

Preparation of alumina – graphene composites by Long Pulsed Laser Ablation

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Abstract

In this work, the alumina - graphene composites were fabricated by laser ablation of graphite target in deionized water with alumina nanoparticles suspension using pulsed Nd:YAG laser. The mechanism of the graphene formation is derived from the insertion of alumina nanoparticles into the interlayer spacing of graphite which expand during laser heating. The synthesized alumina - graphene composites were characterized by field emission scanning electron microscope (FESEM), EDX, and UV-visible spectrophotometer.

Keyword: Laser ablation, graphene, alumina

1. Introduction

Graphene is a flat monolayer of carbon atoms tightly packed into a two-dimensional (2D) honeycomb lattice which was discovered in 2004 by Novoselov and Geim [1]. Graphene has many advantageous characteristics including low sheet resistance, high optical transparency and excellent mechanical properties that make it an ideal material for essential studies as well as for potential applications. For this reason makes many researcher interested in the applications of graphene such as an electrode material in transistors [2], light-emitting diodes [3], solar cells [4] and flexible devices [5]. Several methods have been used to synthesize graphene such as chemical vapor deposition (CVD) [6], epitaxial growth on electrically insulating surfaces [7], electric arc discharge [8], solution-based chemical reduction of graphene oxide [9] and laser ablation in liquid [10]. Among these reported methods, laser ablation in liquid seems to be the most simple preparation and inexpensive approach to synthesize graphene because it does not require a vacuum system. In this method, the laser beam is focused the target settled in the liquid. The graphenes are suspended in the liquid medium, instead of fuming in the air.

In this study, the preliminary results on our work were reported. Graphene – liked sheets were synthesized via laser ablation of graphite target in alumina nanosol. The morphology and chemical composition of graphene – liked sheets were investigated by field emission scanning electron microscopy (FESEM) and EDX technique. The optical property was examined by UV-visible spectroscopy.

2. Experimental

Preparation of aluminium and graphite target

The aluminium and graphite target were obtained from pressing powders under a hydraulic press. The consolidation pressure was 200 bars. Fig. 1 shows the process of consolidation of graphite powder.

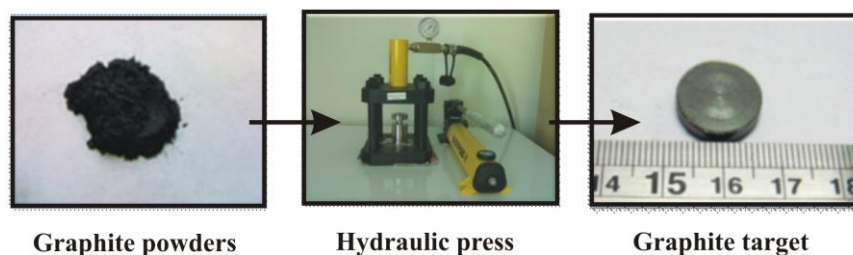


Figure 1 Consolidation of graphite powder with hydraulic press

Synthesis of alumina-graphene composites

The experimental procedure is illustrated by Fig. 2. The alumina nanosol was prepared by ablation of aluminium target using Nd:YAG laser (MIYACHI : ML-2331B), focused by a 5 cm focal-length plano-convex lens on the surface of graphite target. Laser energy employed in this study was 3.0 J/pulse. Pulse repetition rate and pulse duration were 2 Hz and 5 ms, respectively. After 5000 pulses of laser ablation, the alumina nanosol was collected by suction of the suspension. Alumina-graphene composites were synthesized by the similar method, in which the pulsed laser ablation of graphite target in alumina nanosol. Laser energy employed in this study was 1.0 J/pulse. Pulse repetition rate and pulse duration were 2 Hz and 5 ms, respectively.

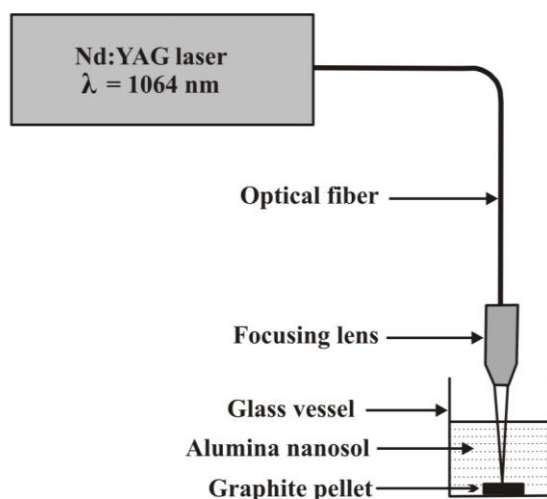


Figure 2 The schematic of the irradiation setup based on Nd:YAG laser ablation of graphite target in alumina nanosol

Characterization

The morphology of the alumina-graphene composites was investigated using field emission scanning electron microscopy (FESEM, Hitachi-S4700) by dropping the suspension onto silicon substrate and drying in air for about one day. The chemical composition was determined using EDS technique. The UV-visible spectra of the suspensions were obtained on a Thermoscientific evolution 600.

