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(54) SYSTEM AND METHOD FOR DENDRITIC WEB SOLAR CELL SHINGLING

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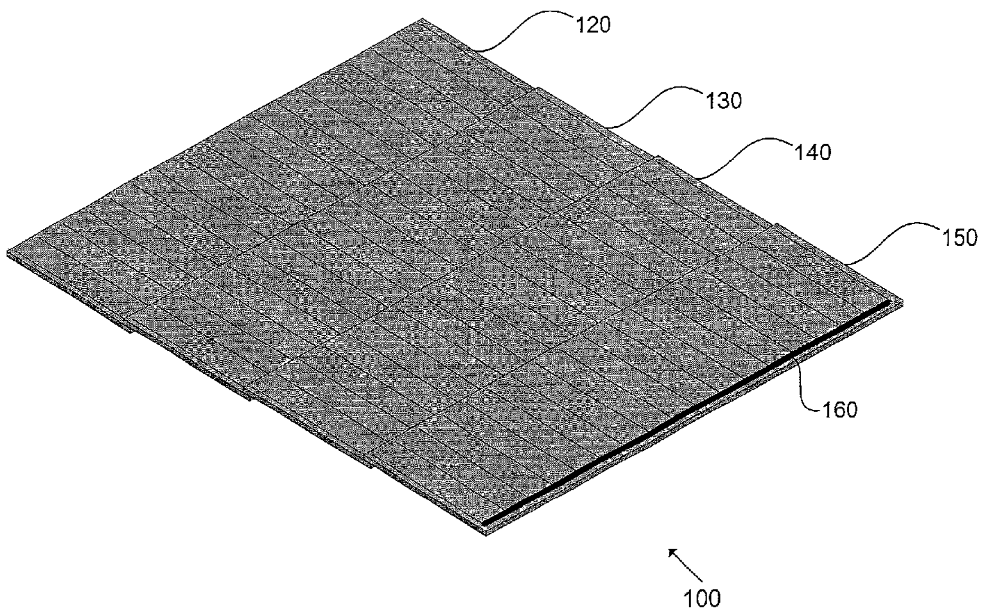
(57) **ABSTRACT**

A dendritic web solar cell shingled array comprises at least two dendritic web solar cells. A first cell overlaps a portion of a second cell such that a back contact of the first cells interconnects with a top contact of the second cell. The cells are less than 150 microns thick, allowing a direct connection between the back contact and top contact of the two cells without the use of a visible busbar. The cells may be shingled together using soldering material and/or electrically conductive adhesives.



