



- (51) International Patent Classification:
H01L 31/05 (2014.01) *H02S 40/36* (2014.01)
- (21) International Application Number:
PCT/US2014/027471
- (22) International Filing Date:
14 March 2014 (14.03.2014)
- (25) Filing Language: English
- (26) Publication Language: English
- (30) Priority Data:
61/794,893 15 March 2013 (15.03.2013) US
- (71) Applicant: **FIRST SOLAR, INC.** [US/US]; A Corporation In The State of Delaware, 28101 Cedar Park Boulevard, Perrysburg, OH 43551 (US).
- (72) Inventors; and
- (71) Applicants : **JANSEN, Scott** [US/US]; 819 Wood Sorrel, Perrysburg, OH 43551 (US). **POWELL, Rick** [US/US]; 4497 Boulder Pond Drive, Ann Arbor, MI 48108 (US). **ROUSSILLON, Yann** [US/US]; 4140 Hollister Lane, Perrysburg, OH 43551 (US). **WICKERSHAM, Charles** [US/US]; 26609 Amberwood Drive, Perrysburg, OH 43551 (US).
- (74) Agent: **DOCKINS, Michael E.**; Fraser Clemens Martin & Miller LLC, 28366 Kensington Lane, Perrysburg, OH 43551 (US).

(81) Designated States (*unless otherwise indicated, for every kind of national protection available*): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

- with international search report (Art. 21(3))
- before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))

(54) Title: PHOTOVOLTAIC DEVICE INTERCONNECTION AND METHOD OF MANUFACTURING

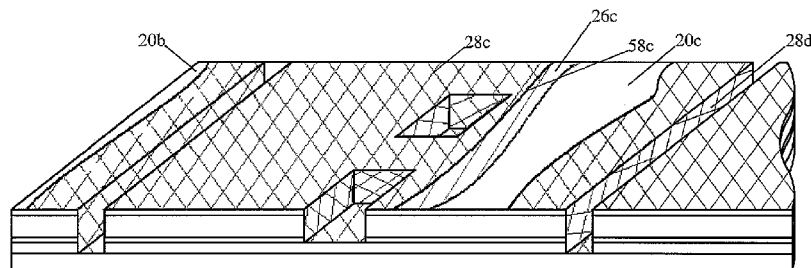


Fig. 11a

(57) Abstract: A photovoltaic device includes a substrate and has a transparent conductive oxide layer, a conductive back layer, and at least one intermediate semiconductor layer formed thereon. An isolation scribe divides and electrically isolates the oxide layer, the back layer and the semiconductor layer to define two photovoltaic cells. A conductor extends across the isolation scribe and connects the back layer of one photovoltaic cell to the oxide layer of the other photovoltaic cell.



TITLE

PHOTOVOLTAIC DEVICE INTERCONNECTION AND METHOD OF
MANUFACTURING

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims the benefit of priority of United States Provisional Patent Application Serial No. 61/794,893 filed on March 15, 2013 hereby incorporated herein by reference in its entirety.

BACKGROUND OF THE INVENTION

[0002] This invention relates in general to a photovoltaic module. Thin film photovoltaic modules are formed by the deposition of multiple semiconductor or organic thin films on rigid or flexible substrates or superstrates. Electrical contact to the solar cell material on the substrate side is provided by an electrically conductive substrate material or an additional electrically conductive layer between the solar cell material and the substrate such as a transparent conductive layer.

[0003] Photovoltaic modules typically comprise submodules connected in parallel. Each submodule comprises multiple photovoltaic cells, typically connected in series. It would be desirable to have an improved photovoltaic module.

SUMMARY OF THE INVENTION

[0004] Concordant and congruous with the present invention, an improved photovoltaic module has surprising been discovered.

[0005] In one embodiment, a photovoltaic device comprises a substrate having a transparent conductive oxide layer, a conductive back contact layer, and a semiconductor layer formed thereon; an isolation scribe formed through the transparent conductive oxide layer, the conductive back contact layer, and the semiconductor layer to define a first photovoltaic cell and a second photovoltaic cell, the isolation scribe electrically isolating the first photovoltaic cell from the second photovoltaic cell; and an interconnection scribe formed by a series of discontinuous

ablations of the back contact layer and the semiconductor layer of the second photovoltaic cell, the interconnection scribe facilitating a series connection between the first photovoltaic cell and the second photovoltaic cell, the discontinuous ablations separated by non-scribed layers of the photovoltaic cell.

[0006] In another embodiment, a photovoltaic device comprises a plurality of photovoltaic cells formed on a substrate, each of the photovoltaic cells comprising a transparent conductive oxide layer, a conductive back contact layer, and a semiconductor layer formed thereon; a plurality of isolation scribes electrically isolating each of the photovoltaic cells from an adjacent photovoltaic cell, each isolation scribe formed through the transparent conductive oxide layer, the conductive back contact layer, and the semiconductor layer of each photovoltaic cell; an interconnection scribe within each of the plurality of photovoltaic cells, each interconnection scribe formed by a series of discontinuous ablations of the back contact layer and the semiconductor layer of each photovoltaic cell, the interconnection scribe facilitating a series connection between the first photovoltaic cell and the second photovoltaic cell; and a dielectric material disposed within each of the plurality of isolation scribes, contacting at least a portion of the back contact layer of each of the plurality of photovoltaic cells, and contacting at least a portion of the interconnection scribe of each of the plurality of photovoltaic cells.

[0007] In another embodiment, a method for manufacturing a photovoltaic device comprises forming a plurality of isolation scribes in a photovoltaic device through a transparent conductive oxide layer, a semiconductor layer, and a back contact layer of disposed upon a substrate to define an array of photovoltaic cells on the photovoltaic device; and forming discontinuous interconnection scribes through the semiconductor layer and the back contact layer of each of the photovoltaic cells, each of the discontinuous scribes separated by non-scribed layers of each cell.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] Fig. 1 is a perspective view of a photovoltaic device.

[0009] Fig. 2 is a schematic, side view taken along the cut line 2-2 of Fig. 1, showing a photovoltaic cell.

- [0010]** Fig. 3 is a schematic, side view taken along the cut line 3-3 of Fig. 1, showing a photovoltaic cell including a bus bar.
- [0011]** Fig. 4 is a schematic, side view taken along the cut line 4-4 of Fig. 1, showing a photovoltaic cell including a second bus bar.
- [0012]** Fig. 5 is a flow chart of one method to manufacture the photovoltaic device shown in Fig. 1.
- [0013]** Fig. 6a is a perspective view of a portion of the photovoltaic device before any scribes have been cut.
- [0014]** Fig. 6b is a schematic, side view of the photovoltaic device shown in Fig. 6a.
- [0015]** Fig. 7a is a perspective view of a portion of the photovoltaic device shown in Fig. 6a after isolation scribes have been cut.
- [0016]** Fig. 7b is a schematic, side view of the photovoltaic device shown in Fig. 7a.
- [0017]** Fig. 8a is a perspective view of a portion of the photovoltaic device shown in Fig. 7a after interconnection scribes have been cut in the photovoltaic device.
- [0018]** Fig. 8b is a schematic, side view of the photovoltaic device shown in Fig. 8a.
- [0019]** Fig. 9a is a perspective view of a portion of the photovoltaic device shown in Fig. 8a after a dielectric material has been added to cover portions of the photovoltaic device.
- [0020]** Fig. 9b is a schematic, side view of the photovoltaic device shown in Fig. 9a.
- [0021]** Fig. 10a is a perspective view of a portion of the photovoltaic device shown in Fig. 9a after portions of the dielectric material have been removed.
- [0022]** Fig. 10b is a schematic, side view of the photovoltaic device shown in Fig. 10a.
- [0023]** Fig. 11a is a perspective view of a portion of the photovoltaic device shown in Fig. 10a after a metallic interconnection material has been added to portions of the photovoltaic device.

