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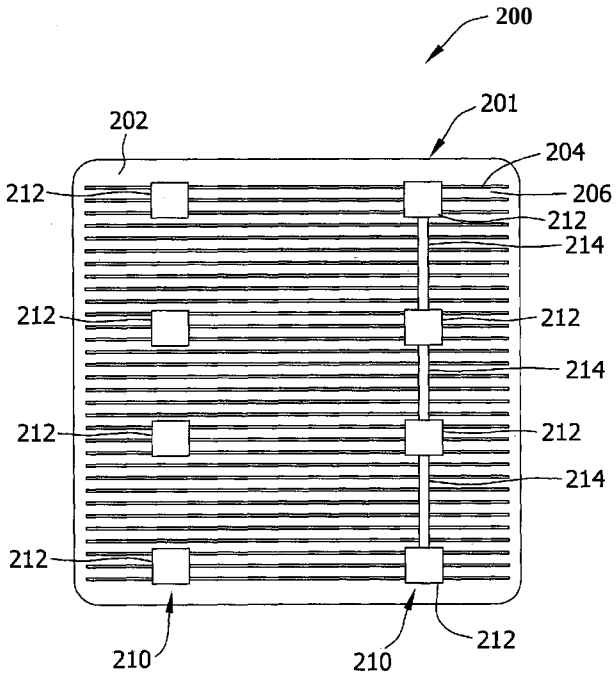
(54) **Title:** BUS BARS FOR SOLAR MODULES



(57) **Abstract:** A solar module includes a photovoltaic cell having a front surface and a rear surface. The photovoltaic cell is configured for converting light into electricity. Fingers are disposed on the front surface of the cell and are electrically connected to the cell to conduct electricity generated by the cell. The fingers are spaced apart from each other by gaps. A bus bar is disposed on the front surface of the cell and connected to at least the fingers to conduct electricity from the fingers. The bus bar is configured to facilitate the transfer of heat generated during soldering of a conductor to the bus bar away from locations of the soldering.

WO 2013/100856 A2

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BUS BARS FOR SOLAR MODULES

FIELD

[0001] This disclosure relates generally to solar modules used to convert solar energy into electricity and, more specifically, to solar modules having improved bus bars.

BACKGROUND

[0002] Solar modules conventionally include a photovoltaic cell to generate electricity from light. The photovoltaic cell is laminated between an upper layer (e.g., made of glass or similar transparent material) and a bottom layer that is generally water resistant. Two layers of encapsulant are positioned between these outer layers, and the cells are position within the encapsulant.

[0003] A typical photovoltaic cell is shown in Figures 1 and 2 and indicated generally at 100. Electrically conducting fingers 102 (only one of which is numbered) are disposed on a surface 104 of the cell 100. These fmgers 102 are electrically connected to the surface 104 of the cell 100 and conduct electricity generated by the cell. Two bus bars 106 are disposed on the surface 104 of the cell 100 and are electrically connected to the fmgers 102. A conductor 108 (e.g., a metallic ribbon) is positioned atop each bus bar 106 and is electrically connected to the bus bar by soldering. Wires (not shown) are used to electrically connect the conductors 108 and a rear contact on the opposite side of the cell 100 to an electrical device (e.g., an inverter).

[0004] A concern in the design and manufacture of photovoltaic cells is the thermal stresses generated and imparted on the cells during soldering of the conductors to the bus bars. Numerous attempts have been made to address this concern. These prior attempts have been inefficient and/or ineffective. There is a need for an improved system for reducing and/or eliminating the thermal stresses generated and imparted on the cell during soldering of the conductors to the bus bars.

[0005] This section is intended to introduce the reader to various aspects of art that may be related to various aspects of the disclosure, which are described and/or claimed below. This discussion is believed to be helpful in providing the reader with background information to facilitate a better understanding of the various aspects of the present disclosure. Accordingly, it should be understood that these statements are to be read in this light, and not as admissions of prior art.

SUMMARY

[0006] In one aspect, a solar module comprises a photovoltaic cell having a front surface and a rear surface. The photovoltaic cell is configured for converting light into electricity. Fingers are disposed on the front surface of the cell and are electrically connected to the cell to conduct electricity generated by the cell. The fingers are spaced apart from each other. A bus bar is disposed on the front surface of the cell and connected to at least the fingers to conduct electricity from the fingers. The bus bar includes segments and at least one segment has a different shape than a shape of another segment of the bus bar. The different shapes of the segments of the bus bar facilitate the transfer of heat generated during soldering of a conductor to the bus bar away from locations of the soldering.

[0007] In another aspect, a solar module comprises a photovoltaic cell configured for converting light into electricity. Fingers are disposed on the cell and are electrically connected to the cell to conduct electricity generated by the cell. A bus bar is disposed on the cell and electrically connected to the fingers to conduct electricity from the fingers. The bus bar includes segments separated from each other by a gap. The gap between the segments permits thermal expansion of the bus bar. A conductor is electrically connected to the segments of the bus bar.

[0008] In still another aspect, a solar module comprises a photovoltaic cell having a front surface and a rear surface. The photovoltaic cell is configured for converting light into electricity. Fingers are disposed on the front surface of the cell and are electrically connected to the cell to conduct electricity generated by the cell. Insulating members are disposed on the front surface of the cell

between the fingers. A bus bar is disposed on the front surface of the cell and is electrically connected to the fingers to conduct electricity from the fingers. The bus bar overlies the insulating members.

