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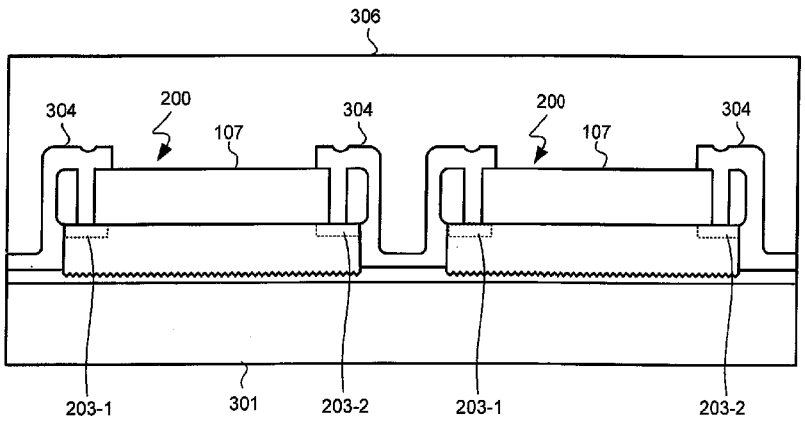

FIG. 9

(57) **Abstract**: A solar cell module includes serially connected solar cells (200). A solar cell (200) includes a carrier (107) that is attached to the backside of the solar cell (200). Solar cells (200) are attached to a top cover (301), and vias are formed through the carriers (107) of the solar cells (200). A solar cell (200) is electrically connected to an adjacent solar cell (200) in the solar cell module with metal connections (304) in the vias.

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INTERCONNECTION OF SOLAR CELLS IN A SOLAR CELL MODULE

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TECHNICAL FIELD

[0001] Embodiments of the subject matter described herein relate generally to solar cells and solar cell modules.

BACKGROUND

[0002] Solar cells are well known devices for converting solar radiation to electrical energy. A solar cell has a front side that faces the sun during normal operation to collect solar radiation and a backside opposite the front side. Solar radiation impinging on the solar cell creates electrical charges that may be harnessed to power an external electrical circuit, such as a load. Solar cells may be electrically connected to form a solar cell array. The solar cell array may be packaged to form a solar cell module, which may then be deployed in the field along with other solar cell modules.

BRIEF SUMMARY

[0003] In one embodiment, a solar cell module includes serially connected solar cells. A solar cell includes a carrier that is attached to the backside of the solar cell. Solar cells are attached to a transparent top cover, and vias are formed through the carriers of the solar cells. The vias are filled with metal connections that electrically connect a solar cell to an adjacent solar cell in the solar cell module.

[0004] These and other features of the present disclosure will be readily apparent to persons of ordinary skill in the art upon reading the entirety of this disclosure, which includes the accompanying drawings and claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] A more complete understanding of the subject matter may be derived by referring to the detailed description and claims when considered in conjunction with the following figures, wherein like reference numbers refer to similar elements throughout the figures. The figures are not drawn to scale.

[0006] FIGS. 1-5 show cross-sections that schematically illustrate fabrication of a solar cell in accordance with an embodiment of the present disclosure.

[0007] FIGS. 6-9 show cross-sections that schematically illustrate fabrication of a solar cell module in accordance with an embodiment of the present disclosure.

[0008] FIGS. 10 and 11 show plan views of solar cells in a solar cell module being fabricated in accordance with an embodiment of the present disclosure.

[0009] FIG. 12 shows a flow diagram of a method of fabricating a solar cell module in accordance with an embodiment of the present disclosure.

DETAILED DESCRIPTION

[0010] The following detailed description is merely illustrative in nature and is not intended to limit the embodiments of the subject matter or the application and uses of such embodiments. As used herein, the word "exemplary" means "serving as an example, instance, or illustration." Any implementation described herein as exemplary is not necessarily to be construed as preferred or advantageous over other implementations. Furthermore, there is no intention to be bound by any expressed or implied theory presented in the preceding technical field, background, brief summary or the following detailed description.

[0011] This specification includes references to "one embodiment" or "an embodiment." The appearances of the phrases "in one embodiment" or "in an embodiment" do not necessarily refer to the same embodiment. Particular features, structures, or characteristics may be combined in any suitable manner consistent with this disclosure.

[0012] "First," "Second," etc. As used herein, these terms are used as labels for nouns that they precede, and do not imply any type of ordering (e.g., spatial, temporal, logical, etc.). For example, reference to a "first" via does not necessarily imply that this via is the first via in a sequence; instead the term "first" is used to differentiate this via from another via (e.g., a "second" via).

[0013] "Based On." As used herein, this term is used to describe one or more factors that affect a determination. This term does not foreclose additional factors that may affect a determination. That is, a determination may be solely based on those factors or based, at least in part, on those factors. Consider the phrase "determine A based on B." While B may be a factor that affects the determination of A, such a phrase does not foreclose the determination of A from also being based on C. In other instances, A may be determined based solely on B.

[0014] "Coupled" – The following description refers to elements or nodes or features being "coupled" together. As used herein, unless expressly stated otherwise, "coupled" means that one element/node/feature is directly or indirectly joined to (or directly or indirectly communicates with) another element/node/feature, and not necessarily mechanically.

[0015] FIGS. 1-5 show cross-sections that schematically illustrate fabrication of a solar cell in accordance with an embodiment of the present disclosure. In the example of FIGS. 1-5, the solar cell being fabricated is a thin epitaxial silicon all back contact solar cell, in that all the P-type and N-type doped regions of the solar cell and the metal contacts electrically connected to the P-type and N-type doped regions are on the backside of the solar cell. The substrate of the solar cell being fabricated is an epitaxial silicon layer, instead of a silicon wafer. A solar cell has a plurality of P-type and N-type doped regions but only some of the P-type and N-type doped regions are shown in the following examples. Additional P-type and N-type doped regions and other features of the solar cell are not shown for clarity of illustration.