[0024] Fig. 11b is a schematic, side view of the photovoltaic device shown in Fig. 11a.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0025] Referring now to the drawings, there is illustrated in Fig. 1 a perspective view of a photovoltaic device, indicated generally at 10. The photovoltaic device 10 includes a plurality of photovoltaic cells, 12a, 12b, 12c, etc. The illustrated photovoltaic cells 12a, 12b, 12c, etc. are not shown to scale, and are provided for purposes of explanation of the features of the photovoltaic device 10. The photovoltaic device 10 may have a different number of photovoltaic cells from that illustrated. Each photovoltaic cell is electrically connected to at least one adjacent photovoltaic cell, as will be described below. Furthermore as will be described herein, each cell of the device 10 will include one or more layers of material. Each layer can cover all or a portion of the device 10 and/or all or a portion of a layer or a substrate underlying the layer. For example, a “layer” can include any amount of any material that contacts all or a portion of a surface. Furthermore, layers herein may be described generally by a numeral (e.g., 18) or individually for a particular cell by a numeral and a character (e.g., 18c). It is understood that disclosure with respect to a particular layer for a particular cell may apply in similar fashion to layers of other cells or of the layer generally, except where noted otherwise.

[0026] Referring to Fig. 2, a side view of a portion of the photovoltaic device 10, taken along the cut line 2-2 of Fig. 1 is shown. The photovoltaic device 10 includes a transparent substrate 14. The transparent substrate 14 is formed of a material that provides rigid support, light transmission, chemical stability and typically includes one of a float glass, soda lime glass, polymer, or other suitable material. The photovoltaic device 10 includes a transparent conductive oxide (TCO) layer 16. The transparent conductive oxide layer 16 is formed of a material that provides low resistance electrical conduction, chemical and dimensional stability and typically includes one of a tin oxide, zinc oxide, cadmium stannate, combinations or doped variations thereof, or any other suitable material. The photovoltaic device 10 includes a semiconductor layer 18. The semiconductor layer 18 is formed of a photoactive

material or combination of materials. Typically, the semiconductor layer 18 includes one or more n-type and/or one or more p-type semiconductors to form a p-n junction. In one embodiment, the semiconductor layer 18 is a semiconductor bi-layer including an n-type cadmium sulfide and a p-type cadmium telluride, however other compounds and materials may be used, including silicon based semiconductors, copper indium gallium selenide, and other suitable materials. The photovoltaic device 10 includes a back contact layer 20. The back contact layer 20 is an electrically conductive material, typically selected from among silver, nickel, copper, aluminum, titanium, palladium, chromium, molybdenum, gold, and combinations thereof.

[0027] As previously described in reference to Fig. 1, the photovoltaic device 10 is divided into a plurality of photovoltaic cells 12a, 12b, 12c, etc. Adjacent photovoltaic cells are separated by isolation scribes 22a, 22b, 22c, etc., which electrically isolate each photovoltaic cell from the one or more adjacent photovoltaic cells. For example, in reference to Fig. 2, the photovoltaic cell 12c is isolated from the photovoltaic cell 12b by the isolation scribe 22b, and is isolated from the photovoltaic cell 12d by the isolation scribe 22c. The isolation scribes 22a, 22b, 22c, etc. divide the several layers of the photovoltaic device 10 into separate cells, and so the photovoltaic cell 12c includes a cell transparent conductive oxide layer 16c, a cell semiconductor layer 18c, and a cell back contact layer 20c. These layers are isolated from the similar layers of adjacent photovoltaic cells 12b and 12d by the isolations scribes 22b and 22c.

[0028] The photovoltaic cell 12c includes an interconnection scribe 24c. The interconnection scribe 24c is an opening through a portion of the back contact layer 20 and the semiconductor layer 18. A dielectric material 26c is disposed within the isolation scribe 22b. The dielectric material 26c also covers a portion of the back contact layer 20b of the photovoltaic cell 12b, a portion of the back contact layer 20c of the photovoltaic cell 12c, and a portion of the interconnection scribe 24c of the photovoltaic cell 12c.

[0029] The photovoltaic device 10 includes a metallic interconnection material 28c that is disposed in electrical contact with a portion of the transparent conductive oxide material 16c of the photovoltaic cell 12c, and in electrical contact with a portion of the back contact layer 20b of the adjacent photovoltaic cell 12b. The metallic

interconnection material 28 may include titanium, aluminum, nickel, chromium, tantalum, copper, tungsten, titanium nitride, tantalum nitride, tungsten nitride and various compounds and combinations thereof. One example embodiment of photovoltaic cell 12 may include a back contact layer 20 comprising a compound of molybdenum, nickel, aluminum and a metallic interconnection layer 28 comprising a compound of titanium and aluminum. Alternatively, a second exemplary embodiment may include a back contact layer 20 comprising a compound of molybdenum, nickel, aluminum, and chromium, and a metallic interconnection layer 28 comprising a compound of tungsten and copper. This forms a series connection between the photovoltaic cell 12c and the adjacent photovoltaic cell 12b. As shown in Fig. 8a, the interconnection scribe 24c is a series of discrete (also referred to as discontinuous) scribes that are separated by non-scribed space 30c, the non-scribed space 30c including the various layers of the cell 12c. Therefore, the back contact layer 20c of the photovoltaic cell 12c extends from a first side of the interconnection scribe 24c to a second side of the interconnection scribe 24c and provides a conductive pathway across the full width of the photovoltaic cell 12c. Referring back to Fig. 2, an electrical current flow path is shown by the dashed line 32.

[0030] Although photovoltaic cell 12c and its connection to adjacent photovoltaic cell 12b has been described in detail, it should be appreciated that all the photovoltaic cells in the photovoltaic device 10 may be similarly connected to the adjacent photovoltaic cells. The other photovoltaic cells will not be described in detail, with the exception of a photovoltaic cell 12h and a photovoltaic cell 12i.

[0031] Referring to Fig. 3, side, schematic view of the photovoltaic cell 12h is shown. The photovoltaic cell 12h includes many features similar to the previously described photovoltaic cell 12c, and similar features are identified with similar numbers with the suffix letter "h." The photovoltaic cell 12h includes a bus bar 34 that is in electrical contact with a front contact layer 16h. The configuration of the photovoltaic cell 12h is such that the space below the bus bar 34 is photovoltaically active, and is not dead space. The bus bar 34, along with other bus bars in the module, provide electrically accessible features within the photovoltaic module to engage with other integration components (not shown), including conductive tapes and foils which

may pass through an edge encapsulant, back cover glass or other module enclosure to facilitate the interconnection of multiple modules, the connection of the module to an electrical load, grid, array, or otherwise.

[0032] Referring to Fig. 4, a side, schematic view of the photovoltaic cell 12j is shown. The photovoltaic cell 12j includes many features similar to the previously described photovoltaic cell 12c, and similar features are identified with similar numbers with the suffix letter "j." The photovoltaic cell 12j includes a bus bar 36 that is in electrical contact with a back contact layer 20j. The configuration of the photovoltaic cell 12j is such that the space below the bus bar 36 is photovoltaically active, and is not dead space. The bus bar 36 creates an electrical circuit with the bus bar 34 in the photovoltaic cell 12h.

[0033] It should be appreciated that the photovoltaic device 10 may include the bus bar 34 at one end, and the bus bar 36 at the opposite end, placing all the photovoltaic cells in the photovoltaic device 10 in series. Alternatively, the photovoltaic device 10 may include two matching bus bars similar to one of bus bar 34 and bus bar 36 at each end of the photovoltaic device, and a single bus bar similar to the other of bus bar 36 and bus bar 34 in the center of the photovoltaic device. In that case, the photovoltaic device 10 would include two submodules, and the center bus bar would be connected to two series of photovoltaic cells, extending to each edge of the photovoltaic device. It should be appreciated that the center bus bar would include a mirror image, taken through the center line of the bus bar, of the configuration shown in one of Fig. 3 and Fig. 4. Additionally, it should be appreciated that the photovoltaic device 10 may be divided into more than two submodules, if desired, with the appropriate number and placement of bus bars.

[0034] Referring now to Fig. 5, a flow chart of a method for manufacturing the photovoltaic device 10 is shown generally at 38. The steps of the method shown in Fig. 5 are best understood in further reference to Figs. 6a and 6b through 11a and 11b.