[0009] Various refinements exist of the features noted in relation to the above-mentioned aspects of the present disclosure. Further features may also be incorporated in the above-mentioned aspects of the present disclosure as well. These refinements and additional features may exist individually or in any combination. For instance, various features discussed below in relation to any of the illustrated embodiments of the present disclosure may be incorporated into any of the above-described aspects of the present disclosure, alone or in any combination.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] Figure 1 is a perspective view of a prior art photovoltaic cell and bus bars;

[001 1] Figure 2 is a top plan view of the photovoltaic cell of Figure i ;

[0012] Figure 3 is a top plan view of an embodiment of a photovoltaic cell and bus bars;

[0013] Figure 4 is a top plan view of bus bar segments for use with the photovoltaic cell of Figure 3;

[0014] Figure 5 is a top plan view of another embodiment of a photovoltaic cell and bus bars.

[001 5] Figure 6 is a top plan of an enlarged portion of Figure 5;

[0016] Figure 7 is a cross-sectional view of the photovoltaic cell of Figure 6 taken along the 7-7 line;

[0017] Figure 8 is a top plan view of an enlarged portion of Figure 5;

[001 8] Figure 9 is a cross-sectional view of the photovoltaic cell of Figure 8 taken along the 8-8 line; and

[0019] Figure 10 is a perspective view of another embodiment of a photovoltaic cell and a bus bar.

[0020] Corresponding reference characters indicate corresponding parts throughout the drawings.

DETAILED DESCRIPTION

[002 1] Referring to the drawings, an exemplary solar module system is shown in Figure 3 and indicated generally at 200. As described in greater detail below, the rapid heating and cooling during soldering of components in the system 200 can cause defects in the system. These defects can negatively affect the efficiency of the system 200 in its generation of electricity. The systems 200 described herein are generally operable to reduce the effects of thermal stress generated during soldering of a conductor (e.g., a metallic ribbon) to a bus bar of the system.

[0022] The solar module 200 includes a photovoltaic cell 201 (referred to interchangeably as "the cell") having a front surface 202 and a rear surface. The photovoltaic cell 201 is operable to convert the energy of light (e.g., solar energy) into electricity via the photovoltaic effect.

[0023] Fingers 204 are disposed on the front surface 202 of the cell 201 according to any suitable process, such as screen printing. The number, size, configuration, and spacing of fingers 204 shown in the Figures is exemplary in nature and may be modified. Moreover, only one such finger 204 is numbered in the Figures. These fingers 204 are electrically connected to the front surface 202 of the cell 201 to conduct electricity generated by the cell. As shown in the Figures, the fingers 204 are spaced apart from each other and thus separated by gaps 206, only one of which is numbered.

[0024] A bus bar 210 is disposed on the front surface 202 of the cell 201 and is connected to the fingers 204 to conduct electricity from the fingers. Two bus bars 210 are depicted in the embodiment of Figure 3, although other embodiments may use different numbers of bus bars. The bus bars 210 include discrete first segments 212 and second segments 214. At least some of the segments 212, 214 have different shapes than other segments. These segments are connected by a conductor (e.g., a metallic ribbon), which is omitted for clarity in Figure 3. The conductor is connected to the bus bar 210 at multiple, discrete locations by soldering. In other embodiments, the conductor is connected to the bus bar 210 along at least a majority of its length by soldering.

[0025] These shapes of the segments 212, 214 facilitate the transfer of heat generated during soldering of the conductor to the bus bar 210 away from the locations of soldering. As shown in the Figures, a plurality of first segments 212 and second segments 214 are provided. The first segments 212 have a surface area that is greater than a surface of the second segments 214. The first segments 212 are also shaped differently than the second segments 214. The conductor is soldered to the bus bar 210 at locations along the bus bar that are coincident with at least a portion of the first segments 212. In other embodiments, only some of the locations are coincident with at least a portion of the first segments 212.

[0026] The larger surface area of the first segments 212 facilitates the transfer of heat generated during soldering of the conductor to the bus bar 210 away from the coincident locations. In effect, the first segments 212 function equivalently to a heat sink, and draw away and dissipate heat generated during soldering.

[0027] Figure 4 depicts a variety of different shaped bus bar segments 216, 218, 220, 222, 224, 226, 228 which may be substituted for the rectangular-shaped first segments 212 shown in Figure 3. These segments of Figure 4 may be further altered according to other embodiments. Moreover, each segment also includes a respective location 217, 219, 221, 223, 225, 227, 229 where the conductor is soldered thereto.

[0028] In prior systems lacking such segments, the heat generated during the soldering process could cause thermal stresses to develop in the photovoltaic cell 201 and/or other components of the system 200. These thermal stresses are due in part to the different coefficients of thermal expansion (CTE) of the bus bar 210, photovoltaic cell 201, fingers 204, conductor, and solder. Thus when heated during soldering, these components may expand by differing amounts if their CTEs differ. This differential expansion can cause cracks in the photovoltaic cell 201 which decrease its electrical output. Moreover, the differential thermal expansion may cause delamination between the bus bars 210 and the conductors. This delamination may be especially evident in instances where the adhesion between the bus bars 210 and the front surface 202 of the photovoltaic cell 201 and/or fingers 204 is weak.