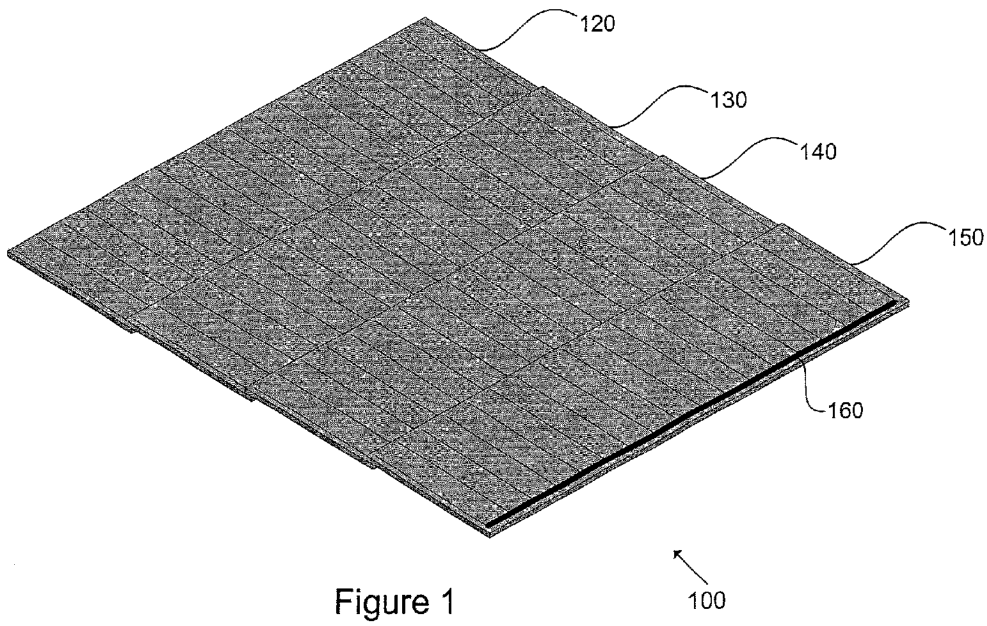


Figure 1

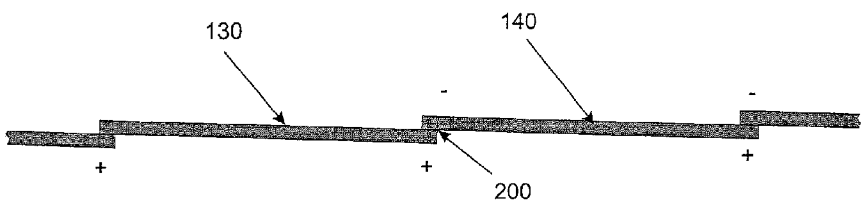


Figure 2

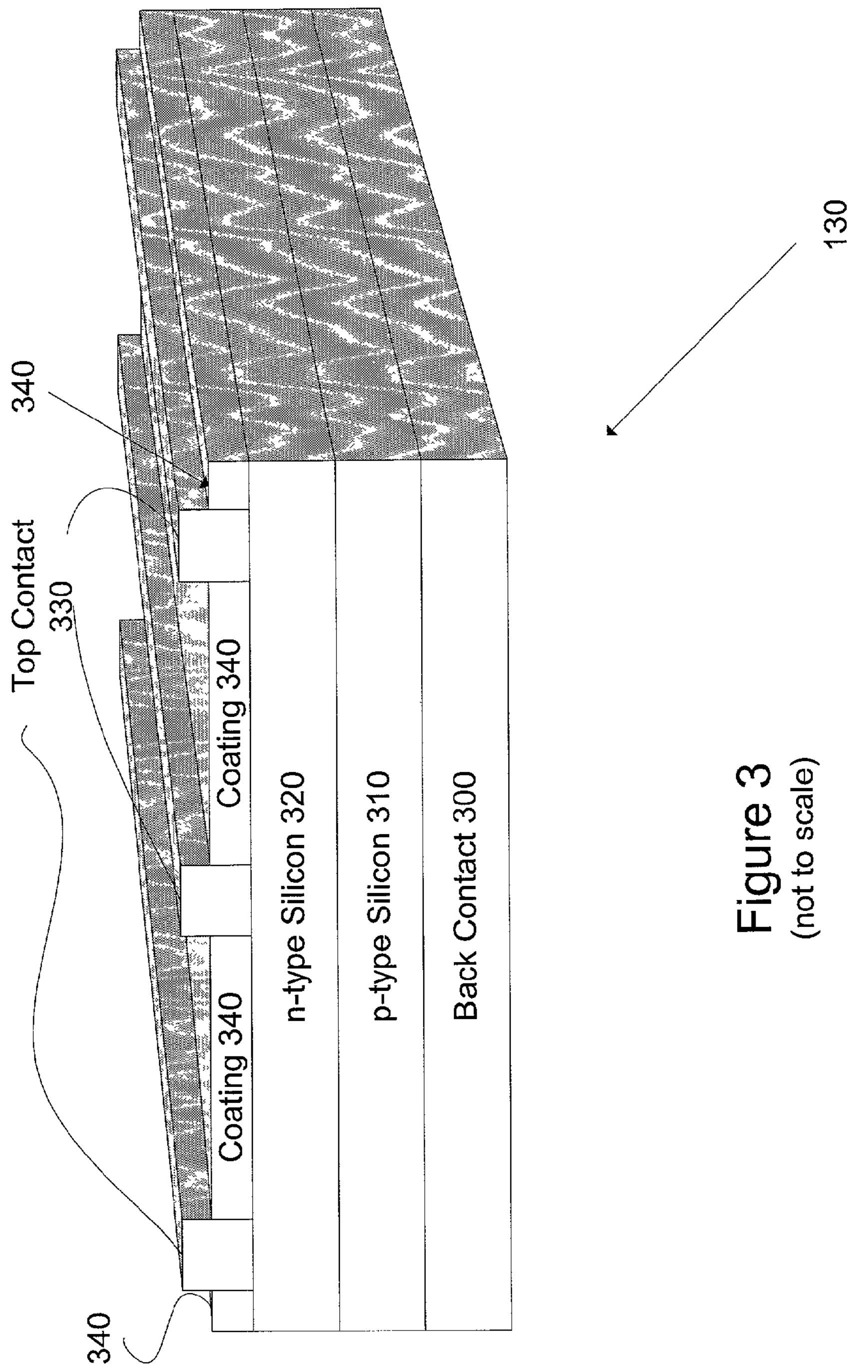


Figure 3
(not to scale)

