Polymer Testing 27 (2008) 971–976

Contents lists available at ScienceDirect

Polymer Testing

journal homepage: www.elsevier.com/locate/polytest

Material Properties

Effect of particle sizes of zinc oxide on mechanical, thermal and morphological properties of polyoxymethylene/ zinc oxide nanocomposites

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ARTICLE INFO

Article history:
Received 6 June 2008
Accepted 21 August 2008

Keywords:
Polymer nanocomposites
Polyoxymethylene
Zinc oxide
Mechanical properties

ABSTRACT

The effects of particle size of zinc oxide (ZnO) on mechanical, thermal and morphological properties of pure polyoxymethylene (POM) and POM/ZnO nanocomposites were investigated. POM/ZnO nanocomposites with varying concentration of ZnO were prepared by a melt mixing technique in a twin screw extruder. The dispersion of ZnO particles in POM composites was studied by scanning electron microscopy (SEM). The agglomeration of ZnO71 (71 nm) particles in the polymer matrix increased with increasing ZnO content. The POM/ZnO71 and POM/ZnO250 (250 nm) nanocomposites showed decrease in tensile strength with increasing filler content. Young's modulus and stress at break of POM/ZnO71 and POM/ZnO250 nanocomposites increased with increasing filler contents. The impact strength of POM nanocomposites increased up to a ZnO content of 1.0 wt%. However, the POM/ZnO71 nanocomposites had higher mechanical properties than the POM/ZnO250 nanocomposites. The degradation temperature of POM/ZnO71 nanocomposites was higher than that of POM/ZnO250 nanocomposites.

1. Introduction

Developing nanocomposites based on polymers and nanoscale fillers has been an attractive approach to achieving good properties [1]. Various nanoscale fillers, including montmorillonite [2,3], silica [4–6], calcium carbonate [1,7–9], aluminum oxide [10] and titanium dioxide [11,12], have been reported to enhance mechanical and thermal properties of polymers, such as toughness, stiffness and heat resistance [9,13–15]. The properties of particulate filled polymer composites depend on the particle size, shape and loading, together with distribution of filler particles in the matrix polymer and good adhesion at the interface surface [16–18]. POM is one of the major engineering thermoplastics because of its high strength, stiffness and excellent chemical resistance. However, its poor impact resistance limits its range of applications [19]. Ma et al. [20] investigated the effects of nanoscale zinc oxide (ZnO) on the electrical and physical characteristics of the polystyrene (PS) nanocomposites. It was reported that the addition of ZnO nanopowder increased the flexural modulus and reduced the flexural strength. The glass-transition temperatures and thermal degradation temperatures of the ZnO/PS nanocomposites increased with ZnO content. Tang et al. [21] studied the effects of

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0142-9418/$ – see front matter
doi:10.1016/j.polymertesting.2008.08.012

organic nucleating agents and ZnO nanoparticles on isotactic polypropylene (iPP). It was found that the nonisothermal crystallization temperature of isotactic polypropylene increases by 7 °C when an aliphatic triamine was distributed efficiently within the polymeric matrix by coating this nucleating agent onto ZnO nanoparticles. Chae and Kim [22] prepared PS/ZnO nanocomposites by solution mixing and investigated the effects of ZnO nanoparticles on the physical properties of PS. They found that the thermal stability of PS was enhanced with increasing ZnO content. Liufu et al. [23] investigated the thermal degradation behaviour of polyacrylate and its zinc oxide composites by differential scanning calorimetry (DSC), thermogravimetry (TG) and Fourier transform infrared spectroscopy (FTIR). Filler-free polyacrylate exhibited one DSC peak, indicating that the polymer was degraded with only one stage of weight loss. Polyacrylate/ZnO composites underwent two minor weight losses as well as the major weight loss. ZnO stabilized or destabilized the polymer molecules according to the temperature region.

This work studied the influence of particle sizes of ZnO on morphology, mechanical and thermal properties of POM/ZnO nanocomposites. POM/ZnO nanocomposites with varying concentration of ZnO were prepared by a melt mixing technique in a twin screw extruder.