[0029] Figures 5-9 depict another embodiment of bus bars 310 (shown in Figures 6-9) disposed on a front surface 302 of a photovoltaic cell 301 in a solar module system 300. The photovoltaic cell 301, conductors 303, and associated fingers 304 are of the same or similar type as those described above in relation to Figure 3. The bus bars 310 of Figures 5-9 are electrically connected to the fingers 304 to conduct electricity from the fingers.

[0030] As shown in Figures 6 and 8, each of the bus bars 310 includes segments 312, 314 that are separated from each other by a gap 306. The bus bars 310 can be formed using a mesh pattern during screen printing of the segments onto the surface 302 of the photovoltaic cell 301. In other embodiments, they may be formed by plating onto a seed layer deposited in this pattern using any suitable patterning method.

[0031] The right-most bus bar 310 shown in greater detail in Figures 6 and 7. In Figure 6, the conductor 303 is omitted for clarity. The gaps 306 in this embodiment have a length that is less than their width. Their width is parallel to a lateral axis XA of the cell 301, i.e., the gaps are "horizontal". Accordingly, during soldering of the bus bars 310 to the conductor 303 the segments 312 are able to expand in a direction parallel to a longitudinal axis YA of the cell 301. They are thus

able to expand in this direction unimpeded by contact with other adjacent segments 312.

[0032] The left-most bus bar 310 is shown in greater detail in Figures 8 and 9, though in Figure 8 the conductor 303 is omitted for clarity. The gaps 306 in this embodiment have a length that is greater than their width. Their length is parallel to the longitudinal axis YA, i.e., the gaps 306 are "vertical". Accordingly, during soldering of the bus bars 310 to the conductor 303 the segments 314 are able to expand in a direction parallel to the lateral axis XA of the cell 301. They can expand in this direction unimpeded by contact with other adjacent segments 314.

[0033] In bus bars 310 using horizontal or vertical gaps 306 between segments 312, 314, the segments of the bus bar expand into the gaps adjacent each of their edges during soldering of the bus bar to the conductor 303. Thus the gaps 306 permit unimpeded thermal expansion of the segments 312, 314 of the bus bars 310 during soldering and subsequent cooling of the bus bars. The amount of stress imparted by the expansion and subsequent contraction of the bus bars 310 to the surface of the photovoltaic cells 301 is significantly reduced or eliminated. This reduction or elimination of thermal stress on the cell 301 surface reduces or eliminates cracking of the surface and subsequent decrease in output of the cell.

[0034] Figure 10 depicts another embodiment of bus bars 410 disposed on a front surface 402 of a photovoltaic cell 401 in a solar module system 400. Only a portion of the system 400 is shown in Figure 10. The photovoltaic cell 401, conductors (not shown), and associated fingers 404 are of the same or similar type as those described above in relation to Figure 3. The embodiment of Figure 10 may be used in instances where the photovoltaic cell 401 is formed from silicon hetero junction cells (SHJ) where their surface 401 is a transparent conducting oxide (TCO) capable of conducting charge carriers as well as heat. Examples of TCOs include indium tin oxide and aluminum zinc oxide.

[0035] Insulating members 420 (only a portion of one of which is shown) are disposed on the front surface 402 of the cell between the fingers 404.

These insulating members 420 are disposed between gaps 406 which separate the fingers 404. The insulating members 420 have a width W1 that is greater than a width W2 of the bus bar 410 in the example embodiment. In other embodiments, the relative widths of the insulating members 420 may be different. For example, the width of the insulating members 420 may be equal to that of the bus bar 410.

[0036] In the example embodiment, the insulating members 420 are dielectric material. Examples of such materials include silicon dioxide, silicon nitride, or other suitable transparent dielectric materials. The members 420 may be deposited on the surface 402 of the photovoltaic cell 401 by any suitable process, such as a physical vapor deposition or sputter deposition process.

[0037] In operation, the insulating members 420 reduce the amount of heat that is transferred away from the locations where the bus bar 410 is soldered to the conductor. The members 420 thus reduce the thermal stresses imparted on the surface 402 of the cell 401, which in turn reduces the formation of cracks in the cell surface 402. As discussed above, such cracks cause a reduction in the output of the cell 401. Moreover, in prior systems, the TCOs may peel off the surface 401 of the cell 402 after soldering because the thermal stresses of soldering can exceed the adhesion strength of the TCOs. As the system described herein reduces and/or eliminates thermal stresses during soldering, these effects are reduced and/or eliminated.

[0038] The different embodiments of the systems described each function to reduce the deleterious effects of heat generated during soldering of conductors to bus bars in photovoltaic cells. This heat generated during soldering results in the expansion of the components of the cells. As such components have different CTEs, they expand and later contract by different amounts. This differential expansion can damage components of the system, which in turn can reduce the electrical output of the system. Moreover, cells that can withstand the thermal stress of soldering without significant damage are likely to have a longer service life in the field.

[0039] When introducing elements of the present disclosure or the embodiments thereof, the articles "a", "an", "the" and "said" are intended to mean that there are one or more of the elements. The terms "comprising," "including," "containing" and "having" are intended to be inclusive and mean that there may be additional elements other than the listed elements. The use of terms indicating a particular orientation (e.g., "top", "bottom", "side", etc.) is for convenience of description and does not require any particular orientation of the item described.

