

Mechanical Properties and Miscibility of Polyethersulfone/Phenoxy Blends

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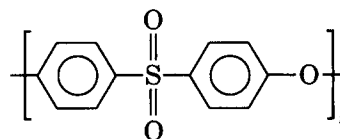
SYNOPSIS

The blends of polyethersulfone and phenoxy were prepared by melt mixing in a Brabender-like apparatus. The specimens for measurements were made by compression molding and then were water-quenched at room temperature under pressure. The tensile strength, tensile modulus, elongation at break and yield, density, thermal analysis, and dynamic mechanical properties were each measured. The dependence of tensile strength, tensile modulus, elongation at break and yield, and density on composition was obtained. The relationship between tensile modulus and elongation at break and yield and speed of the crosshead at different weight ratios of the blends is shown. The effects of composition and miscibility on the mechanical properties are discussed. © 1996 John Wiley & Sons, Inc.

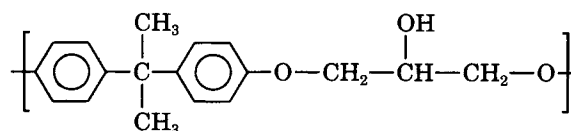
INTRODUCTION

The modification of polymer properties with the aid of blending has been used increasingly to obtain inexpensive materials with improved characteristics. Polymer blends may be classified into homogeneous (miscible) and heterogeneous (immiscible) blends in general. However, ones generally considers that the positive effects can be obtained only by using heterogeneous blends with partial miscibility, except for the system of poly(2,6-dimethyl-*p*-phenylene oxide) and polystyrene.¹ Flory² predicted that the driving force for miscibility is provided by specific interactions between the polymers; if the specific interactions were strong enough in the polymer blends, they would be miscible polymer blends. Obviously, obtaining a heterogeneous material with the synergism by improving some properties of polymers is not expected.

Polyethersulfone (PES) with the following structure



is a high-performance engineering plastics with good mechanical and electrical properties; the high glass transition temperature ($T_g \approx 220^\circ\text{C}$) enables the sample to retain its modulus at an elevated temperature. Unfortunately, it has a relatively high melt viscosity and low ultimate elongation. To improve the properties of PES, several blends of PES with other polymers have been made.³⁻¹⁰ Phenoxy with the repeat unit



is a amorphous polymer with excellent ductility. The blends with PES and phenoxy make up a miscible system with a lower critical solution temperature.¹¹ In this article, a heterogeneous system of PES/phenoxy blends was made by compression-molding quenching methods. The effects of composition,

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miscibility, and speed of the crosshead on the tensile, density, dynamic mechanical, and thermal behavior of PES/phenoxy blends are discussed.

EXPERIMENTAL

Materials

The polyethersulfone (PES) used in this study was synthesized by desalting from a bisphenol solution; the logarithmic specific-volume viscosity was 0.36–0.37. Phenoxy, YP-50, was obtained from Tohto Kasei. Both “as-received” polymers were amorphous.

Sample Preparation

The blends with PES/phenoxy with different weight ratios were prepared by melt mixing using a Brabender-like apparatus (Rheocoder XSS-300) at 305°C for 8 min. The blends were dried under vacuum at 110°C for 2 h. The specimens for measurements were obtained by compression molding at 305–310°C and then were quenched in water. The thickness of the specimens was about 0.4 mm. The specimens for the dynamic test were made by compressing the blends on a dewared glass cloth at 305–310°C.

Methods and Instrumentation

The tensile test was carried out on a Instron with different crosshead speeds. The tensile specimens were cut by a dumbbell-shaped knife (the effective dimension was 20 × 4 × 0.4 mm).

Calorimetric measurements were performed with a MAS Science DSC 3100 differential scanning calorimeter with a heating rate of 20°C/min. The dynamic mechanical analysis was conducted using torsion braid analysis (TBA). The dimensions of the specimens were 50 × 5 × (0.3–0.5) mm. Data were collected at a heating rate of 2°C/min under N₂.

The density of the blends was measured in a density gradient solution prepared continuously with a H₂O—Ca(NO₃)₂ mixture. The test temperature was 20 ± 0.5°C.

