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Effect of Zinc Oxide on Morphology and Mechanical Properties of Polyoxymethylene/Zinc Oxide Composites

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Summary: This paper studies the effects of zinc oxide (ZnO) on morphology and mechanical properties of pure polyoxymethylene (POM) and POM/ZnO composites. POM/ZnO composites with varying concentration of ZnO were prepared by melt mixing technique in a twin screw extruder. The dispersion of ZnO particles on POM composites was studied by scanning electron microscope (SEM). It is observed that the dispersion of ZnO particles is relatively good. The mechanical properties of the composites such as tensile strength, stress at break, Young's modulus and impact strength were measured. Increasing content of ZnO up to 4.0 wt% increases the impact strength of POM. Addition of ZnO beyond 4.0 wt% decreases the impact strength. The composites containing ZnO content greater than 2.0 wt% show increased Young's Modulus. The tensile strength and stress at break decrease with increasing ZnO content. This may be due to the compatibility between ZnO and POM.

Keywords: composite; morphology; polyoxymethylene; zinc oxide

Introduction

The purpose of adding inorganic mineral fillers are used to fulfill a functional rule, such as increasing the stiffness, dimension stability, heat distortion temperature, hardness and toughening of the polymers.[1–4] The properties of particulate filled polymer composites depend on the particle size, shape, loading, and distribution on filler particles in the matrix polymer and good adhesion at the interface surface.[5–7] The dispersion of fillers in polymer matrix has influence on the physical, mechanical, and thermal properties of polymers. POM conventionally called polyacetal 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.[8] Ma et al.[9] investigated the effects of nanoscale zinc oxide (ZnO) 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 silane coupling agents improved the flexural properties of the nanocomposites. The glass-transition temperatures and thermal degradation temperatures of the ZnO/PS nanocomposites increased with ZnO content. Chae et al.[10] 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. In this work, we study the influence of ZnO on morphology and mechanical properties of POM/ZnO composites. POM/ZnO composites with varying concentration of ZnO were prepared by melt mixing technique in a twin screw extruder.

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Experimental Part

Materials

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

Sample Preparation

POM pellets and ZnO particles were dried in an oven at 70 °C for 3 hrs before melt extrusion. The POM/ZnO composites were melt-compounding in desired compositions in a twin screw extruder at temperatures in a range of 170–210 °C and a screw speed of 30 rpm. After compounding, the composites were compression molded into standard dumb-bell tensile bars and rectangular bars, the mold temperature was kept at 190 °C.

Tensile Test

Tensile tests were conducted according to ASTM D 638 with a universal tensile testing machine LR 50 k from Lloyd instruments. The tensile tests were performed at cross-head speed of 50 mm/min. Each value obtained represented the average of five samples.

Charpy Impact Test

Charpy impact strength tests were performed according to D 6110-06 standard at room temperature. Each value obtained represented the average of five samples.

Scanning Electron Microscopy (SEM)

SEM was taken to study the morphology of the POM/ZnO composites and to evaluate the dispersion quality of the ZnO particles. The morphology of the impact fracture surfaces of the POM/ZnO composites were carried out using a JSM-58000 LV, JEOL scanning electron microscope. All specimens were coated with gold before SEM.

Results and Discussion

Tensile Properties

The tensile strength and stress at break for the composites of POM/ZnO as a function of composite composition are represented in Figure 1 and 2. The trend in variation of the tensile strength of POM/ZnO composites is presented in Figure 1. The values of tensile strength do not change much by adding 1.0–4.0 wt% of ZnO and the tensile strength decreases with the addition of 8.0–12.0 wt% of ZnO. It is shown that the ZnO content do not improve on tensile strength of POM that the specimens prepared by compression molding. This is due to the decrease in the degree of crystallinity with increasing content of ZnO.

