Versatile Water Soluble Graphene Nanoplatelets for Water-Based Polymers

Hong Ngee Lim*

Materials Synthesis and Characterization Laboratory, Institute of Advanced Technology, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia

**Corresponding Autor's Email: hongngee@upm.edu.my*

Abstract: Water insoluble graphene nanoplatelets was converted to water soluble graphene nanoplatelets (GNPs) by a facile modification method. The water soluble GNPs easily dispersed in water-based polymers such as latex and polyvinyl alcohol with only mild agitation. The GNPs-fortified latex and GNPs-fortified polyvinyl alcohol (PVA) film yielded an average resistance of 1.8 x 10^4 Ω and 1.4 x 10^4 Ω, respectively. A mixture of water soluble GNPs and PVA was electrospun to produce a GNPs-fortified PVA nanofibre membrane. Subsequently, the nanofibre membrane was carbonized to produce a GNPs-fortified carbon nanofibre (CNF) membrane. The electrochemical performance of the GNPs-CNF membrane was measured. The current density of GNPs-CNF membrane increased by twofold, and the galvanostatic charge-discharge duration doublefold, as opposed to the neat CNF membrane. The GNPs-CNF membrane achieved an average stability of more than 95% for 1,000 cycles of galvanostatic charge-discharge.

Keywords: water soluble graphene, polymer, latex, supercapacitor, carbon nanofibre

INTRODUCTION

Graphene nanoplatelets (GNPs) is ubiquitous in many state-of-the-art polymeric applications [1] but its superlative properties are hindered by its inability to solubilize easily in solvents, especially in the universal solvent, water [2]. Water-based polymers such as latex and polyvinyl alcohol (PVA) are widely used in various industries, which include gloves, condoms, footwear, coatings and electronics. The conversion of water insoluble GNPs to water soluble GNPs, by modifying GNPs with surface active agents, provides a solution to dispersing GNPs effortlessly in water-based polymers.

MATERIALS AND METHODS

PVA containing graphene was electrospun using an electrospinner setup. The carbonisation process was carried out using a quartz tube furnace. The electrochemical properties were evaluated using a two-electrode configuration with a potentiostat-galvanostat

RESULTS AND DISCUSSION

The water soluble GNPs dispersed in water by mild stirring in less than 20 s. Fig. 1 shows the water soluble GNPs in powder and solution. When the water soluble GNPs was added into latex (Fig. 2) and PVA (Fig. 3), uniform composites were attained.

The GNPs-PVA solution was electrospun to produce a nanofibre membrane, which was carbonize to produce a GNPs-CNF membrane. The GNPs-CNF membrane consisted of nanofibres that were punctuated by GNPs, implying a homogeneous dispersion of GNPs in PVA during electrospinning. The presence of GNPs not only increased the current density of CNF by more than twofold, but also improved the shape of cyclic voltammetry loop from skewed and narrow, to quasirectangular. The quasi-rectangular shape is indicative of an electrical double layer capacitance. The galvanostatic charge-discharge duration of GNFs-CNF increased by twofold, compared to that of the neat CNF. This suggests that the GNPs manifested its electrical conductivity in CNF, promoting the charging and discharging of ions within the matrix of the fibrous membrane. It is noteworthy that the cycling stability of GNPs-CNF membrane was more than 95% after 1,000 cycles of continuous charging/discharging. This demonstrates its potential as an electrode material for the fabrication of a high-performance supercapacitor.

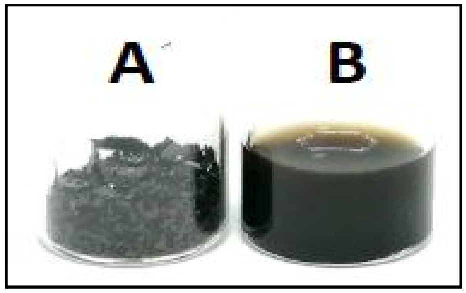

Fig. 1. Water soluble GNPs in (A) powder and (B) solution.

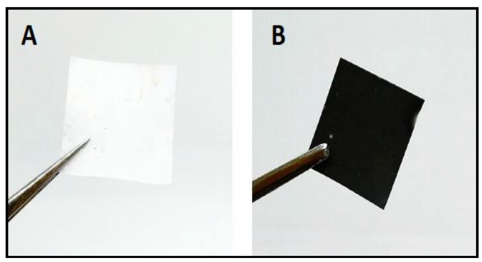

Fig. 2. (A) Latex film and (B) GNPs-latex film.

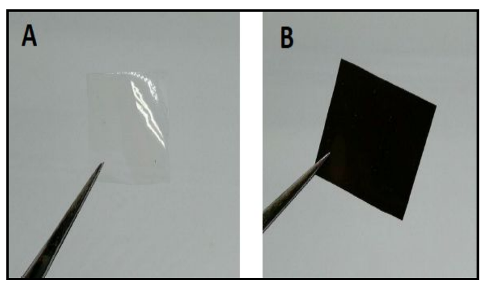

Fig. 3. (A) PVA film and (B) GNPs-PVA film.

CONCLUSIONS

The as-synthesized water soluble GNPs are highly compatible with water-based polymers such as latex and PVA, which are crucial polymers in many industries such as electronics, medical products, footwear, flooring, automobile and sports. These polymers, when reinforced with GNPs, are able to display value-added properties such as improved durability, lightweight, anti-static and electrochemical performance. The water soluble GNPs can be easily produced at a scalable quantity. This highly dispersive GNPs consequently ease the manufacturing and production of GNPs-fortified hydrophilic polymers. The prowess of the water soluble GNPs was successfully demonstrated by the delicate and intricate fabrication of a solid-state supercapacitor.

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