Scopus

Documents

Abu Bakar, M.A.[a] , Danial, W.H.[b] , Norhisham, N.A.[b] , Majid, Z.A.[c] , Ibrahim, A.R.[d] , Mat Jafri, M.Z.[d] , Ahmad, F.[e] , Abdullah, M.[a d]

Electrochemically exfoliated functionalized graphene flakes: Facile synthesis, 3rd order optical nonlinearity and optical limiting response

(2022) *Optics and Laser Technology*, 151, art. no. 108030, .

DOI: 10.1016/j.optlastec.2022.108030

[a] Institute of Nano Optoelectronics Research and Technology (INOR), Universiti Sains Malaysia, Penang, USM, 11800, Malaysia

[b] Department of Chemistry, Kulliyyah of Science, International Islamic University Malaysia, Pahang, Kuantan, 25200, Malaysia

[c] Department of Chemistry, Faculty of Science, Universiti Teknologi Malaysia, Johor, UTM Johor Bahru, 81310, Malaysia

[d] School of Physics, Universiti Sains Malaysia, 11800 Penang, Malaysia

[e] Malaysia – Japan International Institute of Technology (MJIIT), University Teknologi Malaysia, Jalan Sultan Yahya Petra, Kuala Lumpur, 54100, Malaysia

Abstract

High quality graphene production is prerequisite for good performance in nonlinear optics application such as fast optical communications, all-optical switching, and optical limiting. Graphene journey begins with the method of synthesizing graphene which need to be simple, fast, and environmentally friendly. Hence, we introduce the method by exfoliating graphite by electrochemical route to produce good quality functionalized graphene for various nonlinear optics application. In this work, functionalized graphene flakes are synthesis by using two different electrodes; furnaced graphite rod (Gr-FG) and non-furnaced graphite electrode (Gr-NFG). Visual inspection on the synthesized Gr-FG and Gr-NFG show dark murky color solutions give the impression of high yield functionalized graphene flakes. Further observation under transmission electron microscopy (TEM), selected area electron diffraction (SAED), and UV–vis and Raman analysis confirm the good quality functionalized graphene structure. The nonlinear optical behavior of the functionalized graphene was accessed via Z-scan technique with 637 nm laser source operating in continuous mode with simultaneous monitoring of the close and open aperture signal. Close aperture profile of Gr-FG and Gr-NFG display nonlinear refraction, whereas open aperture profile shows reverse saturable absorption (RSA). Equation fitting reveals higher n2 magnitude for Gr-FG compared to Gr-NFG, but the later possess higher magnitude of β. Further analysis on the 3rd order of optical nonlinearity by z-scan technique reveal the admirable value at the range of 10−6 esu. Optical limiting performance conducted via transmittance-based measurement shows superior limiting of Gr-NFG compared to Gr-FG.

Author Keywords

Electrolysis; Functionalized graphene flakes; Reverse saturable absorption; Z-scan

Index Keywords

Graphite, Graphite electrodes, High resolution transmission electron microscopy, Nonlinear optics, Optical communication, Optical switches, Quality control; Facile synthesis, Functionalized graphene, Functionalized graphene flake, High quality, Optical limiting, Optical nonlinearity, Optics application, Reverse saturable absorption, Z-scan, Z-scan technique; Graphene

References

- Zhao, J., Liu, H., Yu, Z., Quhe, R., Zhou, S., Wang, Y., Liu, C.C., Wu, K.
  Rise of silicene: A competitive 2D material
  (2016) *Prog. Mater. Sci.*, 83, pp. 24-151.

- Cui, Z., Luo, Y.I., Yu, J., Xu, Y.
  Tuning the electronic properties of MoSi2N4 by molecular doping: A first principles investigation
  (2021) *Phys. E Low-Dimensional Syst. Nanostruct.*, 134, p. 114873.