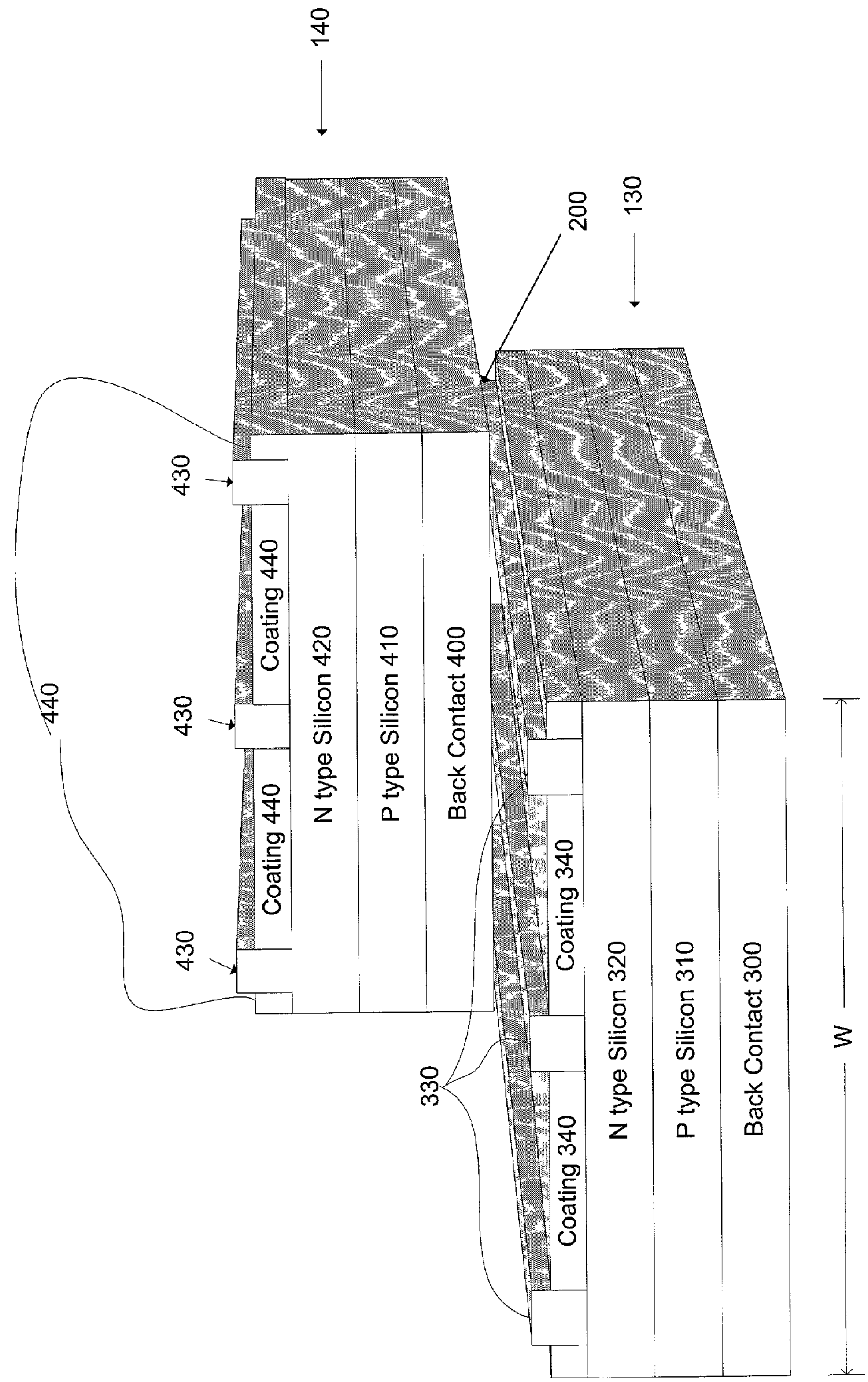


Figure 4
(not to scale)

