



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

(10) **Patent No.:** **US 9,410,040 B2**
(45) **Date of Patent:** **Aug. 9, 2016**

(54) **SOLUBLE GRAPHENE NANOSTRUCTURES AND ASSEMBLIES THEREFROM**

(2013.01); *C01P 2002/82* (2013.01); *C01P 2002/89* (2013.01); *C01P 2006/40* (2013.01); *Y10T 428/265* (2015.01)

(75) Inventors: **Liang-shi Li**, Bloomington, IN (US);
Xin Yan, Bloomington, IN (US)

(58) **Field of Classification Search**
CPC B82Y 30/00; B82Y 40/00; H01B 1/04
USPC 252/500-511; 977/734, 755, 788, 932
See application file for complete search history.

(73) Assignee: **Indiana University Research and Technology Corporation**, Indianapolis, IN (US)

(56) **References Cited**

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 730 days.

U.S. PATENT DOCUMENTS

(21) Appl. No.: **13/520,735**

6,506,928 B1 * 1/2003 Hirsch 560/80
2003/0001141 A1 * 1/2003 Sun et al. 252/301.35
2008/0221240 A1 9/2008 Swager et al.

(22) PCT Filed: **Jan. 7, 2011**

(Continued)

(86) PCT No.: **PCT/US2011/020501**

FOREIGN PATENT DOCUMENTS

§ 371 (c)(1),
(2), (4) Date: **Jul. 5, 2012**

JP 2009151956 * 7/2009 H01M 4/60

(87) PCT Pub. No.: **WO2011/085185**

PCT Pub. Date: **Jul. 14, 2011**

OTHER PUBLICATIONS

Si ("Synthesis of Water Soluble Graphene." *NanoLetters*, 8(6), p. 1479-1682, Web May 23, 2008).*

(Continued)

(65) **Prior Publication Data**

US 2012/0279570 A1 Nov. 8, 2012

Primary Examiner — Tri V Nguyen

(74) *Attorney, Agent, or Firm* — Barnes & Thornburg LLP

Related U.S. Application Data

(60) Provisional application No. 61/293,337, filed on Jan. 8, 2010.

(57) **ABSTRACT**

(51) **Int. Cl.**

H01B 1/04 (2006.01)
B82Y 20/00 (2011.01)
B82Y 30/00 (2011.01)
C09C 1/44 (2006.01)
C01B 31/04 (2006.01)

Disclosed herein is a method for preparing large soluble graphenes. The method comprises attaching one or more hindering groups to the graphene, which can prevent face-to-face graphene stacking by reducing the effects of inter-graphene attraction. The large graphenes can absorb a wide spectrum of light from UV to near infrared, and are useful in photovoltaic devices and sensitizers in nanocrystalline solar cells.

(52) **U.S. Cl.**

CPC **C09C 1/44** (2013.01); **C01B 31/0438**

14 Claims, 10 Drawing Sheets