- Yang, M., Sun, C., Wang, T., Chen, F., Sun, M., Zhang, L., Shao, Y., Hao, X.
  Graphene-Oxide-Assisted Synthesis of Ga2O3 Nanosheets/Reduced Graphene Oxide Nanocomposites Anodes for Advanced Alkali-Ion Batteries
  (2018) *ACS Appl. Energy Mater.*, 1, pp. 4708-4715.

- Cui, Z., Wang, M., Lyu, N., Zhang, S., Ding, Y., Bai, K.
  Electronic, magnetism and optical properties of transition metals adsorbed puckered arsenene
  (2021) *Superlattices Microstruct.*, 152, p. 106852.

- Choi, W., Lahiri, I., Seelaboyina, R., Kang, Y.S.
  Synthesis of Graphene and Its Applications: A Review
  (2010) *Crit. Rev. Solid State Mater. Sci.*, 35 (1), pp. 52-71.

- Danial, W.H., Norhisham, N.A., Ahmad Noorden, A.F., Abdul Majid, Z., Matsumura, K., Iqbal, A.
  A short review on electrochemical exfoliation of graphene and graphene quantum dots
  (2021) *Carbon Lett.*, 31 (3), pp. 371-388.

- Chang, D.W., Baek, J.-B.
  Eco-friendly synthesis of graphene nanoplatelets
  (2016) *J. Mater. Chem. A.*, 4 (40), pp. 15281-15293.

- Danial, W.H., Farouzy, B., Abdullah, M., Majid, Z.A.
  Facile One-Step Preparation and Characterization of Graphene Quantum Dots Suspension via Electrochemical Exfoliation
  (2021) *Malaysian J. Chem.*, 23, pp. 127-135.
  (accessed July 30, 2021)

- Vermeulen, N., Castelló-Lurbe, D., Khoder, M., Pasternak, I., Krajewska, A., Ciuk, T., Strupinski, W., Van Erps, J.
  Graphene's nonlinear-optical physics revealed through exponentially growing self-phase modulation
  (2018) *Nat. Commun.*, 91 (9), pp. 1-9.

- Turchinovich, D., Hafez, H.A., Deinert, J.-C., Jan-Tielrooij, K., Gensch, M., Bonn, M., Kovalev, S., Turchinovich, D.
  (2019), Graphene: The Ultimate Nonlinear Material at Terahertz Frequencies, Int. Photonics Optoelectron. Meet. 2019 (OFDA, OEDI, ISST, PE, LST, TSA), Pap. TTu2G.1. Part F154-TSA 2019 TTu2G.1.

- Khurgin, J.B.
  Graphene—A rather ordinary nonlinear optical material
  (2014) *Appl. Phys. Lett.*, 104 (16), p. 161116.

- Wang, F., Zhang, Y., Tian, C., Girit, C., Zettl, A., Crommie, M., Shen, Y.R.
  Gate-Variable Optical Transitions in Graphene
  (2008) *Science*, 320 (5873), pp. 206-209.

- Lim, G.-K., Chen, Z.-L., Clark, J., Goh, R.G.S., Ng, W.-H., Tan, H.-W., Friend, R.H., Chua, L.-L.
  Giant broadband nonlinear optical absorption response in dispersed graphene single sheets

(2011) *Nature Photon*, 5 (9), pp. 554-560.

- Majles Ara, M.H., Koushki, E., Salmani, S., Mousavi, S.H.
  χ(3) measurement in “5-oxo-4,5-dihydroindeno [1,2-b] pyrans” using the z-scan and the moiré deflectometry techniques
  (2007) *Opt. Commun.*, 278 (2), pp. 418-422.

- Yamashita, S.
  Nonlinear optics in carbon nanotube, graphene, and related 2D materials
  (2019) *APL Photonics*, 4 (3), p. 034301.

- Hendry, E., Hale, P.J., Moger, J., Savchenko, A.K., Mikhailov, S.A.
  Coherent Nonlinear Optical Response of Graphene
  (2010) *Phys. Rev. Lett.*, 105.