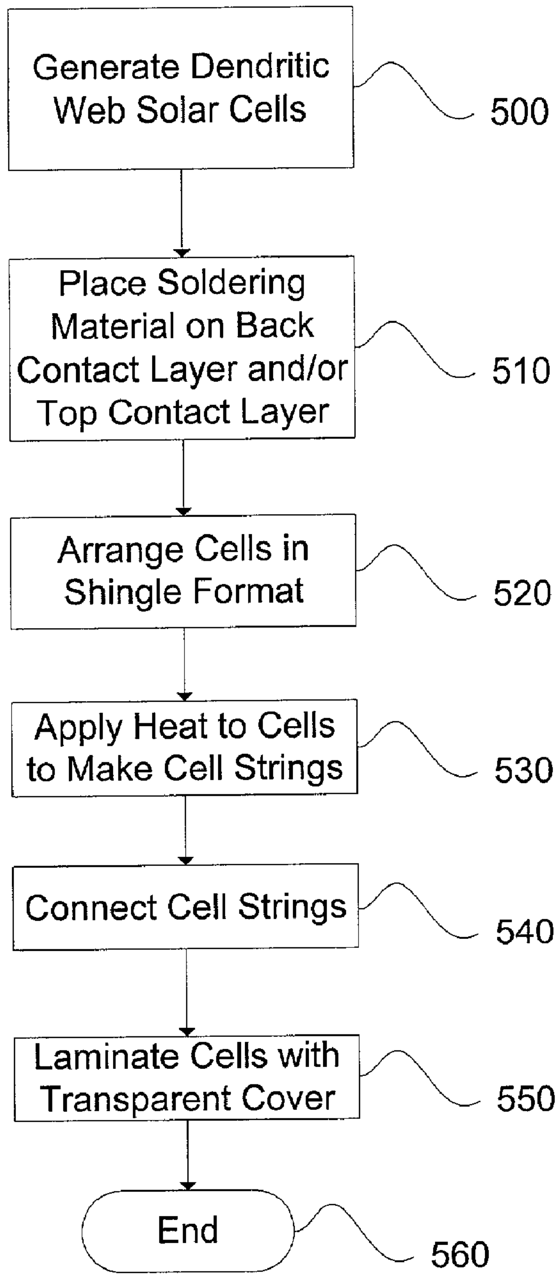

Generate Dendritic Web Solar Cells
500
Place Soldering Material on Back Contact Layer and/or Top Contact Layer
510
Arrange Cells in Shingle Format
520
Apply Heat to Cells to Make Cell Strings
530
Connect Cell Strings
540
Laminate Cells with Transparent Cover
550
End
560