2. Experimental

2.1. Materials

Polyoxymethylene (POM) was supplied with the trade name of "DURACON" by Polyplastics Co., Ltd. The melting temperature of the POM was around 165 °C. ZnO in the form of a white powder with average particle sizes of 71 nm (ZnO71) and 250 nm (ZnO250) was purchased from Aldrich and S.R. LAB Co., Ltd, respectively.

2.2. Sample preparation

POM pellets and ZnO particles were dried in an oven at 70 °C for 3 h before melt extrusion. The POM/ZnO nanocomposites were melt-compounded in the desired compositions in a twin screw extruder at temperatures in the range of 170–200 °C and a screw speed of 50 rpm. After compounding, the nanocomposites were injection-molded into standard dumb-bell tensile bars and rectangular bars.

2.3. Sample characterization

Tensile tests were conducted according to ASTM D 638 (ISO 527) with a universal tensile testing machine LR 50k from Lloyd instruments. The tensile tests were performed at a crosshead speed of 50 mm/min. Charpy impact strength tests were performed according to D 6110-06 (ISO 179) at room temperature. Each value reported represents the average of five samples.

Thermal properties were studied by thermogravimetric analysis (TGA) with a Perkin Elmer instrument, TGA 7. The samples were cut into small pieces and then heated from room temperature to 400 °C at a heating rate of 10 °C/min under a nitrogen atmosphere.

Scanning electron microscopy (SEM) was used to study the morphology of the impact fracture surfaces of the POM/ZnO nanocomposites and to evaluate the dispersion quality of the ZnO particles. All specimens were coated with gold before SEM study.

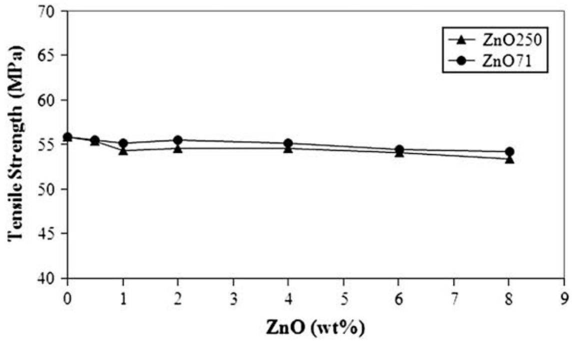

Fig. 1. Tensile strength of pure POM and POM/ZnO nanocomposites at various particle sizes of ZnO.

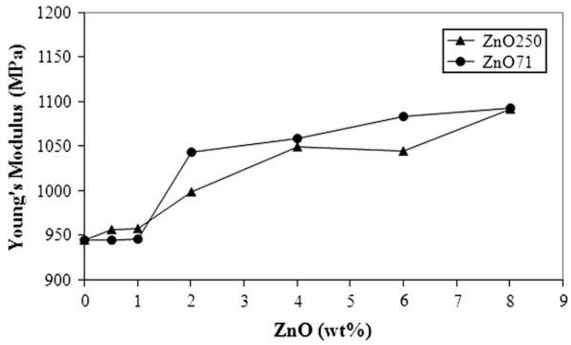

Fig. 2. Young's modulus of pure POM and POM/ZnO nanocomposites at various particle sizes of ZnO.

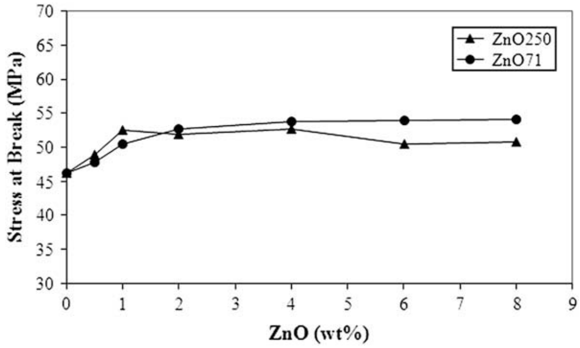

Fig. 3. Stress at break of pure POM and POM/ZnO nanocomposites at various particle sizes of ZnO.