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(54) Title: SULFUR CONTAINING NANOPOROUS MATERIALS, NANOPARTICLES, METHODS AND APPLICATIONS



(57) Abstract: Sulfur containing nanoparticles that may be used within cathode electrodes within lithium ion batteries include in a first instance porous carbon shape materials (i.e., either nanoparticle shapes or "bulk" shapes that are subsequently ground to nanoparticle shapes) that are infused with a sulfur material. A synthetic route to these carbon and sulfur containing nanoparticles may use a template nanoparticle to form a hollow carbon shape shell, and subsequent dissolution of the template nanoparticle prior to infusion of the hollow carbon shape shell with a sulfur material. Sulfur infusion into other porous carbon shapes that are not hollow is also contemplated. A second type of sulfur containing nanoparticle includes a metal oxide material core upon which is located a shell layer that includes a vulcanized polymultiene polymer material and ion conducting polymer material. The foregoing sulfur containing nanoparticle materials provide the electrodes and lithium ion batteries with enhanced performance.



WO 2012/064702 A3

## INTERNATIONAL SEARCH REPORT

International application No.  
**PCT/US2011/059722**

<b>A. CLASSIFICATION OF SUBJECT MATTER</b>		
<i>H01M 4/583(2010.01)i, H01M 4/58(2010.01)i, B82B 3/00(2006.01)i, H01M 4/13(2010.01)i, H01M 10/0525(2010.01)i</i>		
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) H01M 4/583; H01M 4/00; H01M 4/60; C01F 17/00; C09K 11/02; C09K 11/54; H01M 10/02; A61K 8/19; H01M 4/58		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Korean utility models and applications for utility models Japanese utility models and applications for utility models		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) eKOMPASS(KIPO internal) & Keywords: nano particle,carbon,sulfur,cyclic voltammogram,lithium sulfur cell,conductive,bulk carbon,core,shell layer,		
<b>C. DOCUMENTS CONSIDERED TO BE RELEVANT</b>		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2007-0237990 A1 (KIM, YOUNG NAM) 11 October 2007 See the whole document.	1-34
A	KR 10-2003-0013553 A (LG ELECTRONICS INC.) 15 February 2003 See the whole document.	1-34
A	US 6194099 B1 (GERNOV, YORDAN M. et al.) 27 February 2001 See the whole document.	1-34
A	JP 2009-196843 A (NATIONAL INSTITUTE OF ADVANCED INDUSTRIAL & TECHNOLOGY) 03 September 2009 See the whole document.	1-34
A	WO 2009-040553 A2 (NANOCO TECHNOLOGIES LIMITED) 02 April 2009 See the whole document.	1-34
<input type="checkbox"/> Further documents are listed in the continuation of Box C. <input checked="" type="checkbox"/> See patent family annex.		
* 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 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 23 MAY 2012 (23.05.2012)		Date of mailing of the international search report <b>24 MAY 2012 (24.05.2012)</b>
Name and mailing address of the ISA/KR  Korean Intellectual Property Office 189 Cheongsu-ro, Seo-gu, Daejeon Metropolitan City, 302-701, Republic of Korea Facsimile No. 82-42-472-7140		Authorized officer Cho Ki Yun Telephone No. 

**INTERNATIONAL SEARCH REPORT**

International application No.

**PCT/US2011/059722****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:

Group 1: Claims 1-23 relate to a nanoparticle, comprising 1) a carbon material support, and 2) a sulfur material supported on the carbon material support.

Group 2: Claims 24-34 relate to a nanoparticle, comprising 1) a core comprising a metal oxide material, and 2) a shell layer located upon the core and comprising a sulfur cross-linked polymultiene polyer material.

The inventions listed as groups 1-2 do not relate to a single general inventive concept under PCT Rule 13.1, because, under PCT Rule 13.2 they do not share the same or corresponding technical features.

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 an additional fee, this Authority did not invite payment of any additional fee.
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**

Information on patent family members

International application No.

**PCT/US2011/059722**

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2007-0237990 A1	11. 10. 2007	CN 100550485 C	14. 10. 2009
		CN 1910771 A	07. 02. 2007
		CN 1910771 C0	07. 02. 2007
		EP 1706911 A1	04. 10. 2006
		JP 2007-527099 A	20. 09. 2007
		KR 10-0511363 B1	31. 08. 2005
		KR 10-0584671 B1	30. 05. 2006
		US 2004-0241532 A1	02. 12. 2004
		US 7531267 B2	12. 05. 2009
		WO 2005-069412 A1	28. 07. 2005
		KR 10-2003-0013553 A	15. 02. 2003
US 6194099 B1	27. 02. 2001	AU 1999-18119 A1	12. 07. 1999
		WO 99-33132 A1	01. 07. 1999
JP 2009-196843 A	03. 09. 2009	None	
WO 2009-040553 A2	02. 04. 2009	AT 513890 T	15. 07. 2011
		AU 2008-303396 A1	02. 04. 2009
		AU 2008-303396 A2	20. 05. 2010
		CA 2700179 A1	02. 04. 2009
		CN 101815774 A	25. 08. 2010
		EP 2190944 A2	02. 06. 2010
		EP 2190944 B1	22. 06. 2011
		EP 2341117 A2	06. 07. 2011
		EP 2341117 A3	27. 07. 2011
		IL 204558 D0	30. 11. 2010
		JP 2010-540709 A	24. 12. 2010
		JP 2010-540709 T	24. 12. 2010
		KR 10-2010-0085941 A	29. 07. 2010
		TW 200927642 A	01. 07. 2009
		US 2010-0283005 A1	11. 11. 2010
		WO 2009-040553 A3	23. 07. 2009