



(51) International Patent Classification:
H01L 31/042 (2006.01)

(21) International Application Number:
PCT/US2010/036894

(22) International Filing Date:
1 June 2010 (01.06.2010)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
61/184,215 4 June 2009 (04.06.2009) US

(71) Applicant (for all designated States except US): **FIRST SOLAR, INC.** [US/US]; 28101 Cedar Park Boulevard, Perrysburg, OH 43551 (US).

(72) Inventors; and

(75) Inventors/Applicants (for US only): **CHENG, Long** [CN/US]; 1938 Ottawa Lane, Perrysburg, OH 43551 (US). **GUPTA, Akhlesh** [US/US]; 2213 Stony Brook Boulevard, Sylvania, OH 43560 (US). **ABKEN, Anke** [DE/US]; 10254 S. Blue Ridge, Whitehouse, OH 43571 (US). **BULLER, Benjamin** [IL/US]; 8733 North Stone Mill Road, Sylvania, OH 43560 (US).

(74) Agents: **FOX, Harold, H.** et al.; Steptoe & Johnson LLP, 1330 Connecticut Avenue, NW, Washington, DC 20036 (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, 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, IS, JP, KE, KG, KM, 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, PE, PG, PH, PL, PT, RO, RS, RU, 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.

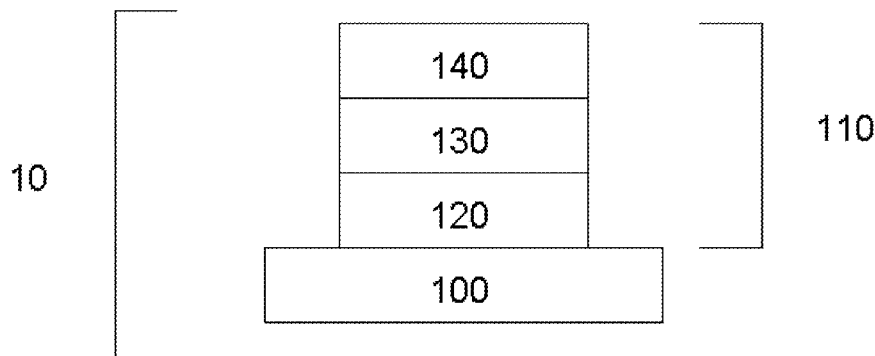
(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE,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

Published:

— with international search report (Art. 21(3))

(54) Title: DOPANT-CONTAINING CONTACT MATERIAL

FIG. 1



(57) Abstract: A photovoltaic device can include a doped contact layer adjacent to a semiconductor absorber layer, where the doped contact layer includes a metal base material and a dopant.

DOPANT-CONTAINING CONTACT MATERIAL

CLAIM FOR PRIORITY

This application claims priority under 35 U.S.C. §119(e) to U.S. Provisional
5 Patent Application Serial No. 61/184,215 filed on June 4, 2009, which is hereby
incorporated by reference.

TECHNICAL FIELD

The present invention relates to photovoltaic devices and methods of production.
10

BACKGROUND

Photovoltaic devices can include semiconductor material deposited over a
substrate, for example, with a first layer serving as a window layer and a second layer
serving as an absorber layer. The semiconductor window layer can allow the penetration
15 of solar radiation to the absorber layer, such as a cadmium telluride layer, which converts
solar energy to electricity. Photovoltaic devices can also contain one or more transparent
conductive oxide layers, which are also often conductors of electrical charge.

DESCRIPTION OF DRAWINGS

20 FIG. 1 is a schematic of a photovoltaic device having multiple layers.
FIG. 2 is a schematic of a photovoltaic device having multiple layers.

DETAILED DESCRIPTION

Photovoltaic devices can include multiple layers created on a substrate (or
25 superstrate). For example, a photovoltaic device can include a barrier layer, a transparent
conductive oxide (TCO) layer, a buffer layer, and a semiconductor layer formed in a stack
on a substrate. Each layer may in turn include more than one layer or film. For example,
the semiconductor layer can include a first film including a semiconductor window layer,
such as a cadmium sulfide layer, formed on the buffer layer and a second film including a
30 semiconductor absorber layer, such as a cadmium telluride layer formed on the
semiconductor window layer. Additionally, each layer can cover all or a portion of the
device and/or all or a portion of the layer or substrate underlying the layer. For example,
a “layer” can include any amount of any material that contacts all or a portion of a
surface.