[0016] Referring first to FIG. 1, a sacrificial silicon layer 102 is formed on a backside surface of a handle wafer 101. The handle wafer 101 may comprise pure silicon, doped, or compound silicon wafer. The handle wafer 101 facilitates handling of the solar cell during processing of device elements on the backside of the solar cell, such as P-type and N-type doped regions and metal contacts to the P-type and N-type doped regions. The handle wafer 101 is not the substrate of the solar cell and is separated from the solar cell in a subsequent release process.

[0017] The sacrificial layer 102 may comprise porous silicon, which is formed by exposing the backside surface of the handle wafer 101 in a hydrofluoric acid bath with bias. The sacrificial layer 102 may also comprise silicon with, for example, germanium doping and/or a carbon doping, either of which may be formed by epitaxial deposition or a chemical vapor deposition (CVD) process. The sacrificial layer 102 is relatively thin, e.g., on the order of approximately 700 micrometers, to facilitate subsequent release of the handle wafer 101 from the solar cell being fabricated. As can be appreciated, the thickness and composition of the sacrificial layer 102 may be varied depending on the particulars of the solar cell fabrication process. For example, the sacrificial layer 102 may be as thin as 10 micrometers in some embodiments.

[0018] The epitaxial silicon layer 103 may be grown directly on the backside surface of the sacrificial layer 102 by a kerfless epitaxial growth process. The epitaxial silicon layer 103 is also referred to as "thin silicon film" in that it is relatively thin compared to a silicon wafer. For example, the epitaxial silicon layer 103 may be grown to a thickness of 20μm to 150μm (e.g., 50 μm).

[0019] FIG. 2 shows the P-type and N-type doped regions (labeled as "P" and "N") formed on the backside (see arrow 112) of the solar cell being fabricated. The backside is opposite the front side (see arrow 113). The front side of the solar cell is also referred to as the "sun side" in that it is directed towards the sun during normal operation to collect solar radiation.

[0020] The P-type and N-type doped regions may be formed within or external to the epitaxial silicon layer 103. For example, the P-type and N-type doped regions may be formed by diffusing P-type and N-type dopants into the epitaxial silicon layer 103. As another example, the P-type and N-type doped regions may be formed in a polysilicon layer that that is formed on the backside surface of the epitaxial silicon layer 103. P-type and N-type dopants are then diffused into the polysilicon to form the P-type and N-type doped regions. The polysilicon may also be pre-doped with P-type and N-type dopants.

[0021] One or more dielectric layers 104 may be formed on the P-type and N-type doped regions. For example, a dielectric layer 104 serving as a backside anti-reflective coating (e.g., silicon nitride) may be formed on the P-type and N-type doped regions. Contact holes that expose the P-type and N-type doped regions are formed through the dielectric layer 104. Metal contacts 105 are formed in the contact holes to electrically connect to corresponding P-type and N-type doped regions. Metal pads (e.g., see FIGS. 6-11, pads 203), or other nodes that connect a plurality of metal contacts, may be formed during the metallization process that forms the metal contacts 105. The metal contacts 105 may be formed by plating, sputtering, printing, or other metallization process. The handle wafer 101 facilitates handling of the solar cell being fabricated during formation of the P-type and N-type doped regions, the dielectric layer 104, and the metal contacts 105.

[0022] FIG. 3 shows a carrier 107 attached on the backside of the solar cell. In the example of FIG. 3, a bonding agent 106 is applied on the backside of the solar cell, on the dielectric layer 104 and on the metal contacts 105. The carrier 107 is then pressed against the bonding agent 106, thereby bonding the carrier 107 to the backside of the

solar cell. The carrier 107 may comprise a structure that has sufficient rigidly and, in some embodiments, flatness, to support the solar cell during the subsequent release process. The carrier 107 may comprise an optically transparent dielectric material to allow for alignment (e.g., automated optical inspection (AOI) alignment) in a laser process to form vias through the carrier 107. For example, the carrier 107 may comprise polyimide that is about 1μm to 250 μm thick. The carrier 107 may also comprise organic materials (e.g., polyethylene terephthalate), composite materials with resin and fibers, inorganic materials (e.g., silicon carbide), etc. In embodiments where the carrier 107 comprises an opaque material, fiducial marks may be formed on the carrier 107 for alignment. Alignment may also be performed by aligning the edges of the carrier 107 or the epitaxial silicon layer 103. The carrier 107 may have an area that is slightly wider than that of the device portion of the solar cell (e.g., see FIG. 6). That is, the carrier 107 may have an area that extends past the perimeter of the device portion of the solar cell. It is to be noted that unlike an interlayer dielectric, the carrier 107 has no metal fingers on top of it. As shown in FIG. 3, the metal contacts 105, which may include the metal fingers of the solar cell, are between the carrier 107 and the doped regions.

[0023] FIG. 4 shows the handle wafer 101 being released from the rest of the solar cell being manufactured. In the example of FIG. 4, a mechanical or electro-chemical release process breaks the sacrificial layer 102 to separate the handle wafer 101 from the epitaxial silicon layer 103. The release process may partially of fully destroy the sacrificial layer 102 to release the handle wafer 101 from the epitaxial silicon layer 103. The release process may be a selective etch process, including wet etch processes, for example. The carrier 107 advantageously allows for handling of the solar cell and protects the backside of the solar cell, including the metal contacts 105, during the release process. The bonding agent 106 also provides additional protection to the metal contacts 105 during the release process and other subsequent processing, including during texturing of the front side of the solar cell.

[0024] Portions of the sacrificial layer 102 may remain on the surface of the epitaxial silicon layer 103 and/or the surface of the handle wafer 101 after the release process. Sacrificial layer 102 remaining on the handle wafer 101 may be re-used to grow another epitaxial silicon layer of another solar cell. In that case, the surface of the sacrificial layer 102 may be washed or cleaned prior to re-use. The sacrificial layer 102 may also

be dissolved entirely, requiring a new sacrificial layer to be formed on the handle wafer 101 for re-use.

