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Full Length Article

Excimer laser assisted very fast exfoliation and reduction of graphite oxide at room temperature under air ambient for Supercapacitors electrode

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ABSTRACT

Excimer laser was used for reduction and exfoliation of graphite oxide (GO) at room temperature under air ambient. The prepared excimer laser reduced graphite oxide (XLRGO) is characterized by scanning electron microscopy (SEM), atomic force microscopy (AFM), nitrogen adsorption/desorption (BET method), X-ray diffraction (XRD), X-ray photoemission spectroscopy (XPS), Fourier transform infrared spectroscopy (FTIR) and UV–vis absorption techniques for surface, structural functional groups and band gap analysis. Electrochemical properties are investigated using cyclic voltammetry, galvanostatic charge-discharge, electrochemical impedance spectroscopy (EIS) and continues cyclic voltammetry (CCV) in 0.5 M Na2SO4 as electrolyte. Electrochemical investigations revealed that XLRGO electrode has enhanced supercapacitive performance including specific capacitance of 299 F/g at a scan rate of 2 mV/s. Furthermore, CCV measurement showed that XLRGO electrode kept 97.8% of its initial capacitance/capacity after 4000 cycles. The obtained results from electrochemical investigations confirm that the reduction of GO by using an excimer laser produces high-quality graphene for supercapacitor applications without the need for additional operations.

1. Introduction

The batteries store energy chemically in the electrode bulk, and this leads to their low life cycle and charge and discharge rate. While supercapacitors do this only by separating electric charges from the electrolyte and adsorbing them onto their porous conductive electrodes, resulting in their very high rate of charge and discharge which leads to a much longer life cycle than batteries [1,2]. It makes supercapacitors have far greater power density than batteries [3,4]. However, the best supercapacitors still are far away from the best batteries in terms of energy density. In order to achieve higher specific capacitances in supercapacitors, the surface area available to ions must be increased. Activated carbon has received much attention as a porous material in recent years. In a mental model, it can be assumed that the materials in form of a bulk have lower surface area to volume ratio than shell structures or nano-particles. Shell structures are two dimensional nano materials that are nano only in one dimension, in which atoms are arranged in such a way that connect together in two dimensions and are totally free in the third dimension. Hollow nanotubes are good examples of this type of structure. However, it should be noted that only increasing the surface area is not enough to increase the specific capacitance of supercapacitor, because electrolyte ions should have access to them, too. Therefore an electrode made by small diameter nanotubes might not be able to create a high capacity in relation to its surface area because the inner surface of the nanotubes is not as easily accessible as its outer surface for ions that are covered with solvent molecules [5]. A single layer atomic flat structure must have a very high surface area to volume ratio, and at the same time it is quite understandable that all of its surface is accessible to electrolyte ions. Graphene has this amazing property. If with the same mental model we imagine an electrode made of a bulk of perfectly flat graphene sheets like flat and wrinkle-free sheets of aluminium foil put over each other, we observe that the speed and possibility of ions' access to surface areas between the sheets are lower. This can be tested by putting the sheets in a cylindrical container with a grid floor. If the sheets cover the floor completely and then we pour water into the container, although aluminium foils are separated, water will not be

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able to easily penetrate between them and will exit from the bottom of the container very slowly. However, if the aluminium foil sheets are crumpled, there will be some canals between them that will let the water to pass easily through. In case of electrodes, any changes in the amount and form of crumpling of graphene sheets changes the ions' access to the surface of the sheets. Studies on the use of graphene as a supercapacitor electrode indicated that disordered graphene structures have much better performance than activated carbon and ordered graphene in the bulk form because of the random pores and canals between them that create more surface area and greater access for the ions in the bulk form [2,6–19]. Many approaches have been investigated for fabricating disordered graphene [20,21]. Most of these methods are based on the fabrication of graphite oxide and then its reduction to graphene [15,19,22]. The amount of crumpling and exfoliation of graphene layers will be different in reduction of graphite oxide method. The crumpling amount depends on several factors, including: number of atomic layers, type and amount of functional groups remaining on the surface and edges after reduction, amount of remaining functional groups on the surface compared to the edges, and dimensions of the sheets. The prediction of the role of these factors in a certain way of graphite oxide reduction is quite difficult and usually the final results will be determined only by testing. Therefore, the examination of new ways to reduce the graphene oxide was considered. It has been found that faster methods have better results. Reduction with hydrazine hydrate, focused sunlight, laser and microwave ovens have been studied [15,16]. Lasers have been used for fabrication of thin-film electrodes for micro supercapacitors [18]. Laser, especially Excimer laser have not been used for volumetric reduction of graphite oxide and fabrication of supercapacitor electrodes on a large scale yet. There has been no report on supercapacitors fabricated based on reduction of graphite oxide by excimer laser method at room temperature under air ambient, to the best of author's knowledge.