Photovoltaic devices can be formed on optically transparent substrates, such as glass. Because glass is not conductive, a transparent conductive oxide (TCO) layer is typically deposited between the substrate and the semiconductor bi-layer to serve as a front contact. A metal layer can be deposited onto the p-type absorber layer to serve as a back contact. The front and back contacts can serve as electrodes for the photovoltaic device. A variety of materials are available for the metal layer, including, but not limited to molybdenum, aluminum, chromium, iron, nickel, titanium, vanadium, manganese, cobalt, zinc, ruthenium, tungsten, silver, gold, and platinum. Molybdenum functions particularly well as a back contact metal due to its relative stability at processing temperatures and low contact resistance. Copper has also proven effective for preserving fill factor. The inventions disclosed herein relate to the composition and deposition of back contacts for photovoltaic devices.

In one aspect, a photovoltaic device can include a doped contact layer adjacent to a semiconductor absorber layer. The doped contact layer can include a metal base material and a dopant.

The metal base material can include a molybdenum. The dopant can include a copper. The doped contact layer can include a copper-doped molybdenum. The doped contact layer can include a copper concentration of about 0.1% to about 10%. The metal base material can include molybdenum, aluminum, chromium, iron, nickel, titanium, vanadium, manganese, cobalt, zinc, ruthenium, tungsten, silver, gold, or platinum. The dopant can include copper, antimony, potassium, sodium, cesium, silver, gold, phosphorous, arsenic, or bismuth. The semiconductor absorber layer can include a cadmium telluride layer. The photovoltaic device can include a semiconductor window layer. The semiconductor absorber layer can be positioned adjacent to the semiconductor window layer. The semiconductor window layer and the semiconductor absorber layer can be at least a part of a semiconductor bi-layer. The semiconductor window layer can include a cadmium sulfide layer. The photovoltaic device can include a transparent conductive oxide stack. The semiconductor bi-layer can be positioned adjacent to the transparent conductive oxide stack. The photovoltaic device can include a first substrate. The transparent conductive oxide stack can be positioned adjacent to the first substrate. The first substrate can include a glass, for example, a soda-lime glass. The transparent conductive oxide stack can include a buffer layer positioned adjacent to a transparent conductive oxide layer. The transparent conductive oxide layer can be positioned adjacent to one or more barrier layers. The transparent conductive oxide layer can

include a cadmium stannate. The buffer layer can include a zinc tin oxide, tin oxide, zinc oxide, or zinc magnesium oxide. Each of the one or more barrier layers can include a silicon nitride, aluminum-doped silicon nitride, silicon oxide, aluminum-doped silicon oxide, boron-doped silicon nitride, phosphorous-doped silicon nitride, silicon oxide-nitride, or tin oxide. The photovoltaic device can include a back support adjacent to the back contact.

In one aspect, a method for manufacturing a photovoltaic device can include depositing a doped contact layer adjacent to a semiconductor absorber layer. The doped contact layer can include a metal base material and a dopant.