[0025] FIG. 5 shows texturing of the front side surface of the solar cell to form a textured front side surface 108. The texturing process may form random pyramids on the surface of the epitaxial silicon layer 103, or on the surface of the sacrificial layer 102 in the case where the sacrificial layer 102 is not fully removed from the epitaxial silicon layer 103. The texturing process may comprise a wet or dry etch process, including buffered oxide etching (BOE) to create the textured front side surface 108. One etchant that may be used for the texturing process is potassium hydroxide, for example. The textured front side surface 108 may have a regular, repeating pattern, such as triangular or rectangular pyramids, or may have a randomly determined pattern.

[0026] The carrier 107 advantageously protects the backside of the solar cell (which includes the metal contacts 105) during the texturing process and other front side processing, including formation of passivation regions on the front side. In some embodiments, the texturing process may be performed at a temperature less than 400°C. Generally speaking, the texturing process is performed at a temperature that is compatible with the material of the carrier 107. For example, with a carrier 107 that comprises polyimide, the texturing process can be performed at a temperature that is less than or equal to approximately 200°C.

[0027] In FIG. 5, the fabricated solar cell, now referred to as "solar cell 200", comprises a device portion 201 and the carrier 107. The device portion 201 comprises the main electrical elements of the solar cell 200, including the epitaxial silicon layer 103, the P-type and N-type doped regions, and metal contacts 105. The carrier 107 remains on the backside of the solar cell 200, being bonded to the backside surface of the device portion 201. FIG. 5 schematically shows the solar cell 200 at the end of the solar cell fabrication process, which is also referred to as "cell level" manufacturing.

[0028] Although usable by itself, a solar cell is typically packaged with other solar cells in a solar cell module. At "module level" manufacturing, the solar cell is serially connected to other solar cells and enclosed in a protective package to protect the solar cells from environmental conditions. One problem with thin epitaxial silicon solar cells is that they are relatively difficult to handle, especially during metallization to electrically connect the solar cells together. As will be more apparent below, the carrier 107 not only protects and facilitates handling of the solar cell during manufacture at the

cell level, but also facilitates handling of the solar cell and electrical connection of the solar cell to other solar cells at the module level. In addition, the carrier 107 does not have to be removed from the device portion 201, advantageously eliminating a de-bonding step.

[0029] FIGS. 6-9 show cross-sections that schematically illustrate fabrication of a solar cell module in accordance with an embodiment of the present disclosure.

[0030] Referring to FIG. 6, an encapsulant 302 is placed on a transparent top cover 301 of the solar cell module being fabricated. In one embodiment, the transparent top cover 301 comprises glass. A plurality of solar cells 200 are placed on the encapsulant 302, with the front sides of the solar cells 200 contacting the encapsulant 302. The solar cells 200 are packaged with the encapsulant 202 and the transparent top cover 201 by, for example, laminating the solar cells 200, the encapsulant 202, and the transparent top cover 201 together. As deployed in the field, the solar cell module is oriented such that the transparent top cover 301 faces the sun to allow solar radiation to reach the front sides of the solar cells 200.

[0031] Each solar cell 200 comprises a device portion 201 with an attached carrier 107 as previously discussed. The P-type and N-type doped regions and other previously discussed features of a device portion 201 are not shown in FIGS. 6-9 for clarity of illustration. A solar cell module typically has a plurality of solar cells, but only two are shown in FIGS. 6-9 for clarity of illustration.

[0032] FIG. 6 also schematically shows the metal pads 203 (i.e., 203-1, 203-2) of each solar cell 200. A metal pad 203 provides a relatively large area that provides a common connection node for a plurality of doped regions of a solar cell 200. In one embodiment, the P-type doped regions of a solar cell 200 electrically connect to a metal pad 203-1 and the N-type doped regions of the solar cell 200 electrically connect to a metal pad 203-2. Electrically connecting a metal pad 203-2 of a solar cell 200 to a metal pad 203-1 of another solar cell 200 thus serially connects the two solar cells 200 together.

[0033] FIG. 7 shows vias 303 being formed through the carrier 107. A via 303 exposes a metal pad 203, thereby allowing electrical connection to the metal pad 203 and corresponding doped region of the solar cell 200. In one embodiment, the vias 303 are formed by a laser process. More particularly, a laser beam may be impinged on the carrier 107 to form a via 303. An optically transparent carrier 107 facilitates location of

the metal pads 203 (e.g., by AOI alignment) by the laser system employed to form the vias 303. A metal pad 203 may serve as a laser stop during formation of a via 303, thereby advantageously preventing laser damage to underlying structures.

[0034] FIG. 10 schematically shows a plan view of the solar cells 200 after the laser process to form the vias 303 through the carriers 107. As shown in FIG. 10, the vias 303 may be formed over corresponding metal pads 203 through the carrier 107. In the example of FIG. 10, each solar cell 200 has six vias 303, one for each of the metal pads 203. As can be appreciated, the number of vias and metal pads may be varied depending on the particulars of the solar cell.

[0035] As can be appreciated, instead of forming vias 303 at the module level, the vias 303 may also be incorporated into a carrier 107 at the cell level. That is, the carrier 107 may already have the vias 303 before being placed on the transparent top cover 301. For example, the carrier 107 may include the vias 303 as formed on the backside of the solar cell 200. More specifically, the carrier 107 may be printed (e.g., by screen printing) on the backside of the solar cell 200 to include the vias 303. In that example, the carrier 107 may comprise a printable organic, such as polyimide. After the carrier 107 with the vias 303 is printed on the backside of the solar cell 200, the solar cell 200 is placed on the encapsulant 302.

[0036] Continuing in FIG. 8, a metal connection 304 is formed to electrically connect one solar cell 200 to an adjacent solar cell 200 through the vias 303. In the example of FIG. 8, the metal connection 304 fills a via 303 of a first carrier 107 of a first solar cell 200 and a via 303 of a second carrier 107 of a second solar cell 200. The metal connection 304 extends between the vias 303 of the first and second carriers 107 to electrically connect a metal pad 203-2 of the first solar cell 200 to the metal pad 203-1 of the second solar cell 200. The metal connection 304 thus electrically connects the N-type doped region of the first solar cell 200 to the P-type doped region of the second solar cell 200 to electrically connect the first and second solar cells 200 in series.

