Polymer (Korea) Vol. 16, No. 4, pp 505－508 (1992)

NOTE

에폭시수지와 스티렌으로부터 제조한 열경화성 블렌드의 동력학적 특성

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(1991년 11월 19일 접수)

Dynamic Mechanical Properties of Thermoset Blends Made from Epoxy Resin and Styrene

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(Received November 19, 1991)

INTRODUCTION

Due to the extensive uses of epoxy resins in electrical laminates, molding compounds, aerospace composites, and sporting goods industries, the interests of academic and industrial researchs have been particularly focused on these epoxy resin systems and fiber-reinforced composites.[1~3] Filament winding is a process for the fabrication of reinforced composites in which a series of continuous resin-impregnated filaments are applied to a mandrel according to a predetermined geometrical relationship.[4,5] Its main use is to make tube and pipe-shaped objects, such as chemical storage tanks, liners for smokestacks, golf club shafts, aerospace missiles, and drive shafts.[3,6~8] Various epoxy resin formulations have been used for the fabrication of high performance composite structures.[11]

Polymeric blends consisting of unsaturated polyester and styrene monomer are standard commercial products and widely used.[12,13] However, to our knowledge, there is a little report on the resin formulation examples which consist with epoxy resin and styrene monomer(as reactive diluent to reduce viscosity).

There are some handling criteria that are unique for filament winding as follows. i) viscosity should be 1500 cps or lower. ii) pot life should be as long as possible(preferably more than 6 hr). iii) toxicity should be low. And also the thermomechanical property of cured matrix should be considered.[5,8] In these view points, we studied on the viscosity behaviors and mechanical properties of thermoset blends consisted with epoxy resin and styrene.[14] From our previous studies, It was found that the epoxy resin formulations containing 5~10 % styrene moiety can be used for filament winding in the view points of viscosity, pot life, and mechanical property. In the present time, we have a need to evaluate the thermomechanical properties of epoxy-styrene thermoset blends.

The present paper deals with the dynamic mechanical properties of the cured five epoxy blends

with varying styrene content.

EXPERIMENTAL

The properties of epoxy resin(YD 128, Kukdo Chemical Industry Co. Ltd) and curing agent(KH-100, Kukdo Chemical Industry Co. Ltd.) are listed in Table 1. Styrene(Oriental Chemical Co. Ltd. 99 %) was used after simple distillation. Five epoxy blends, labeled A, B, C, D, and E, with different compositions of YD 128, KH-100, and styrene, were prepared as shown in Table 2. Test specimens were made in flat rectangular block(size 20 ×10×4 mm) in steel(SCM 4) mold [release agent : MS 443, cure cycle : 80℃(2hr)+120℃(2 hr)+155℃(6hr)]. The DMA measurements were made using Dupont 983 Dynamic Mechanical Analyzer with 9900 computor/thermal analyzer at a heating rate of 5℃/min. The DSC thermograms were taken on Dupont 910 differential scanning calorimeter under nitrogen atmosphere at a scanning rate of 10℃/min.

Table 1. Properties of Epoxy YD-128 and Hardner KH-100

Properties	YD-128	KH-100
Epoxy equivalent (g/eq)	184-190	–
Amine equivalent (g/eq)	–	44.6
Viscosity (cps at 20℃)	11500-13500	180
Color(Gardner)	0.5 max	13 max
Specific gravity (g/cc)	1.17	1.022
Chlorine content (%)	0.05 max	–
Flash point (℃)	–	>135
Specification	DGEBA-type epoxy resin	Aromatic amines with aliphatic chains

Table 2. Compositions of Five Epoxy-Styrene Blends

Code	Component, wt%		
	YD-128	KH-100	Styrene
A	100	25	0
B	100	25	3
C	100	25	5
D	100	25	7
E	100	25	10

RESULTS AND DISCUSSION

The micromechanical behaviors of five thermoset blends made from epoxy resin and styrene monomer, were examined by DMA. The DMA data for five epoxy blends, designated as A, B, C, D, and E, are given in Fig. 1, 2, and 4, for flexural storage modulus, flexural loss modulus, and tan δ traces, respectively.