Figure 2 presents the variation in the stress at break with varying concentrations

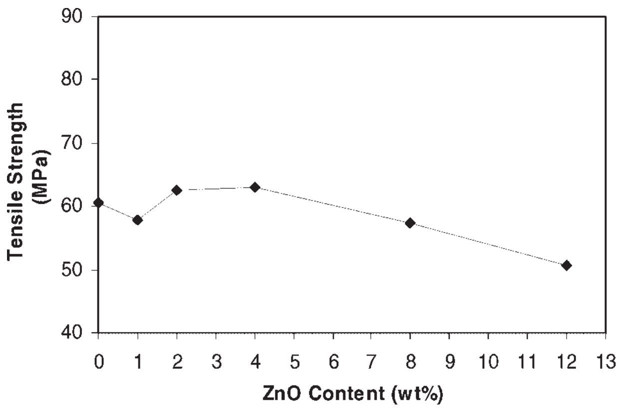

Figure 1.
Tensile strength of pure POM and POM/ZnO composites.

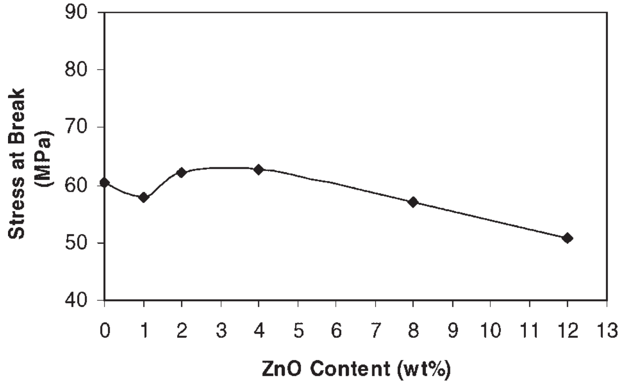

Figure 2.
Stress at Break of pure POM and POM/ZnO composites.

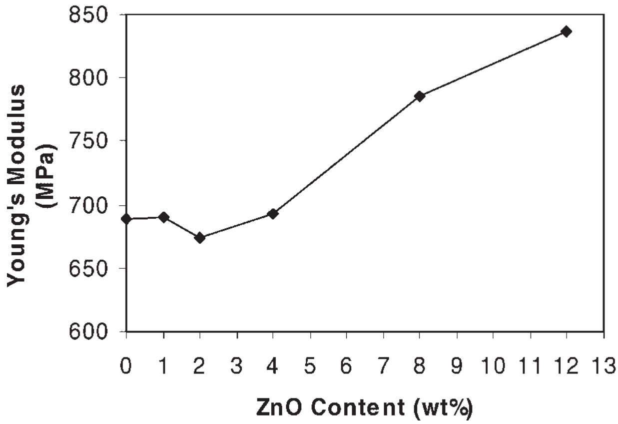

Figure 3.
Young's modulus of pure POM and POM/ZnO composites.

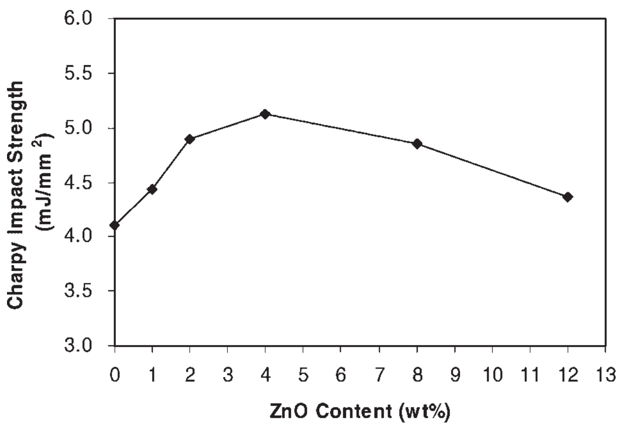

Figure 4.
Impact strength of Pure POM and POM/ZnO composites.

of ZnO. It is observed that in POM/ZnO composites the stress at break decreases with increasing ZnO content. A significant decrease in the tensile strength and stress at break has been observed in composites containing ZnO content greater than 4.0 wt%. This may be due to the compatibility between ZnO and POM.

The Young's Modulus of POM/ZnO composites is presented in Figure 3. The composites containing ZnO content greater than 2.0 wt% show increased Young's Modulus.

