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GRAPHENE: ELECTROCHEMICAL PRODUCTION AND ITS ENERGY STORAGE PROPERTIES

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ABSTRACT

Graphene oxide was prepared by the Hummers' method and then electrochemically reduced to produce graphene nanosheets. Physicochemical characterizations were performed using XRD, FTIR, FESEM, TEM, Raman and UV-Vis techniques to elucidate the structure and morphology of the prepared material. The electrochemical study had been conducted on graphene by cyclic voltammetry, galvanostatic charge-discharge and impedance measurements, indicating its superb energy storage properties. The specific capacitance of graphene was 131 F g-1 at 0.1 A g-1. Impedance spectra showed low resistance of electrochemically produced graphene, supporting its suitability for energy storage applications, such as supercapacitor.

Keywords: electrochemical reduction graphene, supercapacitor cyclic voltammetry impedance.

INTRODUCTION

The capacitance properties of carbon materials are based on electrodouble layer (EDL) mechanism. In EDL supercapacitors, a double layer of electrolyte ions is formed on the surface of active materials. No charge transfer from chemical reactions in the electrode takes place. The charge distribution on the surface of the electrode depends on the porosity and the crystal structure of the electrode material. The EDL materials should have high surface area for high charge accumulation and a suitable pore structure to allow a rapid motion of the electrolyte ions (Endo *et al.*, 2001, Lota *et al.*, 2008). Different carbon materials have been studied for supercapacitors application such as activated carbon, carbon nanoparticles, carbon nanospheres, carbon nano-onion, carbon nanotubes and graphene (Ali *et al.*, 2014, Borgohain *et al.*, 2012, Lota *et al.*, 2008, Lota *et al.*, 2011, Stoller *et al.*, 2008, Tashima *et al.*, 2011).

Graphene is atomically thin two-dimensional (2D) system of sp2 carbon atoms organized in a hexagonal lattice structure so it exhibits many interesting electronic, optical and mechanical properties. The porous nature of graphene facilities ion transport processes, and therefore improves the performance of supercapacitors. Graphene has a large theoretical specific surface area (2630 m2 g−1), leading to high theoretical capacitance of 550 F g-1(Zhu *et al.*, 2010). Moreover, it has low electrical resistivity and long life time. Graphene can be prepared by chemical, electrochemical or thermal reduction of graphene oxide (Buglione *et al.*, 2012, Stoller *et al.*, 2008, Yang and Gunasekaran, 2013, Teo *et al.*, 2012). Electrochemical preparation is most provable as it is less time consuming as well as lower cost where no reducing agents are needed. Graphene has been prepared by chemical vapor deposition on Ni foam substrate and shows a specific capacitance of 55.3 F g-1 at 5 mV s-1 (Chen *et al.*, 2013). In addition, Cyclic voltammetry (CV) scanning was used to electrochemically reduce graphene oxide (GO) on glassy carbon electrode (Chen *et al.,* 2011, Yang and Gunasekaran, 2013). So far, there are no studies reported on the CV reduction of GO on Ni foam substrate. Reduction of GO on Ni foam (a few milligrams on 1 cm2) is an encouraging method, as it produce high amount of graphene and the electrode will be ready to be used as supercapacitor electrode directly without any further treatment or processing. Moreover, Ni foam provides high accessible surface area for loading materials with 3D porous network structure and acts as a current collector (Lu *et al.*, 2011).

In this work, reduced graphene oxide (rGO) was prepared by cyclic voltammetric reduction of the GO pasted on Ni foam electrode. The prepared material was characterized by XRD, FTIR, FESEM, TEM, Raman and UV-Vis techniques. The electrochemical properties were investigated using cyclic voltammetry, galvanostatic charge-discharge and electrochemical impedance spectroscopy.

EXPERIMENTAL PROCEDURES AND TECHNIQUES

Samples preparation

GO was synthesized by modified Hummers' method (Hummers and Offeman, 1958). Then GO was coated on Ni foam electrode. The electrochemical reduction process was performed in phosphate buffer solution pH 9 in potential window from 1.2 to 0 V vs. Ag/AgCl reference electrode for 500 cycles at 50 mV s-1.

Samples Characterization

The crystal structure was analyzed using a Rigaku X-ray diffractometer (Miniflex II with Cu-Kα radiation at 40 kV, 30 mA, λ = 1.5406 Å) within the 2 θ range of 5° to 80°. The functional groups were examined using a Perkin Elmer (Spectrum 100) infrared spectrophotometer over the range of 400–4000 cm-1. The UV tests were carried out using a Thermo Scientific (Genesys 10S) UV spectrophotometer at room temperature in the wavelength range from 200 to 900 nm. Raman