[0040] As various changes could be made in the above constructions and methods without departing from the scope of the disclosure, it is intended that all matter contained in the above description and shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

WHAT IS CLAIMED IS:

1. A solar module comprising:

a photovoltaic cell having a front surface and a rear surface, the photovoltaic cell configured for converting light into electricity;

fingers disposed on the front surface of the cell and electrically connected to the cell to conduct electricity generated by the cell, wherein the fingers are spaced apart from each other; and

a bus bar disposed on the front surface of the cell and connected to at least the fingers to conduct electricity from the fingers,

the bus bar including segments, at least one segment having a different shape than a shape of another segment of the bus bar, wherein the different shapes of the segments of the bus bar facilitate the transfer of heat generated during soldering of a conductor to the bus bar away from locations of the soldering.

2. The solar module of claim 1 wherein the bus bar comprises a first segment and a second segment, and wherein the first segment has a surface area that is greater than a surface area of the second segment.

3. The solar module of claim 2 further comprising a conductor soldered to the bus bar, wherein the conductor is spot soldered to the bus bar at locations along the bus bar, and wherein at least some of the locations are coincident with at least a portion of the first segment.

4. The solar module of claim 3 wherein the first segment facilitates the transfer of heat generated during soldering of the conductor to the bus bar away from the coincident locations.

5. The solar module of claim 2 wherein the first segment and second segment are electrically connected.

6. The solar module of claim 2 wherein the bus bar comprises a plurality of first segments and a plurality of second segments.

7. The solar module of claim 2 wherein the first segment has at least one of a width that is greater than a width of the second segment and a length that is greater than a length of the second segment.

8. A solar module comprising:

a photovoltaic cell configured for converting light into electricity;

fingers disposed on the cell and electrically connected to the cell to conduct electricity generated by the cell;

a bus bar disposed on the cell and electrically connected to the fingers to conduct electricity from the fingers, the bus bar including segments separated from each other by a gap, wherein the gap between the segments permits thermal expansion of the bus bar; and

a conductor electrically connected to the segments of the bus bar.

9. The solar module of claim 8 wherein the conductor is soldered to the bus bar at locations coincident with the segments and the gap between the segments permits thermal expansion of the bus bar.

10. The solar module of claim 8 wherein the solar module has a longitudinal axis and a lateral axis, and wherein the fingers are parallel to the lateral axis.

11. The solar module of claim 10 wherein the gaps separating the segments have a length and a width, and wherein the width is parallel to the lateral axis of the solar module, and wherein the length is less than the width.

12. The solar module of claim 10 wherein the gaps separating the segments have a length and a width, and wherein the length is greater than the width, and wherein the length is parallel to the longitudinal axis of the solar module.

13. The solar module of claim 12 wherein at least a portion of the fingers are disposed in the gaps.

14. The solar module of claim 8 wherein the gaps in the bus bar are located such that the fingers are spaced from the gaps.

15. The solar module of claim 8 wherein the gaps in the bus bar are located such that at least a portion of the fingers are disposed in the gaps.

16. The solar module of claim 8 wherein the conductor is a metallic ribbon.

17. A solar module comprising:

a photovoltaic cell having a front surface and a rear surface, the photovoltaic cell configured for converting light into electricity;

fingers disposed on the front surface of the cell and electrically connected to the cell to conduct electricity generated by the cell; and

insulating members disposed on the front surface of the cell between the fingers; and

a bus bar disposed on the front surface of the cell and electrically connected to the fingers to conduct electricity from the fingers, the bus bar overlying the insulating members.

18. The solar module of claim 17 wherein the fingers are spaced-apart and separated by gaps, and wherein the insulating members are disposed in the gaps.

19. The solar module of claim 18 wherein the insulating members have a width and the bus bar has a width, and wherein the width of the members is greater than the width of the bus bar.

20. The solar module of claim 17 wherein the insulating members are made of a dielectric material.

21. The solar module of claim 17 wherein the insulating members are deposited on the cell by one of a vapor deposition or sputter deposition process.

22. The solar module of claim 17 wherein the insulating members reduce the amount of heat transferred to the cell during soldering of a conductor to the bus bar.

