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Tensile properties of graphene nano-platelets reinforced polypropylene composites

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ABSTRACT

The tensile properties of polypropylene (PP) composites filled separately with three kinds of graphene nano-platelets (GNPs) with different size were measured using a universal materials tester at room temperature and rate of extension of 50 mm/min. It was found that the values of the Young's modulus of the composites increased, the values of the tensile yield strength and tensile fracture of the composites increased slightly while the values of the tensile elongation at break decreased with increasing the GNPs weight fraction. The reinforcement of the composites could be attributed to the relatively big interfacial area and good interfacial adhesion between the matrix and the GNPs.

1. Introduction

Polypropylene (PP) is one of general type thermoplastic resins, and it is used extensively owing to its ease of processing, light-weight, low cost, and high recyclability. However, the applications of PP are certainly limited due to some disadvantages, including high molding shrinkage, low stiffness, and poor impact toughness. PP is usually modified with the introduction of inorganic fillers, such as talcum powder [1], calcium carbonate [2,3], mica [4], wood powder [5], metallic powder [6,7], and glass fiber [8], carbon fiber [9] and Graphite-like carbon nitride and functionalized layered double hydroxide [10]. Graphene nano-platelets (GNPs) are a kind of planar thin sheet made of carbon atoms [11]. GNPs are extensively used in industry owing to good physical and mechanical properties, such as high specific strength and excellent conductivity [12,13]. For instance, a small amount of GNPs can lead to a significant improvement in properties of polymers, including electrical properties [14,15], thermal properties [16,17] and mechanical properties [17–20]. Moreover, the thermal stability and flammability of PP can be improved with the addition of GNPs [21–24].

Mechanical properties including tensile, impact and flexural properties are important service performances. There have been a number of studies on the mechanical properties of PP composites, such as PP/glass bead [25], PP/nano-$CaCO_3$ [26], PP/Mg $(OH)_2$ [27] and PP/$CaSO_3$ [28] composite systems. However, there have been relatively few studies on the mechanical properties of PP/GNPs composites. Inuwa et al. [18] measured the mechanical and thermal properties of exfoliated graphite nano-platelets reinforced polyethylene terephthalate/polypropylene composites, and found that the values of the flexural and impact strength of the composites were maximum when the GNPs content was 3 phr. Wang et al. [19] investigated the mechanical properties of graphene/poly (vinyl alcohol) nanocomposites in the grapheme weight fraction range from 0 to 3 wt.%, and the results showed that the value of the tensile strength of the nanocomposites was the highest when the grapheme weight fraction was 0.5 wt.%. GNPs are thin sheet shape inorganic nanometer particles with different thickness. Then, how does the GNPs size affect the mechanical properties of polymeric materials? However, there have been relatively few studies in this field. Therefore, it is necessary to have an in-depth study on the reinforced mechanisms of polymer/GNPs composite systems. The objective of the present study is to investigate the influence of the size and content of GNPs on the tensile properties of PP/GNPs composites to discuss the reinforced mechanisms of the GNPs in the matrix.

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2. Experimental

2.1. Materials

The polypropylene with trademark CJS-700, serving as the matrix material was supplied by the Guangzhou Petrochemical Works in Guangdong province (Guangzhou, China), and the density in solid state was 910 kg/m^3 and the melt flow rate was 10 g/10 min (230 °C, 2.16 kg).

Three types of GNPs were selected as the fillers for investigating the effects of the size on the thermal stability of the composite systems. They are: (1) trademark SGNP-F01005 was supplied by the Nanjing Kefu Nano-Tech Co. Ltd (Nanjing, China), it was abbreviated as G1; (2) trademark HQNANO-GR-003 was supplied by the Suzhou Hengqiu Graphene Technol. Co. Ltd (Suzhou, China), it was abbreviated as G2; (3) trademark JCGNP-15-10 was supplied by the Nanjing Jichang Kefu Nano-Tech Co. Ltd (Nanjing, China), it was abbreviated as G3.

2.2. Preparation

The PP was separately mixed with the three GNPs with different sizes in the high speed compounding machine (model GH-10) supplied by Beijing Plastics Machinery (Beijing, China), and then the PP/GNPs blends were melt-blended in a twin-screw extruder (model SHJ-26) supplied by Nanjing Chengmeng Machinery Ltd. Co. (Nanjing, China) at a screw speed of 100 rev/min and in a temperature range from 190 to 210 °C, to prepare the three PP/GNPs composites: PP/G1, PP/G2 and PP/G3, in which the weight fractions of the GNPs were 0.1, 0.2, 0.3, 0.4 and 0.5 wt.%. The screw diameter was 26 mm, while the length to diameter ratio of the screw was 40. The granules of the fabricated composites were dried at 80 °C for 5 h before injection of the specimens.

The specimens for tensile test were molded by using a plastic injection machine with model UN120A supplied by Yizumi Precision Mechanism Ltd (Foshan city, China). The temperature was varying from 170 to 210 °C, and the mold temperature was from 40 to 50 °C.

