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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**:
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(54) **Title**: ENERGY STORAGE MEDIA FOR ULTRACAPACITORS

(57) **Abstract**: An ultracapacitor includes at least one electrode that includes carbon nanotubes. The carbon nanotubes may be applied in a variety of ways, and a plurality of layers may be included. Methods of fabrication of carbon nanotubes and ultracapacitors are provided.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 12/41438

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - H01G 9/00 (2012.01)
USPC - 361/502
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)
USPC -- 361/502

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
USPC -- 361/502,15,42;977/762,742;429/121,209

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
PubWEST (USPT,PGPB,JPAB,EPAB); Google
Search Terms: vertically aligned carbon nanotubes array metal catalyst substrate base raw gas ethane methane ethanol methanol metal copper zinc oxide alloy aluminum zinc magnesium silicon density diameter inert helium argon oxidizing apparatus loader frame

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 2009/0272935 A1 (Hata et al.) 05 Nov 2009 (05.11.2009), entire document especially Abstract, para [0114]-[0115], [0108], [0107], [0144], [0122], [0112], [0115] and [0118]	1-6 and 9-25 --- 7-8, 34-43, 59 and 61
X ---- Y	US 2010/0196600 A1 (Shibuya et al.) 05 Aug 2010 (05.08.2010), entire document especially Abstract, para [0163]-[0164], [0138], [0006], [0029], [0095], [0060], [0074], [0133]-[0134] and [0137]	26-29 and 31-33 --- 7-8, 30
X	US 6,454,816 B1 (Lee et al.) 24 Sep 2002 (24.09.2002), entire document especially Abstract, col 2, ln 63 to col 3, ln 12 and col 3, ln 35-65	56-58, 60, 62-69, 73-76, 129-130, 132-179 --- 34-43, 50, 59, 61, 70-72
X -- Y	US 2009/0272946 A1 (Lu) 05 Nov 2009 (05.11.2009), entire document especially Abstract, para [0122], [0139], [0241], [0130], [0123] and [0248]	77-96, 108-115, 117-128 and 131 --- 97-107 and 116
Y	US 7,785,558 B2 (Hikata) 31 Aug 2010 (31.08.2010), entire document especially Abstract and col 10, ln 5-20	30

☒ 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
30 Oct 2012 (30.10.2012)	19 NOV 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

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 12/41438

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:
---------- See Continuation 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.:
1-43, 50 and 56-179

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 12/41438

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2008/0316678 A1 (Ehrenberg et al.) 25 Dec 2008 (25.12.2008), entire document especially para [0067] and [0010]	70-72
Y	US 2005/0231893 A1 (Harvey) 20 Oct 2005 (20.10.2005), entire document especially Abstract, para [0030]; [0037]	50, 97-107 and 116

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/US 12/41438

Box III: Observations where Unity of Invention is Lacking:

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 1-33 directed method of producing an aggregate of vertically aligned carbon nanotubes, the method comprising: loading a base material into a substantially oxygen free environment; disposing a catalyst onto the base material to provide a substrate; subjecting the substrate to a raw material gas and heating at least one of the raw material gas and the substrate for growing the aggregate onto the substrate; and cooling the aggregate in a substantially oxygen free environment

Group II: claims 34-43 directed to a method of producing an electrode for an ultracapacitor, the electrode comprising an aggregate of vertically aligned carbon nanotubes, the method comprising: selecting aggregate that has been fabricated by loading a base material into a substantially oxygen free environment; disposing a catalyst onto the base material to provide a substrate; subjecting the substrate to a raw material gas and heating at least one of the raw material gas and the substrate to grow the aggregate thereon; cooling the aggregate in a substantially oxygen free environment; and one of joining the aggregate with a current collector, removing the aggregate from the substrate and disposing a current collector onto the aggregate and combining the aggregate with other carbonaceous material an joining the combination with a current collector.

Group III: claims 44-49 directed to a method of producing an electrode for an energy storage system, the method comprising: selecting a substrate comprising a thickness of vertically aligned carbon nanotubes (CNT) disposed thereon; disposing a bonding layer onto the thickness of CNT; bonding the bonding layer to a current collector and compressing the thickness of CNT; and removing the substrate from the CNT to provide the electrode.

Group IV: claim 50 directed to an electrode for an energy storage system, the electrode comprising: a current collector comprising a bonding layer disposed thereon; at least one layer of compressed vertically aligned carbon nanotubes (CNT) comprising a bonding layer disposed thereon; wherein the bonding layer of the current collector is bonded to the bonding layer of the layer of compressed CNT.

Group V: claim 51-52 directed to an ultracapacitor comprising: at least one electrode comprising a current collector comprising a bonding layer disposed thereon, at least one layer of compressed vertically aligned carbon nanotubes (CNT) comprising a bonding layer disposed thereon, wherein the bonding layer of the current collector is bonded to the bonding layer of the layer of compressed CNT; and an electrolyte that wets the at least one electrode.

Group VI: claim 53-55 directed to method of producing an ultracapacitor, the ultracapacitor comprising at least one electrode comprising an aggregate of vertically aligned carbon nanotubes, the method
comprising: selecting an electrode that has been fabricated by selecting aggregate that has been fabricated by loading a base material into a substantially oxygen free environment; disposing a catalyst onto the base material to provide a substrate; subjecting the substrate to a raw material gas and heating at least one of the raw material gas and the substrate to grow the aggregate thereon; cooling the aggregate in a substantially oxygen free environment; and one of transferring the aggregate onto a current collector, removing the aggregate from the substrate and disposing a current collector onto the aggregate and combining the aggregate with other carbonaceous material on a current collector to provide the electrode; and incorporating the electrode into the ultracapacitor.

Group VII: claim 129--130 directed to an electrode for an energy storage, the electrode comprising:
a compressed layered stack of vertically aligned carbon nanotubes (CNT) and a current collector disposed onto the stack.

Group VIII: claims 56-128 and 131-179 directed to method of producing/fabricating an electrode for an energy storage system, the method comprising: selecting a base comprising a current collector and a first joining layer disposed over the current collector; and joining a second joining layer to the first joining layer, the second joining layer comprising a carbonaceous layer/aggregate of carbon nanotubes disposed thereon, the carbonaceous layer comprising material for storing charge.

The inventions listed as Groups I-VIII 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:

Groups I-VII do not include the inventive concept of a sensor of first and second joining layers of Group VIII

Groups I-III, VI and VIII do not include the inventive concept of compressed stack of Groups IV, V and VII

Groups III-V and VII-VIII do not include the inventive concept of catalyst of Groups I-II and VI

Groups I-IV and VI-VIII do not include the inventive concept of electrolyte of Group V

Group I do not include the inventive concept of current collector comprising a bonding layer of Group II-VIII

Groups I-II and IV-VIII do not include the inventive concept of thickness of vertically aligned carbon nanotube of Group III

Groups III-V, VII-VIII do not include the inventive concept of heating at least one of the raw material gas Group I-II and VI

The common feature of vertically aligned carbon nanotubes groups I-VII is taught by US 2008/0001284 A1 (Yuen et al.), Jan 3, 2008 (see para [0042]; [0099]) and therefore fails to make a unifying contribution over the prior art.

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.