[0035] Step 40 is the application of the transparent conductive oxide layer 16 to the transparent substrate 14. Processes to apply the transparent conductive oxide layer 16 to the transparent substrate 14 are known in the art, and will not be detailed here. The transparent conductive oxide layer 16 is applied across the full surface of the

transparent substrate 14. Step 42 is the application of the semiconductor layer 18. Processes to apply the semiconductor layer 18 are known in the art, and will not be detailed here. The semiconductor layer 18 is applied across the full surface of the transparent conductive oxide layer 16. Step 44 is the application of the back contact layer 20. Processes to apply the back contact layer 20 are known in the art, and will not be detailed here. The back contact layer 20 is applied across the full surface of the semiconductor layer 18. The back contact layer 20 may be sealed with, for example, chromium. At this point, the photovoltaic device 10 is in the condition shown in Figs. 6a and 6b. It should be appreciated that the back contact layer 20, by covering the full surface of the semiconductor layer 18, provides protection against undesirable oxidation, contamination or deterioration of the semiconductor layer 18. As a result, the photovoltaic device 10 may be brought through step 44, and then moved to a different facility where additional steps may be performed, without degradation of the materials of photovoltaic device.

[0036] At step 46 the isolation scribes 22a, 22b, 22c, etc. are cut into the photovoltaic device 10. The disposition of the photovoltaic device 10 after step 46 is shown in Figs. 7a and 7b. The isolation scribes 22a, 22b, 22c, etc. are cut using a laser that ablates the transparent conductive oxide layer 16, the semiconductor layer 18, and the back contact layer 20 without affecting the transparent substrate 14.

[0037] At step 48 interconnection scribes 24a, 24b, 24c, etc. are cut into the photovoltaic device 10. The disposition of the photovoltaic device 10 after step 48 is shown in Figs. 8a and 8b. The interconnection scribes 24a, 24b, 24c, etc. are cut using a laser that ablates the semiconductor layer 18 and the back contact layer 20 without affecting the transparent substrate 14 and the transparent conductive oxide layer 16. The interconnection scribes 24a, 24b, 24c, etc. may comprise a series of discontinuous ablations of material between two isolation scribes (as shown in Fig. 8a), for example isolation scribes 22b and 22c, or alternatively, between an isolation scribe and an end edge of the photovoltaic device, for example isolation scribe 22a. The discontinuous ablations of the interconnection scribes 24a, 24b, 24c, etc. may result in a series of substantially circular dots or short rectilinear scribes (not shown) or the discontinuous ablation may result in a dashed line scribe, as best shown in Fig. 8a.

[0038] At step 50 dielectric material 26a, 26b, 26c, etc. is applied to the photovoltaic device 10. The disposition of the photovoltaic device 10 after step 50 is shown in Figs. 9a and 9b. The dielectric material 26a, 26b, 26c, etc. is applied using an ink jet printing process, though any other desired process suitable to apply the dielectric material 26a, 26b, 26c, etc. may be used.

[0039] At step 52 at least a portion of the dielectric material 26a, 26b, 26c, etc. in contact with the transparent conductive oxide layer 16 within the interconnection scribe 24a, 24b, 24c, etc. is removed. The disposition of the photovoltaic device 10 after step 52 is shown in Figs. 10a and 10b. The dielectric material 26a, 26b, 26c, etc. is removed using a laser that ablates the dielectric material 26a, 26b, 26c, etc. without damaging the transparent substrate 14 and the transparent conductive oxide layer 16.

[0040] At step 54, metallic interconnection material 28a, 28b, 28c, etc. is applied to the photovoltaic device. The disposition of the photovoltaic device 10 after step 54 is shown in Figs. 11a and 11b. The metallic interconnection material 28a, 28b, 28c, etc. is applied using an ink jet printing process, though any other desired process suitable to apply the material may be used. The metallic interconnection material 28a, 28b, 28c, etc., may be deposited over the entirety of the photovoltaic device's exposed surface, or alternatively may be selectively deposited within certain regions and not others. For example, as shown in Figs. 11a and 11b, the metallic interconnection material 28a, 28b, 28c, etc. may be selectively deposited to overlap slightly onto the back contact layer 20a, 20b, 20c, etc. of the photovoltaic cell adjacent to photovoltaic cell 12c and continuously over dielectric material 26c to the interconnection scribe 24c.

[0041] At optional step 56, an edge 58a, 58b, 58c, etc. is created on the metallic interconnection material 28a, 28b, 28c, etc. The disposition of the photovoltaic device 10 after step 56 is shown in Figs. 11a and 11b. In the situation where the metallic interconnection material 28a, 28b, 28c, etc. is deposited over the entirety of the photovoltaic device's exposed surface, the edge 58a, 58b, 58c, etc. is created to prevent electrical connection between, for example, metallic interconnection material 28c and back contact layer 20c, since such contact would create a short circuit that would allow current flow to bypass photovoltaic cell 12c. The edge 58a, 58b, 58c,

etc. may be created by acid etch, mechanical removal (abrasion), laser ablating, or any other desired method.

[0042] The described method for manufacturing 38 may be performed on an automated assembly line using known techniques. The isolation scribes and interconnection scribes may be cut or ablated using lasers. Multiple laser sources may be used in the method of manufacturing 38. Alternatively, light from a single laser source may be manipulated using known optics techniques in order to cut various scribes, either simultaneously or sequentially.

[0043] The principle and mode of operation of this invention have been explained and illustrated in its preferred embodiment. However, it must be understood that this invention may be practiced otherwise than as specifically explained and illustrated without departing from its spirit or scope.

What is claimed is:

1. A photovoltaic device comprising:
 - a substrate having a transparent conductive oxide layer, a conductive back contact layer, and a semiconductor layer formed thereon;
 - an isolation scribe formed through the transparent conductive oxide layer, the conductive back contact layer, and the semiconductor layer to define a first photovoltaic cell and a second photovoltaic cell, the isolation scribe electrically isolating the first photovoltaic cell from the second photovoltaic cell; and
 - an interconnection scribe formed by a series of discontinuous openings of the back contact layer and the semiconductor layer of the second photovoltaic cell, the interconnection scribe facilitating a series connection between the first photovoltaic cell and the second photovoltaic cell, the discontinuous openings separated by non-scribed layers of the photovoltaic cell.
2. The photovoltaic device of Claim 1, further comprising a metallic interconnection material providing electrical communication between the conductive back contact layer of the first photovoltaic cell and the transparent conductive oxide layer of the second photovoltaic cell exposed by the interconnection scribe.
3. The photovoltaic device of Claim 2, wherein the metallic interconnection material is one of titanium, aluminum, nickel, chromium, tantalum, copper, tungsten, titanium nitride, tantalum nitride, tungsten nitride, and a combination of at least two of the foregoing.
4. The photovoltaic device of Claim 2, wherein the metallic interconnection material is disposed on a dielectric material that fills the isolation scribe.
5. The photovoltaic device of Claim 1, wherein the interconnection scribe is one of a series of substantially circular dots, a series of short rectilinear scribes, and a dashed line scribe.

6. The photovoltaic device of Claim 1, further comprising a dielectric material filling the isolation scribe.

7. The photovoltaic device of Claim 1, the dielectric material covering at least a portion of the back contact layer between the isolation scribe and the interconnection scribe and in contact with the interconnection scribe.

8. The photovoltaic device of Claim 1, wherein the transparent conductive oxide is one of tin oxide, zinc oxide, cadmium stannate, combinations of the foregoing, and doped variations of the foregoing.

9. The photovoltaic device of Claim 1, wherein the semiconductor layer includes an n-type semiconductor and a p-type semiconductor.

10. The photovoltaic device of Claim 9, wherein the n-type semiconductor is cadmium sulfide and the p-type semiconductor is cadmium telluride.