Depositing a doped contact layer adjacent to a semiconductor absorber layer can include sputtering a copper-doped metal base material onto a cadmium telluride. Depositing a doped contact layer adjacent to a semiconductor absorber layer can include sputtering a doped molybdenum onto a cadmium telluride layer. Depositing a doped contact layer adjacent to a semiconductor absorber layer can include sputtering a copper-doped molybdenum onto a cadmium telluride layer. The copper-doped molybdenum can include a copper concentration of about 0.1% to about 10%. The metal base material can include molybdenum, aluminum, chromium, iron, nickel, titanium, vanadium, manganese, cobalt, zinc, ruthenium, tungsten, silver, gold, or platinum. The dopant can include copper, antimony, potassium, sodium, cesium, silver, gold, phosphorous, arsenic, or bismuth. The method can include doping the metal base material with a dopant to form a doped contact layer. Doping the metal base material with a dopant can include dry-doping a molybdenum in a metallizer. Doping the metal base material with a dopant can include doping a molybdenum with about 0.1% to about 10% copper. The method can include depositing the semiconductor absorber layer adjacent to a semiconductor window layer. The semiconductor absorber layer can include a cadmium telluride layer. The semiconductor window layer can include a cadmium sulfide layer. The method can include depositing the semiconductor window layer adjacent to a transparent conductive oxide stack. The transparent conductive oxide stack can include a buffer layer adjacent to a transparent conductive oxide layer. The transparent conductive oxide layer can be positioned adjacent to one or more barrier layers. The method can include depositing the transparent conductive oxide stack adjacent to a first substrate. The first substrate can include a glass, for example, a soda-lime glass. Each of the one or more barrier layers can include a silicon nitride, aluminum-doped silicon nitride, silicon oxide, aluminum-doped silicon oxide, boron-doped silicon nitride, phosphorous-doped silicon nitride,

silicon oxide-nitride, or tin oxide. The transparent conductive oxide layer can include a cadmium stannate. The buffer layer can include zinc tin oxide, tin oxide, zinc oxide, or zinc magnesium oxide. The method can include annealing the transparent conductive oxide stack. The method can include depositing a back support adjacent to the doped contact layer.

In one aspect, a photovoltaic module may include a plurality of photovoltaic cells adjacent to a substrate. The photovoltaic module may include a back cover adjacent to the plurality of photovoltaic cells. The plurality of photovoltaic cells may include a doped contact layer adjacent to a semiconductor absorber layer. The doped contact layer may include a metal base material and a dopant.

The photovoltaic module may include a first strip of tape having a length distributed along each doped contact layer. The first strip of tape may include a front surface and a back surface. Each surface may contain an adhesive. The photovoltaic module may include a first lead foil distributed along the length of the first strip of tape.

The photovoltaic module may include a second strip of tape, having a length shorter than that of the first strip of tape, distributed along the length and between the ends of the first strip of tape. The second strip of tape may include a front and back surface. Each surface may contain an adhesive. The photovoltaic module may include a second lead foil, having a length shorter than that of the second strip of tape, distributed along the length of the second strip of tape. The photovoltaic module may include a plurality of parallel bus bars, positioned adjacent and perpendicular to the first and second strips of tape. Each one of the plurality of parallel bus bars may contact one of the first or second lead foils. The photovoltaic module may include first and second submodules. The first submodule may include two or more cells of the plurality of photovoltaic cells connected in series.

The second submodule may include another two or more cells of the plurality of photovoltaic cells connected in series. The first and second submodules may be connected in parallel through a shared cell.

In one aspect, a method for generating electricity may include illuminating a photovoltaic cell with a beam of light to generate a photocurrent. The method may include collecting the generated photocurrent. The photovoltaic cell may include a doped contact layer adjacent to a semiconductor absorber layer. The doped contact layer may include a metal base material and a dopant.

Referring to FIG. 1, a photovoltaic device 10 can include a transparent conductive oxide layer 130 adjacent to a substrate 100. Transparent conductive oxide layer 130 can

be deposited adjacent to substrate 100, or the layers can be pre-fabricated. Transparent conductive oxide layer 130 can be deposited using any known deposition technique, including sputtering. Transparent conductive oxide layer 130 can include a cadmium stannate. Transparent conductive oxide layer 130 can be part of transparent conductive oxide stack 110. Transparent conductive oxide stack 110 can include a barrier layer 120 and a buffer layer 140. Transparent conductive oxide layer 130 can be deposited adjacent to barrier layer 120 to form transparent conductive oxide stack 110. Transparent conductive oxide layer 130 can be deposited using any known deposition technique, including sputtering. Barrier layer 120 can include a silicon dioxide or a silicon nitride. Buffer layer 140 can be deposited adjacent to transparent conductive oxide layer 130 to form transparent conductive oxide stack 110. Buffer layer 140 can be deposited using any known deposition technique, including sputtering. Buffer layer 140 can include a zinc stannate or a tin oxide. Transparent conductive oxide stack 110 from FIG. 1 can be annealed to form annealed transparent conductive oxide stack 200 from FIG. 2.

