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Enhanced electrical conductivity properties of Graphene Oxide nanocomposites functionalized with Polyvinyl Alcohol

ABSTRACT

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We report the synthesized and preparation of graphene oxide (GO) nanocomposite functionalized with polyvinyl alcohol (PVA) with different concentration of graphene oxide 0, 1, 1.5, 2, 2.5, 3, 3.5 and 4% weight. This synthesized confirmed by FT-IR. The electrical conductivity of the all nanocomposite was measured at 25°C for all samples and the resulted showed electrical conductivity was increased with increasing % weight graphene in nanocomposite.

Keywords: *Graphene; Graphene Oxide; Nanocomposite; Polyvinyl alcohol; Electrical conductivity.*

INTRODUCTION

Graphene is a one-atom-thick planar sheet of sp²-bonded carbon atoms densely packed in a honeycomb crystal lattice. It is the mother element of some carbon allotropes, including graphite, carbon nanotubes, and fullerenes [1]. Graphene, the building block of graphite, was theoretically established in 1940 [2]. Boehm and co-workers separated thin lamellae of carbon by heating and chemical reduction of graphite oxide in 1962 [3]. However, until single-layer graphene was believed to be thermodynamically unstable under ambient conditions [4]. Geim and co-workers at Manchester University successfully identified single layers of graphene in a simple tabletop experiment [5]. Graphene is also capable of replacing metal conductors in electronic and electrical devices due to its excellent electrical conductivity and mechanical flexibility [6]. Ongoing research shows that graphene can replace brittle and chemically unstable indium tin oxide in flexible displays and touch screens. Therefore, graphene as an electronic circuit material is considered to be potentially superior to other carbon-based nano-fillers [7]. It is well established that the superior properties of graphene are associated with its single-layer. However, the fabrication of single-layer graphene is difficult at ambient temperature.

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Graphene sheets with a high specific surface area tend to form irreversible agglomerates or even restack to form graphite through π - π stacking and van der Waals interactions if the sheets are not well separated from each other [8]. Aggregation can be reduced by the attachment of other small molecules or polymers to the graphene sheets. The presence of hydrophilic or hydrophobic groups prevents aggregation of graphene sheets by strong polar-polar interactions or by their bulky size [8]. The attachment of functional groups to graphene also aids in dispersion in a hydrophilic or hydrophobic media, as well as in the organic polymer. The perfect structures of graphene shows low chemical reactivity, but one graphene derivative, contain a range of reactive oxygen functional groups and is widely used for chemical functionalization [9]. In recent years, the oxygen-containing hydroxyl, carbonyl, carboxyl, and epoxy functional groups have been successfully utilized as sites for the deposition of metal nanoparticles and organic macromolecules onto graphene oxide [10]. Currently, polymer composites have grown into one of the largest classes of materials science and offer significant potential for the development of advanced materials in numerous and diverse applications [11, 12]. When nano-fillers were dispersed in a polymer matrix on a molecular scale, they interact with the matrix by chemical bonding. This chemical functionalization have been found to be a feasible and effective way for improving the dispersion of graphene materials as well as the interfacial bonding between graphene and the polymer matrix [13]. Based on these considerations, We report the synthesized and preparation of graphene oxide (GO) nanocomposite functionalized with polyvinyl alcohol (PVA) with different concentration of graphene oxide 0, 1, 1.5, 2, 2.5, 3, 3.5 and 4% weight. The electrical conductivity of the all nanocomposite was measured at 25 °C for all samples.

EXPERIMENTAL

GO was obtained following a modified Hummers–Offeman method [14, 15]. Briefly, graphene (2.0 g), sodium nitrate (1.0 g), concentrated sulfuric acid (98%, 150 mL), and potassium permanganate (6.0 g) were consistently

mixed in an ice bath for 2 h, with the mixture gradually becoming pasty and black-greenish (all material prepared from Merck Company, Germany). Next, the mixture was placed in a 35 °C water bath and kept at that temperature for 60 min, followed by the slow addition of distilled water (100 mL) to keep the solution from effervescing; the resulting solution was placed at well below 100 °C for 3 h. With progression of the reaction, the color turned a little yellowish. After further treatment with H₂O₂ (5%, 100 mL), the filtered cake was washed with distilled water several times. Then the cake was dispersed in water for further ultra-sonication for 1 h. Of note, for facilitating the following experiments, we selected solutions with GO centrifuged at speeds ranging from 2500 to 5000 rpm [16]. PVA was purchased from Merck Company, Germany. The procedures for preparing PVA/GO nanocomposite were described as follows. Five 5 of PVA was dissolved in 95 g de-ionized water at 80 °C to give a 5 wt. % solution. Then, 5 mL PVA (5 wt.%) solution was added to 0, 1, 1.5, 2, 2.5, 3, 3.5 and 4% mL GO dispersion (1 mg/mL), and the mixtures were immediately subjected to sonication at room temperature for 1 h to obtain uniform dispersions. Vacuum filtration of these dispersions through porous polycarbonate membranes, 47mm in diameter and 0.2 μ m in pore size yielded freestanding PVA/GO nanocomposite. The nanocomposites were further dried overnight under vacuum at 60 °C without further hot press. The weight contents of GO in the three films described above were calculated to be about 0, 1, 1.5, 2, 2.5, 3, 3.5 and 4wt. %, respectively. It should be noted here that part PVA of the mixed dispersion inevitably passed through the pores of polycarbonate membrane during filtration.