[0037] In one embodiment, a metal connection 304 may be formed by filling the vias 303 with electrically conductive paste (e.g., silver paste). The conductive paste may be applied on the carriers 107 to fill up and connect the vias 303 of adjacent solar cells 200 to form a metal connection 304 in the same step. For example, the conductive paste may be printed (e.g., by screen printing) into the vias 303 and between the solar cells 200 to form the metal connection 304. Alternatively, the metal connection 304 may also

comprise a conductive tape that is applied and pressed into the vias 303 and between adjacent solar cells 200. In another embodiment, the vias 303 are filled by conductive paste or other metal in a first step and, in a second step, a conductive tape or metal interconnect is electrically connected to the filled vias 303 to form a metal connection 304 between adjacent solar cells 200. FIG. 11 schematically shows a plan view of the solar cells 200 after formation of the metal connections 304.

[0038] Continuing in FIG. 9, a rear cover 306 is attached to the backside of the solar cells 200. The rear cover 306 may comprise a roll tape or plastic sheet, among other examples, that provides bottom protection for the solar cell module.

[0039] FIG. 12 shows a flow diagram of a method of fabricating a solar cell module in accordance with an embodiment of the present disclosure. The method of FIG. 12 may, in some embodiments, include additional or fewer blocks than illustrated.

[0040] In the example of FIG. 12, a first carrier is attached to a first solar cell and a second carrier is attached to a second solar cell (step 401). The first and second carriers may comprise a transparent dielectric material. The first carrier may be attached to a backside of the first solar cell, and the second carrier may be attached to a backside of the second solar cell. Thereafter, the first and second solar cells are attached to a transparent top cover of a solar cell module with their respective carriers in place (step 402). For example, the front sides of the first and second solar cells may be placed on an encapsulant, which in turn is placed on the transparent top cover. The first and second solar cells, the encapsulant, and the transparent top cover are then packaged together by lamination, for example.

[0041] A first set of vias may be formed through the first carrier and a second set of vias may be formed through the second carrier (step 403). The first and second set of vias may be formed through the first and second carriers, respectively, after the first and second solar cells are attached to the transparent top cover of the solar cell module. The first and second set of vias may also be formed with their respective carriers before the first and second solar cells are attached to the transparent top cover. Each via may expose an underlying metal pad of the corresponding solar cell.

[0042] The first solar cell is serially connected to the second solar cell through the first and second set of vias (step 404). For example, each via may be filled with a conductive material, and filled vias of adjacent solar cells may be electrically connected.

The rear of the solar cell module may then be covered by a rear cover attached to the backsides of the solar cells (step 405).

[0043] Although specific embodiments have been described above, these embodiments are not intended to limit the scope of the present disclosure, even where only a single embodiment is described with respect to a particular feature. Examples of features provided in the disclosure are intended to be illustrative rather than restrictive unless stated otherwise. The above description is intended to cover such alternatives, modifications, and equivalents as would be apparent to a person skilled in the art having the benefit of this disclosure.

[0044] The scope of the present disclosure includes any feature or combination of features disclosed herein (either explicitly or implicitly), or any generalization thereof, whether or not it mitigates any or all of the problems addressed herein. Accordingly, new claims may be formulated during prosecution of this application (or an application claiming priority thereto) to any such combination of features. In particular, with reference to the appended claims, features from dependent claims may be combined with those of the independent claims and features from respective independent claims may be combined in any appropriate manner and not merely in the specific combinations enumerated in the appended claims.

CLAIMS

What is claimed is:

1. A method of fabricating a solar cell module, the method comprising:

attaching a first carrier to a first solar cell;

attaching a second carrier to a second solar cell;

attaching the first solar cell with the first carrier and the second solar cell with the second carrier to a top cover of a solar cell module;

forming a first set of vias through the first carrier and forming a second set of vias through the second carrier; and

connecting the first solar cell to the second solar cell through the first and second set of vias.

2. The method of claim 1, wherein connecting the first solar cell through the first and second set of vias comprises:

forming a metal connection between a first via in the first set of vias and a second via in the second set of vias.

3. The method of claim 2, wherein forming the metal connection between the first via in the first set of vias and the second via in the second set of vias comprises placing conductive paste in the first and second set of vias.

4. The method of claim 2, wherein forming the metal connection between the first via in the first set of vias and the second via in the second set of vias comprises applying a conductive tape to the first and second set of vias.

5. The method of claim 1, wherein attaching the first solar cell with the first carrier and the second solar cell with the second carrier to the top cover of the solar cell module comprises attaching the first and second solar cells to a glass top cover of the solar cell module.

6. The method of claim 1, further comprising:

after attaching the first carrier to the first solar cell but before attaching the first solar cell to the transparent top cover, texturing a front side surface of the solar cell.

7. The method of claim 1, wherein attaching the first solar cell with the first carrier and the second solar cell with the second carrier to the top cover of the solar cell module includes placing the first and second solar cells on an encapsulant that is on the top cover.

8. The method of claim 7, further comprising laminating the first and second solar cells, the encapsulant, and the top cover.

9. The method of claim 1, wherein forming the first set of vias through the first carrier comprises:

directing a laser on the first carrier.

10. The method of claim 1, further comprising:

before attaching the first carrier to the first solar cell, applying a bonding agent on a backside surface of the first solar cell;

wherein attaching the first carrier to the first solar cell includes bonding the first carrier to the backside surface of the first solar cell.

11. The method of claim 1,

wherein forming the first set of vias through the first carrier and forming the second set of vias through the second carrier is performed after attaching the first and second solar cells to the top cover of the solar cell module.