Transparent conductive oxide stack 200 can be manufactured using a variety of deposition techniques, including for example, low pressure chemical vapor deposition, atmospheric pressure chemical vapor deposition, plasma-enhanced chemical vapor deposition, thermal chemical vapor deposition, DC or AC sputtering, spin-on deposition, and spray-pyrolysis. Each deposition layer can be of any suitable thickness, for example in the range of about 1 to about 5000Å.

Referring to FIG. 2, a photovoltaic device 20 can include a semiconductor bi-layer 210 deposited adjacent to transparent conductive oxide layer 130. Semiconductor bi-layer 210 can be deposited using any known deposition technique, including sputtering and vapor transport deposition. Semiconductor bi-layer 210 can include a semiconductor absorber layer 230 and a semiconductor window layer 220. Semiconductor window layer 220 can be deposited adjacent to transparent conductive oxide layer 130. Semiconductor window layer 220 can be deposited using any known deposition technique, including vapor transport deposition. Semiconductor window layer 220 can include a cadmium sulfide layer. Semiconductor absorber layer 230 can be deposited adjacent to semiconductor window layer 220. Semiconductor absorber layer 230 can be deposited using any known deposition technique, including vapor transport deposition. Semiconductor absorber layer 230 can include a cadmium telluride layer.

In continuing reference to FIG. 2, doped contact layer 240 can serve as a back contact of photovoltaic device 20 and be deposited adjacent to semiconductor bi-layer

210. Doped contact layer 240 can be deposited adjacent to semiconductor absorber layer 230. Doped contact layer 240 can be deposited using any known deposition technique, including sputtering, and can include a metal base material and a dopant. For example, doped contact layer 240 can include a copper-doped molybdenum. However, doped contact layer 240 is not limited to any specific metal base material or dopant and can thus include various suitable materials. For example, the metal base material can include molybdenum, aluminium, chromium, iron, nickel, titanium, vanadium, manganese, cobalt, zinc, ruthenium, tungsten, silver, gold, or platinum. And the dopant can include copper, antimony, potassium, sodium, cesium, silver, gold, phosphorous, arsenic, or bismuth.

Doped contact layer 240 can either be pre-fabricated, or it can be formed using any suitable materials and process. Doped contact layer 240 can include any suitable amount of copper. For example, a doped molybdenum can include a copper concentration of about 0.1% to about 10% copper. The molybdenum can be doped using any suitable process, including dry-doping. For example, contact layer 240 can be formed by dry-copper-doping a molybdenum in a metallizer. Doped contact layer 240 can also be of a suitable thickness, for example greater than about 10 Å, greater than about 20 Å, greater than about 50 Å, greater than about 100 Å, greater than about 250 Å, greater than about 500 Å, less than about 2000 Å, less than about 1500 Å, less than about 1000 Å, or less than about 750 Å. In continuing reference to FIG. 2, a back support 250 can be deposited adjacent to doped contact layer 240. Back support 250 can include a glass, for example a soda-lime glass.

In one experiment, the performance of a photovoltaic device with a copper-doped molybdenum back contact was compared with that of a control device. Secondary ion mass spectroscopy (SIMS) indicated higher copper concentration in the copper-doped molybdenum device than in the control cell. The effectiveness of the doped back contact can be increased by augmenting the thickness of the copper-doped molybdenum. In general, devices with doped contact layers exhibited higher efficiency, open circuit voltage, and fill factor than the control cells. In another experiment, the light-soaking stability of copper-doped molybdenum devices was analyzed. Results indicated higher efficiency and open circuit voltage for devices with copper-doped molybdenum contact layers.

