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(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, QA, RO, RS, RU, RW, 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.

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**Declarations under Rule 4.17:**

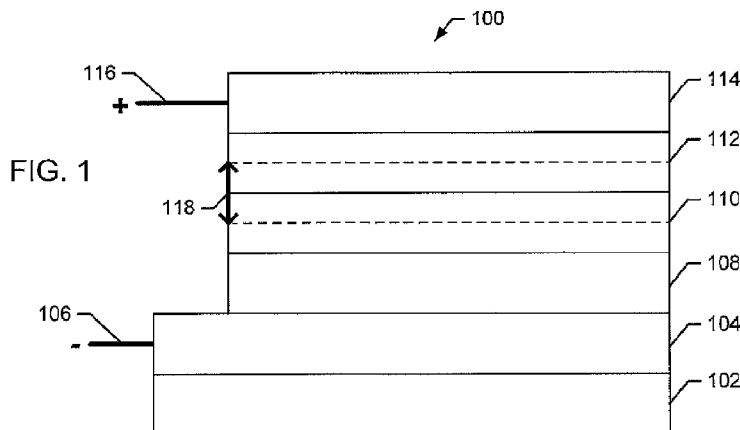
— of inventorship (Rule 4.17(iv))

**Published:**

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

[Continued on next page]

(54) **Title:** IMPROVED CdTe DEVICES AND METHOD OF MANUFACTURING SAME



(57) **Abstract:** A method of producing polycrystalline CdTe materials and devices that incorporate the polycrystalline CdTe materials are provided. In particular, a method of producing polycrystalline p-doped CdTe thin films for use in CdTe solar cells in which the CdTe thin films possess enhanced acceptor densities and minority carrier lifetimes, resulting in enhanced efficiency of the solar cells containing the CdTe material are provided.



**(88) Date of publication of the international search report:**  
10 May 2013

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 12/43404

<b>A. CLASSIFICATION OF SUBJECT MATTER</b> IPC(8) - H01L 29/22; C01B 19/00 (2012.01) USPC - 257/614; 206/710 According to International Patent Classification (IPC) or to both national classification and IPC		
<b>B. FIELDS SEARCHED</b> Minimum documentation searched (classification system followed by classification symbols) IPC(8)- H01L 29/22; C01B 19/00 (2012.01); USPC- 257/614; 206/710 Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched USPC- 257/E29.099; 423/508; 257/E31.093; Patents and NPL (classification, keyword; search terms below) Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) PubWest (US Pat, PgPub, EPO, JPO), GoogleScholar (PL, NPL), FreePatentsOnline (US Pat, PgPub, EPO, JPO, WIPO, NPL); search terms: cadmium, tellurium, Cd, Te, CdS, sulfide, sulphide, chalcogen, substrate, minority, carrier, lifetime, net, acceptor, density, donor, dope, dopant, titanium, phosphorus, TiP		
<b>C. DOCUMENTS CONSIDERED TO BE RELEVANT</b>		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X -- Y	US 2011/0139249 A1 (GARNETT et al.) 16 June 2011 (16.06.2011), para [0007], [0011], [0014], [0021], [0028], [0032], [0039], [0045], [0067]	1-4, 6-11 ----- 5
X -- Y	CHAKRABARTI et al. "Surface photovoltage measurement in CdS/CdTe solar cell: Grain boundary effect." Solar Energy Materials and Solar Cells [online], March 2000 [Retrieved on 2012-10-09], Vol. 61, Iss. 2, pp. 113-126, Retrieved from the Internet: <URL: <a href="http://www.sciencedirect.com/science/article/pii/S092702489900104X">http://www.sciencedirect.com/science/article/pii/S092702489900104X</a> >, see entire document, especially pg 115, para 1; pg 116, para 3; Tables 1, 3	1 -- 5
Y, P	US 2012/0042950 A1 (CHIN) 23 February 2012 (23.02.2012), para [0026]-[0063]	1-11
Y	US 7,608,830 B1 (KINCH) 27 October 2009 (27.10.2009), col 5-14	1-11
Y	US 5,578,502 A (ALBRIGHT et al.) 26 November 1996 (26.11.1996), col 2-60	1-11
Y	US 4,296,188 A (HODES et al.) 20 October 1981 (20.10.1981), col 2-4	1-11
<input type="checkbox"/> Further documents are listed in the continuation of Box C. <input type="checkbox"/>		
* 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 09 October 2012 (09.10.2012)		Date of mailing of the international search report <b>28 JAN 2013</b>
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: Lee W. Young PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

**INTERNATIONAL SEARCH REPORT**

International application No.

PCT/US 12/43404

**Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)**

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1.  Claims Nos.:  
because they relate to subject matter not required to be searched by this Authority, namely:
  
2.  Claims Nos.:  
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
  
3.  Claims Nos.:  
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

**Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)**

This International Searching Authority found multiple inventions in this international application, as follows:  
This application contains the following inventions or groups of inventions which are not so linked as to form a single general inventive concept under PCT Rule 13.1. In order for all inventions to be examined, the appropriate additional examination fees must be paid.