12. A solar cell module, comprising:

a first solar cell coupled to a first carrier that has a first set of vias;

a second solar cell coupled to a second carrier that has a second set of vias, the first and second solar cells being serially connected by a metal connection that electrically connects to a metal pad of the first solar cell through the first set of vias and to a metal pad of the second solar cell through the second set of vias; and

a transparent top cover, wherein the first and second solar cells are attached to the transparent top cover.

13. The solar cell module of claim 12, wherein the metal connection comprises a conductive tape.

14. The solar cell module of claim 12, wherein the metal connection comprises a conductive paste.

15. The solar cell module of claim 12, further comprising:

a cover on a rear of the solar cell module.

16. A method of fabricating a solar cell, the method comprising:

laminating a first solar cell and a second solar cell to a glass cover of a solar cell module;

after laminating the first and second solar cells to the glass cover, forming a first via through a first carrier of the first solar cell and a second via through a second carrier of the second solar cell; and

placing a conductive material in the first and second vias to electrically connect a metal pad of the first solar cell to a metal pad the second solar cell through the first and second vias.

17. The method of claim 16, wherein placing the conductive material in the first and second vias comprises placing conductive paste in the first and second vias.

18. The method of claim 16, wherein forming the first via through the first carrier of the first solar cell comprises impinging a laser beam on the first carrier.

19. The method of claim 16, further comprising:

before laminating the first solar cell and the second solar cell to the glass cover of the solar cell module, applying a bonding agent on a backside surface of the first solar cell: and

bonding the first carrier to the backside surface of the first solar cell.

20. The method of claim 19, further comprising:

removing a handle wafer from a front side surface of the first solar cell; and

while the first carrier is bonded to the backside surface of the first solar cell, texturing the front side surface of the first solar cell.

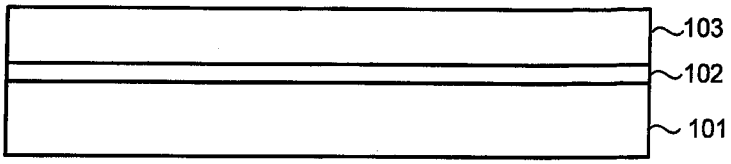

FIG. 1

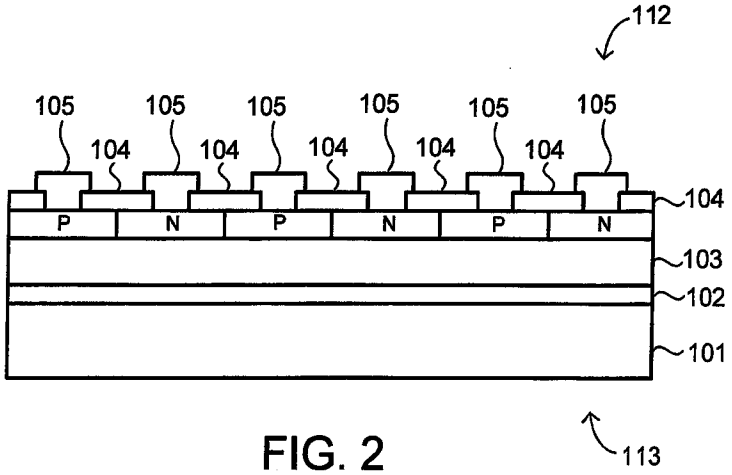

FIG. 2

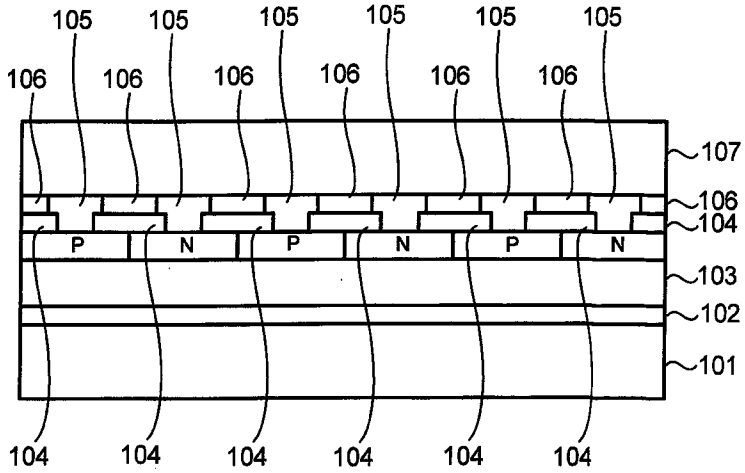

FIG. 3

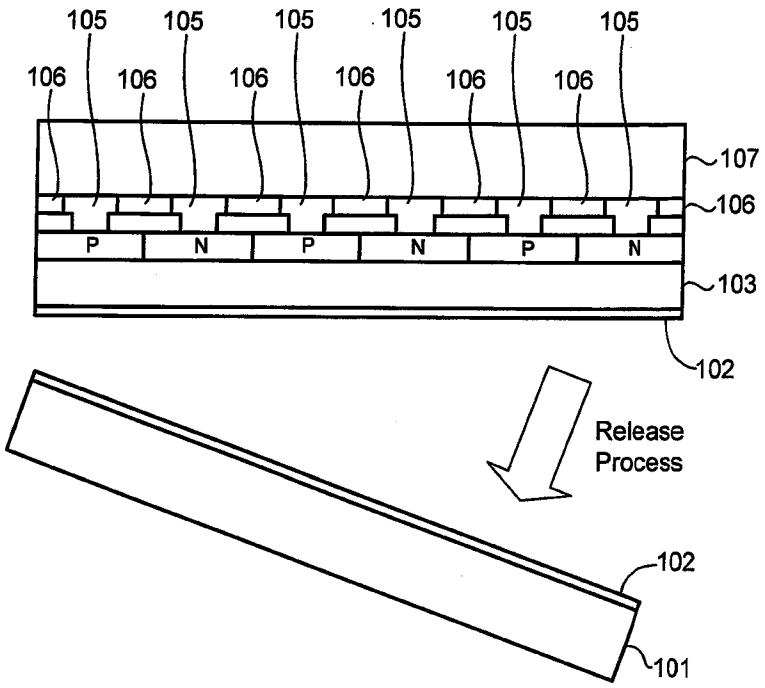
105
106
107
P
N
103
102
Release
Process
101