Impact Properties

The Charpy impact strength for the composites of POM/ZnO is shown in Figure 4. It is indicated that the impact strength increases up to ZnO content of 4.0 wt% for

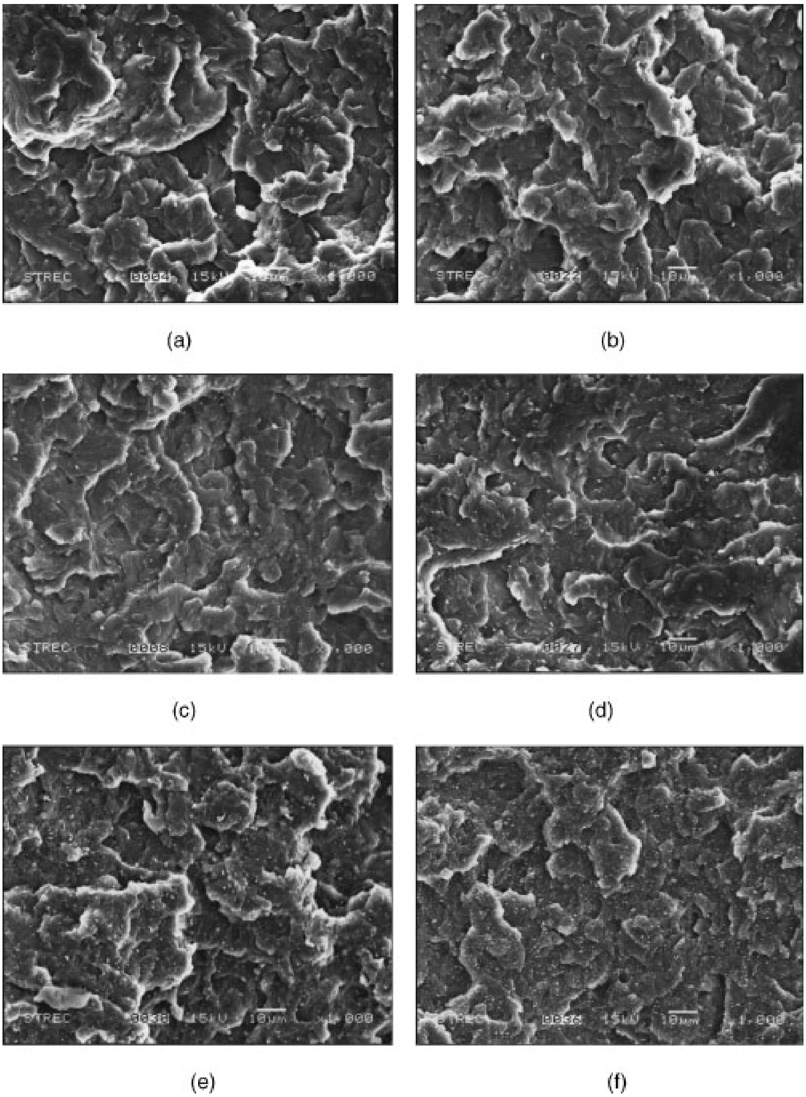

Figure 5.
SEM micrographs (a) pure POM, (b) POM after adding 1.0 wt% of ZnO, (c) POM after adding 2.0 wt% of ZnO, (d) POM after adding 4.0 wt% of ZnO, (e) POM after adding 8.0 wt% of ZnO and (f) POM after adding 12.0 wt% of ZnO.

POM/ZnO composites. Addition of ZnO beyond this level drastically decreases the impact strength. A significant improvement in the impact strength is observed due to the increased energy absorption during impact.[11]

As the ZnO content increases, the composites exhibit higher Young's modulus but lower impact strength.

Morphological Characteristics

The morphologies of fracture surface of impact specimen of composites filled with ZnO particles were examined by SEM. Figure 5(a) shows the micrographs of the fracture surface of impact sample of pure POM. Figure 5(b–f) show the micrographs of the fracture surface of impact sample of POM composites filled with 1.0, 2.0, 4.0, 8.0 and 12.0 wt% of ZnO, respectively. It is observed that the dispersion of ZnO particles is relatively good, only few aggregated exist as shown in Figure 5(b–f). The dispersion of particle ZnO may be influence on the mechanical properties of POM composites.

Conclusions

POM/ZnO composites were prepared by melt compounding in a twin screw extruder. The Young's modulus increases with increasing ZnO content in POM/ZnO composites. The impact strength increases up to ZnO content of
4.0 wt%. The tensile strength and stress at break of composites of 1.0–4.0 wt% of ZnO is almost the same with the pure POM, while the tensile strength and stress at break decrease in composites containing ZnO content greater than 4.0 wt%.

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