

THERMAL REDUCTION OF GRAPHITE OXIDE IN THE PRESENCE OF MALONIC ACID

Rūta Aukštakojytė¹, Justina Gaidukevič¹, Jurgis Barkauskas¹

¹ Institute of Chemistry, Faculty of Chemistry and Geosciences, Vilnius University,
Naugarduko 24, LT-03225 Vilnius, Lithuania
ruta.aukstakojyte@chgf.vu.lt

Graphene is a plane sheet of sp² hybridized carbon atoms arranged into a honeycomb lattice. In recent decades it has drawn wide attention due to its unique physicochemical characteristics such as a high specific surface area (2630 m² g⁻¹), large Young's modulus (1.0 TPa), excellent thermal conductivity (~5000 W m⁻¹ K⁻¹) and high electron mobility (2.5 · 10⁵ cm² V⁻¹ s⁻¹). These properties of graphene lattice are important in many applications including lithium-ion batteries, solar cells, photocatalysts, biosensors, transistors, water purification systems, super capacitors and etc. [1].

Chemical reduction of graphite oxide (GO) is the one of most facile ways for low-cost, high yield and rapid production of graphene. However, the most popular chemical reducing agents, such as hydrazine, hydroquinone, sodium borohydride, lithium aluminium hydride, are hazardous and corrosive. The product obtained using these reagents has poor electrical conductivity, due to the defects remaining in crystal lattice and have negative impact on bio-related applications, too [2,3]. Therefore, effective and environmentally-friendly reducers for GO are still in focus.

In this work, we present the thermal reduction of GO in the presence of malonic acid, which is a green and inexpensive reducer decomposing thermally at 135 °C. Graphite oxide was prepared from the natural graphite by the synthesis protocol reported by Yan et al. [4]. In a typical experiment, graphite powder was treated with conc. H₂SO₄, K₂S₂O₈ and P₂O₅. Later, this pre-oxidized graphite was subjected to oxidation by Hummers method using NaNO₃, H₂SO₄ and KMnO₄ [5]. The obtained GO was reduced by adding malonic acid with molar ratio of 1:3 or 1:5 and thermal annealing under Ar gas atmosphere for 30 min at different temperatures 200 °C, 300 °C, 600 °C, 800 °C. Reduced GO products were analyzed by Fourier Transform infrared (FTIR), Raman spectroscopy and X-ray diffraction (XRD) analysis.

The results show that the level of GO reduction to graphene phase depends on the reduction conditions. Reduction of GO at low temperatures results formation of an amorphous product. XRD analysis of GO-MA-600 and GO-MA-800 shows a similar 'd' spacing of 0.350 nm with a hexagonal structure, indicating the formation of a more ordered graphitic structure after annealing. Moreover, IR analysis of these sample exhibits a significant reduction of oxygen functionalities.

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