FIG. 1
PRIOR ART

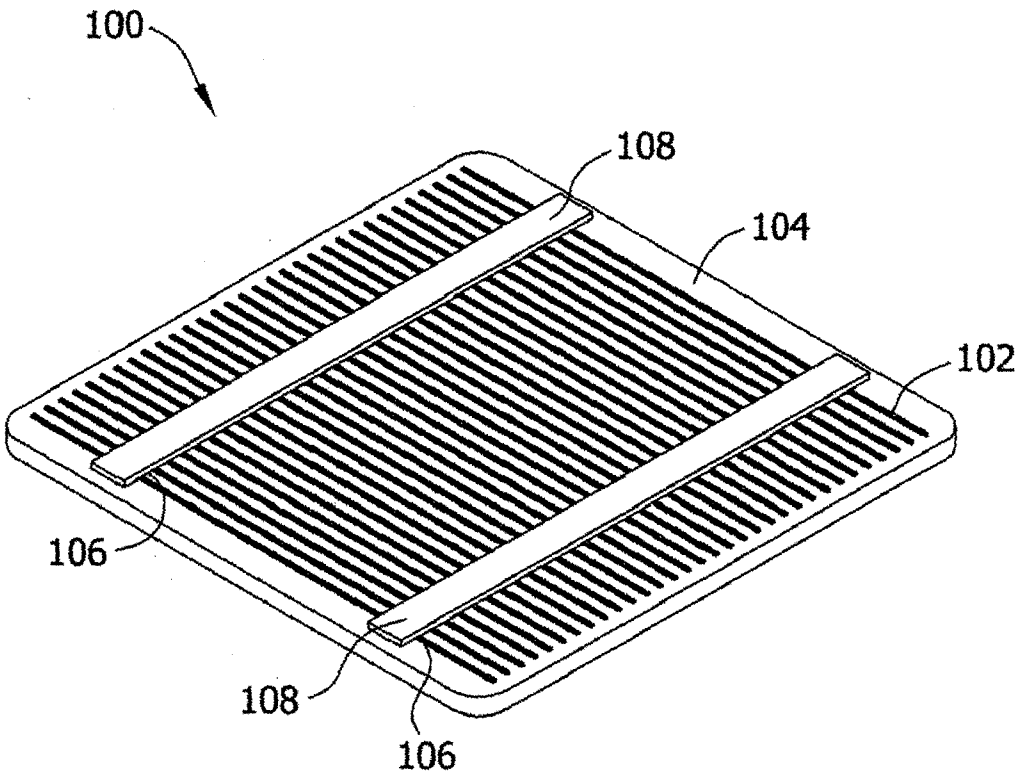

FIG. 2
PRIOR ART

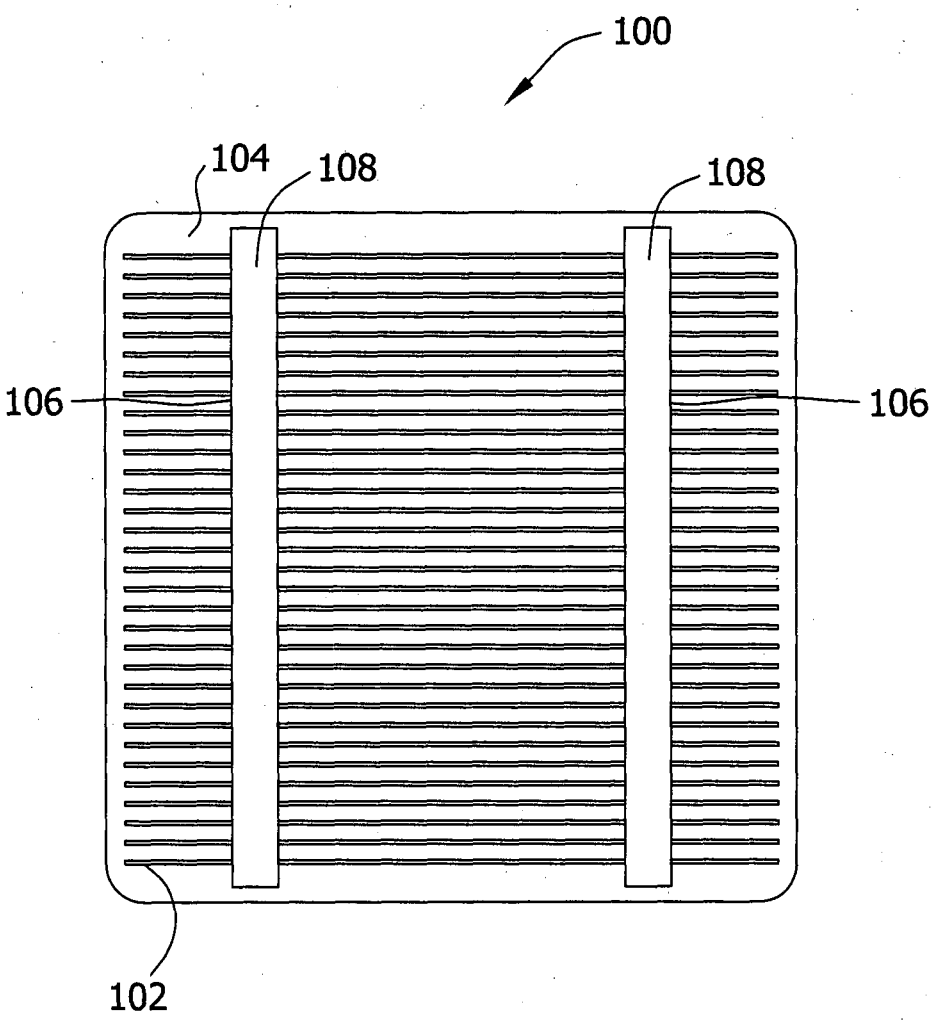

FIG. 3