Figure 5

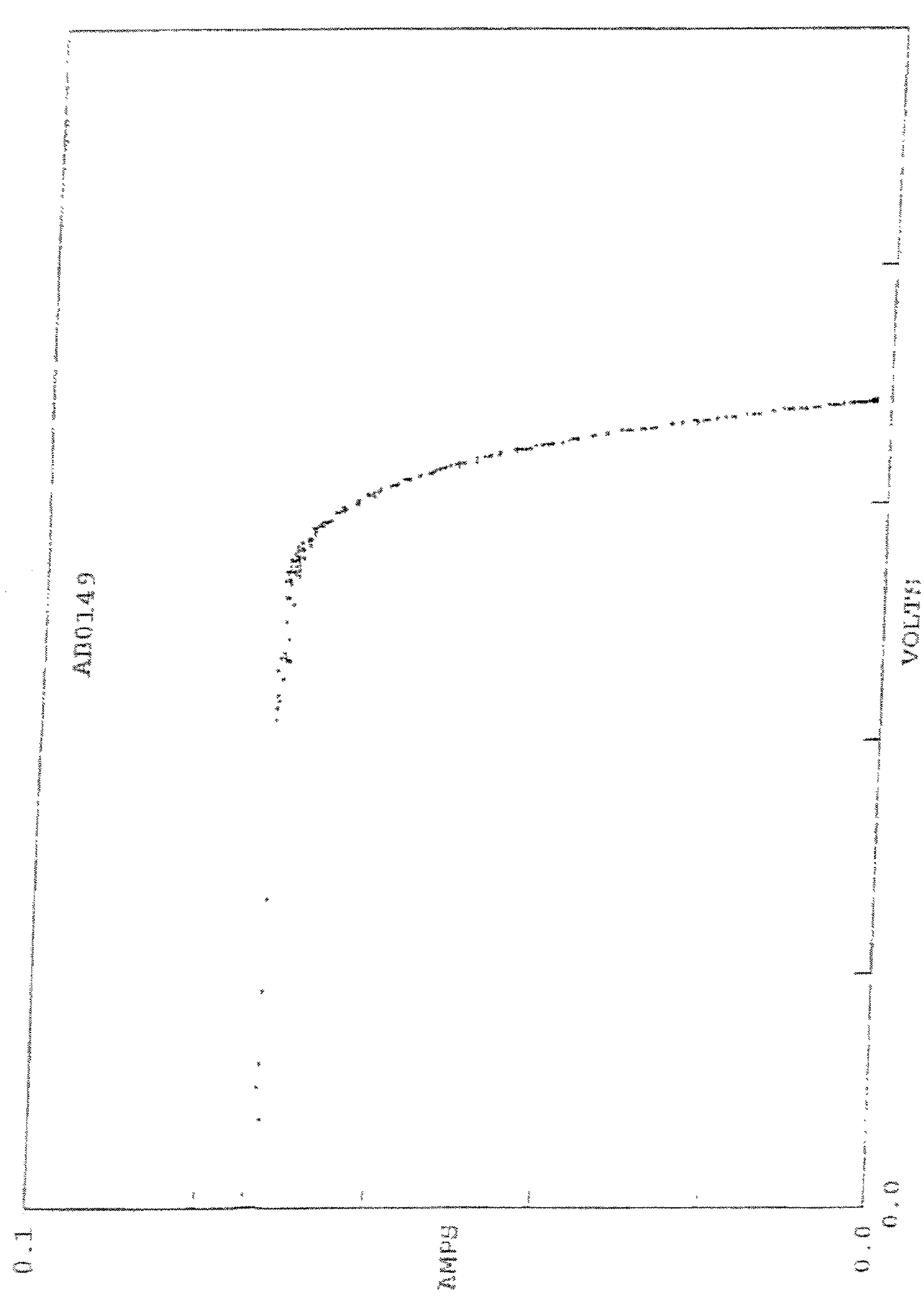


Fig. 6

SYSTEM AND METHOD FOR DENDRITIC WEB SOLAR CELL SHINGLING

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] This invention relates generally to solar cells, and more particularly provides a system and method for dendritic web solar cell shingling.

[0003] 2. Description of the Background Art

[0004] Solar cells convert sunlight into electricity through a photovoltaic process and can be used in small installations, such as in watches or calculators, to provide small amounts of electrical power. In another embodiment, solar cells can be grouped into large arrays or modules, which may contain thousands of individual cells, to convert sunlight into large amounts of electrical power to provide power to homes or industry.

[0005] A conventional solar cell comprises several layers, including an n-type silicon layer generally doped with phosphorus, which faces the sunlight; a p-type silicon layer located beneath the n-type silicon layer and generally doped with boron; an antireflective coating on top of the n-type silicon to reduce reflection of sunlight; and two electrical contact layers made of conducting material. The solar cell may also be laminated with ethylene vinyl acetate and have a glass layer to protect the cell from the environment, i.e., from airborne particles, snow, rain, etc.

[0006] The first electrical contact layer includes a back contact layer that is generally made of a conducting material and covers the entire back surface area of the cell. The second contact layer is located on the face of the cell on top of n-type silicon layer facing the sun and is also made of a conducting material. The second electrical contact layer is conventionally arranged in a grid-type pattern such that the second electrical contact layer does not cover the entire face of the cell since sunlight cannot typically pass through the second electrical contact layer.

[0007] In order to increase electrical power output, a plurality of solar cells may be grouped together into an array. Increasing the surface area available by increasing the number of solar cells increases the amount of electrical power that can be produced. In a conventional array, there is usually a gap between solar cells to allow for circuitry for coupling the cells together. This gap reduces the proportion of total solar cell surface area in a solar cell array, thereby reducing the proportion of solar cell surface area exposed to sunlight that produces electrical power. In addition, an interconnect tab that goes from a back of one cell to a top of another cell may be used to couple cells together. This interconnect tab technique for coupling cells leads to undesirable stress on the cells.