3. Result and discussion

The morphology of dried sample of alumina-graphene composites was investigated using field emission scanning electron microscopy. For comparison, the morphology of alumina nanoparticles and graphite microstructure were also investigated. Fig. 3(a) shows that alumina nanoparticles obtain by this method are in the range of tens of nanometer. The synthesized graphene – liked sheet has a very smooth surface (Fig. 3(c)-(d)). We can clearly see the alumina nanoparticles on the surface of graphene – liked sheets. The alumina nanoparticles adhesion to the surface of graphene – liked sheets help to prevent aggregation of the graphene – liked sheet. In order to understand more, Fig. 4 shows the schematic of the alumina nanoparticles adhesion to the surface of graphene – liked sheets. The thickness of graphene – liked sheets will be further characterization by AFM.

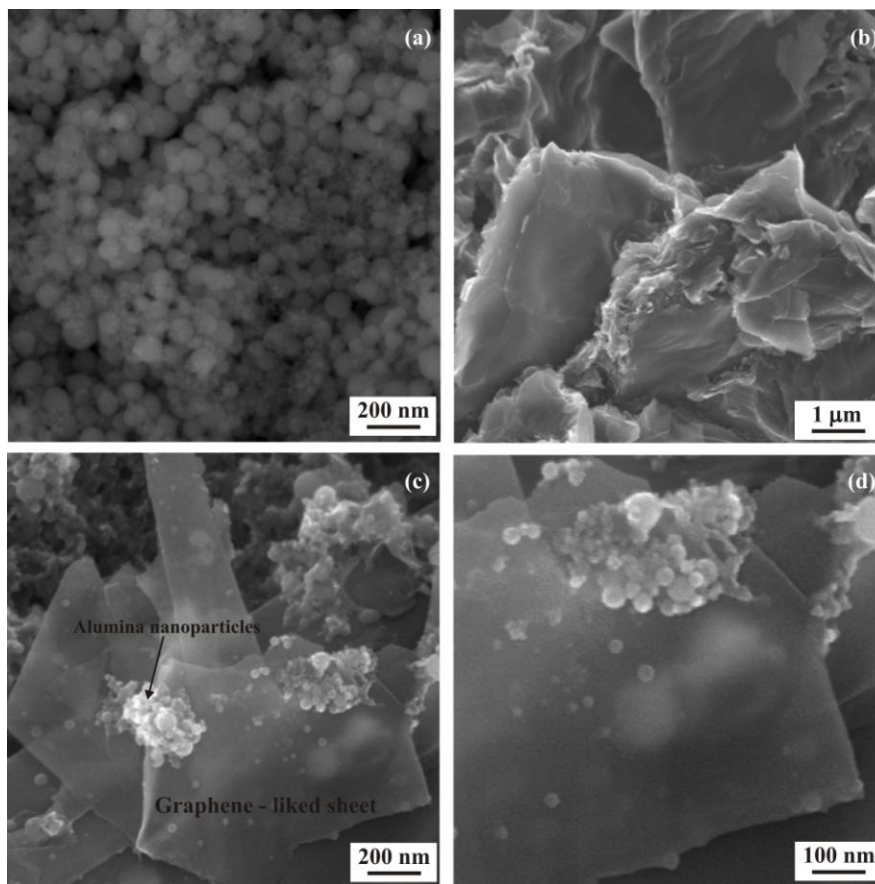


Figure 3 SEM images. (a) alumina nanoparticles , (b) graphite microstructure , (c) and (d) alumina-graphene composites



Figure 4 The schematic of alumina-graphene composites

Moreover, EDS shows the presence of C, O and Al in sample (Fig.5). The elemental composition shows 14.737, 57.217 and 28.045% wt for C, O and Al, respectively.