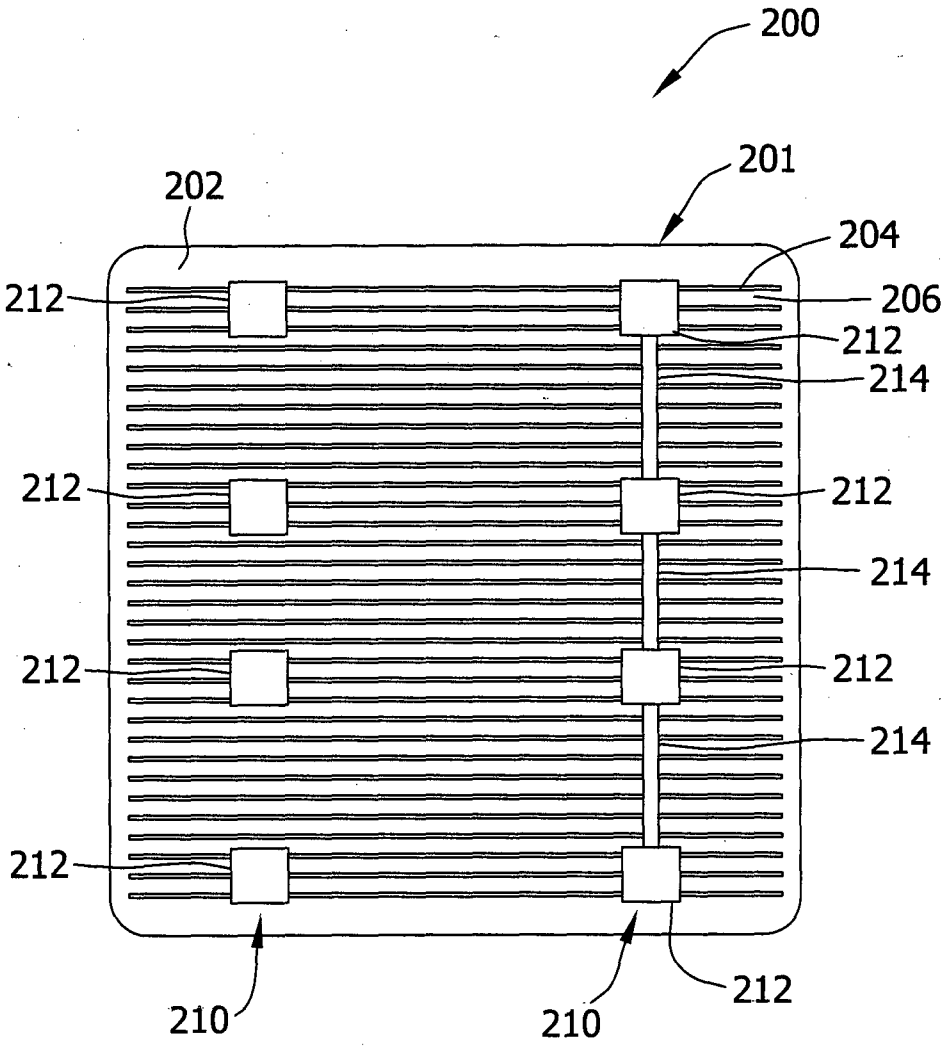

FIG. 4

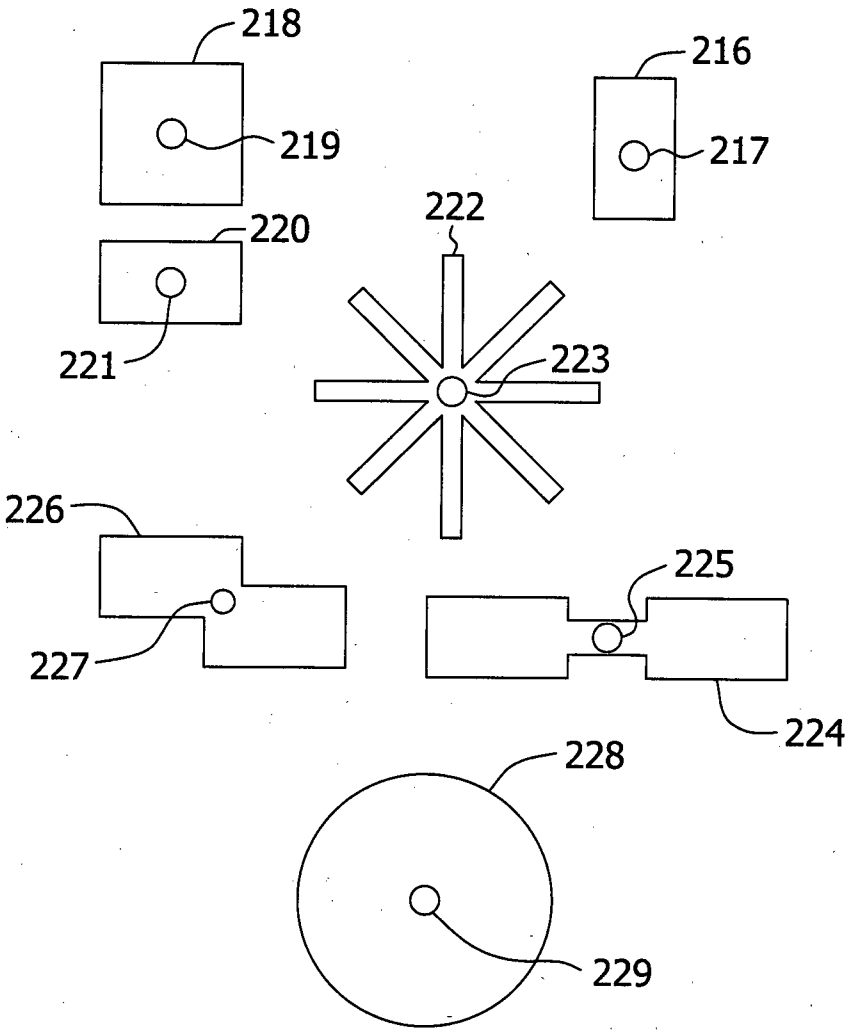

FIG. 5

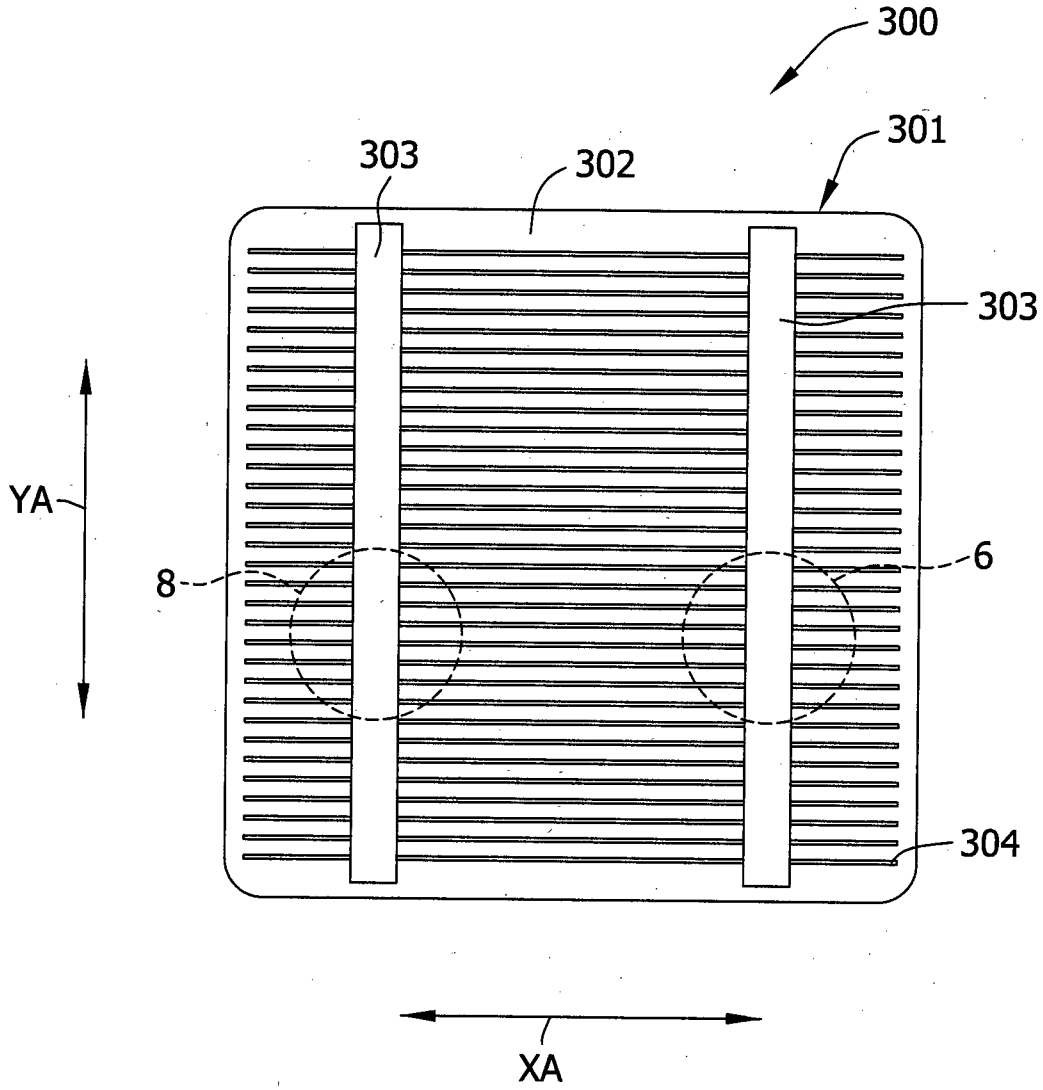

FIG. 6