FIG. 4

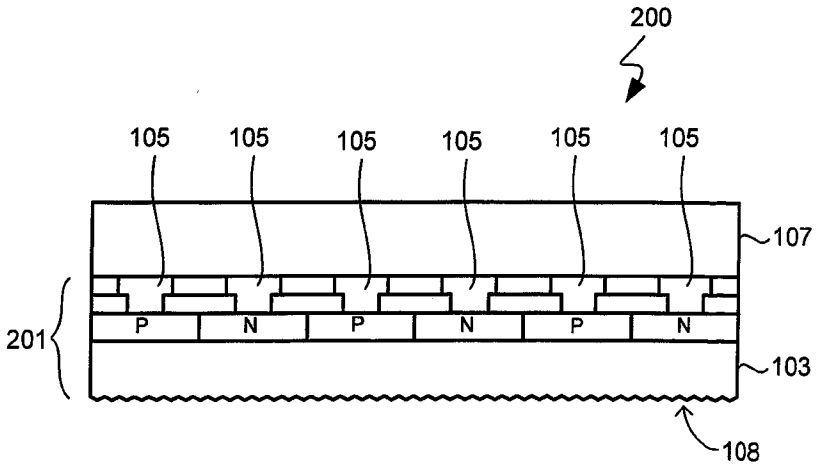
200
105
106
107
P
N
201
103
108

FIG. 5

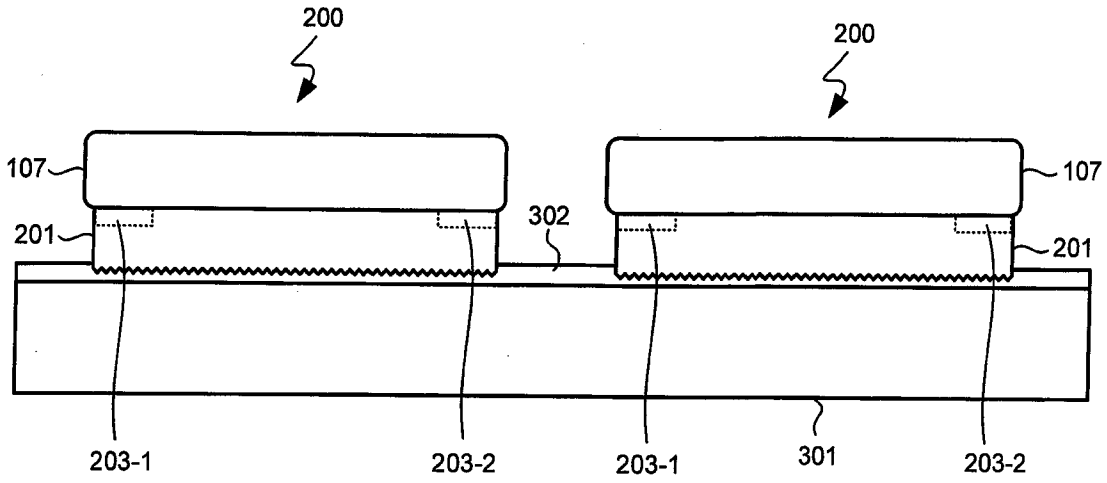
200
200
107
107
201
302
201
203-1
203-2
203-1
301
203-2

FIG. 6

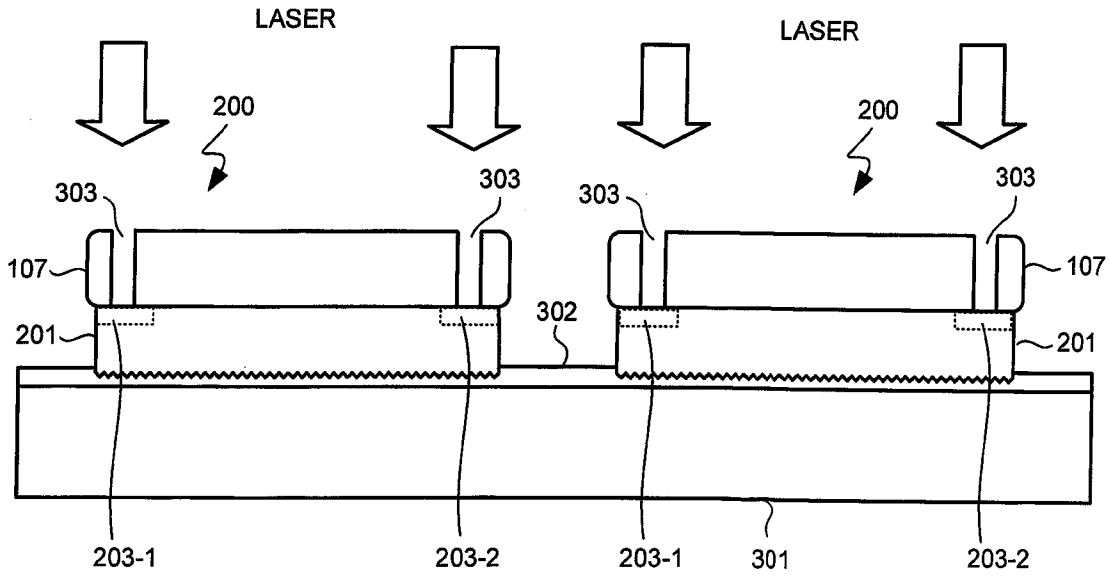
LASER
LASER
200
200
303
303
303
303
107
107
201
302
201
203-1
203-2
203-1
301
203-2

