THE MECHANICAL PROPERTIES OF POLYSTYRENE/Al_2O_3 NANOCOMPOSITES

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Introduction

In the last few years, great attention has been focused on organic polymer/inorganic nanocomposites, from either a scientific or technological point of view [1]. These polymer nanocomposites can exhibit increased modulus, decreased thermal expansion coefficients, reduced gas permeability, increased solvent resistance and enhanced thermal stability [2-5] when compared with polymer alone. Polymer/Al_2O_3 nanocomposites have attracted much significant academic and industrial interest due to their remarkable enhancement dimensional stability and gas barrier performance, in addition to mechanical and thermal properties as compared with the conventional microcomposites. Polymer/Al_2O_3 nanocomposites have become an important area of polymer composite research.

This paper discusses a proprietary process to manufacture the inorganic/organic of polystyrene (PS)/Al_2O_3 nanocomposites by bulk polymerization, and then test their mechanical properties of nanocomposites. The synthesis of nanocomposites materials include styrene monomer, initiator of benzoyl peroxide (BPO) and micro and nano Al_2O_3. To investigate the improvement properties on the static mechanical properties and dynamic mechanical properties of polystyrene/Al_2O_3 nanocomposites. The static mechanical properties include tensile properties. The dynamic mechanical properties include dynamic storage modulus (E') and dynamic damping curves tanδ (T_g).

Experimental

Materials

The styrene monomer was a commercially available materials, it has a specific gravity of 0.9045, a viscosity of 10 mPa.s at 25^{o}C, and a molecular weight of 104. The initiator benzoyl peroxide (BPO) $(C_6H_5CO)_2O_2$ used was a guaranteed reagent supplied by the Kanto Chemical Co., Japan; it has a molecular weight of 242. The nano Al_2O_3 has a diameter of 38.2 nm, a specific surface area of 43.6 m^2/g, a boiling point of 2980^{o}C, a specific gravity of 3.60. The micro Al_2O_3 has a diameter of 2 μm, a boiling point of 2980 ^{o}C, a specific gravity of 3.60.

Preparation of nanocomposites

(1) One phr (parts per hundred resin) initiator (BPO) was added to the styrene monomer and was stirred continuously 10 min to ensure mixing was complete, and reacted at 75 ^{o}C and 2 hrs to get the polystyrene prepolymer.
(2) The contents 1 wt%, 4 wt% and 7 wt% of nano Al_2O_3 and micro Al_2O_3 were mixed with polystyrene prepolymer under a nitrogen gas atmosphere at room temperature.
(3) The mixture was molded in an ASTM standard stainless steel die, the surfaces of the stainless steel die have been treated by chrome plating.
(4) The mixture of mold was polymerized in an oven at 65^{o}C for 48 hrs by bulk polymerization.

Results and Discussion

Static mechanical properties

Fig.1 illustrated the tensile strength versus nano and micro Al_2O_3 content of PS/Al_2O_3 composites. From this figure, it can be seen that the tensile strength increased with increasing of Al_2O_3 content. In the meantime, the tensile strength of PS/nano-Al_2O_3 composites were better than that of PS/micro-Al_2O_3 composites. This can be explained that the nano-sized inorganic particles have long been used in polymer industry to increase strength and modulus. The enhancement in strength and modulus is directly attributable to the reinforcement provided by the dispersed Al_2O_3 nano-layers which contribute to dangling chain formation in the matrix, as well as to conformational effects on the polymer at the Al_2O_3-matrix interface.

Dynamic mechanical properties

Fig.2 showed the dynamic storage modulus (E') versus temperature of PS/Al_2O_3 composites at 4 wt% nano and micro Al_2O_3. From this figure, it is evident that the PS/Al_2O_3 composites exhibit enhanced storage modulus (E') compared with virgin PS. At the same time, the E' for the PS/nano-Al_2O_3 is higher than for the PS/micro-Al_2O_3.

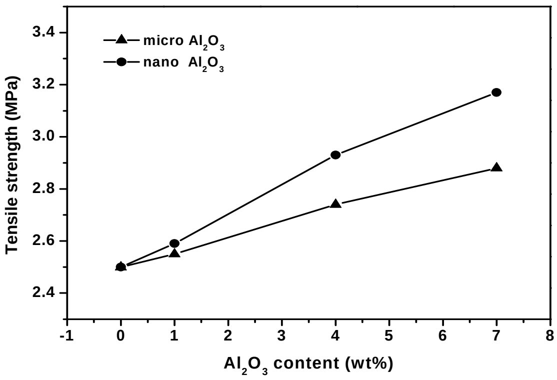

Fig.1 Tensile strength versus nano and micro Al_2O_3 content of PS/Al_2O_3 composites.