[0008] A conventional solution for increasing the proportion of solar cell surface area in a solar array is to remove the gap by shingling solar cells. The shingling architecture is implemented by applying soldering material to the bottom of the back contact layer on a first solar cell and/or the top of a busbar of the second contact layer on the face of a second solar cell. The contact layers of the two cells are then soldered together, forming a continuous conducting medium between the contact layers of the two solar cells, thereby allowing electrical current to flow from the first solar cell to the second solar cell.

[0009] However, due to the thickness of the solar cells (usually 300-600 microns), a large height differential can develop between the first and last solar cells in a long series of shingled cells in a solar array, thereby leading to difficulty in handling and installing the solar array. Further, the busbars of a face contact layer on the solar cell block sunlight, thereby reducing solar cell area available for electrical power production. In addition, the busbars may expand at a different rate than the rest of the solar cell due to thermal heating, thereby possibly disconnecting one solar cell from another.

[0010] Accordingly, a new solar cell array is highly desirable that may allow for increased solar cell area without creating a height differential between a first and last solar cell in a solar cell array.

SUMMARY

[0011] The present invention provides a shingled solar cell array system. The system comprises solar cells made of dendritic web silicon substrates arranged in series in a solar cell shingling array. The solar cells have a thickness of about 80-150 microns. The solar cells are coupled together by soldering a back contact layer of one cell to a face (top) contact layer (or grid) of a second solar cell. In another embodiment of the invention, the cells are coupled together using electrically conductive adhesives. Further, unlike conventional solar cells, the solar cells of an embodiment of the present invention are much thinner, allowing for easier handling of the array due to a low height differential between the first and last cells, and lack exposed busbars, thereby preventing possible problems relating to uneven thermal expansion of the different materials of the solar cell.

[0012] The present invention further provides a method for solar cell shingling. The method comprises generating a dendritic web solar cell having a thickness of under 150 microns; placing solder material on a face/top contact of a first cell and/or on a back contact layer of a second cell; aligning the cells in series such that the face contact layer of the first cell is in place with the back contact layer of the second cell; and applying heat to the cells such that the solder material bonds the two cells together.

[0013] The system and method may advantageously increase solar cell array efficiency by shingling dendritic web solar cells.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] **FIG. 1** is a diagram illustrating a solar cell array in accordance with an embodiment of the present invention;

[0015] **FIG. 2** is a cross section of the solar cell array of **FIG. 1**;

[0016] **FIG. 3** is a perspective view of a solar cell from the array of **FIG. 1**;

[0017] **FIG. 4** is a perspective view of two interconnected solar cells from the array of **FIG. 1**;

[0018] **FIG. 5** is a flowchart of steps for solar cell shingling to form the array of **FIG. 1**; and

[0019] **FIG. 6** depicts an I-V curve, which shows a light energy to electrical energy conversion efficiency of 12.2% for a shingled solar cell array having twelve dendritic web silicon substrate solar cells arranged in series.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0020] The following description is provided to enable any person skilled in the art to make and use the invention, and is provided in the context of a particular application and its requirements. Various modifications to the embodiments will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other embodiments and applications without departing from the spirit and scope of the invention. Thus, the present invention is not intended to be limited to the embodiments shown, but is to be accorded the widest scope consistent with the principles, features and teachings disclosed herein.

[0021] **FIG. 1** is a diagram illustrating a solar cell array **100** in accordance with an embodiment of the present invention. The solar cell array **100** comprises four individual solar cells **120**, **130**, **140**, and **150**, which are made of dendritic web silicon and may be identical to each other. In alternative embodiments, the solar cell array **100** may comprise any number of solar cells.

[0022] The solar cells **120**, **130**, **140**, and **150** of solar cell array **100** are arranged in a tile or shingle format such that the bottom of one cell overlaps the top of another cell. The overlapping area is generally less than 10% of the total area of a solar cell. Due to the thin nature of the dendritic web silicon solar cells, the overlapping of the cells causes a back contact layer of one cell to come into direct contact with the top contact layer of the next cell, thereby allowing electrical current to flow from the first cell to the next cell. Accordingly, exposed busbars, as used in conventional solar cells, are not required, thereby increasing available effective surface area as compared to conventional cells. However, a last cell in a series, such as cell **150**, may have an exposed busbar **160**. Further, an additional advantage of the solar cell array **100** as compared to conventional arrays is that the thin nature of the solar cells **120**, **130**, **140** and **150** lead to less of height differential between the first and last cells in the series array, leading to easier handling of the array **100**.

