US010000384B2

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

(10) **Patent No.: US 10,000,384 B2**
(45) **Date of Patent: Jun. 19, 2018**

(54) **METHOD OF LASER DIRECT SYNTHESIS OF GRAPHENE**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 783 days.

(21) Appl. No.: **13/906,057**

(22) Filed: **May 30, 2013**

(65) **Prior Publication Data**

US 2013/0323158 A1 Dec. 5, 2013

Related U.S. Application Data

(60) Provisional application No. 61/655,540, filed on Jun. 5, 2012.

(51) **Int. Cl.**

C01B 31/04	(2006.01)
C01B 32/184	(2017.01)
B82Y 30/00	(2011.01)
B82Y 40/00	(2011.01)
C30B 29/18	(2006.01)

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

CPC ***C01B 32/184*** (2017.08); ***B82Y 30/00*** (2013.01); ***B82Y 40/00*** (2013.01); *C30B 29/18* (2013.01)

(58) **Field of Classification Search**

CPC B82Y 30/00; B82Y 40/00; C01B 31/0446; C03C 17/22

See application file for complete search history.

(56) **References Cited**

PUBLICATIONS

Laser direct growth of graphene on silicon substrate, Wei et al., Applied Physics Letters 100, 023110 (2012).*

Direct Formation of Wafer Scale Graphene Thin Layers on Insulating Substrates by Chemical Vapor Deposition, Su et al., Nano Lett. 2011, 11, 3612-3616.*

Wei et al., Laser direct growth of graphene on silicon substrate, Applied Physics Letters 100, 023110, 2012.*

Su et al., Direct Formation of Wafer Scale Graphene Thin Layers on Insulating Substrates by Chemical Vapor Deposition, Nano Lett. 2011, 11, 3612-3616.*

De Heer, W. A. MRS Bull. 2011, 36, 632-639.

Hwang, D. J.; Ryu, S. G.; Grigoropoulos. C. P. Nanotechnol. 2011, 22, 385303.

Malard, L. M.; Pimenta, M. A.; Dresselhaus, G.; Dresselhaus, M. S. Phys. Rep. 2009, 473, 51-87.

Tang, B.; Guoxin, H.; Gao, H. Y. Appl. Spectrosc. Rev. 2010, 45, 367-407.

Scheibe, H. J.; Drescher, D.; Alers, P. Fresenius J. Anal. Chem. 1995, 353, 695-697.

(Continued)

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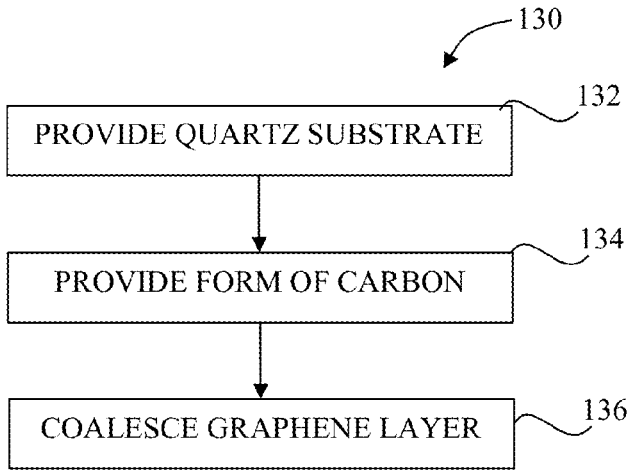
(57) **ABSTRACT**

A method of forming single and few layer graphene on a quartz substrate in one embodiment includes providing a quartz substrate, melting a portion of the quartz substrate, diffusing a form of carbon into the melted portion to form a carbon and quartz mixture, and precipitating at least one graphene layer out of the carbon and quartz mixture.

12 Claims, 9 Drawing Sheets