RESULTS AND DISCUSSION

Effects of Composition on Tensile Behavior

From the results of the tensile tests, it can be seen that the elongation at yield decreases with increase

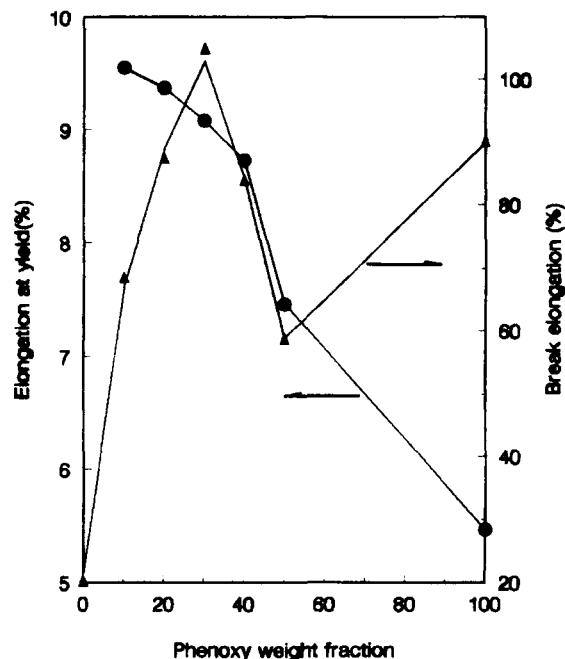


Figure 1 Dependence of elongation at yield and break on composition: (●) experimental values for elongation at yield; (▲) experimental values for elongation at break.

of the phenoxy weight fraction and the elongation at break increases with the phenoxy content before 30 wt % phenoxy and decreases with increase of the phenoxy content between 30 and 50 wt % phenoxy (see Fig. 1). In Figure 2, one finds that the tensile strength decreases with increase of the phenoxy content and is basically identical with the additive curve and the tensile modulus increases with the phenoxy content before 50 wt % phenoxy. In the above description, the elongation at break exhibits a synergism in a wide range up to 50 wt % phenoxy and a higher elongation at break, more than five times of that of PES, can be seen around 30 wt % phenoxy. The tensile modulus is increased by a big margin, e.g., 10 MPa, more than that of PES for 30 wt % phenoxy. According to the relationship between composition and tensile behavior, it is known that the elongation at break and tensile modulus of PES can obviously be improved by blending some phenoxy into PES (e.g., 30 wt % phenoxy) and the other tensile properties of PES basically show no change. This gives a method to improve the tensile properties of PES.

Effects of Crosshead Speed on Tensile Behavior

Figures 3–5 show the elongation at yield and break and tensile strength of blends with different com-

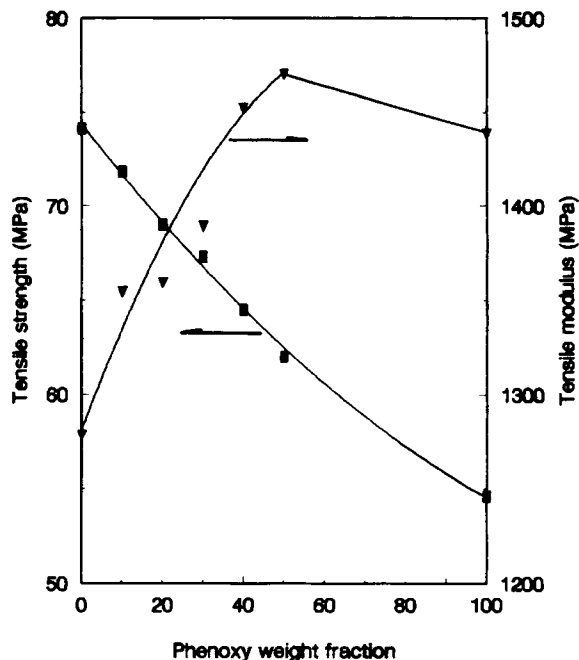


Figure 2 Dependence of tensile strength and modulus on composition: (■) experimental values for tensile strength; (▼) experimental values for tensile modulus.

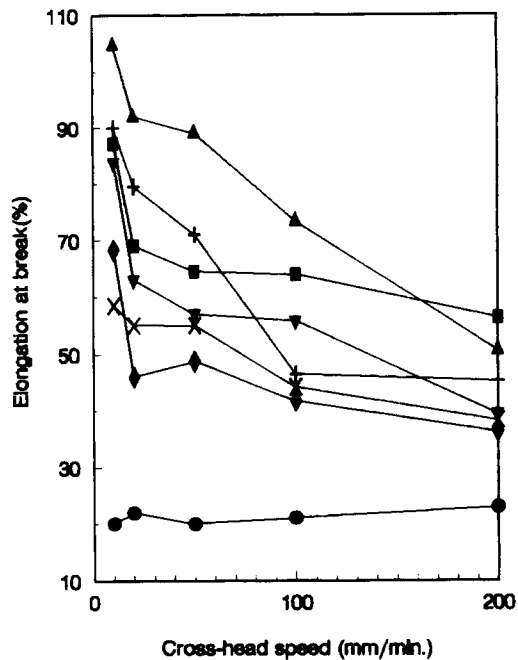


Figure 4 Plots of elongation at break against crosshead speed for different composition blends: (●) pure PES; (◆) 10 wt % phenoxy; (■) 20 wt % phenoxy; (▲) 30 wt % phenoxy; (▼) 40 wt % phenoxy; (×) 50 wt % phenoxy; (+) pure phenoxy.