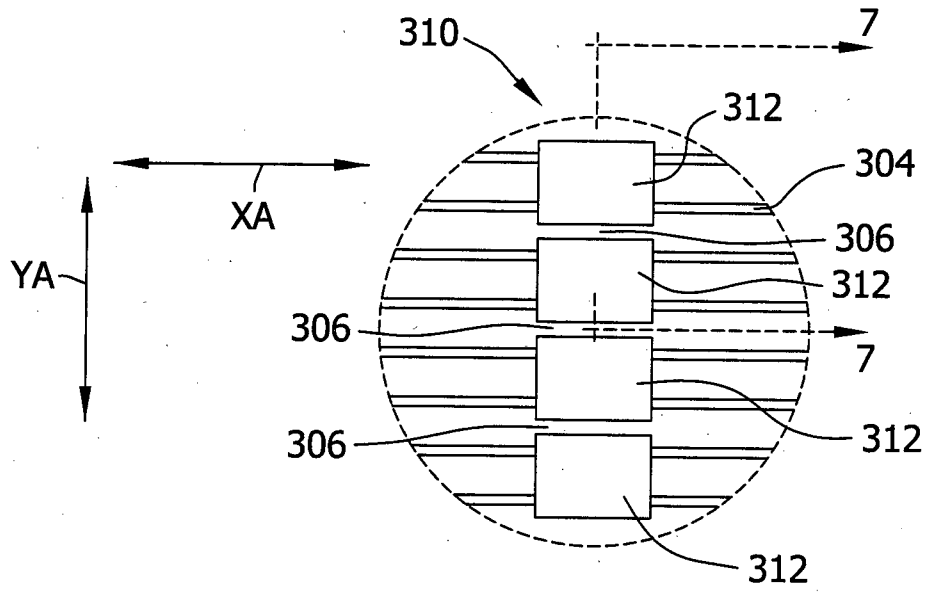

FIG. 7

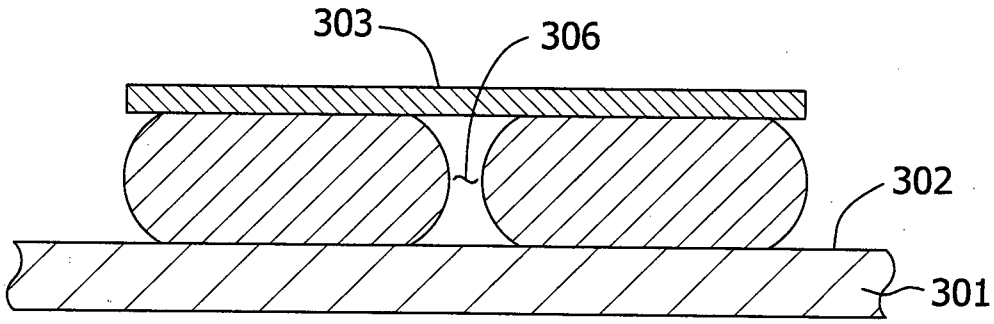

FIG. 8

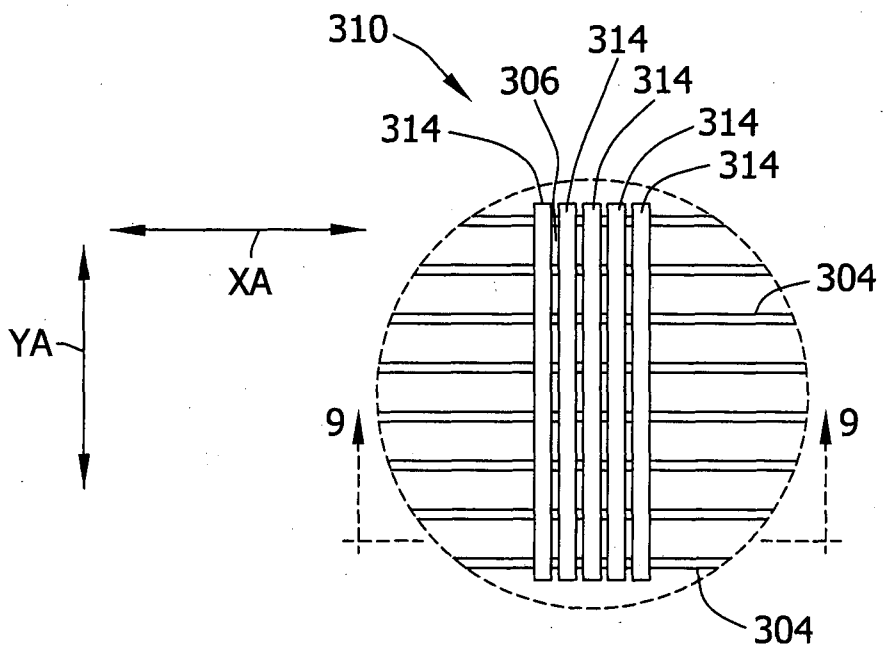