- Bourlinos, A.B., Bakandritsos, A., Liaros, N., Couris, S., Safarova, K., Otyepka, M., Zbořil, R.
  Water dispersible functionalized graphene fluoride with significant nonlinear optical response
  (2012) *Chem. Phys. Lett.*, 543, pp. 101-105.

- Zhang, M., Li, G., Li, L.
  Graphene nanoribbons generate a strong third-order nonlinear optical response upon intercalating hexagonal boron nitride
  (2014) *J. Mater. Chem. C.*, 2, pp. 1482-1488.

- Zhu, B., Wang, F., Cao, Y., Wang, C., Wang, J., Gu, Y.
  Nonlinear optical enhancement induced by synergistic effect of graphene nanosheets and CdS nanocrystals
  (2016) *Appl. Phys. Lett.*, 108 (25), p. 252106.

- Zhu, B., Wang, F., Li, P., Wang, C., Gu, Y.
  Surface oxygen-containing defects of graphene nanosheets with tunable nonlinear optical absorption and refraction
  (2018) *Phys. Chem. Chem. Phys.*, 20 (42), pp. 27105-27114.

- Stavrou, M., Dalamaras, I., Karampitsos, N., Couris, S.
  Determination of the Nonlinear Optical Properties of Single- and Few-Layered Graphene Dispersions under Femtosecond Laser Excitation: Electronic and Thermal Origin Contributions
  (2020) *J. Phys. Chem. C.*, 124 (49), pp. 27241-27249.

- Ren, J., Zheng, X., Tian, Z., Li, D., Wang, P., Jia, B.
  Giant third-order nonlinearity from low-loss electrochemical graphene oxide film with a high power stability
  (2016) *Appl. Phys. Lett.*, 109 (22), p. 221105.

- Islam, S., Bakhtiar, H., Duralim, M.B., Binti Sapingi, H.H.J., Riaz, S., Naseem, S., Musa, N.B., bin Abdullah, M.
  Influence of organic pH dyes on the structural and optical characteristics of silica nanostructured matrix for fiber optic sensing
  (2018) *Sensors Actuators A Phys.*, 282, pp. 28-38.

- David, S., Chateau, D., Chang, H.-J., Karlsson, L.H., Bondar, M.V., Lopes, C., Le Guennic, B., Andraud, C.
  High-Performance Optical Power Limiting Filters at Telecommunication Wavelengths: When Aza-BODIPY Dyes Bond to Sol-Gel Materials
  (2020) *J. Phys. Chem. C.*, 124 (44), pp. 24344-24350.

- Danial, W.H., Chutia, A., Majid, Z.A., Sahnoun, R., Aziz, M.
  Electrochemical synthesis and characterization of stable colloidal suspension of graphene using two-electrode cell system
  (2015) *AIP Conf. Proc.*, 1669.

- Sharif, F., Zeraati, A.S., Ganjeh-Anzabi, P., Yasri, N., Perez-Page, M., Holmes, S.M., Sundararaj, U., Roberts, E.P.L.
  Synthesis of a high-temperature stable electrochemically exfoliated graphene
  (2020) *Carbon N. Y.*, 157, pp. 681-692.

- Yang, S., Brüller, S., Wu, Z.S., Liu, Z., Parvez, K., Dong, R., Richard, F., Müllen, K.
  Organic Radical-Assisted Electrochemical Exfoliation for the Scalable Production of High-Quality Graphene
  (2015) *J. Am. Chem. Soc.*, 137, pp. 13927-13932.

- Wu, X., Liu, J., Wu, D., Zhao, Y., Shi, X., Wang, J., Huang, S., He, G.
  Highly conductive and uniform graphene oxide modified PEDOT:PSS electrodes for ITO-Free organic light emitting diodes
  (2014) *J. Mater. Chem. C.*, 2 (20), pp. 4044-4050.