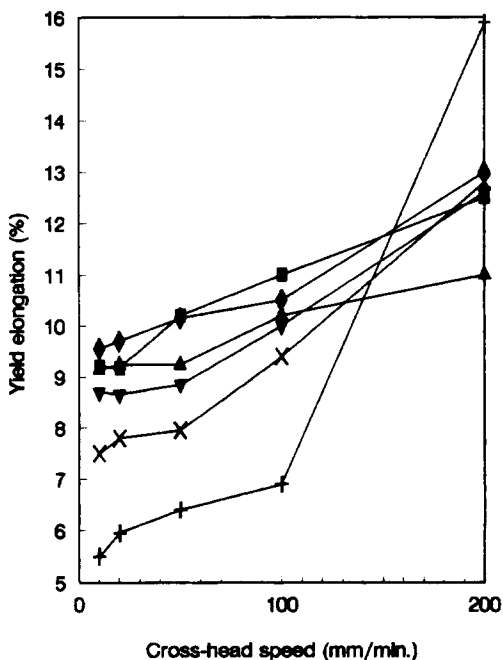


Figure 3 Plots of elongation at yield against crosshead speed for different composition blends: (◆) 10 wt % phenoxy; (■) 20 wt % phenoxy; (▲) 30 wt % phenoxy; (▼) 40 wt % phenoxy; (×) 50 wt % phenoxy; (+) pure phenoxy.

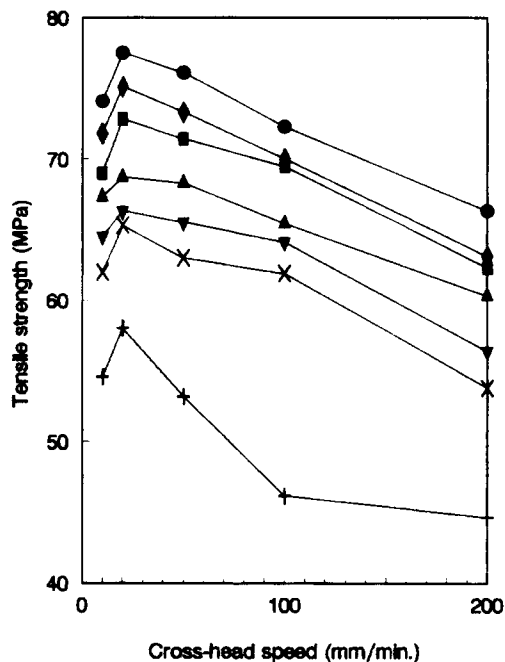


Figure 5 Plots of tensile strength against crosshead speed for different composition blends: (●) pure PES; (◆) 10 wt % phenoxy; (■) 20 wt % phenoxy; (▲) 30 wt % phenoxy; (▼) 40 wt % phenoxy; (×) 50 wt % phenoxy; (+) pure phenoxy.

positions and crosshead speeds. One finds that the elongation at yield of the blends increases with the crosshead speed (Fig. 3). It is suggested that the tensile yield is retarded due to the increase of the crosshead speed. In Figure 4, the elongation at break decreases with increase of the crosshead speed in the blends and pure phenoxy. This is the reason that the relaxation of polymer chains does not keep pace with the increase of the crosshead speed. However, the elongation at break is basically constant for pure PES. One considers that the change of PES elongation at break is not remarkable because PES shows a brittle fracture. The tensile strength with different compositions increases at first and then decreases with increase of the crosshead speed (see Fig. 5). The maximum values are found around the speed of 20 mm/min. To sum up, it is necessary to consider the influences of the tensile speed on the mechanical properties for the PES/phenoxy blends used as engineering materials.

Relationship Between Mechanical Properties and Miscibility

As is well known, the partial miscibility of polymer blends is an essential condition to obtain a synergism of mechanical properties. For a partial miscible system, an interfacial layer is formed between the two phases so that the stress can be effectively transferred through the interface region. From the DSC measurements (Fig. 6) it is found that the two glass transitions are shown for the PES/phenoxy systems, i.e., PES/phenoxy blends, are two-phase systems. The same results are obtained from the TBA diagrams of blends (Fig. 7). In addition, one also finds

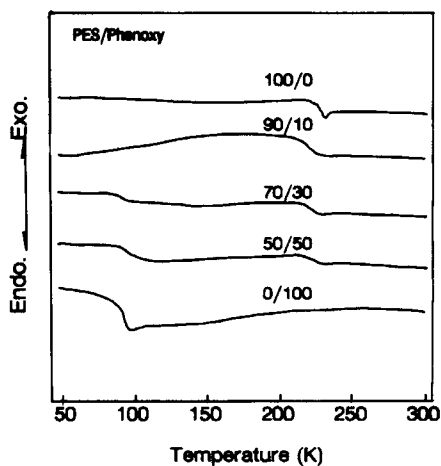


Figure 6 DSC thermograms for different composition blends.