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FIG. 9

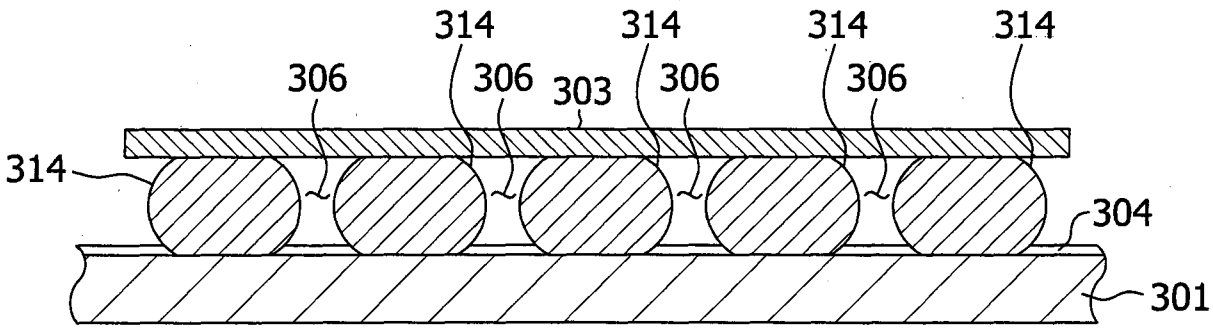
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FIG. 10