Graphene/graphene oxide – multifunctional platform for drug delivery and photodynamic therapy in cancer treatment

Malgorzata Wojtoniszak[1], Dorota Rogińska[2], Magdalena Perużyńska[3], Mateusz Kurzawski[3], Marek Droździk[3], Bogusław Machaliński[2], Ewa Mijowska[1]

[1] West Pomeranian University of Technology in Szczecin, Institute of Chemical and Environment Engineering, Pulaskiego 10, 70-322, Szczecin, Poland
[2] Pomeranian Medical University, Department of General Pathology, Powstańców Wlkp. 72, 70-111, Szczecin, Poland
[3] Pomeranian Medical University, Department of Pharmacology, Powstańców Wlkp. 72, 70-111, Szczecin, Poland
mwojtoniszak@zut.edu.pl

Abstract

Recently, graphene has attracted a great scientific interest in many fields such as electronics, gas storage, catalysis, and medicine among others [1-4]. Because of its electronic, optical and structural properties it has been explored as a carrier of variety molecules such as drugs for cancer chemotherapy, ferromagnetic for hyperthermia or photosensitizers for photothermal therapy and photodynamic therapy [5-7].

In this study, potential of graphene oxide biomedical applications will be presented. Firstly, in vitro cytocompatibility tests of graphene oxide and reduced graphene oxide dispersed in different polymers will be shown. Here, type of dispersant and concentration of nanomaterials effects on mice fibroblast cells (L929) viability will be reported. Secondly, graphene oxide (GO) functionalization with methylene blue (MB) and its performance in singlet oxygen generation (SOG) under irradiation of laser with excitation wavelengths of 785 nm will be reported. Remarkably, it was noted that GO functionalized with MB (MB-GO) showed an enhanced efficiency in singlet oxygen generation compared to pristine MB. The efficiency in SOG was detected by photobleaching of 9,10-anthracenediyl-bis(methylene)dimalonic acid (ABMDMA). Detailed characterization of the obtained material was carried out with UV-Vis spectroscopy, Raman spectroscopy, FT-IR spectroscopy, and confocal laser scanning microscopy. Interestingly, in contrast to previous study [8], fluorescence confocal microscopy demonstrated that the adsorption of MB on GO resulted in an enhanced fluorescence when the material was excited with light from blue to orange range. Finally, covalent functionalization of graphene oxide with anticancer drug methotrexate (MTX) through amide bonding will be shown. A kinetics of the drug release from graphene oxide in physiological solution – phosphate buffered saline (PBS) containing different biocompatible polymers will be investigated. It was discovered that dispersion of MTX-GO in poly sodium-4-styrene sulfonate (PSS) and poly ethylene glycol (PEG) resulted in significant increase of the release time. The material was characterized with transmission electron microscopy (TEM), atomic force microscopy (AFM), Raman spectroscopy, Fourier transform infrared spectroscopy (FTIR) and UV-vis spectroscopy. Furthermore, antineoplastic action against human breast adenocarcinoma cell line MCF7 of MTX-functionalized graphene oxide and empty graphene oxide was explored. It was found that the anti-proliferative activity of MTX-GO depended on dispersant used to stabilize the suspension.

References

[1] H. Park, J.A. Rowehl, K.K. Kim, V. Bulovic, J. Kong, Nanotechnology, 21 (2010) 505204.

[2] T. Truong-Huu, K. Chizari, I. Janowska, M.S. Moldovan, O. Ersen, L.D. Nguyen, M.J. Ledoux, C. Pham-Huu, D. Begin, Catalysis today, 189 (2012) 77-82.

[3] Y. Li, G. Zhao, C. Liu, Y. Wang, J. Sun, Y. Gu, Y. Wang, Z. Zeng, Intern. J. Hydrogen Energy, 37 (2012) 5754–5761.

[4] H. Wang, T. Chen, S. Wu, X. Chu, R. Yu, Biosensors and Bioelectronics, 34 (2012) 88-93.

[5] X. Yang, Y. Wang, X. Huang, Y. Ma, Y. Huang, R. Yang, H. Duan, Y. Chen, Journal of materials chemistry, 21 (2011) 3448–3454.

[6] L.Z. Bai, D.L. Zhao, Y. Xu, J.M. Zhang, Y.L. Gao, L.Y. Zhao, J.T. Tang, Materials letters, 68 (2012) 399–401.

[7] K. Yang, L. Hu, X. Ma, S. Ye, L. Cheng, X. Shi, C. Li, Y. Li, Z. Liu, Advanced materials, 24 (2012) 1868–1872.

[8] K. Haubner, J. Murawski, P. Olk, L.M. Eng, C. Ziegler, B. Adolphi, E. Jaehne, Chemphyschem A European Journal Of Chemical Physics And Physical Chemistry, 11 (2010) 2131-2139.

Figures

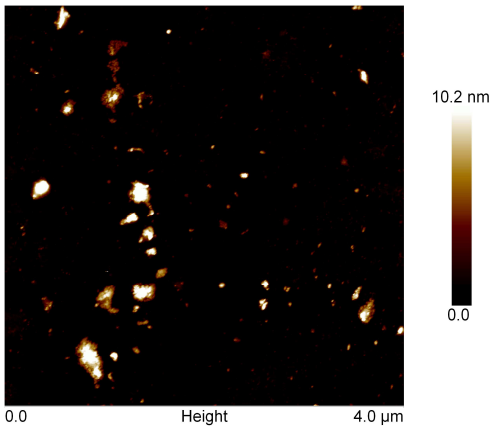

Figure 1. AFM image of graphene oxide functionalized with methotrexate (MTX-GO).

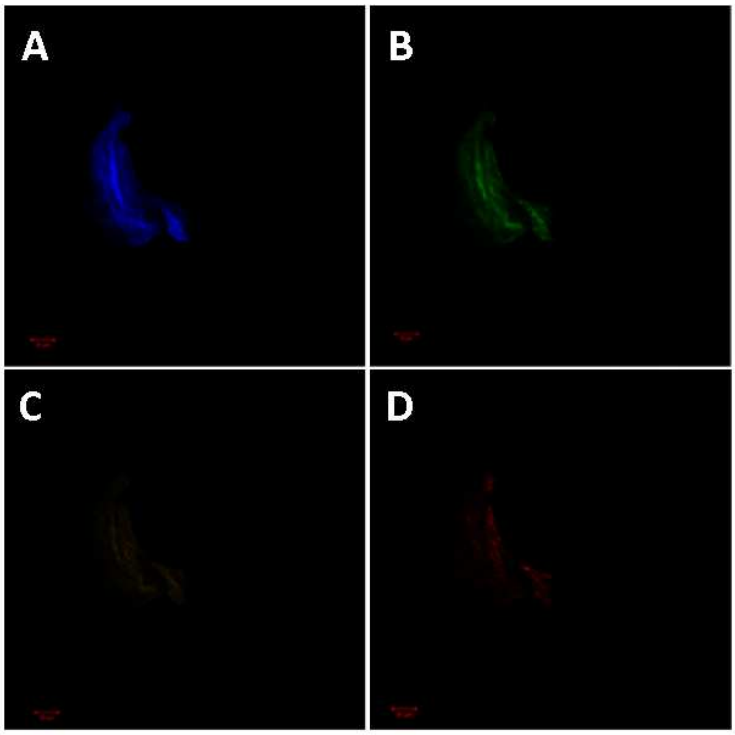

Figure 2. Fluorescent confocal images of MB-GO obtained in different excitations (blue: A, green: B, orange: C, far red: D).