11. A photovoltaic device comprising:

a plurality of photovoltaic cells formed on a substrate, each of the photovoltaic cells comprising a transparent conductive oxide layer, a conductive back contact layer, and a semiconductor layer formed thereon;

a plurality of isolation scribes electrically isolating each of the photovoltaic cells from an adjacent photovoltaic cell, each isolation scribe formed through the transparent conductive oxide layer, the conductive back contact layer, and the semiconductor layer of each photovoltaic cell;

an interconnection scribe within each of the plurality of photovoltaic cells, each interconnection scribe formed by a series of discontinuous openings of the back contact layer and the semiconductor layer of each photovoltaic cell, the interconnection scribe facilitating a series connection between the first photovoltaic cell and the second photovoltaic cell; and

a dielectric material disposed within each of the plurality of isolation scribes, contacting at least a portion of the back contact layer of each of the plurality of photovoltaic cells, and contacting at least a portion of the interconnection scribe of each of the plurality of photovoltaic cells.

12. The photovoltaic device of Claim 11, further comprising a metallic interconnection material disposed over at least a portion of the dielectric material of each of the plurality of photovoltaic cells and providing electrical communication between the conductive back contact layer of one of the photovoltaic cells and the transparent conductive oxide layer of an adjacent cell of the plurality of photovoltaic cells exposed by the interconnection scribe of the adjacent cell of the plurality of photovoltaic cells.

13. The photovoltaic device of Claim 12, wherein the metallic interconnection material is disposed on the dielectric material.

14. The photovoltaic device of Claim 11, wherein the interconnection scribe is one of a series of substantially circular dots, a series of short rectilinear scribes, and a dashed line scribe.

15. A method for manufacturing a photovoltaic device comprising:

forming a plurality of isolation scribes in a photovoltaic device through a transparent conductive oxide layer, a semiconductor layer, and a back contact layer of disposed upon a substrate to define an array of photovoltaic cells on the photovoltaic device; and

forming discontinuous interconnection scribes through the semiconductor layer and the back contact layer of each of the photovoltaic cells, each of the discontinuous scribes separated by non-scribed layers of each cell.

16. The method of Claim 15, further comprising a step of depositing a dielectric material into the plurality of isolation scribes, wherein at least a portion of the dielectric material is disposed on at least a portion of the back contact layer of one of the photovoltaic cells, a portion of the back contact layer of a another of the photovoltaic cells adjacent to the one of the photovoltaic cells, and at least a portion of the interconnection scribe of the one of the photovoltaic cells.

17. The method of Claim 16, further comprising a step of removing a portion of the dielectric material in the interconnection scribe to expose a portion of the transparent conductive oxide.

18. The method of Claim 16, further comprising a step of depositing a metallic interconnection layer at least partially covering the dielectric material and in contact with the transparent conductive oxide of the one of the photovoltaic cells and the back contact layer of the another of the photovoltaic cells to provide a series electrical connection between the one of the photovoltaic cells and the another of the photovoltaic cells.

19. The method of Claim 16, wherein the dielectric material is deposited using an ink jet printing process.

20. The method of Claim 15, wherein each of the discontinuous interconnection scribes is one of a series of substantially circular dots, a series of short rectilinear scribes, and a dashed line scribe.

