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Tensile and flexural properties of graphene oxide coated-short glass fiber reinforced polyethersulfone composites

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ABSTRACT

It is the first time to report the effects of graphene oxide (GO) coating on the mechanical properties of short glass fiber (SGF) reinforced polymer composites. GO-coated SGF reinforced polyethersulphone (PES) composites are manufactured using extrusion compounding and injection molding techniques. The micro-structures and morphologies of GO and GO-coated SGFs are investigated using scanning electron microscopy, small-angle X-ray scattering, atomic force microscope and Fourier transform infrared techniques. Then, the tensile and flexural properties of the GO-coated SGF/PES composites are systematically studied taking into account the effect of GO coating content. It is observed that both the tensile and flexural strengths are effectively enhanced by the GO coating on the SGF surfaces. This observation is mainly attributed to the enhanced interfacial adhesion between SGFs and PES due to the GO coating. Moreover, the tensile and flexural moduli are also improved by the addition of GO due to the fact that GO has a much higher modulus than the PES matrix.

1. Introduction

In the past decades, short glass fiber (SGF) and short carbon fiber (SCF) reinforced polymer composites have been intensively investigated because of their ease of fabrication and superior mechanical properties. Particularly, low density thermoplastic composites based on SGFs and SCFs exhibit great potential in automotive or aviation industries as light-weight replacement materials. It is well known that the mechanical properties of short fiber reinforced polymer composites are critically related with fiber content, aspect ratio, orientation and fiber-matrix interfacial adhesion [1,2]. In order to achieve high mechanical performance for short fiber reinforced composites, a strong interfacial adhesion between short fibers and polymer matrix is necessary for transferring load from the matrix to the fibers [3,4].

To improve the fiber-polymer interfacial adhesion, the conventional methods include either enhancing the chemical bond between the fibers and the polymer matrix with coupling agent or introducing newly activated components or surface roughness onto the fiber surfaces with plasma treatment etc. [5,6]. Recently, graphene oxide (GO), which consists of a two-dimensional sheet of covalently bonded carbon atoms bearing various oxygen functional groups (e.g. hydroxyl, epoxy, and carbonyl groups) on their basal planes and edges, has shown a great potential as multifunctional sizing agent to enhance the interfacial bonding between the micro-sized fibers and the polymer [7–12]. The surface configuration of micro-sized fibers changed by GO sheets could enhance the strength and toughness of the fiber-matrix interfacial region [13].

Polyethersulphone (PES), an amorphous thermoplastic polymer, has attracted much attention due to its fascinating properties such as high glass transition temperature (T_g around 225 °C), excellent thermal stability (operation temperature up to 180 °C), great flame retardancy, low creep, high dielectric strength, extraordinary dimensional stability and chemical resistance etc. [14]. With these outstanding properties, PES is highly desirable as replacement for metals or ceramics in automotive, aerospace and microelectronics industries [14–16]. However, its relatively low mechanical properties still impede its broader applications.

Recently, the fabrication of GO-coated SCF/PES composited was reported by our group [4]. The results reveal that GO coating on SCF surfaces leads to an obvious SCF/PES interfacial adhesion enhancement. A better stress transfer due to the enhanced

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interfacial bonding leads to the enhanced mechanical properties by the incorporation of GO-coated SCFs into the PES matrix compared to the un-treated SCF case [4]. However, comparing with SCF reinforced polymer composites, SGF reinforced composites are more attractive for industry applications because they have the most favorable cost-mechanical property relationships [17]. But, the knowledge obtained for SCF reinforced polymer composites cannot be simply transferred to the SGF reinforced polymer composites since SGFs and SCFs are two different types of micro-sized fibers. In order to explore the application of PES, it is of significance to study the enhancement effectiveness of SGFs by GO coating on PES. At the same time, based on our knowledge, there has been no report related with the effects of GO sheets on the interfacial characteristics between SGFs and PES and hence on the mechanical properties of SGF/PES composites.

In the present work, short glass fiber reinforced PES composites are prepared using the melting blending and injection molding techniques. Meanwhile, to improve the mechanical properties of SGF/PES composites, GO as sizing agent is employed to improve the interfacial adhesion between SGFs and PES. First, the microstructures of GO and GO-coated SGFs are investigated using atomic force microscope (AFM), scanning electron microscopy (SEM), X-ray scattering (XRD), and Fourier transform infrared (FT-IR). Then, the mechanical properties of the GO-coated SGF/PES composites are systematically investigated. The results reveal that the surfaces of SGFs are covered with wrinkled and roughened GO sheets after coating treatment. Importantly, the tensile and flexural properties of PES are effectively enhanced by the GO coating on SGF surfaces.