[0023] In addition, as there is no need for a separate interconnect between cells, undesirable stress in thin cells is avoided as a tab connecting the back of one cell to a front of a next cell is absent. Further, due to the lack of a tab between cells, resistance is lowered over a series of cells, thereby increasing power delivery. The layout of the solar cells will be discussed further in conjunction with **FIG. 3** and **FIG. 4** below.

[0024] **FIG. 2** is a cross section of the solar cell array **100** of **FIG. 1**. As mentioned in conjunction with **FIG. 1**, the bottom of one solar cell overlaps the top of the next solar cell. For example, at junction **200** the bottom of solar **140** overlaps the top of solar cell **130**, thereby forming a connection between the top contact layer of cell **130** and the bottom contact layer of cell **140**, as will be discussed further in conjunction with **FIG. 4** below.

[0025] **FIG. 3** is a perspective view of solar cell **130** from the solar cell array **100** of **FIG. 1**. Solar cell **130** has a thickness of about 80 to 150 microns as compared to 300 to 600 microns for conventional solar cells. Solar cell **130** comprises a p-type silicon layer **310** made of dendritic web silicon crystal doped with boron or other suitable material; an n-type silicon layer **320** also made of dendritic web silicon crystal doped with phosphorus or other suitable material disposed on top of the p-type silicon layer **310**; a back or bottom contact layer **300** located beneath the p-type silicon layer **310**; and a top (or face) contact layer **330** disposed on the n-type silicon layer **320**. Solar cell **130** may also comprise an antireflective coating **340** disposed on top of the n-type silicon layer **320**, in which case, the top contacts **330** fire through the anti-reflective coating **340**. The anti-reflective coating can be made of silicon nitride, titanium dioxide or other suitable materials and reduces reflection of photons from n-type silicon layer **320**, thereby increasing solar cell efficiency. The top contact layer **330** can be made of silver ohmic contacts or other conducting material and the bottom contact layer **300** may be of a silicon aluminum eutectic metal layer or other conducting material.

[0026] A further example of dendritic web silicon solar cells that can be used in the present invention can be found in PCT Application No. PCT/US00/02609 entitled "An Aluminum Alloy Back Junction Solar Cell and a Process for Fabrication Thereof" published on Sep. 21, 2000 as WO 00/55923, which is incorporated by reference.

[0027] **FIG. 4** is a perspective view of two interconnected solar cells **130** and **140** from the array **100** (**FIG. 1**). Solar cell **130** is interconnected to solar cell **140** at junction **200**. Due to the thin nature of dendritic web silicon solar cells, back contact **400** of solar cell **140** is in contact with the top contacts **330** of solar cell **130**, thereby allowing electrical current to flow between cells without the need for thick screen printed busbars or interconnection materials (such as tinned copper strips), which normally limit the solar cell surface area available for producing electrical current. Further, the lack of interconnection materials may remove some problems associated with uneven thermal expansion of conventional solar cells.

[0028] **FIG. 5** is a flowchart of steps for solar cell shingling to form the solar cell array **100** of **FIG. 1**. At step **500**, dendritic web solar cells are generated using techniques known in the art. For example, a method of generating dendritic web solar cells is disclosed in WO 00/55923. At step **510**, soldering material is placed on the back contact layer of one cell and/or on the face (top) contact layer of a second cell along an edge of the cells. The soldering material may be placed along the entire lengths of the solar cells. In an alternative embodiment, electrically conductive adhesives may be used in place of soldering material.

[0029] At step **520**, the solar cells are arranged in series in a tile format so that the bottom of one solar cell overlaps the top of another solar cell. It is preferred to have not more than 10% of the surface area of any solar cell covered by another solar cell so as not to limit or waste the surface area available for electrical power production. At step **530**, heat is applied to the soldering material or to the solar cells so that the soldering material bonds the solar cells together into a string. It will be appreciated that the melting point of the soldering material may be designed to be lower than the melting point of the cells so that cells are not damaged when the cell/solder combination is heated as a whole to melt the solder. It will be further appreciated that only a portion of the solder need melt to fuse the cells together. If electrically conductive adhesives are used in place of soldering material, heat need not be applied and step **530** may be skipped.

[**0030**] At step **540**, two or more solar cell strings may be connected together, typically in parallel. At step **550**, the interconnected shingled solar cell strings are encapsulated in a lamination process, which is well known in the art. Typical layers in the laminate include a transparent protective cover, such as glass, a potting material, such as ethylene vinyl acetate, the interconnected cell strings, and a protective back layer, such as tedlar. In this way, the solar cell strings **100** are protected from breakage and contaminants such as airborne particles, snow, rainwater, etc.