Group I, Claims 1-11, directed to a method of depositing a layer of a material comprising polycrystalline CdTe onto a substrate, the method comprising providing to a deposition process a source material comprising an amount of Cd and an amount of Te in a non-stoichiometric ratio, wherein: the non-stoichiometric ratio consists of either: a Cd-rich ratio having a larger atomic percentage of Cd relative to the atomic percentage of Te; or a Te-rich ratio having a larger atomic percentage of Te relative to the atomic percentage of Cd.

-- Please see Extra Sheet --

1.  As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2.  As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3.  As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
  
4.  No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:  
1-11

**Remark on Protest**

- The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- No protest accompanied the payment of additional search fees.

Continued from Box No. III, Observations where unity of invention is lacking:

Continued from Box No. 1.(i):

This application contains the following inventions or groups of inventions which are not so linked as to form a single general inventive concept under PCT Rule 13.1. In order for all inventions to be examined, the appropriate additional examination fees must be paid.

Group I, Claims 1-11, directed to a method of depositing a layer of a material comprising polycrystalline CdTe onto a substrate, the method comprising providing to a deposition process a source material comprising an amount of Cd and an amount of Te in a non-stoichiometric ratio, wherein: the non-stoichiometric ratio consists of either: a Cd-rich ratio having a larger atomic percentage of Cd relative to the atomic percentage of Te; or a Te-rich ratio having a larger atomic percentage of Te relative to the atomic percentage of Cd.

Group II, Claims 12-19, directed to a method of forming an ohmic contact on an exposed surface of a polycrystalline CdTe layer, the method comprising: depositing the polycrystalline CdTe layer and at least one additional element incorporated into a crystalline lattice of the polycrystalline CdTe onto a substrate by providing to a deposition process a source material comprising an amount of Cd and an amount of Te in a non-stoichiometric ratio and an amount of the at least one additional element wherein: the non-stoichiometric ratio consists of either: a Cd-rich ratio having a larger atomic percentage of Cd relative to the atomic percentage of Te; or a Te-rich ratio having a larger atomic percentage of Te relative to the atomic percentage of Cd; and the at least one additional element is chosen from an acceptor dopant, a donor dopant, an isoelectronic dopant, and any combination thereof.

Group III, Claims 20-33, directed to a method of forming an ohmic contact on an exposed surface of a polycrystalline CdTe layer, the method comprising: depositing the polycrystalline CdTe layer and at least one additional element incorporated into a crystalline lattice of the polycrystalline CdTe onto a substrate by providing to a deposition process a source material comprising an amount of Cd and an amount of Te in a non-stoichiometric ratio and an amount of the at least one additional element wherein: the non-stoichiometric ratio consists of either: a Cd-rich ratio having a larger atomic percentage of Cd relative to the atomic percentage of Te; or a Te-rich ratio having a larger atomic percentage of Te relative to the atomic percentage of Cd; and the at least one additional element is chosen from an acceptor dopant, a donor dopant, an isoelectronic dopant, and any combination thereof; and depositing a contact layer onto the exposed surface.

The inventions listed as Groups I-III do not relate to a single general inventive concept under PCT Rule 13.1 because under PCT Rule 13.2 they lack the same or corresponding technical features for the following reasons:

Group I does not include the inventive concepts of one additional element being chosen from an acceptor dopant, a donor dopant, an isoelectronic dopant, and any combination thereof, as required by groups II-III; and depositing a contact layer onto the exposed surface, as required by Group III.

Group II does not include the inventive concept of depositing a contact layer onto the exposed surface, as required by Group III.

Group III requires the deposition of a contact layer onto the exposed surface of the CdTe layer, which is not required by the other Groups.

Groups I, II, and III share a method of depositing a layer of a material comprising polycrystalline CdTe onto a substrate, the method comprising providing to a deposition process a source material comprising an amount of Cd and an amount of Te in a non-stoichiometric ratio, wherein: the non-stoichiometric ratio consists of either: a Cd-rich ratio having a larger atomic percentage of Cd relative to the atomic percentage of Te; or a Te-rich ratio having a larger atomic percentage of Te relative to the atomic percentage of Cd.

The common feature of a Te-rich ratio having a larger atomic percentage of Te relative to the atomic percentage of Cd of Groups I, II, and III are taught by US 2011/0139249 A1 to Garnett, et al. (hereinafter 'Garnett'); therefore the common feature is not an improvement over the prior art.

Garnett discloses a method of depositing a layer of a material comprising polycrystalline CdTe onto a substrate (para [0007], [0011], and [0014]), the method comprising providing to a deposition process a source material comprising an amount of Cd and an amount of Te in a non-stoichiometric ratio (para [0011], [0014], and [0021]), wherein: the non-stoichiometric ratio consists of a Te-rich ratio having a larger atomic percentage of Te relative to the atomic percentage of Cd (para [0011], [0014], and [0021]: see, for example, the heterojunction layer comprising  $Cd_xZn_{(1-x)}Te$ , wherein x ranges from 0 up about 0.8 and 0.95.).

Garnett further discloses at least one additional element is chosen from an acceptor dopant (para [0042]), a donor dopant (para [0042]), an isoelectronic dopant, and any combination thereof; and depositing a contact layer onto the exposed surface (para [0011], [0015], and [0065]).

None of these technical features are common to the other groups, nor do they correspond to a special technical feature in the other groups. Therefore, unity of invention is lacking.