Chapter 1

Introductory Chapter: Graphene Oxide: Applications and Opportunities

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Additional information is available at the end of the chapter

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1. Introduction

This chapter aims to introduce the emerging technologies of graphene oxide (GO) in various fields such as industrial, medical, electronics, artificial intelligences, materials and alloys, energy storage devices, optical, physics, mechanical, nanomaterials, and sustainable chemistry. Graphene oxide analogy to graphene was first discovered by chemist Benjamin C. Brodie in 1859 and further quick method was developed by Hummers and Offeman in 1957; globally, the method is known as Hummers' method [1].

2. History of synthesis of GO and structure

Graphene is a two-dimensional (2D) carbon sheet having sp^2 hybridization with molecular weights of more than 106–107 g/mol. It has been packed into a honeycomb lattice (**Figure 1**). The bulk material of graphite that was discrete in single monolayer sheets showed noteworthy properties and hence its single monolayer structure motivated in various applications. The exfoliation of graphene oxide was synthesized by using strong oxidizing agents such as $KMnO_4$ and conc. H_2SO_4 [2, 3].

3. Overview of applications and future opportunities of GO

Many devices of GO overtake reference systems, for example, capacitors [4, 5], foldable electronic devices [6], translucent electrodes [7], biomedical applications [8], pollution management [9], sensors [10], H_2-generation [9] and energy applications [11].

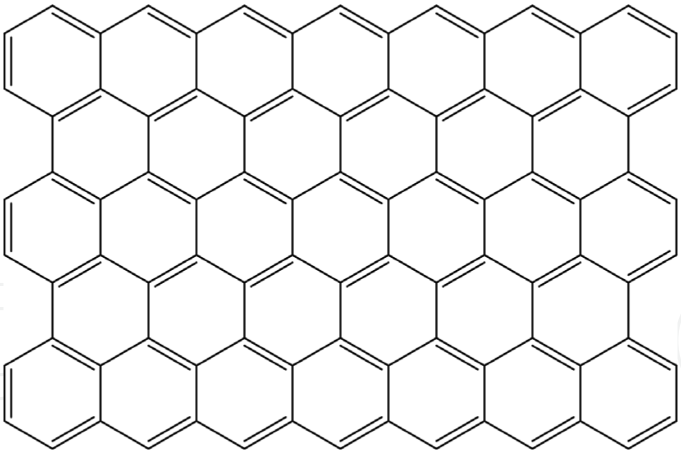

Figure 1. Schematic representation of single layer graphene oxide with zig-zag and arm-chair edges.

Because of its honeycomb lattice with two carbon atoms per unit cell, graphene oxide shows an innumerable of exceptional chemical and physical properties. Due to the valence band and conduction band touch, the Brillouin zone corners [12] so as charge carriers in graphene behave like massless relativistic particles. Due to the delocalized out-of-plane π bonds arising from the sp^2 hybridization carbon atoms, an unprecedented high carrier mobility of ≈200,000 $cm^2\ V^{-1}\ s^{-1}$ has been achieved for suspended graphene [13].

For the bulk production of GO, exfoliation is the most developed attractive method. The pristine graphite is converted into graphite oxide (GO sheets) by using a mixture of $KMnO_4$ and concentrated H_2SO_4 [14–16]. In the oxidation of GO, large numbers of oxygen-containing functional groups such as epoxides, carboxyl and hydroxyl groups are attached onto the graphene basal plane and edges. Due to its hydrophilic nature, it is easily dispersed in water or polar organic solvents. The structural and electrical properties of pristine graphene are obtained by using reducing agents and thermal treatment, sodium borohydride [17], hydrazine [18] and thermal reduction [19, 20], respectively. Due to carcinogenic and highly toxic reducing agents property, in the recent years, reduction of GO is carried out by green reductants agents such as polyphenols of green tea, melatonin, vitamin C, bovine serum, albumin, sugars and even bacteria was also studied. Hydrothermal, solvothermal reduction, catalytic and photocatalytic reductions have also been developed. Furthermore, surfactant and boiling point of solvents also effect on GO.

At the current level of development, the properties and binding structure of graphene are important toward the recent applications. The knowledge produced by the systematic functionalization of graphene could be a much haunting basis for discovering the chemistry and nanomaterials.

Finally, GO and GO-based nanomaterials and its graphene derivatives are essential for future applications such as fuel cells, vivo sensors, supercapacitors, energy storage devices, and transparent electronics, which will undoubtedly improve when defined graphene derivatives are employed. Future technology expected that the full development and growth will depend only on graphene and its functionalized composite materials. This chapter highlights the challenges and opportunities associated with GOs. Subject of interest in this chapter is exploring opportunities and technologies related to energy, pure water and good health.

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