FIG. 7

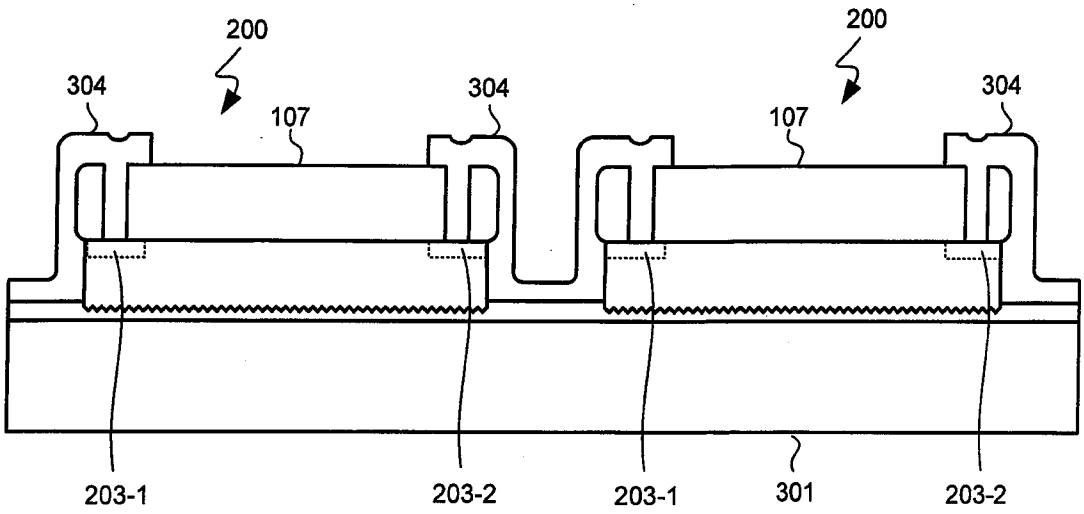
200
200
304
304
304
107
107
203-1
203-2
203-1
301
203-2

FIG. 8

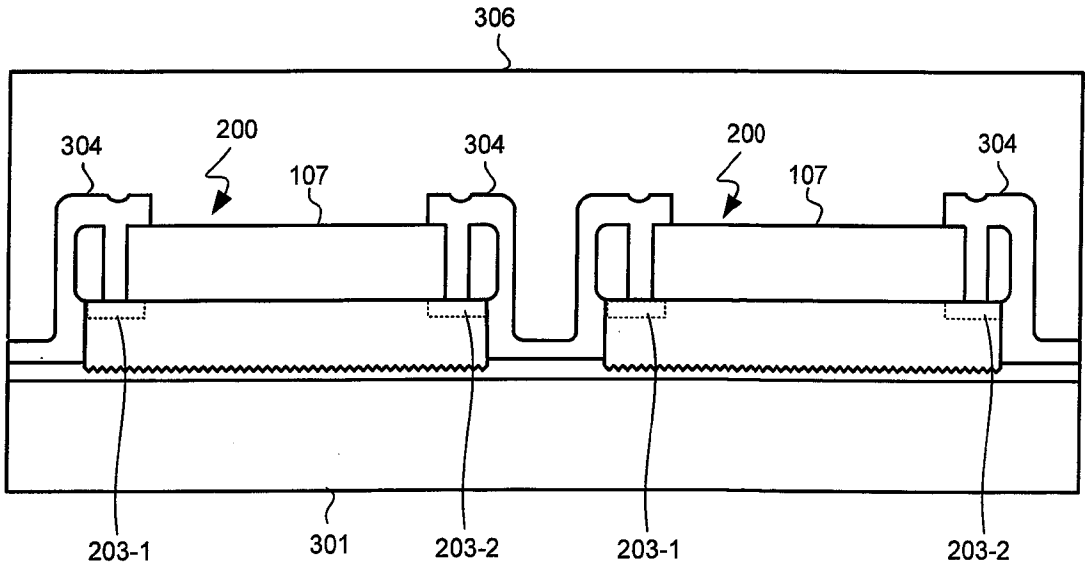
306
304
200
304
200
304
107
107
203-1
301
203-2
203-1
203-2

FIG. 9

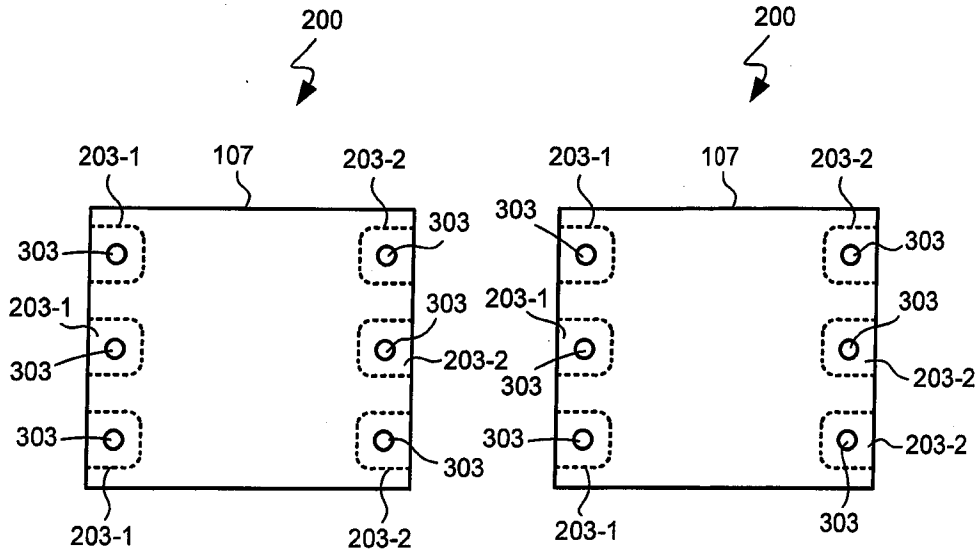
200
200
203-1
107
203-2
303
303
203-1
303
303
303
203-1
303
303
203-2
303
303
203-1
303
303
203-2
303
303
203-2
303
203-1
203-2
303

