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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))*

(88) Date of publication of the international search report:
16 August 2012

(54) Title: NANO-ENGINEERED ULTRA-CONDUCTIVE NANOCOMPOSITE COPPER WIRE

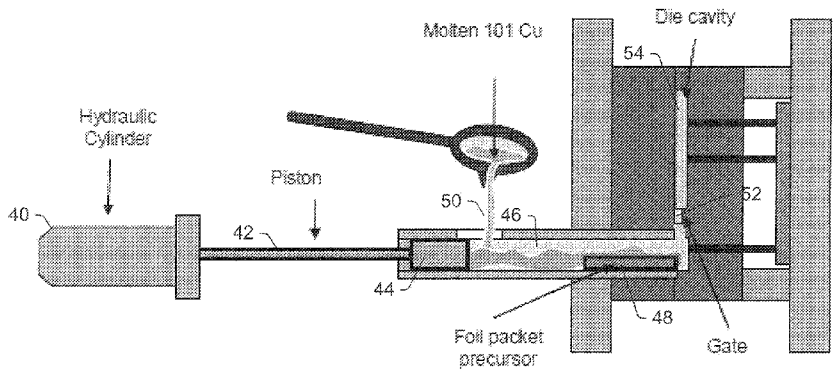

FIG. 2

(57) Abstract: Nano-composite structures are formed by pre-loading carbon nanotubes (CNTs) into at least one of a plurality of channels running the length of a cartridge, placing the pre-loaded cartridge in a piston chamber of a die-casting machine, creating a vacuum therein, and filing the piston chamber with molten metal to soak the pre-loaded cartridge and fill empty cartridge channels. Pressure is applied via the piston to eject the carbon nanotubes and molten metal from the cartridge channels and inject the nano-composite mixture into a rod-shaped die cavity. The internal diameter of the cavity is equal to or less than the final diameter of the nozzle. The nano-composite mixture is cooled to form a solid nano- composite rod having the first predetermined diameter, wherein the carbon nanotubes are aligned in a non-random manner. Furthermore, drawing down the nano-composite rod to smaller diameter wire further disperses the nanotubes along the length of the wire.

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 11/65191

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - D01F 9/12; B82B 1/00 (2012.01)
USPC - 423/447.1; 977/742; 977/762
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)- D01F 9/12; B82B 1/00 (2012.01);
USPC- 423/447.1; 977/742; 977/762

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
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: nanotube, nanocomposite, assembly, wire, lead, interconnect, copper, Cu, wire, cartridge, piston, die, cast, CNT, SWNT, DWNT, MWNT, ball, mill, ultrasound, sonicate, magnesium, chloride

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2005/0115693 A1 (BAUMGARTNER) 02 June 2005 (02.06.2005), Figs. 1, 3; para [0001], [0008], [0013], [0019], [0020], [0022]-[0024], [0027], [0029], [0033]	1-14
Y	US 2010/0203351 A1 (NAYFEH) 12 August 2010 (12.08.2010), Fig. 21; Table 2; para [0036]-[0039], [0040], [0047], [0050], [0053], [0057], [0059], [0077], [0090], [0092], [0096]-[0099], [0102]	1-16
Y	US 6,021,840 A (COLVIN) 08 February 2000 (08.02.2000), Fig. 1; col 1, ln 36-59; col 2, ln 6-12; col 4, ln 58 to col 5, ln 56	15, 16
Y	US 2010/0068526 A1 (ADAMS et al.) 18 March 2010 (18.03.2010), para [0008], [0011], [0014], [0019], [0030]	17-20
Y	US 2008/0210370 A1 (SMALLEY et al.) 04 September 2008 (04.09.2008), para [0012], [0015]-[0017], [0051], [0054], [0061], [0066]-[0070], [0082], [0085], [0086], [0144]	17-20
Y, P	US 2011/0174519 A1 (SHAH et al.) 21 July 2011 (21.07.2011), para [0005]-[0140]	1-16
Y, P	US 2011/0068299 A1 (HONG et al.) 24 March 2011 (24.03.2011), para [0020]-[0075]	17-20
Y	US 2008/0067681 A1 (TSENG et al.) 20 March 2008 (20.03.2008), para [0011]-[0047]	1-16
Y	US 5,259,436 A (YUN et al.) 09 November 1993 (09.11.1993), entire document	1-16

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

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

Date of the actual completion of the international search	Date of mailing of the international search report
23 May 2012 (23.05.2012)	04 JUN 2012
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

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

INTERNATIONAL SEARCH REPORT

International application No.
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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 1-16
Group II: Claims 17-20

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.

-- 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.:

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 11/65191

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

Group I: is drawn to method of forming nano-composite copper wire, comprising: pre-loading carbon nanotubes into at least one of a plurality of channels running a length of a cartridge; placing the pre-loaded cartridge in a piston chamber of a diecasting machine; drawing air out of the piston chamber to create a vacuum therein; filing the piston chamber with molten metal and soaking the preloaded cartridge for a predetermined time, wherein the molten metal fills cartridge channels that are not pre-loaded with carbon nanotubes; applying pressure via the piston to eject the carbon nanotubes and molten metal from the cartridge channels as a nano-composite mixture and inject the nano-composite mixture into a rod-shaped die cavity through a nozzle that draws down the nano-composite mixture to a first predetermined diameter that is not greater than a diameter of the die cavity; and cooling the nano-composite mixture to form a solid nano-composite rod having the first predetermined diameter, wherein the carbon nanotubes are aligned in a non-random manner in the nano-composite rod.

Group II: is drawn to a method of forming carbon nanotube (CNT) precursor material for adding to molten metal to form a nano-composite material, comprising; ball-milling commercial type CNTs to break the CNTs down to a predetermined length; graphitizing the shortened CNTs by heating to a predetermined temperature; ultrasonically mixing the graphitized CNTs with an MgCb solution; and flow -milling the CNTs with the MgCl2 solution for a predetermined number of milling cycles.

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:

Group I includes the technical feature of applying pressure via the piston to eject the carbon nanotubes and molten metal from the cartridge channels as a nano-composite mixture and inject the nano-composite mixture into a rod-shaped die cavity through a nozzle that draws down the nano-composite mixture to a first predetermined diameter that is not greater than a diameter of the die cavity, not found in the other groups.

Group II includes the technical feature of ultrasonically mixing the graphitized CNTs with an MgCb solution; and flow-milling the CNTs with the MgCl2 solution for a predetermined number of milling cycles, not found in the other groups.

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