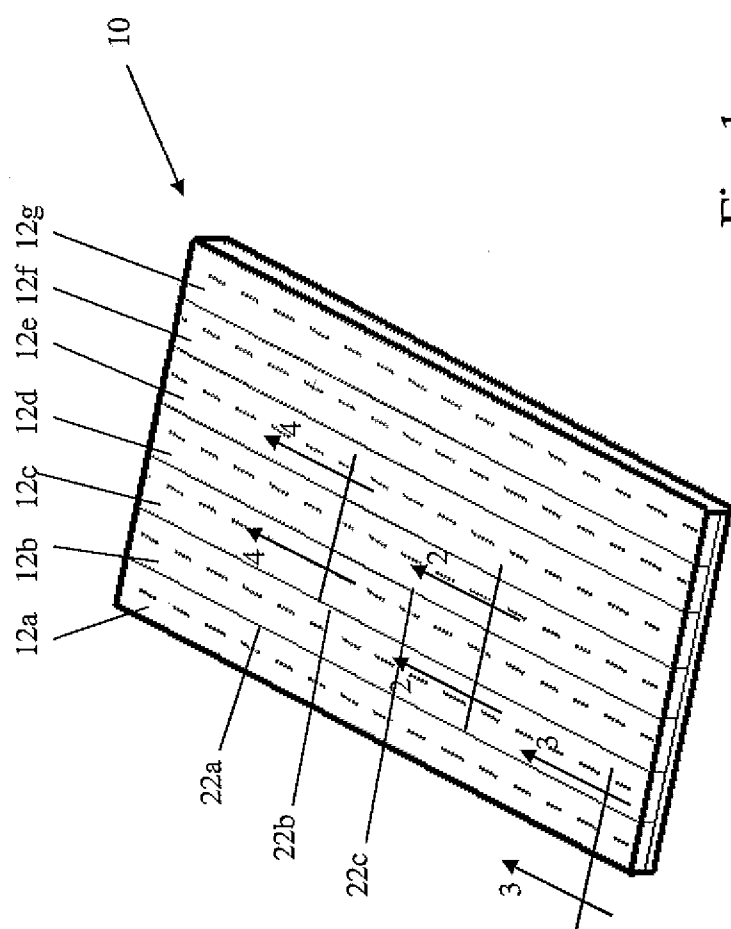


Fig. 1

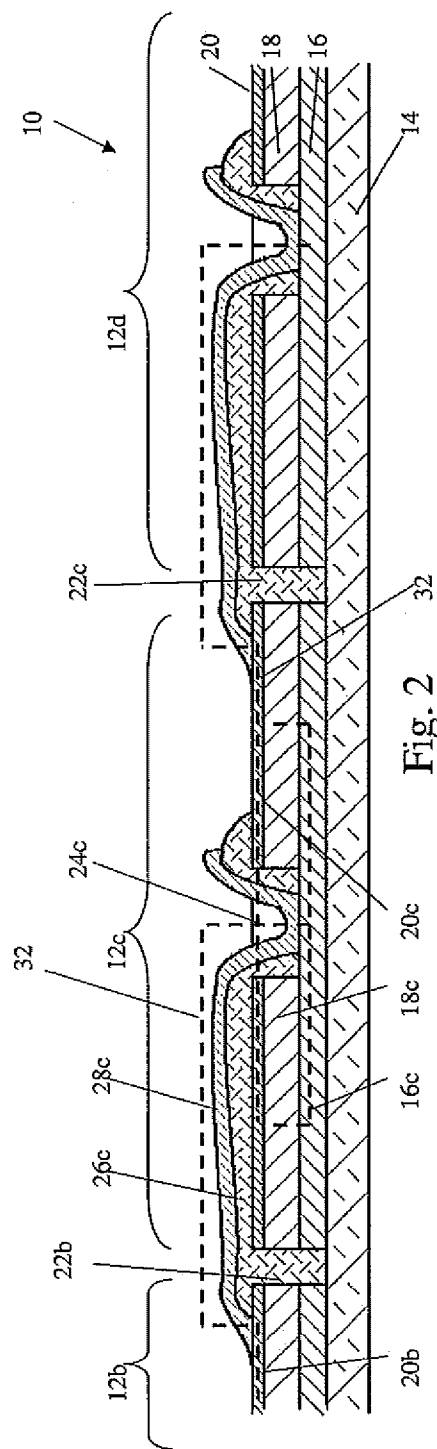


Fig. 2

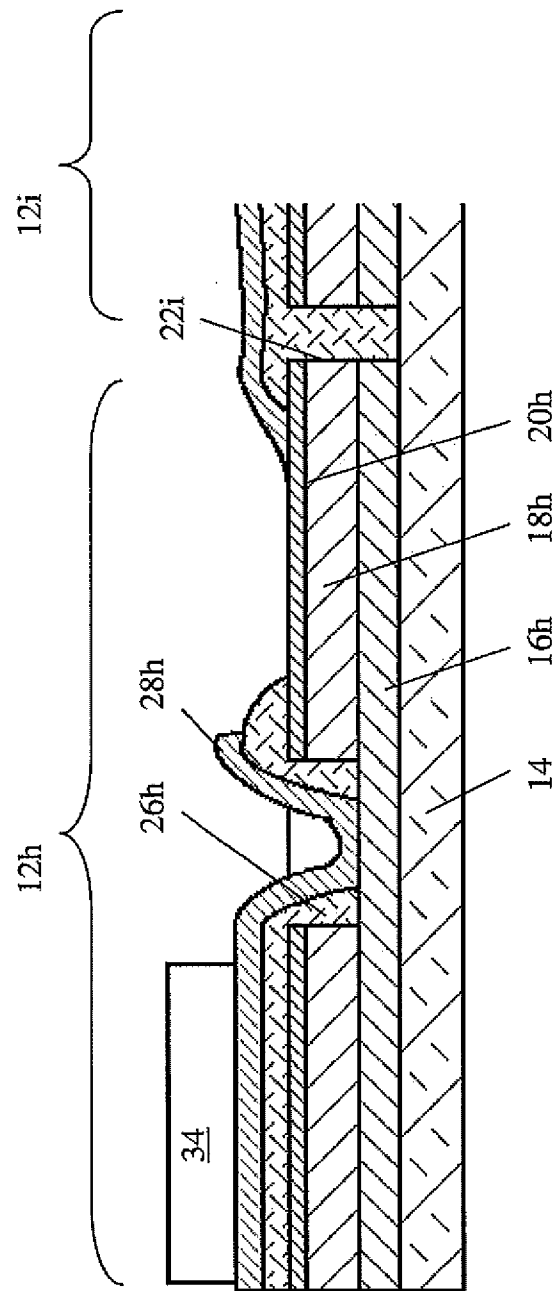


Fig. 3

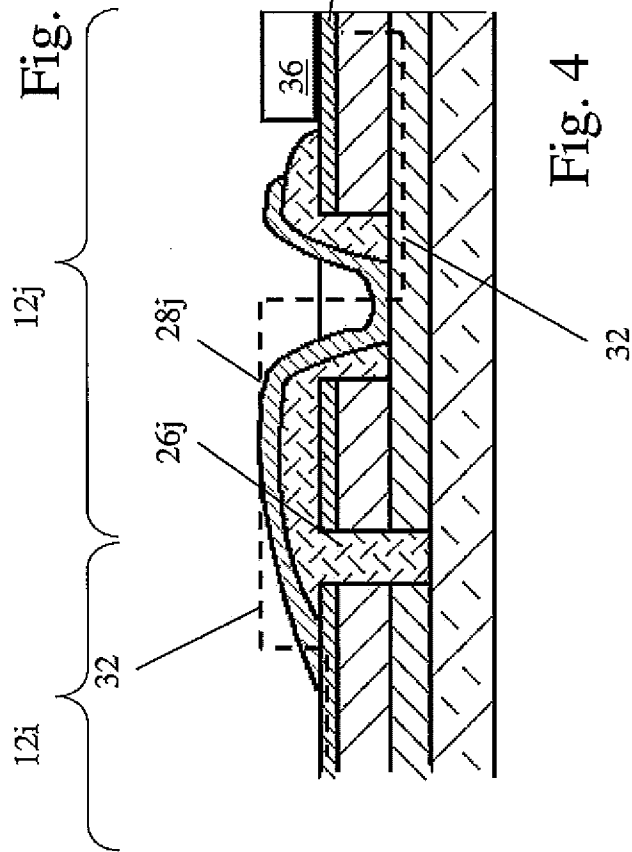


Fig. 4

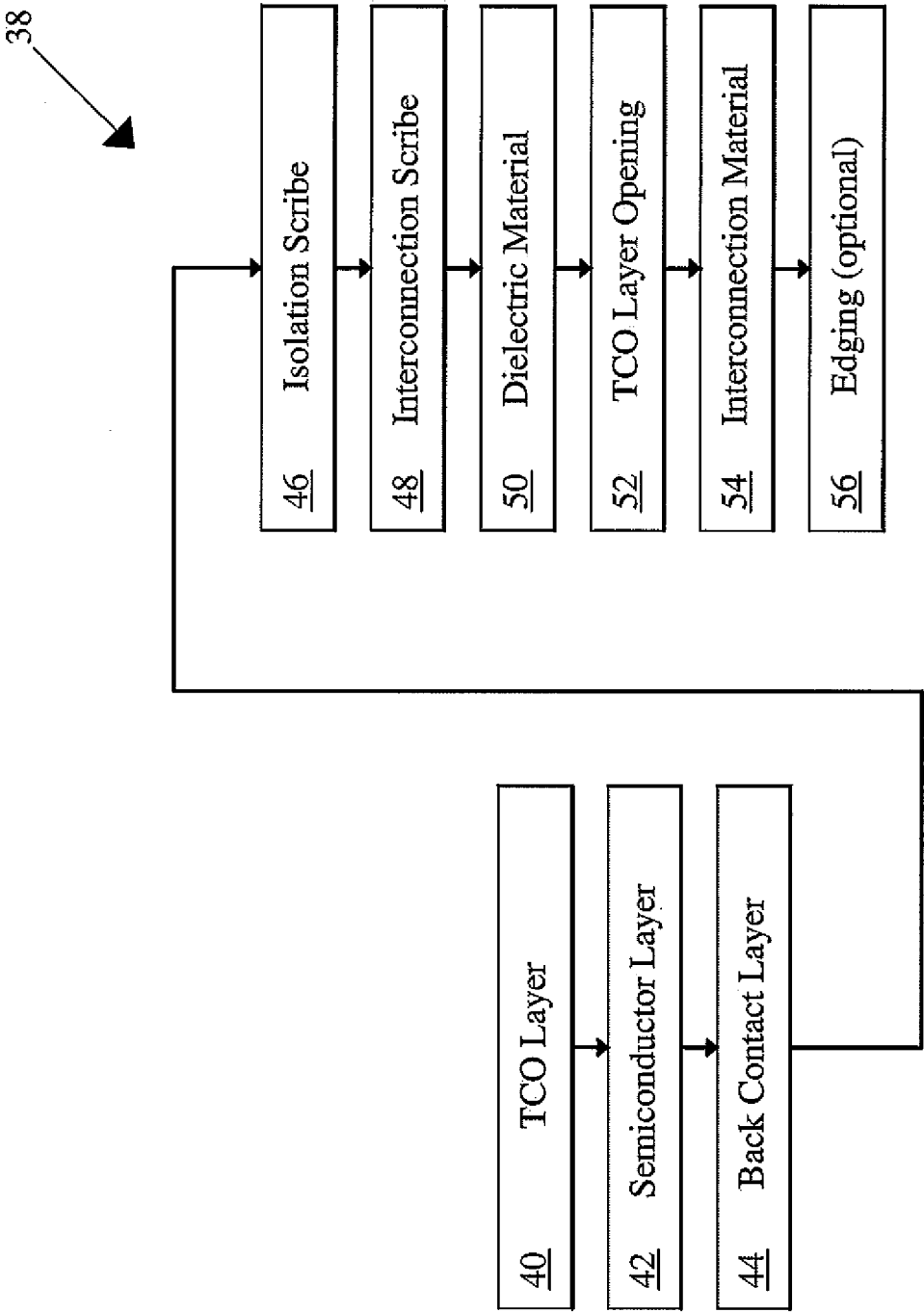


