

Thermoplastic Resin Modified Thermoset Resin: Morphologies and Mechanical Properties

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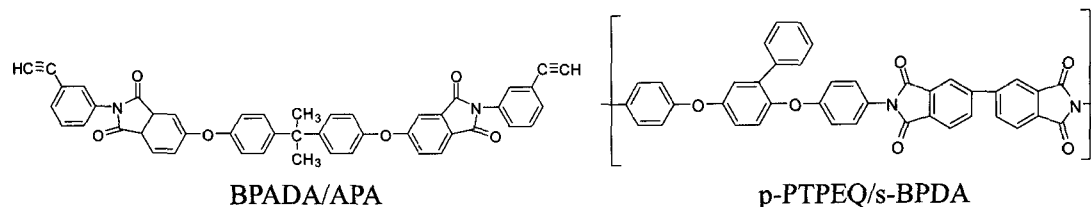
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INTRODUCTION

Thermoset resins have been extensively used, however, a major limitation is their inherent brittleness arising from the crosslinked structure. The purpose of blending a thermosetting polyimide with a thermoplastic polymer is to overcome the brittleness of the former and to improve the processibility and to retain the thermal stability as a whole for the blend. In this case, the thermoplastic polymer is linear while the thermosetting polyimide is crosslinked, and a semi-interpenetrating network (semi-IPN) results after blending and curing. Many works have been done on this type of polymer blends in order to obtain synergistic qualities by the combination of the two polymers.¹⁻⁷ In this article, we present the results of our investigation on the blends of thermosetting polyimide and the toughness thermoplastic polyimide p-TPEQ. The modification of the curing behavior and the phase separation process for a thermoset polyimide blended with a thermoplastic polyimide was investigated. And the mechanical properties of the obtained films were studied. Phase separation taking place during curing of the blend was investigated by differential scanning calorimeters (DSC) and scanning electron microscopy (SEM) in order to get a better understanding of the complex interactions between cure kinetics of thermoset polyimide matrix and thermoplastic polyimide, both influenced by blend composition.

EXPERIMENTAL

Thermoplastic polyamic acid (PAA) were prepared by biphenylenetetracarboxylic dianhydride (s-BPDA) with 2,5-bis(4-aminophenoxy)-biphenyl (p-TPEQ) in the N,N-Dimethylacetamide (DMAc) for 4 h., and thermoset polyamic acid (PAA) were prepared by bisphenol A dianhydride(BPADA) and 3-aminophenylacetylene (APA) in DMAc for 4 h. After mixing two PAAs together, the mixture was cast on the glass plate, and dried in an air-circulated chamber at room temperature and imidization was performed stepwise with a heating program in a vacuum oven. As a result, the polyimide blend films were obtained.



RESULTS AND DISCUSSION

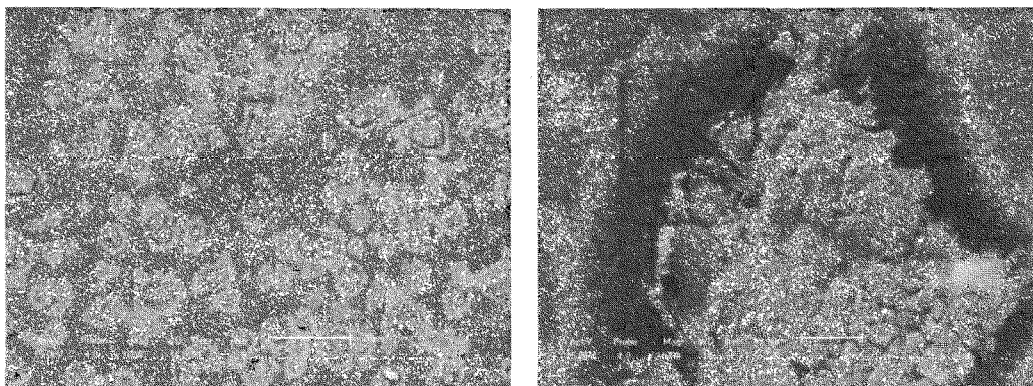
The mechanical properties of thermoplastic polyimide modified thermoset polyimide were shown in Table 1. Five different proportions, the ratio of thermoset/thermoplastic from 1:1 (wt) to 9:1(wt), were investigated. It was clearly seen that there was a significant improvement of the elongation, as the content of p-TPEQ reduced, the elongation show inferior level. But when the content of thermoplastic was about 30% (wt), the elongation increase unusually, the toughness was improved evidently. The elastic nearly had no obvious variation in any proportion, which meant that the optimum mechanical properties could be obtained when the content of p-TPEQ was about 0.3.

Table 1 Mechanical properties of the blending membranes

Sample	Elastic (GPa)	Max_Stress (MPa)	Elongation (%)
5:5	2.38978	95.6844	4.59500
6:4	2.50822	33.3552	1.60500
7:3	2.38701	97.0253	6.42000
8:2	2.36004	38.7120	1.91000
9:1	2.35841	17.3633	0.81500

The film toughness improves due to phase separation. Because of the different compatibility, such a two-phase morphology can be achieved by mechanically dispersing thermoplastic into the matrix or through phase separation driven by a cure reaction. Figure 1 shows scanning electron micrographs of surface of polyimide-toughened thermoset polyimide. As shown in the left picture, the bright domains are thermoset polyimide, Polyimide-rich phase formed continuous domains and the thermoset polyimide was dispersed efficiently. In the right picture the thermoset polyimide was separated in its interior, which was called second-separation. Differential scanning calorimeters (DSC) measures show that the addition of the thermoplastic resin has not reduced the thermal property.

Figure 1



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