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[Continued on next page]

(54) Title: THERMOELECTRIC MATERIALS AND METHODS FOR SYNTHESIS THEREOF

(57) Abstract: Thermoelectric materials with improved thermoelectric properties and methods for synthesis of such thermoelectric materials are disclosed herein. In some embodiment, a method of fabricating a thermoelectric material includes generating a plurality of nanoparticles from a starting material comprising one or more dopant materials and Bismuth Telluride based alloy materials; and consolidating the nanoparticles under pressure at a temperature greater than about 200 °C to form a doped Bismuth Telluride based alloy.

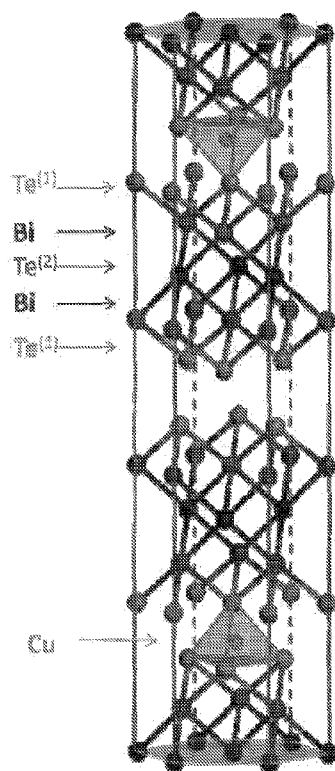


FIG. 2A



(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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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, RS, 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))
- 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))

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6 December 2012

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 12/32495

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - H01L 35/12 (2012.01)

USPC - 136/204; 136/236.1

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 35/12 (2012.01)

USPC - 136/204; 136/236.1

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

IPC (8) - H01L 35/12 (2012.01)

USPC - 136/204; 136/236.1 (keyword delimited)

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

PubWEST (PGPB,USPT,USOC,EPAB,JPAB) Terms - Bi bismuth Se selenium Te telluride Cu copper dopant nanoparticles milling pressing pressure Boston

Google - bismuth-selenium-telluride milled-nanoparticles dopant ball-milling figure-of-merit, bismuth-telluride nanoparticles milling press

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 2008/0202575 A1 (REN, ET AL.) 28 August 2008 (28.08.2008), para [0012], [0018], [0060], [0064], [0085], [0093]	1-4, 6-13 ----- 5
Y	US 7,255,846 B2 (REN, ET AL.) 14 August 2007 (14.08.2007), col 11, ln 52-56	5
Y	US 2,957,937 A (JENSEN, ET AL.) 25 October 1960 (25.10.1960), entire document	5
A	US 3,228,805 A (WASELESKI, ET AL.) 11 January 1966 (11.01.1966), col 1-3	1-13

☐ 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

04 September 2012 (04.09.2012)

Date of mailing of the international search report

21 SEP 2012

Name and mailing address of the ISA/US

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 12/32495

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:

The following claim groups were found:

Group I: Claims 1-13

Group II: Claims 14-20

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.

-- 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.:
1-13

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.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 12/32495

Continuation of Box No. III -- Observations where unity of invention is lacking

Group I: is drawn to a method of fabricating a thermoelectric material comprising: generating a plurality of nanoparticles from a starting material comprising one or more dopant materials and Bismuth Telluride based alloy materials; and consolidating the nanoparticles under pressure at a temperature greater than about 200C to form a doped Bismuth Telluride based alloy.

Group II: is drawn to a thermoelectric material comprising a Bismuth Telluride based alloy having a figure of merit equal to or greater than about 1.06.

The inventions listed in the above-mentioned groups 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 special technical features for the following reasons:

Groups I and II lack unity of invention, because even though the inventions of these groups require the technical feature of a thermoelectric material comprising a Bismuth Telluride based alloy, this technical feature is not a special technical feature as it does not make a contribution over the prior art in view of US 2,957,937 A to Jensen et al., which discloses a thermoelectric material comprising a Bismuth Telluride based alloy (col 2, ln 53-60).

Groups I-II therefore lack unity under PCT Rule 13 because they do not share a same or corresponding special technical feature.