FIG. 10

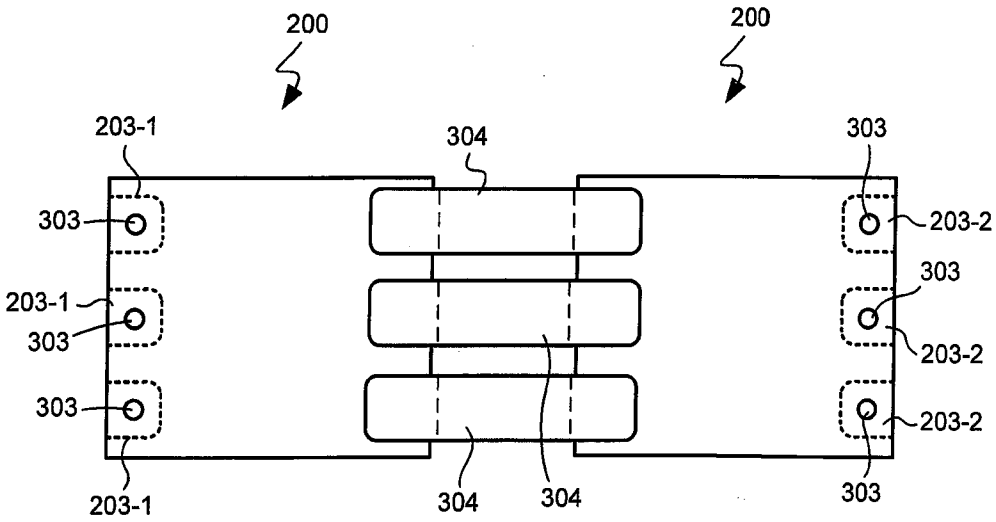
200
200
203-1
304
303
303
203-2
303
203-1
303
203-2
303
303
203-2
203-1
304
304
303

FIG. 11

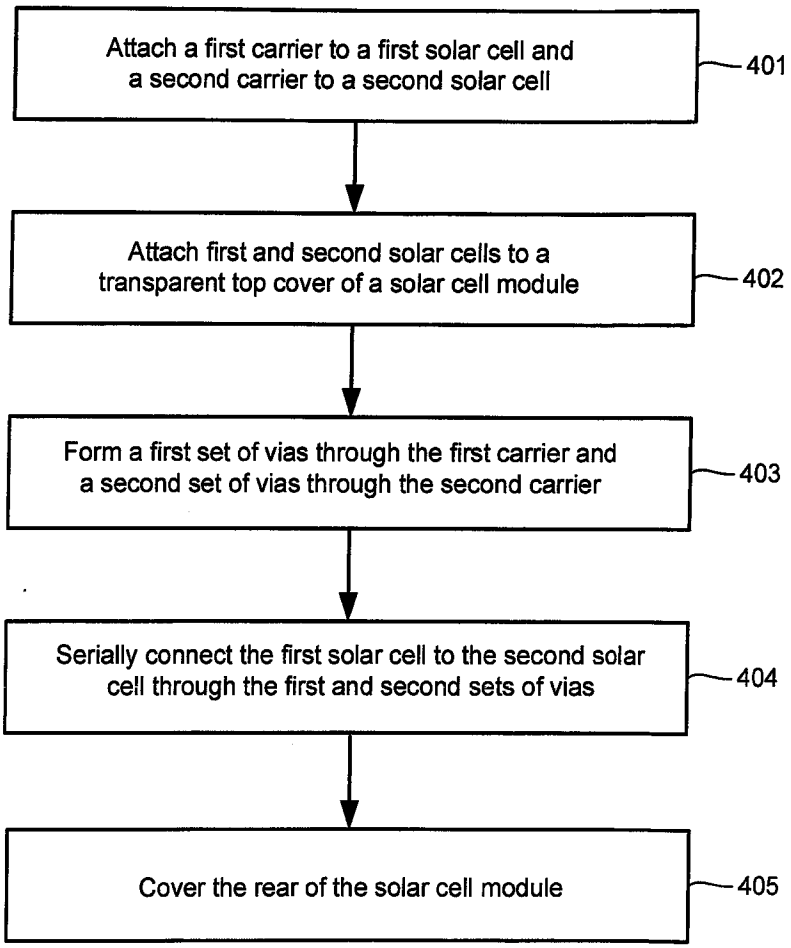
Attach a first carrier to a first solar cell and a second carrier to a second solar cell
401
Attach first and second solar cells to a transparent top cover of a solar cell module
402
Form a first set of vias through the first carrier and a second set of vias through the second carrier
403
Serially connect the first solar cell to the second solar cell through the first and second sets of vias
404
Cover the rear of the solar cell module
405

FIG. 12

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2014/050192

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - H01L 31/042 (2014.01)
CPC - H01L 31/042 (2014.09)
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC(8) - H01L 31/042, 31/00, 21/00 (2014.01)
USPC - 136/244, 251, 252, 256; 438/66, 67, 71

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
CPC - H01L 31/042, 31/05, 31/022425 (2014.09) (keyword delimited)

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2013/0160812 A1 (BORLAND et al) 27 June 2013 (27.06.2013) entire document	1-3, 5, 7-8, 11-12, 14-17
Y		4, 6, 9-10, 13, 18-20
Y	US 2011/0048506 A1 (PICHLER) 03 March 2011 (03.03.2011) entire document	4, 13
Y	US 2012/0298175 A1 (VAN ROOSMALEN et al) 29 November 2012 (29.11.2012) entire document	6
Y	US 2011/0139241 A1 (CLEMENT et al) 16 June 2011 (16.06.2011) entire document	9, 18
Y	US 2009/0162966 A1 (JAWARANI et al) 25 June 2009 (25.06.2009) entire document	10, 19-20
Y	US 2008/0179547 A1 (HENLEY) 31 July 2008 (31.07.2008) entire document	20
A	US 2010/0071743 A1 (YAMANAKA et al) 25 March 2010 (25.03.2010) entire document	1-20
A	US 2013/0160813 A1 (NATARAJAN et al) 27 June 2013 (27.06.2013) entire document	1-20

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

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s).or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
19 October 2014	18 NOV 2014

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

Form PCT/ISA/210 (second sheet) (July 2009)