2. Experimental section

2.1. Materials

Polyethersulfone granules (PES, E3010) was bought from BASF, Germany. Graphite powders were obtained from Qingdao AoKe ShiMo Co. Ltd, China. Short glass fibers (SGFs, 6 mm length, 552B) were provided by Zhejiang JUSHI, China. Ethanol, concentrated sulfuric acid, potassium permanganate, hydrochloric acid and *N*,*N*-dimethyl-Formamide (DMF), were all obtained from Beijing Chemical Works and used as-received. Sodium nitrate was purchased from Tianjin JinKe Fine Chemical Industry Research Institute, China. All of the raw materials were used without any further purification and treatment.

2.2. Preparation of graphene oxide (GO) and GO-coated glass fibers

GO was prepared using the modified Hummers method [18,19]. The obtained GO was subsequently dispersed in deionized water to form a suspension of 0.325 mg/ml. The non-exfoliated graphite oxide sheets were removed by centrifuge, then the GO was obtained by ultrasonic technique (1000 W) for 1.5 h and the homogeneous GO aqueous solution with a specific solubility of GO was formed for later use.

A given amount of GO aqueous solution in terms of the prescribed formulation was used for treating SGFs. An appropriate amount of SGFs in the prescribed ratio was added to the GO aqueous solution under mild magnetic stirring for 24 h. After that, the resultant mixture was dried under vacuum at 100 °C to remove water and then cooled naturally to room temperature. The GO concentration could be easily calculated in terms of the solubility of GO, the amount of GO aqueous solution and the amount of SGFs. The GO-coated SGFs with various GO concentrations were finally prepared. Moreover, the intensive stirring of GO-coated SGFs was conducted for examining the coating efficiency of the GO on to SGFs.

The as-obtained GO-coated SGFs were mixed with PES to prepare GO-coated SGF/PES composite samples with different GO concentrations using a TSE-20/600-4-48 co-rotating twin-screw extruder (NanJing Ruiya Extrusion Systems LTD., China) at a screw speed of 30 rpm and a feed rate of 6 rpm. The temperature profile of the barrel was set at 360-365-370-375-380-380-375°C from the hopper to the die. The materials were crushed by a breaker and dried in an oven at 130 °C for 6 h before injection molding. Standard tensile and flexural test bars were then obtained according to the recommendation of ASTM D 638-96 and ASTM D

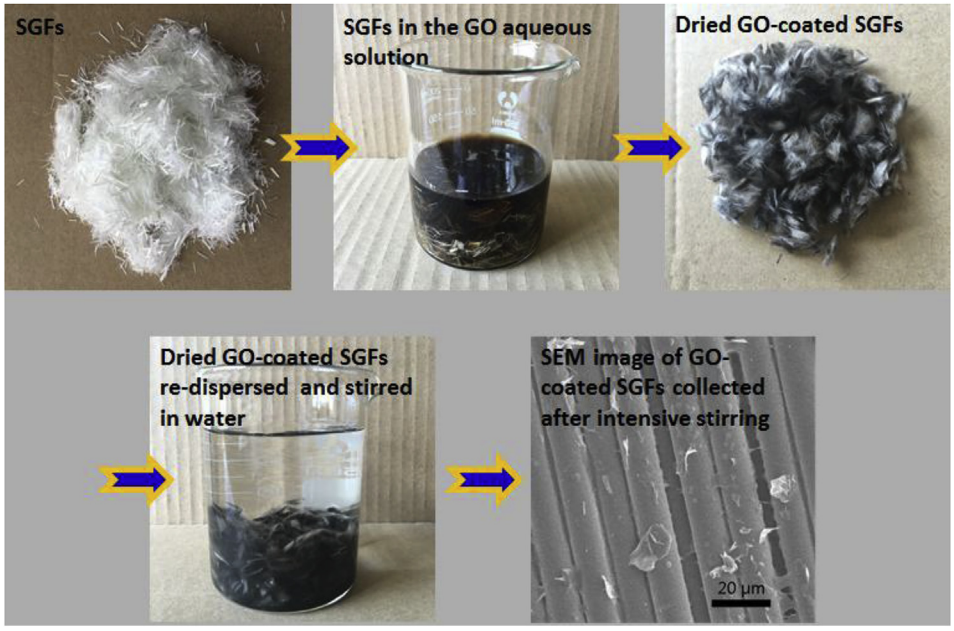

Fig. 1. Evaluation of the coating efficiency of GO onto the surfaces of SGFs.