Fig. 5

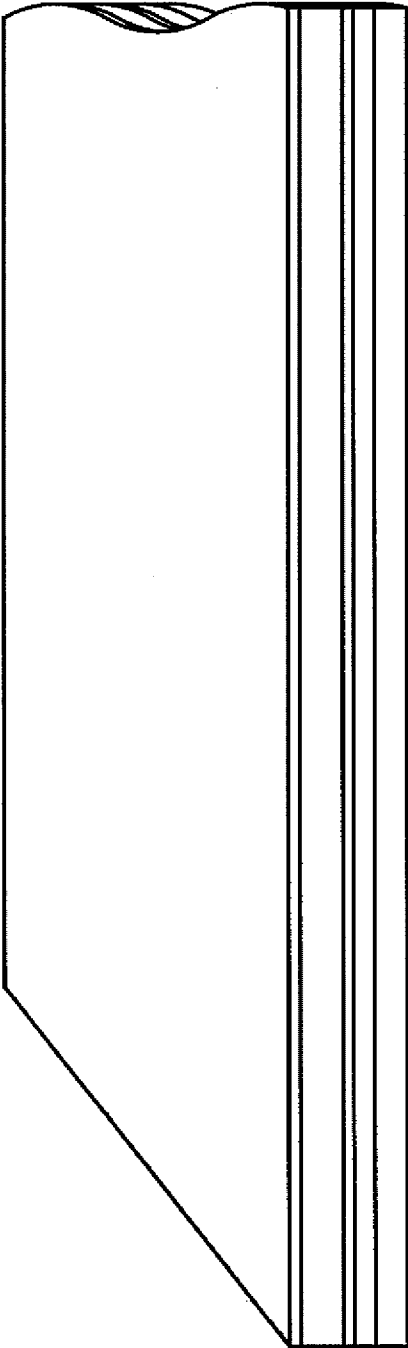


Fig. 6a

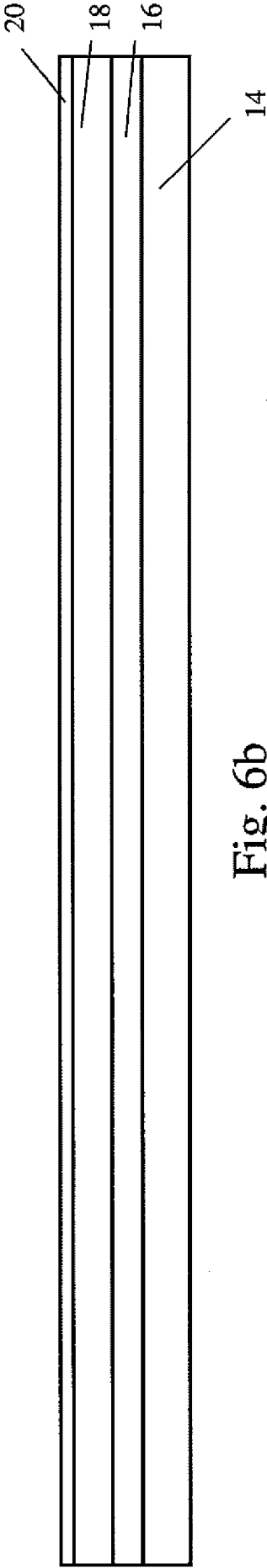


Fig. 6b

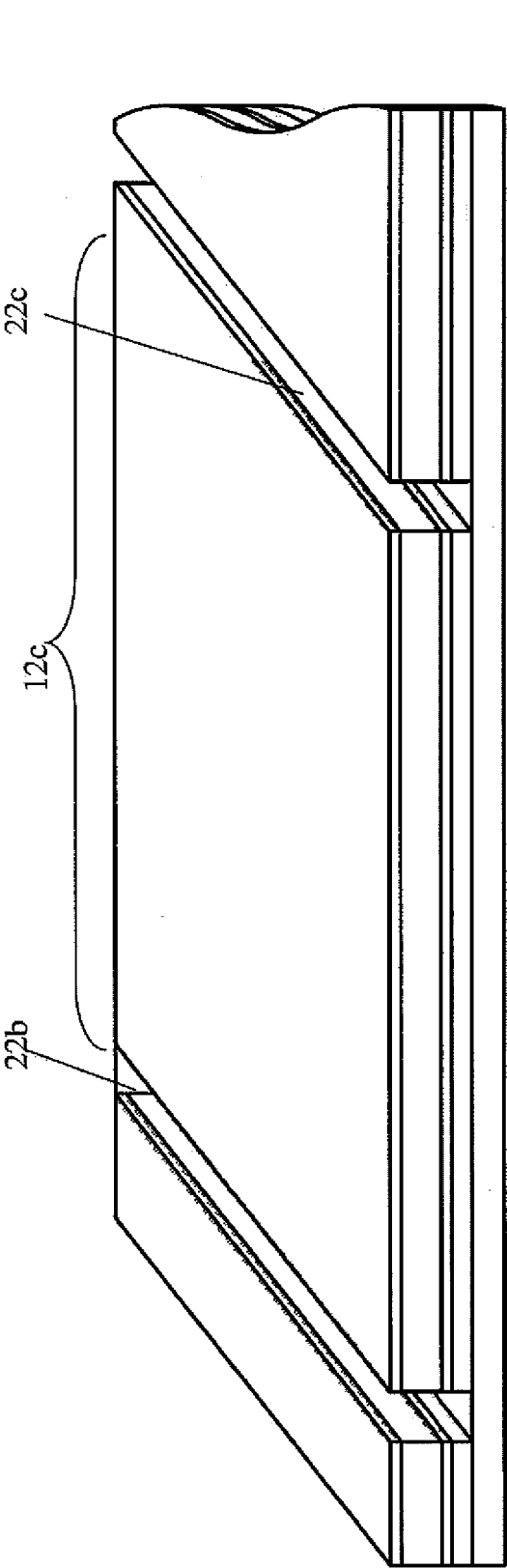


Fig. 7a

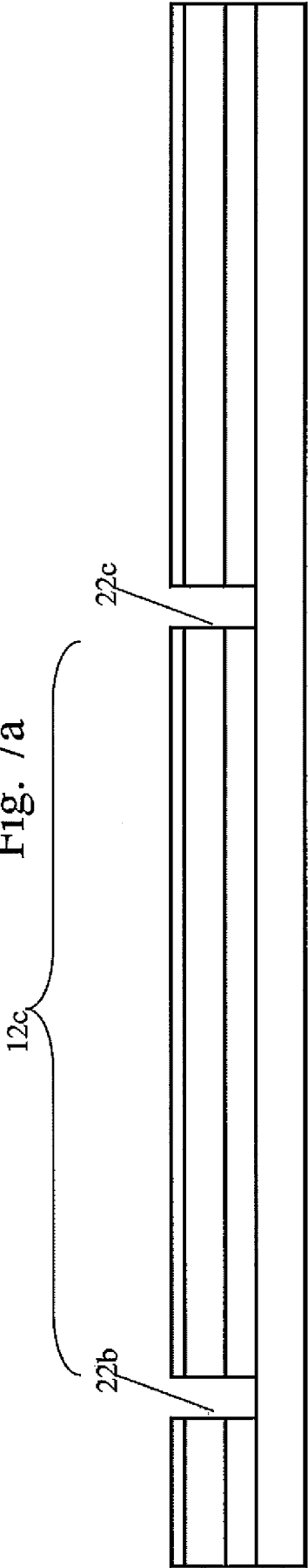


Fig. 7b