Photovoltaic devices/cells fabricated using the methods discussed herein may be incorporated into one or more photovoltaic modules, each of which may include one or

more submodules. Such modules may be incorporated into various systems for generating electricity. For example, a photovoltaic module may include one or more submodules consisting of multiple photovoltaic cells connected in series. One or more submodules may be connected in parallel via a shared cell to form a photovoltaic module.

5 A bus bar assembly may be attached to a contact surface of a photovoltaic module to enable connection to additional electrical components (e.g., one or more additional modules). For example, a first strip of double-sided tape may be distributed along a length of the module, and a first lead foil may be applied adjacent thereto. A second strip of double-sided tape (smaller than the first strip) may be applied adjacent to the first lead
10 foil. A second lead foil may be applied adjacent to the second strip of double-sided tape. The tape and lead foils may be positioned such that at least one portion of the first lead foil is exposed, and at least one portion of the second lead foil is exposed. Following application of the tape and lead foils, a plurality of bus bars may be positioned along the contact region of the module. The bus bars may be positioned parallel from one another,
15 at any suitable distance apart. For example, the plurality of bus bars may include at least one bus bar positioned on a portion of the first lead foil, and at least one bus bar positioned on a portion of the second lead foil. The bus bar, along with the portion of lead foil on which it has been applied, may define a positive or negative region. A roller may be used to create a loop in a section of the first or second lead foil. The loop may be
20 threaded through the hole of a subsequently deposited back glass. The photovoltaic module may be connected to other electronic components, including, for example, one or more additional photovoltaic modules. For example, the photovoltaic module may be electrically connected to one or more additional photovoltaic modules to form a photovoltaic array.

25 The photovoltaic cells/modules/arrays may be included in a system for generating electricity. For example, a photovoltaic cell may be illuminated with a beam of light to generate a photocurrent. The photocurrent may be collected and converted from direct current (DC) to alternating current (AC) and distributed to a power grid. Light of any suitable wavelength may be directed at the cell to produce the photocurrent, including, for
30 example, more than 400 nm, or less than 700 nm (e.g., ultraviolet light). Photocurrent generated from one photovoltaic cell may be combined with photocurrent generated from other photovoltaic cells. For example, the photovoltaic cells may be part of one or more photovoltaic modules in a photovoltaic array, from which the aggregate current may be harnessed and distributed.

The embodiments described above are offered by way of illustration and example. It should be understood that the examples provided above may be altered in certain respects and still remain within the scope of the claims. It should be appreciated that, while the invention has been described with reference to the above preferred

5 embodiments, other embodiments are within the scope of the claims.

WHAT IS CLAIMED IS:

1. A photovoltaic device, comprising:
a doped contact layer adjacent to a semiconductor absorber layer, the
doped contact layer comprising a metal base material and a dopant.
- 5 2. The photovoltaic device of claim 1, wherein the metal base material comprises a molybdenum.
3. The photovoltaic device of claim 1, wherein the dopant comprises a copper.
4. The photovoltaic device of claim 1, wherein the doped contact layer comprises a copper-doped molybdenum.
- 10 5. The photovoltaic device of claim 1, wherein the doped contact layer comprises a copper concentration of about 0.1% to about 10%.
6. The photovoltaic device of claim 1, wherein the metal base material is selected from the group consisting of molybdenum, aluminum, chromium, iron, nickel, titanium, vanadium, manganese, cobalt, zinc, ruthenium, tungsten, silver, gold,
15 and platinum.
7. The photovoltaic device of claim 1, wherein the dopant is selected from the group consisting of copper, antimony, potassium, sodium, cesium, silver, gold, phosphorous, arsenic, and bismuth.
8. The photovoltaic device of claim 1, wherein the semiconductor absorber layer
20 comprises a cadmium telluride layer.
9. The photovoltaic device of claim 1, further comprising a semiconductor window layer, wherein the semiconductor absorber layer is positioned adjacent to the semiconductor window layer, and wherein the semiconductor window layer and the semiconductor absorber layer are at least a part of a
25 semiconductor bi-layer.
10. The photovoltaic device of claim 9, wherein the semiconductor window layer comprises a cadmium sulfide layer.
11. The photovoltaic device of claim 9, further comprising a transparent conductive oxide stack, wherein the semiconductor bi-layer is positioned
30 adjacent to the transparent conductive oxide stack.
12. The photovoltaic device of claim 11, further comprising a first substrate, wherein the transparent conductive oxide stack is positioned adjacent to the first substrate.