[**0031**] **FIG. 6** depicts an I-V curve, which shows a light energy to electrical energy conversion efficiency of 12.2% for a solar cell array having twelve laminated shingled dendritic web silicon crystal solar cells, each with 2.72 cm^2 exposed area, arranged in series. The array has a fill factor of 0.782. The knee of the curve shows the maximum power point P_{max} wherein V_{mp} is approximately 5.78 volts and Imp is approximately 0.069 amps yielding a P_{max} of 0.0399 watts. In comparison, a solar cell array in a non-shingled format using a set of similar twelve solar cells has a conversion efficiency of only 10.9% because of a fill factor of 0.700.

[**0032**] The foregoing description of the preferred embodiments of the present invention is by way of example only, and other variations and modifications of the above-described embodiments and methods are possible in light of the foregoing teaching. For example, the p-type silicon layer **310** may be doped with gallium or aluminum instead of boron. The shingling method described can be used wherever positive and negative contacts are on opposite sides of the solar cell. The embodiments described herein are not intended to be exhaustive or limiting. The present invention is limited only by the following claims.

What is claimed is:

1. A shingled solar cell array, comprising:

at least two dendritic web silicon solar cells shingled together so that a bottom of one cell overlaps a top of a next cell, the cells each having a thickness of less than about 150 microns.

2. The shingled solar cell array of claim 1, wherein less than 10% of the surface area of one cell is overlapped by the next cell.

3. The shingled solar cell array of claim 1, wherein the at least two cells are interconnected via a back contact layer of one cell to a top contact layer of the next cell.

4. The shingled solar cell array of claim 1, wherein the array is has an anti-reflective coating.

5. The shingled solar cell array of claim 1, wherein the array is encapsulated with an encapsulation material.

6. The shingled solar cell array of claim 5, wherein the encapsulation material includes ethylene vinyl acetate.

7. The shingled solar cell array of claim 1, wherein the shingled solar cell array has an interconnect between cells having a low resistance.

8. The shingled solar cell array of claim 1, wherein the shingled solar cell array has an interconnect between cells lacking undesirable stress.

9. A solar cell shingling method, comprising:

placing soldering material on a top contact layer of a first dendritic web silicon solar cell, the first cell having a thickness of less than about 150 microns;

overlapping a second dendritic web silicon solar cell over the soldering material, the second cell having a thickness of less than about 150 microns;

applying heat to the first and second solar cells so that the cells bond.

10. The method of claim 9, further comprising placing soldering material on the back contact layer of the second cell.

11. The method of claim 9, further comprising encapsulating the solar cells with an encapsulation material.

12. The method of claim 11 wherein the encapsulation material includes ethylene vinyl acetate.

13. The method of claim 9, wherein the first and second cells have an anti-reflective coating.

14. The method of claim 9, wherein the second cell does not overlap more than 10% of the surface area of the first cell.

15. A system for solar cell shingling method, comprising:

means for placing soldering material on a top contact layer of a first dendritic web silicon solar cell, the first cell having a thickness of less than about 150 microns;

means for overlapping a second dendritic web silicon solar cell over the soldering material, the second cell having a thickness of less than about 150 microns;

means for applying heat to the first and second solar cells so that the cells bond.

16. A solar cell shingling method, comprising:

placing soldering material on a bottom contact layer of a first dendritic web silicon solar cell, the first cell having a thickness of less than about 150 microns;

coupling the first cell with a second dendritic web silicon solar cell such that a top contact layer of the second cell is in communication with the soldering material, the second cell having a thickness of less than about 150 microns;

applying heat to the first and second solar cells so that the cells bond.

17. A shingled solar cell array, comprising:

at least two dendritic web silicon solar cells shingled together with electrically conductive adhesive so that a bottom of one cell overlaps a top of a next cell, the cells each having a thickness of less than about 150 microns.

18. A solar cell shingling method, comprising:

placing electrically conductive adhesive on a top contact layer of a first dendritic web silicon solar cell, the first cell having a thickness of less than about 150 microns; and

overlapping a second dendritic web silicon solar cell over the adhesive so that the cells bond, the second cell having a thickness of less than about 150 microns.

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