



US008999574B2

(12) **United States Patent**  
**Liu et al.**

(10) **Patent No.:** **US 8,999,574 B2**  
(45) **Date of Patent:** **Apr. 7, 2015**

(54) **METHOD OF PREPARING GRAPHENE-SULFUR NANOCOMPOSITES FOR RECHARGEABLE LITHIUM-SULFUR BATTERY ELECTRODES**

(58) **Field of Classification Search**  
CPC .... B82Y 30/00; H01M 4/136; H01M 4/1397; H01M 4/5815; H01M 4/623; H01M 10/052; H01M 4/049  
USPC ..... 429/213, 231.8; 977/734, 773, 840; 252/182.1  
See application file for complete search history.

(71) Applicant: **Battelle Memorial Institute**, Richland, WA (US)

(72) Inventors: **Jun Liu**, Richland, WA (US); **John P. Lemmon**, Kennewick, WA (US); **Zhenguang Yang**, Bellevue, WA (US); **Yuliang Cao**, Richland, WA (US); **Xiaolin Li**, Richland, WA (US)

(56) **References Cited**  
U.S. PATENT DOCUMENTS  
2009/0246625 A1 10/2009 Lu  
2011/0165466 A1 7/2011 Zhamu et al.

(73) Assignee: **Battelle Memorial Institute**, Richland, WA (US)

FOREIGN PATENT DOCUMENTS  
CN 1485941 3/2004  
JP 2010219047 9/2010

(\* ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

OTHER PUBLICATIONS  
Office Action for Chinese Patent Application No. 201180048678.1 (mailed Nov. 19, 2014).  
(Continued)

(21) Appl. No.: **14/225,561**

(22) Filed: **Mar. 26, 2014**

(65) **Prior Publication Data**  
US 2014/0203469 A1 Jul. 24, 2014

*Primary Examiner* — Milton I Cano  
*Assistant Examiner* — Michael Dignan  
(74) *Attorney, Agent, or Firm* — Klarquist Sparkman, LLP

**Related U.S. Application Data**

(62) Division of application No. 13/023,241, filed on Feb. 8, 2011, now Pat. No. 8,753,772.

(60) Provisional application No. 61/390,945, filed on Oct. 7, 2010.

(51) **Int. Cl.**  
**H01M 4/04** (2006.01)  
**B82Y 30/00** (2011.01)  
(Continued)

(57) **ABSTRACT**  
A method of preparing a graphene-sulfur nanocomposite for a cathode in a rechargeable lithium-sulfur battery comprising thermally expanding graphite oxide to yield graphene layers, mixing the graphene layers with a first solution comprising sulfur and carbon disulfide, evaporating the carbon disulfide to yield a solid nanocomposite, and grinding the solid nanocomposite to yield the graphene-sulfur nanocomposite. Rechargeable-lithium-sulfur batteries having a cathode that includes a graphene-sulfur nanocomposite can exhibit improved characteristics. The graphene-sulfur nanocomposite can be characterized by graphene sheets with particles of sulfur adsorbed to the graphene sheets. The sulfur particles have an average diameter of less than 50 nm.

(52) **U.S. Cl.**  
CPC ..... **H01M 4/049** (2013.01); **B82Y 30/00** (2013.01); **H01M 4/136** (2013.01);  
(Continued)

**10 Claims, 5 Drawing Sheets**