13. The photovoltaic device of claim 12, wherein the first substrate comprises a glass.
14. The photovoltaic device of claim 13, wherein the glass comprises a soda-lime glass.
- 5 15. The photovoltaic device of claim 11, wherein the transparent conductive oxide stack comprises a buffer layer positioned adjacent to a transparent conductive oxide layer, and wherein the transparent conductive oxide layer is positioned adjacent to one or more barrier layers.
- 10 16. The photovoltaic device of claim 15, wherein the transparent conductive oxide layer comprises a cadmium stannate.
17. The photovoltaic device of claim 15, wherein the buffer layer is selected from the group consisting of zinc tin oxide, tin oxide, zinc oxide, and zinc magnesium oxide.
- 15 18. The photovoltaic device of claim 15, wherein each of the one or more barrier layers is selected from the group consisting of silicon nitride, aluminum-doped silicon nitride, silicon oxide, aluminum-doped silicon oxide, boron-doped silicon nitride, phosphorous-doped silicon nitride, silicon oxide-nitride, and tin oxide.
- 20 19. The photovoltaic device of claim 1, further comprising a back support adjacent to the back contact.
20. A method for manufacturing a photovoltaic device, the method comprising:
depositing a doped contact layer adjacent to a semiconductor absorber layer, the doped contact layer comprising a metal base material and a dopant.
- 25 21. The method of claim 20, wherein depositing a doped contact layer adjacent to a semiconductor absorber layer comprises sputtering a copper-doped metal base material onto a cadmium telluride.
22. The method of claim 20, wherein depositing a doped contact layer adjacent to a semiconductor absorber layer comprises sputtering a doped molybdenum onto a cadmium telluride layer.
- 30 23. The method of claim 20, wherein depositing a doped contact layer adjacent to a semiconductor absorber layer comprises sputtering a copper-doped molybdenum onto a cadmium telluride layer.
24. The method of claim 23, wherein the copper-doped molybdenum comprises a copper concentration of about 0.1% to about 10%.