In this study, we synthesized reduced graphite oxide (RGO) by excimer laser-induced method (see Fig. 1). Using an industrial grade excimer laser (308 nm), electrical conductive RGO sheets were produced by one-step laser reduction in air environment. Laser reduction is a facile and time saving method unlike other fast methods like the reduction of graphene oxide via microwave [23,24]. In this method, the production time and efficiency of reduced graphene oxide aren't dependent on initial conductivity and oxidation degree. In addition to other advantages, laser irradiation of graphene oxide is an easily controllable method that appears to be an efficient procedure for fast and large-scale synthesis of graphene.

The supercapacitance performance of excimer laser reduced graphite oxide (XLRGO) was also examined. It was found that illumination of graphite oxide with excimer laser yields graphene

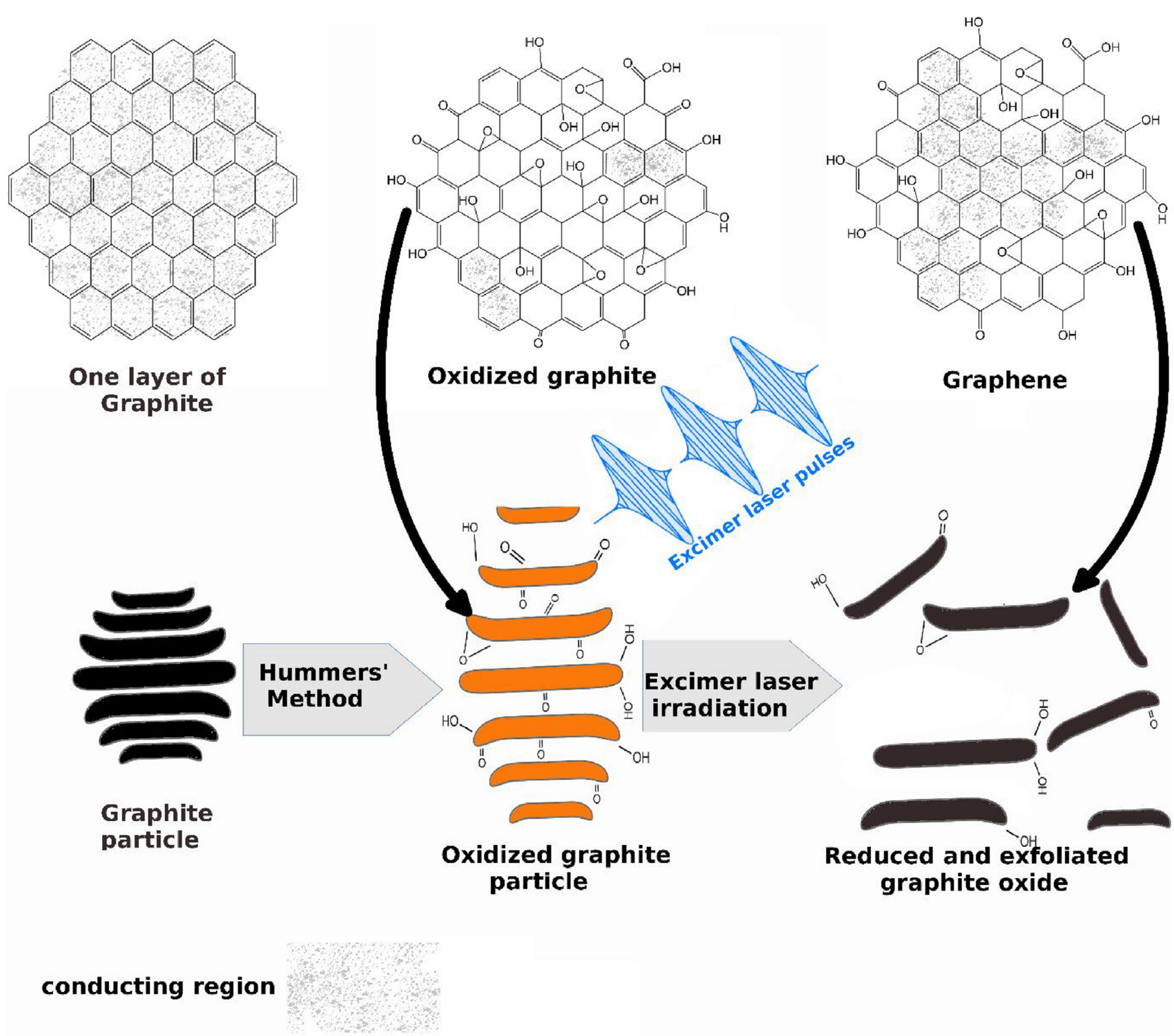

Fig. 1. The schematic illustration for the active materials preparation process. Synthesis of GO and its reduction to XLRGO for supercapacitors.