2.3. Apparatus and methodology

The tensile tests of the PP/GNP composites were conducted at room temperature by means of a universal materials testing machine (model tensiTECH) supplied by Tech-Pro Inc. (Woodstock, USA) at room temperature, and the cross-head descending speeds was 50 mm/min. Each group specimens contained 5 pieces, and the average values of the measured tensile properties were used from the measured data.

3. Results and discussion

3.1. Relationship between tensile stress and strain

Fig. 1 displays the relationship between tensile stress and strain of the PP/G1 composites. It can be seen that the values of the tensile strain at break decreases with increasing the GNPs weight fraction. Fig. 2 presents the relationship between tensile stress and strain for the PP/G2 composites. When the GNPs weight fraction is smaller than 0.3 wt.%, the values of the tensile strain at break are only slightly lower than that of the unfilled PP; while when the GNPs weight fraction is more than 0.3 wt.%, the values of the tensile strain at break significantly decrease with increasing the GNPs weight fraction. Fig. 3 illustrates the relationship between tensile stress and strain for the PP/G3 composites. Similar to the results

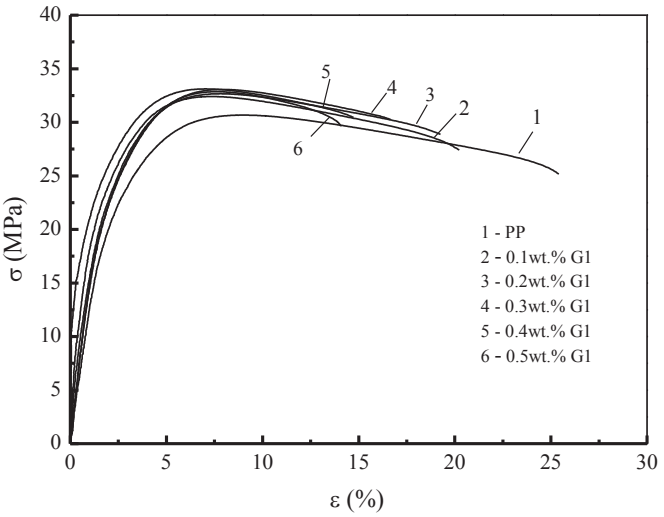

Fig. 1. Relationship between tensile stress and strain of PP/G1 composites.

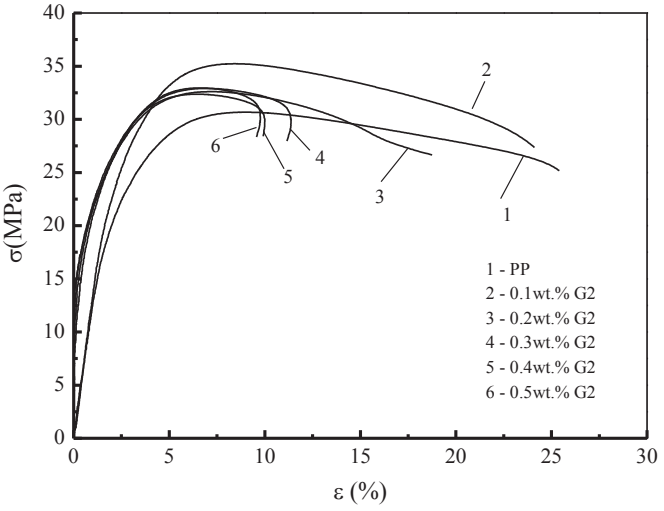

Fig. 2. Relationship between tensile stress and strain of PP/G2 composites.

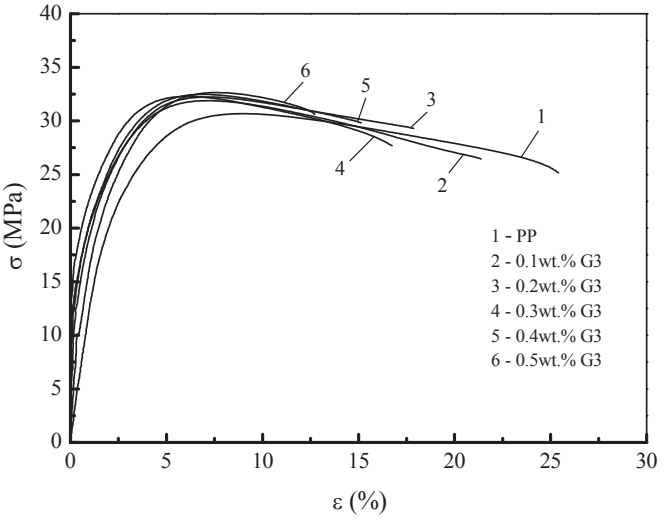

Fig. 3. Relationship between tensile stress and strain of PP/G3 composites.