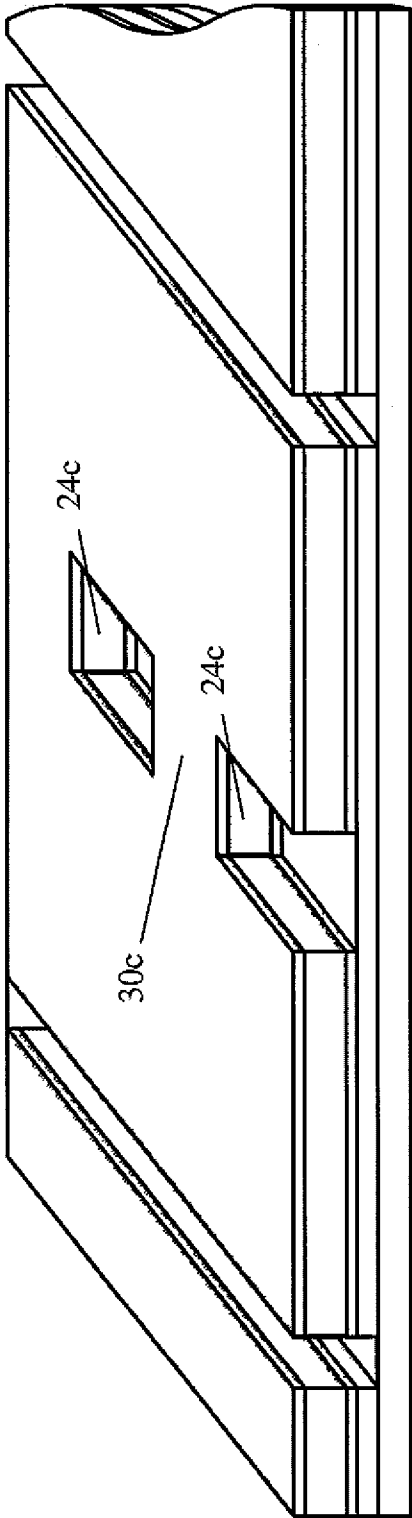


Fig. 8a

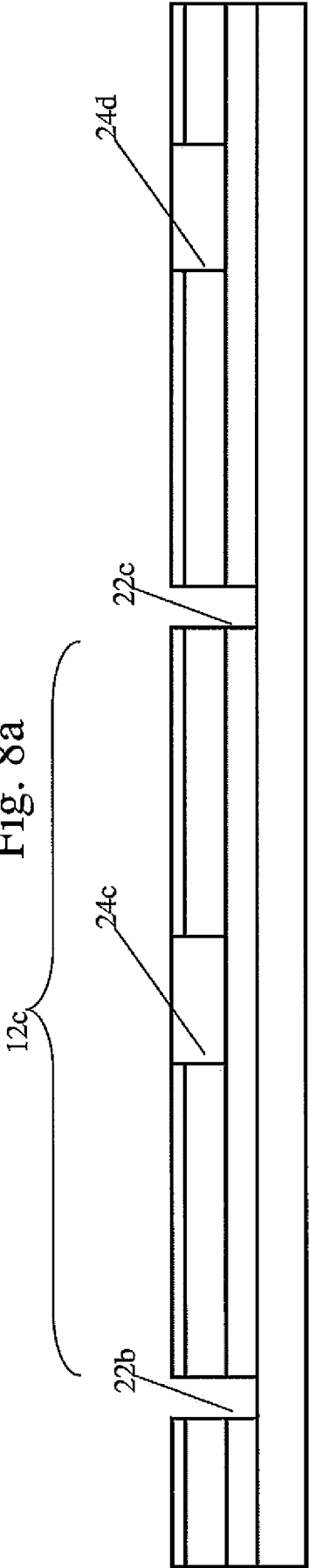


Fig. 8b

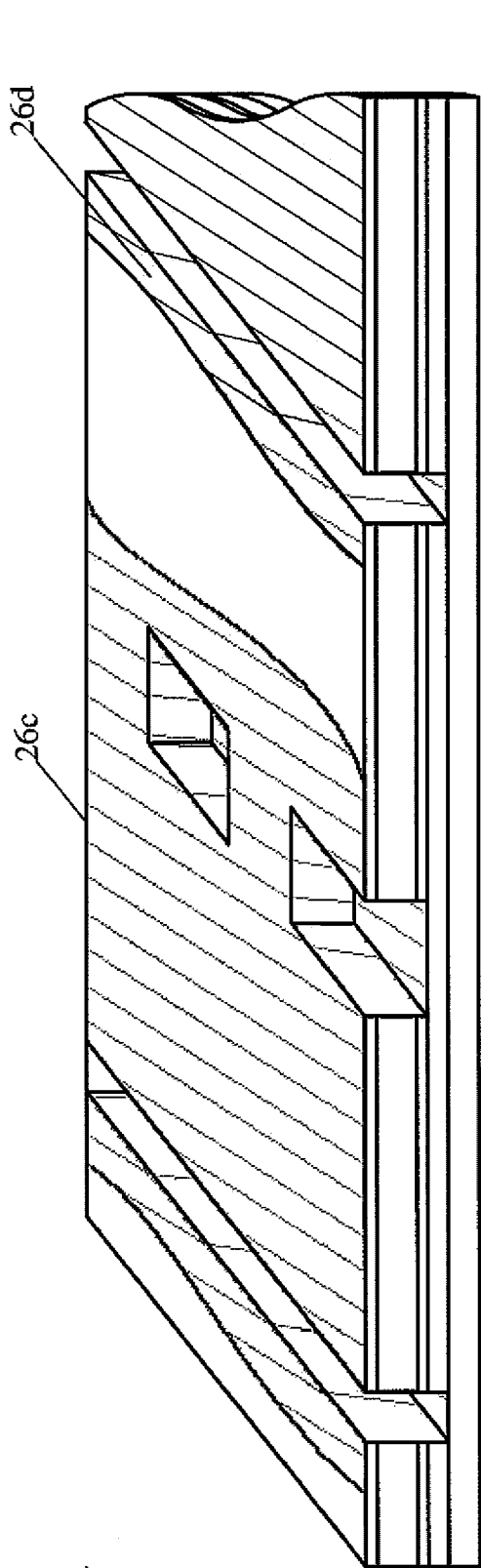


Fig. 9a

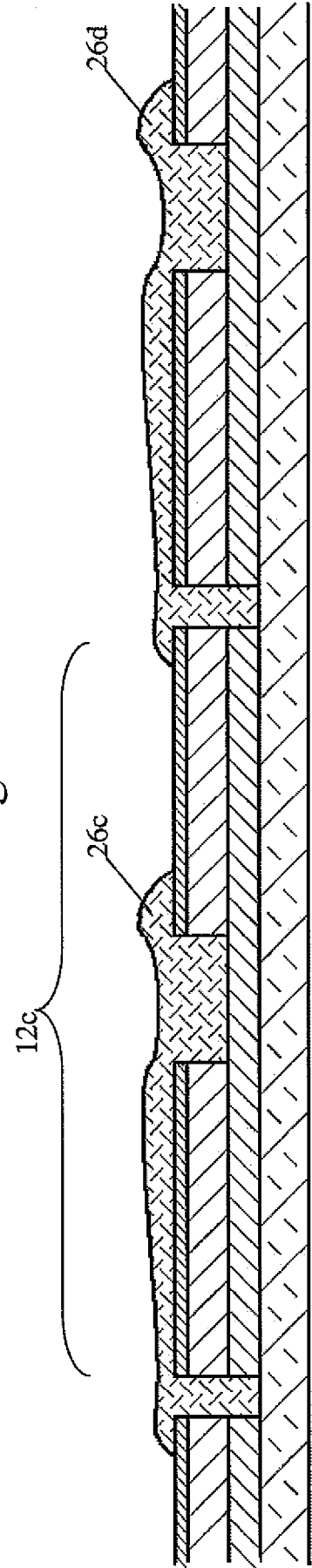
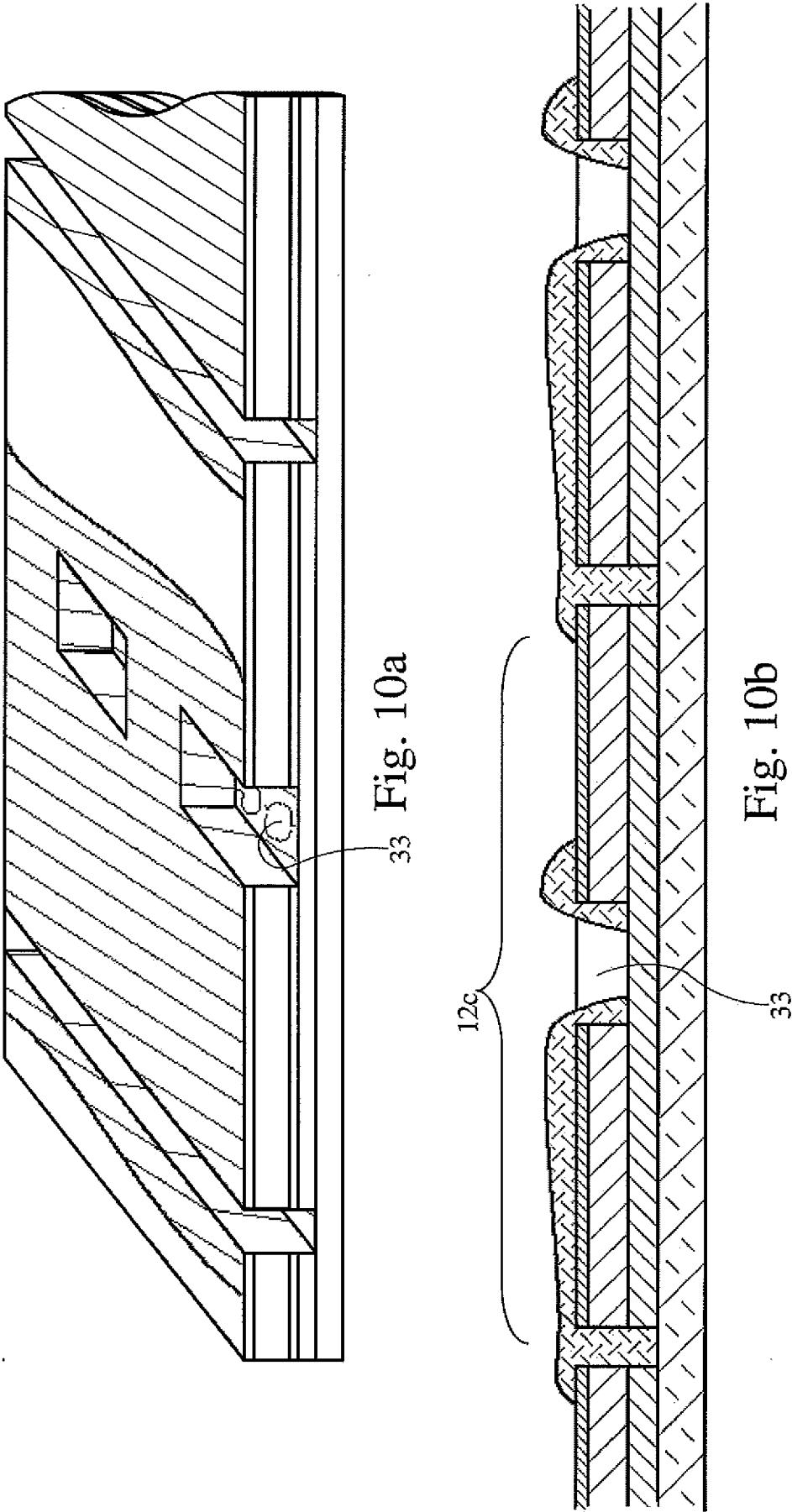