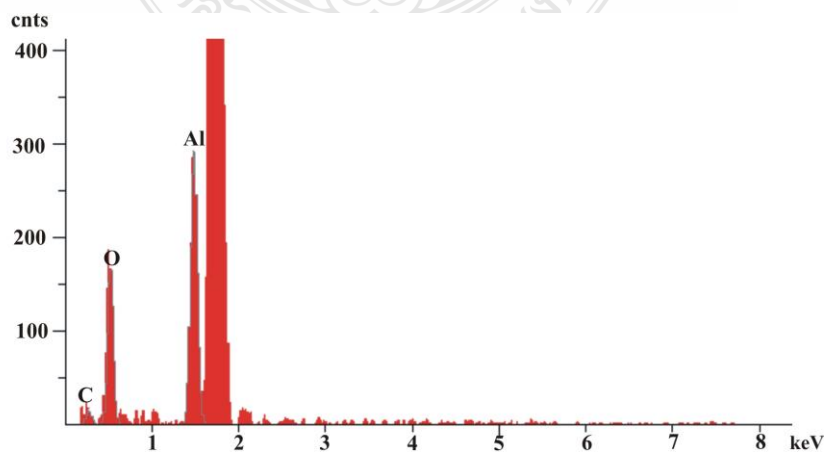


Figure 5 EDS spectrum of alumina-graphene composited

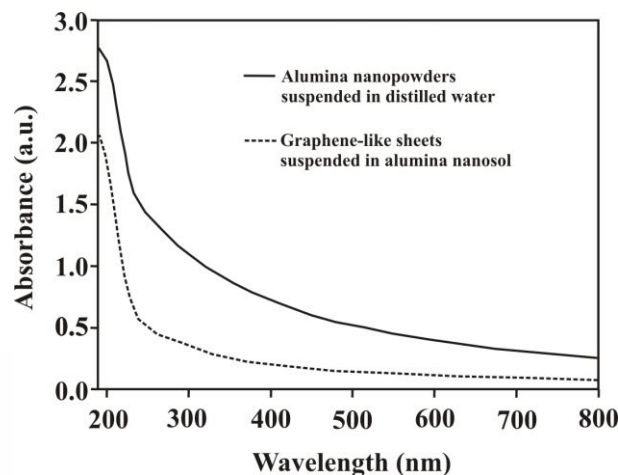


Figure 6 UV-visible spectra of Alumina nanopowders suspended in distilled water and graphene – liked sheets suspended in alumina nanosol

The UV-vis spectra of Alumina nanopowders suspended in distilled water and graphene – liked sheets suspended in alumina nanosol are shown in Fig. 5. The absorption band edges were estimated around 384 and 311 nm (about 3.23 and 3.99 eV).

Conclusion

In summary, a novel fabrication technique is represented for the alumina – graphene composited synthesized using Nd:YAG laser ablation of the graphite target in the alumina nanosol. The graphene with 28.045% wt of aluminium nanoparticles was achieved, with band gap energy close to 4 eV. The novel graphene morphology derived from drying aqueous dispersions of alumina nanoparticles adhered to graphene. The alumina nanoparticles act as spacers resulting in mechanically exfoliated.

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References

- [1] Zhenhua Ni, Yingying Wang, Ting Yu, and Zexiang Shen, 2008, “Raman Spectroscopy and Imaging of Graphene”, **Nano Res**, Vol. 1, pp. 273-291.
- [2] Sae Byeok Jo, Jaesung Park, Wi Hyoung Lee, Kilwon Cho and Byung Hee Hong, 2012, “Large-area graphene synthesis and its application to interface-engineered field effect transistors”, **Solid State Communications**, Vol. 12 (15), pp. 1350-1358.
- [3] Sei-Yong Kim and Jang-Joo Kim, 2012, , “Outcoupling efficiency of organic light emitting diodes employing graphene as the anode”, **Organic Electronics**, Vol. 13(6), pp. 1081-1085.
- [4] Hyonkwang Choi, Hyunkook Kim, Sookhyun Hwang, Wobong Choi and Minhyon Jeon, 2011, “Dye-sensitized solar cells using graphene-based carbon nano composite as counter electrode” , **Solar Energy Materials and Solar Cells**, Vol. 95(1), pp. 323-325.
- [5] Indranil Lahiri, Ved Prakash Verma and Wobong Choi, 2011, “An all-graphene based transparent and flexible field emission device”, **Carbon**, Vol. 49(5), pp. 1614-1619.
- [6] Wei Wu, Zhihong Liu, Luis A. Jauregui, Qingkai Yu, Rajeev Pillai, Helin Cao, Jiming Bao, Yong P. Chen and Shin-Shem Pei, 2010, “ Wafer-scale synthesis of graphene by chemical vapor deposition and its application in hydrogen sensing”, **Sensors and Actuators B: Chemical**, Vol. 150(1), pp. 296-300.
- [7] X.Z. Yu, C.G. Hwang, C.M. Jozwiak, A. Köhl, A.K. Schmid and A. Lanzara, 2011, “ New synthesis method for the growth of epitaxial graphene”, **Journal of Electron Spectroscopy and Related Phenomena**, Vol. 184(3-6), pp. 100-106.
- [8] Baoshou Shen, Jijun Ding, Xingbin Yan, Wangjun Feng, Jun Li and Qunji Xue, 2012, “ Influence of different buffer gases on synthesis of few-layered graphene by arc discharge method”, **Applied Surface Science**, Vol. 258(10), pp. 4523-4531.

- [9] Tuan Anh Pham, Jeong Sik Kim, Jeong Su Kim and Yeon Tae Jeong, 2011, “ One-step reduction of graphene oxide with L- glutathione”, **Colloids and Surfaces A: Physicochemical and Engineering Aspects**, Vol. 384(1-3), pp. 543-548.
- [10] Yin Yang, Min Shi, Qian-Fei Zhou, Yue-Sheng Li and Zheng-Wen Fu, 2012, “ Platinum nanoparticle–graphene hybrids synthesized by liquid phase pulsed laser ablation as cathode catalysts for Li-air batteries”, **Electrochemistry Communications**, Vol. 20, pp. 11-14.