RESULTS AND DISCUSSION

Characterizations of Graphene oxide (GO) and GO/PVA nanocomposite

GO-based samples were characterized using various techniques such as Fourier transform

infrared spectrum (FT-IR). Pristine and oxidized graphene (GO) was characterized using FT-IR spectrometer (BOMEM, made in Canada, 100 spectra accumulation, 2 m^{-1} resolution). FT-IR samples were prepared by grinding dried G and GO together with potassium bromide (KBr) to make a pellet and dried in oven for 8 hour before test. The FT-IR pattern of graphene has a characteristic peak at 1610 cm^{-1} due to the aromatic C=C skeletal vibrations are shown in Figure 1a. The FT-IR pattern of GO, which is shown in Figure 1b, reveals the presence of the oxygen-containing functional groups. The peaks at 1071, 1380, 1630 correspond to C-O-C stretching vibrations, C-OH stretching, C-C stretching mode of the sp^2 carbon skeletal network, respectively, while peaks located at 1730 and 3440 cm^{-1} correspond to C-O stretching vibrations of the COOH groups and O-H stretching vibration, respectively [17].

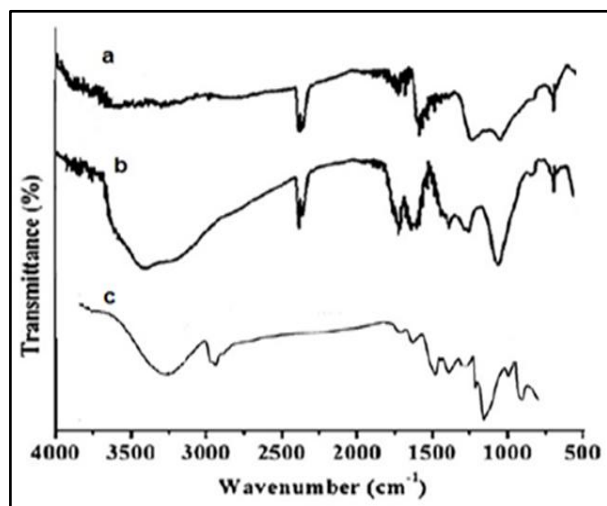


Fig. 1. Fourier transform infrared spectrum (FT-IR) for pristine graphene (a), oxidized graphene (b) and GO/PVA nanocomposite (c)

FT-IR experiments were carried out to determine the interaction between GO and PVA, and the results are shown in Figure 1c. The FT-IR reveals typical bands in PVA and the nanocomposite. It indicates that reducing agents would not react with the PVA. The peak around 3260 cm^{-1} , the characteristic of hydroxyl band, was shifted to a lower wavenumber as the loading of PVA was increased, and the band corresponding to C-OH stretching around 1086 cm^{-1} displays a similar behavior. Both of those phenomena indicate the existence of hydrogen bonding between the

OH in PVA and the remaining oxygen-functional groups in nanocomposites.

Electrical conductivity properties

Graphene also exhibits ultra-high conductivity and extremely large aspect ratios. They are considered as one of the most important conductive fillers for conductive polymer composites. Therefore, the conductivity of PVA/GO nanocomposites has been measured as shown in Figure 2. The conductivity increases sharply from 0 (pure PVA) to 1.0 GO% weight, while the conductivity content is increased from 0.004 to 0.0083 S/m by electrical conductivity meter (SH-120, Torbit, China). This demonstrates a typical insulating-conductive percolation behavior, where the percolation threshold of GO.

The highest conductivity achieved was 0.063 S/m for the composites containing 4.0 wt. % GO. Such as phenomena has been reported literature [18]. However, a second increase of conductivity (in the range of 2–3 wt. %) was different from traditional conductive behavior; the general explanation for this unique phenomena was attributed to the hopping of electrons between filler laminates by tunneling through the polymer layers. The mechanism is still not clear and needs further investigation. In addition, the hydrophilic nature of PVA limits its application in humid environment; chemical treatments on the surface are often needed [19].

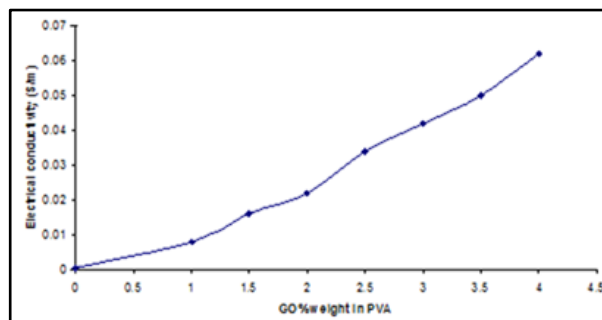


Fig. 2. Conductivity of PVA/GO nanocomposite at 25°C

CONCLUSIONS

This study include synthesized and preparation of graphene oxide (GO) nanocomposite functionalized with polyvinyl alcohol (PVA) with different concentration of graphene oxide 0, 1, 1.5,

2, 2.5, 3, 3.5 and 4% weight. The electrical conductivity of the all nanocomposite was measured at 25 °C for all samples and the resulted showed electrical conductivity was increased with increasing % weight graphene in nanocomposite.

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