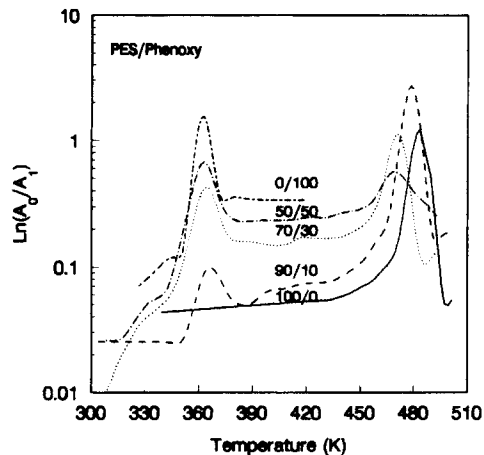
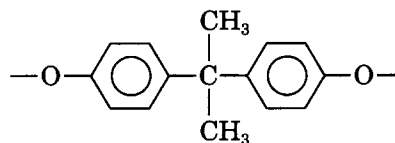
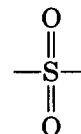


Figure 7 Dynamic mechanical curves for different composition blends.

that a shoulder peak appears between the transition peaks of phenoxy and PES; the transition peak position of PES shifts inward from that of the pure PES. It is speculated that the shoulder peak may be attributed to an interfacial layer between PES and phenoxy. The interfacial layer is the origin of the synergism of elongation at yield and break and tensile modulus in PES/phenoxy blends. This seems far away from the experimental results of Singh and Walsh.¹¹ It may be explained as that the quenching process retains the heterogeneity of PES/phenoxy systems at high temperature. The partial miscibility of the blends results from the specific interactions between PES and phenoxy. The specific interaction may be indirectly shown from the positive derivation of the density vs. composition in blends (Fig. 8). It is also the reason given that the $n-\pi$ complex can be formed by the



of phenoxy, the electron acceptor, and the



of PES, the donor.¹²

The specimens used in the tensile test with the dimensions of $20 \times 4 \times 0.4$ mm were put away for 1 year. The tensile behaviors were then measured

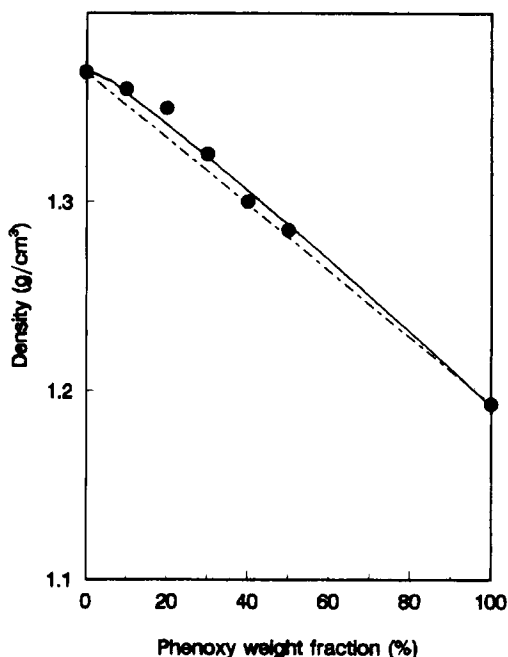


Figure 8 Dependence of density on composition: (●) experimental values; (- - -) additive curve.

by an Instron again. We found that the elongation at break is greatly lost and is only about 40% for the specimens of 30 wt % phenoxy. The reason is not clear yet and further investigation is in progress in our laboratory.

CONCLUSIONS

The quenched blends of polyethersulfone (PES) and phenoxy prepared using melt mixing are two-phase systems with partial miscibility. An interfacial layer is formed between the phases of PES and phenoxy. A synergism of mechanical properties, e.g., elongation at break and tensile modulus, is obtained by

mixing phenoxy into PES. The mechanical properties of PES are greatly improved by blending with some phenoxy. However, the improved properties will be lost after a long time; further investigation on this phenomenon is necessary.

L. A. is grateful to the Changchun Research Center of Applied Chemistry and the Fund of Polymer Physics Laboratory of Chinese Academy of Sciences for their support. Z. J., R. M., and X. K. acknowledge support by the Committee of Science and Technology of Jilin Province.

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Received April 11, 1995

Accepted August 11, 1995