- Chen, W., Shen, J., Lv, G., Li, D., Hu, Y., Zhou, C., Liu, X., Dai, Z.
  Green Synthesis of Graphene Quantum Dots from Cotton Cellulose
  (2019) *ChemistrySelect.*, 4 (10), pp. 2898-2902.

- Ahirwar, S., Mallick, S., Bahadur, D.
  Electrochemical Method To Prepare Graphene Quantum Dots and Graphene Oxide Quantum Dots
  (2017) *ACS Omega*, 2 (11), pp. 8343-8353.

- Devi, M.M., Sahu, S.R., Mukherjee, P., Sen, P., Biswas, K.
  Graphene: a self-reducing template for synthesis of graphene–nanoparticles hybrids
  (2015) *RSC Adv.*, 5 (76), pp. 62284-62289.

- Son, Y.-R., Park, S.-J.
  Green preparation and characterization of graphene oxide/carbon nanotubes-loaded carboxymethyl cellulose nanocomposites
  (2018) *Sci Rep*, 8 (1).

- Peng, J., Zhao, Z., Zheng, M., Su, B., Chen, X., Chen, X.I.
  Electrochemical synthesis of phosphorus and sulfur co-doped graphene quantum dots as efficient electrochemiluminescent immunomarkers for monitoring okadaic acid
  (2020) *Sensors Actuators B Chem.*, 304, p. 127383.

- Sheik-bahae, M., Said, A.A., Wei, T.H., Wu, Y.Y., Hagan, D.J., Soileau, M.J., Van Stryland, E.W.
  Z-Scan: A Simple And Sensitive Technique For Nonlinear Refraction Measurements

(1990) *Nonlinear Opt. Prop. Mater.*, 1148, pp. 41-51.

- Boyd, R.W.
  Nonlinear Optics
  (2003) *Nonlinear Opt.*, pp. 1-578.

- (2013),
  Field Guide to Nonlinear Optics | | Powers | Publications | Spie, (n.d.). (accessed July 30, 2021).

- Rosli, M.I., Abdullah, M., Krishnan, G., Harun, S.W., Aziz, M.S.
  Power-dependent nonlinear optical behaviours of ponceau BS chromophore at 532 nm via Z-scan technique
  (2020) *J. Photochem. Photobiol. A Chem.*, 397, p. 112574.

- Tkachenko, N.V.
  (2006), Optical Spectroscopy - Methods and Applications.

-
  Swinburne Research Bank | Swinburne University of Technology, (n.d.). (accessed July 30, 2021).

- Pramanik, A., Karmakar, S., Kumbhakar, P., Biswas, S., Sarkar, R., Kumbhakar, P.
  Synthesis of bilayer graphene nanosheets by pulsed laser ablation in liquid and observation of its tunable nonlinearity
  (2020) *Appl. Surf. Sci.*, 499, p. 143902.

- Parra, I., Valbuena, S., Racedo, F.
  Measurement of non-linear optical properties in graphene oxide using the Z-scan technique, Spectrochim
  (2021) *Acta Part A Mol. Biomol. Spectrosc.*, 244, p. 118833.

- Liaros, N., Aloukos, P., Kolokithas-Ntoukas, A., Bakandritsos, A., Szabo, T., Zboril, R., Couris, S.
  Nonlinear Optical Properties and Broadband Optical Power Limiting Action of Graphene Oxide Colloids
  (2013) *J. Phys. Chem. C.*, 117 (13), pp. 6842-6850.

Correspondence Address
Abdullah M.; Institute of Nano Optoelectronics Research and Technology (INOR), Penang, Malaysia; email: mundzir@usm.my

Publisher: Elsevier Ltd

ISSN: 00303992
CODEN: OLTCA
Language of Original Document: English
Abbreviated Source Title: Opt Laser Technol
2-s2.0-85125780374
Document Type: Article
Publication Stage: Final
Source: Scopus