segment at least once to form a third segment.

24. The method of claim 18, further comprising bringing said third segment in proximity to said front sheet.
25. The method of claim 18, wherein said front sheet is formed of glass.
26. The method of claim 18, wherein said front sheet is formed of a flexible moisture barrier material.
27. The method of claim 18, wherein said first direction is at an angle that is greater than 0° with respect to the plane.
28. The method of claim 18, wherein said second direction is at an angle that is greater than 180° with respect to the plane.
29. The method of claim 18, wherein (b) and (c) form ridges in said first portion.
30. A method for forming a photovoltaic system, comprising:
   (a) providing a photovoltaic module comprising:
       a front sheet that is transparent to light;
       at least one photovoltaic cell (PV) adjacent to said front sheet, wherein said at least one PV cell is configured to generate electricity upon exposure to light; and
       a metal back sheet adjacent to said at least one PV cell, wherein said metal back sheet is situated along a plane that is parallel to said at least one PV cell, wherein a segment of said metal back sheet is bent one or more times to form a frame of said photovoltaic module, and wherein said segment of said metal back sheet extends away from said plane; and
   (b) securing said segment of said metal back sheet to a securing member of a frame of said photovoltaic system.
31. The method of claim 30, wherein said front sheet is formed of glass.
32. The method of claim 30, wherein said front sheet is formed of a flexible moisture barrier material.
33. The method of claim 30, wherein a portion of said segment of said metal back sheet is in proximity to said front sheet.
34. The method of claim 33, further comprising an adhesive between said front sheet and said portion of said segment.
35. The method of claim 33, wherein said portion of said segment extends away from said plane at an angle that is greater than 0°.
36. The method of claim 30, wherein said segment comprises an end portion that is bent, and wherein (b) further comprises securing said end portion to said securing member.
INTERNATIONAL SEARCH REPORT

PCT/US2013/032485

A. CLASSIFICATION OF SUBJECT MATTER
H01L 31/042(2006.01)i, H01L 31/0749(2012.01)i, H01L 31/18(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)
H01L 31/042; H01L 31/048; H01L 31/04; H01L 25/00; H01L 31/0749; H01L 31/18

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: photovoltaic module, back sheet, bend, frame

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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Further documents are listed in the continuation of Box C.

X See patent family annex.

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