Fig. 9b



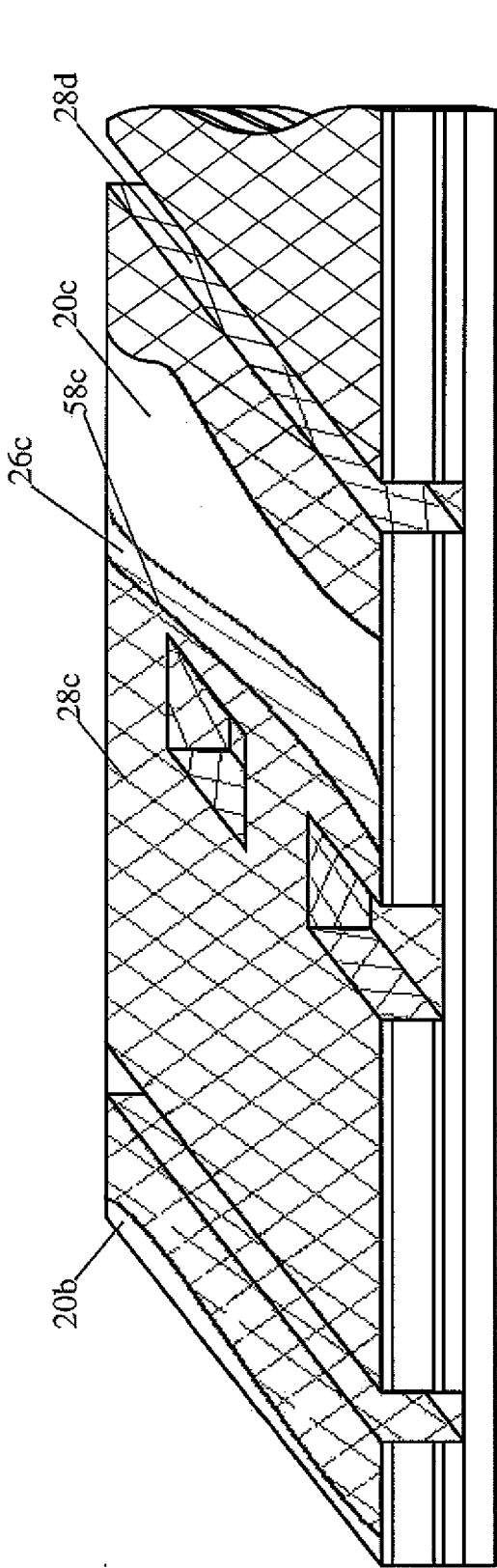


Fig. 11a

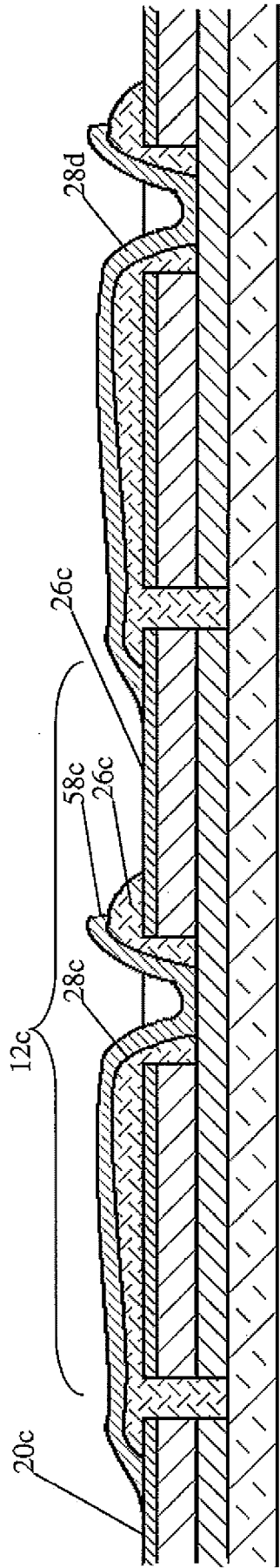


Fig. 11b

INTERNATIONAL SEARCH REPORT

PCT/US14/27471

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - H01L 31/05; H02S 40/36 (2014.01)

USPC - 136/244

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC(8): H01L 31/05, 31/04, 31/18; H02S 40/36 (2014.01)

USPC: 136/244, 249; 428/80

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

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

MicroPatent (US-G, US-A, EP-A, EP-B, WO, JP-bib, DE-C,B, DE-A, DE-T, DE-U, GB-A, FR-A); Google/Google Scholar; IEEE; ProQuest;
Keywords used: photovoltaic cells, series, interconnect, scribe, isolator, PV, module

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2009/0014052 A1 (BORDEN, P et al.) January 15, 2009; paragraphs [0038], [0040], [0043]-[0044]	1-20
Y	US 8,168,881 B2 (BEERNINK, K et al.) May 01, 2012; figures 8, 10, 14, 15; column 1, lines 37-41; column 6, lines 23-49; column 7, lines 36-46, 62-67; column 8, line 1	1-10, 14, 20
Y	US 2005/0145274 A1 (POLCE, N et al.) July 07, 2005; figures 2B, 4A; paragraphs [0035]-[0036], [0038]-[0039]	7, 16-19
Y	US 2012/0048333 A1 (KARPENKO, O et al.) March 01, 2012; paragraphs [0014], [0019], [0024]-[0025]	9, 10
Y	WO 2011/065700 A2 (CHUNG, J et al.) June 03, 2011; paragraphs [12], [43]-[44], [50], [52]; figures 4, 6 (see machine translation)	11-20
Y	US 2013/0008496 A1 (JEE, S) January 10, 2013; figure 8; paragraphs [0005], [0036], [0048]	17

☐ 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

25 June 2014 (25.06.2014)

Date of mailing of the international search report

18 JUL 2014

Name and mailing address of the ISA/US

Mail Stop PCT, Attn: ISA/US, Commissioner for Patents
P.O. Box 1450, Alexandria, Virginia 22313-1450

Facsimile No. 571-273-3201

Authorized officer:

Shane Thomas

PCT Helpdesk: 571-272-4300

PCT OSP: 571-272-7774