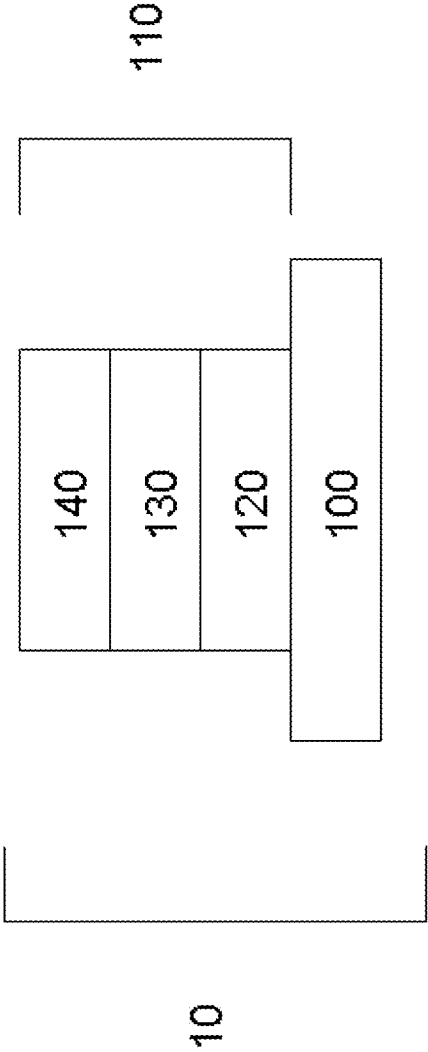
25. The method of claim 20, wherein the metal base material is selected from the group consisting of molybdenum, aluminum, chromium, iron, nickel, titanium, vanadium, manganese, cobalt, zinc, ruthenium, tungsten, silver, gold, and platinum.
- 5 26. The method of claim 20, wherein the dopant is selected from the group consisting of copper, antimony, potassium, sodium, cesium, silver, gold, phosphorous, arsenic, and bismuth.
27. The method of claim 20, further comprising doping the metal base material with a dopant to form a doped contact layer.
- 10 28. The method of claim 27, wherein doping the metal base material with a dopant comprises dry-doping a molybdenum in a metallizer.
29. The method of claim 27, wherein doping the metal base material with a dopant comprises doping a molybdenum with about 0.1% to about 10% copper.
- 15 30. The method of claim 20, further comprising depositing the semiconductor absorber layer adjacent to a semiconductor window layer, the semiconductor absorber layer comprising a cadmium telluride layer, and the semiconductor window layer comprising a cadmium sulfide layer.
- 20 31. The method of claim 30, further comprising depositing the semiconductor window layer adjacent to a transparent conductive oxide stack, wherein the transparent conductive oxide stack comprises a buffer layer adjacent to a transparent conductive oxide layer, wherein the transparent conductive oxide layer is positioned adjacent to one or more barrier layers.
32. The method of claim 31, further comprising depositing the transparent conductive oxide stack adjacent to a first substrate.
- 25 33. The method of claim 32, wherein the first substrate comprises a glass.
34. The method of claim 33, wherein the glass comprises a soda-lime glass.
35. The method of claim 31, wherein each of the one or more barrier layers is selected from the group consisting of silicon nitride, aluminum-doped silicon nitride, silicon oxide, aluminum-doped silicon oxide, boron-doped silicon nitride, phosphorous-doped silicon nitride, silicon oxide-nitride, and tin oxide.
- 30 36. The method of claim 31, wherein the transparent conductive oxide layer comprises a cadmium stannate.
37. The method of claim 31, wherein the buffer layer is selected from the group consisting of zinc tin oxide, tin oxide, zinc oxide, and zinc magnesium oxide.