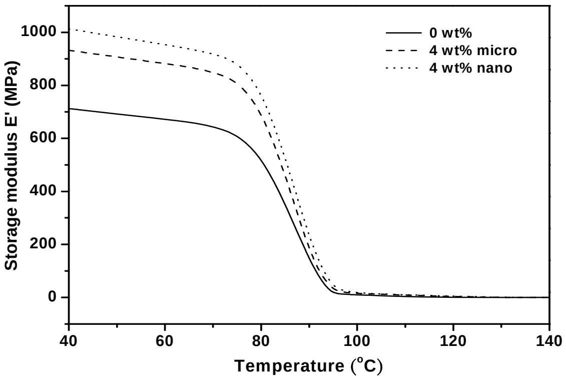

Fig.2 Storage modulus E' versus temperature of PS/Al_2O_3 composites at 4wt% nano and micro Al_2O_3.

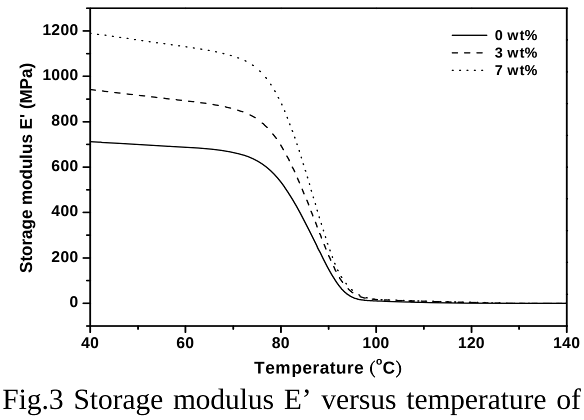

Fig.3 Storage modulus E' versus temperature of PS/nano-Al_2O_3 composites at various nano Al_2O_3 contents.

The effect of the nano-Al_2O_3 contents on the E' as shown in Fig.3. From this figures, it is evident that the PS/nano-Al_2O_3 composites exhibit E' increased with increasing of nano-Al_2O_3. This can be explained that the nano-sized inorganic particles have long been used in polymer industry to increase modulus. The enhancement in moduli is directly attributable to the reinforcement provided by the dispersed nano-Al_2O_3 which contribute to dangling chain formation in the matrix, as well as to conformational effects on the polymer at the Al_2O_3-matrix interface. Fig.4 illustrated the tanδ versus temperature of PS/Al_2O_3 composites at 4 wt% nano and micro Al_2O_3. From this figure, it can be seen that the glass transition temperature (T_g) of PS/Al_2O_3 composites was shifted to a higher temperature when the Al_2O_3 was added into PS matrix. At the same time, the T_g for the PS/nano-Al_2O_3 is higher than for the PS/micro-Al_2O_3.

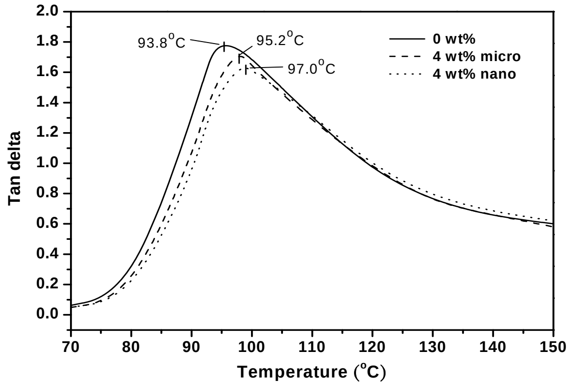

Fig.4 Dynamic tanδ versus temperature of PS/Al_2O_3 composites at 4wt% nano and micro Al_2O_3.

Conclusion

The tensile strength of PS/Al_2O_3 composites increased with increasing of Al_2O_3 content. The PS/nano-Al_2O_3 composites were better than that of PS/micro-Al_2O_3 composites. The PS/Al_2O_3 composites exhibit higher E' compared with virgin PS. The E' for the PS/nano-Al_2O_3 is higher than for the PS/micro-Al_2O_3. The T_g of PS/Al_2O_3 composites was shifted to a higher temperature when the Al_2O_3 was added into PS matrix, and the T_g for the PS/nano-Al_2O_3 is higher than for the PS/micro-Al_2O_3.

References

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