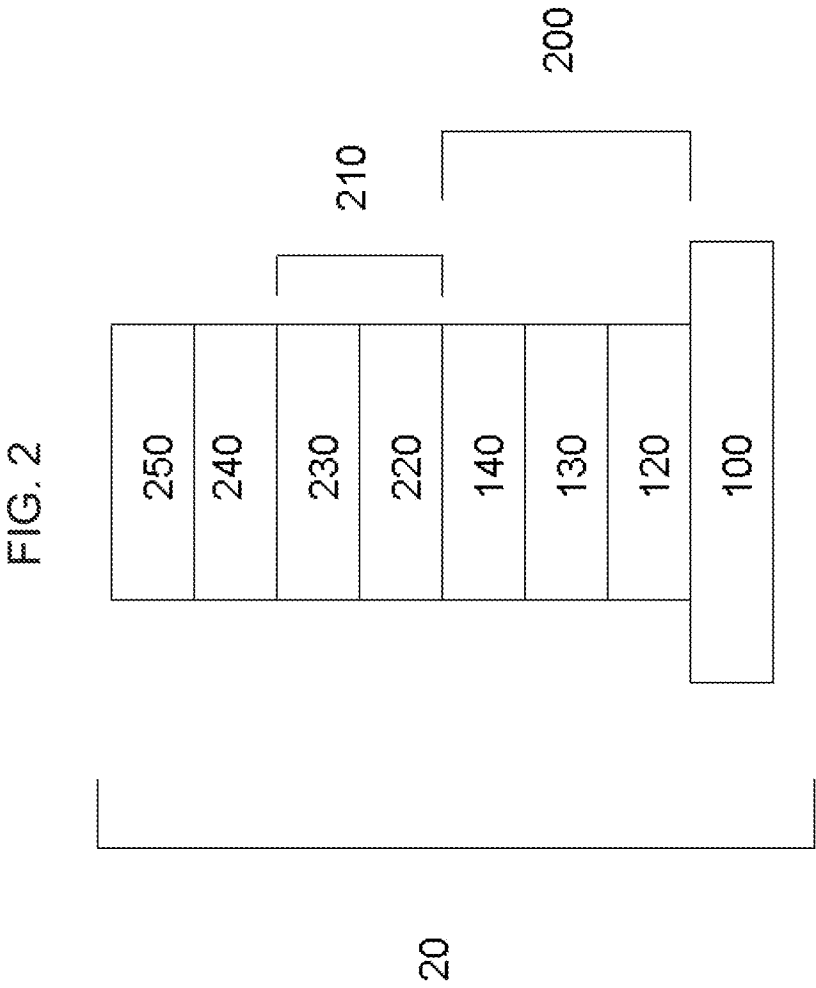
38. The method of claim 31, further comprising annealing the transparent conductive oxide stack.
39. The method of claim 20, further comprising depositing a back support adjacent to the doped contact layer.
- 5 40. A photovoltaic module comprising:
a plurality of photovoltaic cells adjacent to a substrate; and
a back cover adjacent to the plurality of photovoltaic cells, the plurality of photovoltaic cells comprising:
a doped contact layer adjacent to a semiconductor absorber layer, the
10 doped contact layer comprising a metal base material and a dopant.
41. The photovoltaic module of claim 40, further comprising:
a first strip of tape having a length distributed along each doped contact
layer, the first strip of tape comprising a front surface and a back surface, each
surface containing an adhesive;
15 a first lead foil distributed along the length of the first strip of tape;
a second strip of tape, having a length shorter than that of the first strip of
tape, distributed along the length and between the ends of the first strip of
tape, wherein the second strip of tape comprises a front and back surface, each
containing an adhesive;
20 a second lead foil, having a length shorter than that of the second strip of
tape, distributed along the length of the second strip of tape; and
a plurality of parallel bus bars, positioned adjacent and perpendicular to
the first and second strips of tape, wherein each one of the plurality of parallel
bus bars contacts one of the first or second lead foils.
- 25 42. The photovoltaic module of claim 41, further comprising first and second
submodules, wherein the first submodule comprises two or more cells of the
plurality of photovoltaic cells connected in series, and the second submodule
comprises another two or more cells of the plurality of photovoltaic cells
connected in series, wherein the first and second submodules are connected in
30 parallel through a shared cell.
43. A method for generating electricity, the method comprising:
illuminating a photovoltaic cell with a beam of light to generate a
photocurrent; and

collecting the generated photocurrent, wherein the photovoltaic cell comprises:

a doped contact layer adjacent to a semiconductor absorber layer, the doped contact layer comprising a metal base material and a dopant.

FIG. 1





INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2010/036894

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - H01L 31/042 (2010.01)

USPC - 136/265

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 31/00, 31/042 (2010.01)

USPC - 136/240, 260, 264, 265

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, GooglePatent, Google

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y	US 5,626,688 A (PROBST et al) 06 May 1997 (06.05.1997) entire document	1-7, 9-15, 17-20, 25-27, 29, 39-40 ----- 8, 16, 21-24, 28, 30-38, 41-43
Y	US 4,826,777 A (ONDRIS) 02 May 1989 (02.05.1989) entire document	8, 16, 21-24, 30-38, 41-43
Y	US 4,742,014 A (HOOPER et al) 03 May 1988 (03.05.1988) entire document	21, 23, 24
Y	US 4,950,327 A (ECK et al) 21 August 1990 (21.08.1990) entire document	28
Y	US 7,390,961 B2 (ASCHENBRENNER et al) 24 June 2008 (24.06.2008) entire document	41-42
A	MATHEW et al. CdTe/CdS solar cells on flexible substrates. Solar Energy 77 (2004) [Retrieved on 2010-07-16] Retrieved from the Internet: <URL:http://profs.sci.univr.it/~romeo/Publications/Mathew%20et%20al%20SolarEnergy2004.pdf> pages 831-838	1-47

☐ 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

19 July 2010

Date of mailing of the international search report

13 AUG 2010

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:

Blaine R. Copenheaver

PCT Helpdesk: 571-272-4300

PCT OSP: 571-272-7774