Fig. 1 shows the elastic modulus E' over the temperature range of 20℃ to 250℃ for five cured epoxy blends carrying styrene moiety. The elastic moduli E' in the glassy state decreases monotonically and show similiar values up to 155, 150, 146, 140, and 137℃ for the present thermoset blend A, B, C, D, and E, respectively. Above these temperatures the elastic modulus was rapidly decreased. From these results, it was concluded that the more

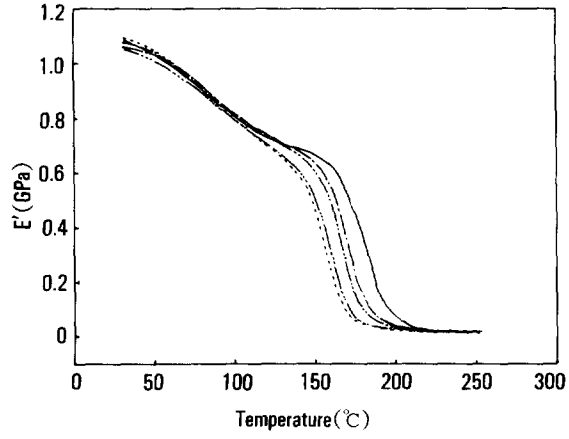

Fig. 1. The elastic modulus(E') of cured five epoxy blends carrying styrene moiety : A(——), B(– · – · –), C(– · · – · · –), D(– · · · – · · · –), and E(· · · · · ·).

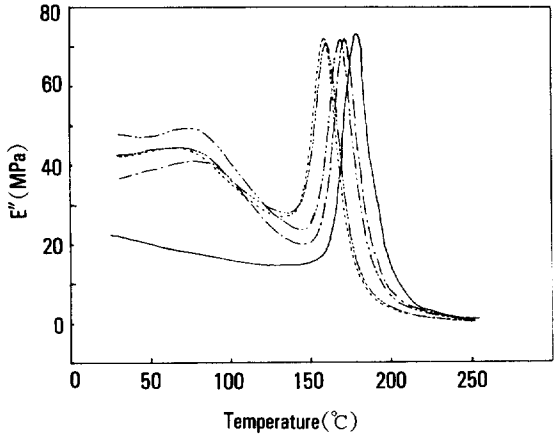

Fig. 2. The flexural loss modulus(E″) of cured five epoxy blends carrying styrene moiety : A(——), B(－・－・－), C(－・・－・・－), D(－・・・－・・・－), and E(・・・・・・).

styrene moiety in thermoset blends is contained, the lower transition temperature is observed.

Fig. 2 shows the flexural loss modulus E″ for the five cured epoxy blends over the temperature range of 20℃ to 250℃. The temperature of maximum flexural loss modulus gradually decreased as the styrene moiety in blends is increased from A(0 part) to E(10 part). The phenomena that Tg of the cured epoxy blends was decreased when the amount of styrene moiety was increased, became more evident from the DSC thermograms of the same blends, as shown in Fig. 3. The Tgs of the five cured epoxy blends also decreased from 166℃ to 136℃ as the styrene moiety increased from 0 to 10 part. The decrease of the transition temperature of the present blends with higher amount of styrene moiety is deduced to be due to the chain softening effect of styrene moiety and/or the decrease of cross-linking density.

Fig. 4 shows the tan δ curves of the five cured epoxy blends. The transition centered at about 90 ℃ has been identified as the ω transition[16] and can be attributed to unreacted molecular segments and/or inhomogeneities in the epoxy blends arising from regions of dissimiliar crosslinking densities. The transition at higher temperature, in which the maximum peak temperature was decreased as the styrene moiety increased, was identified as the α transition and can be clearly attributed to the glass transition of the blends.

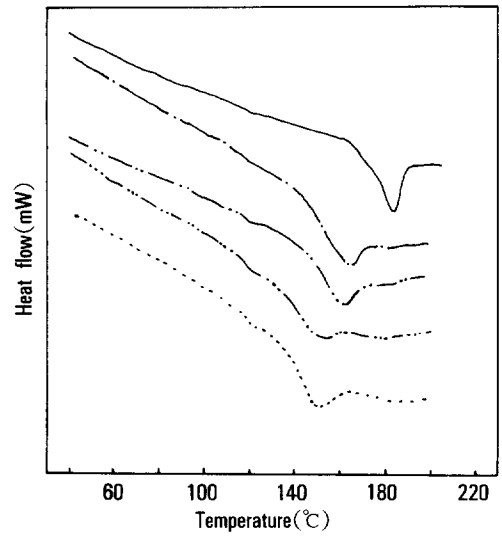

Fig. 3. The DSC thermograms of cured five epoxy blends carrying styrene moiety : A(——), B(－・－・－), C(－・・－・・－), D(－・・・－・・・－), and E(・・・・・・).

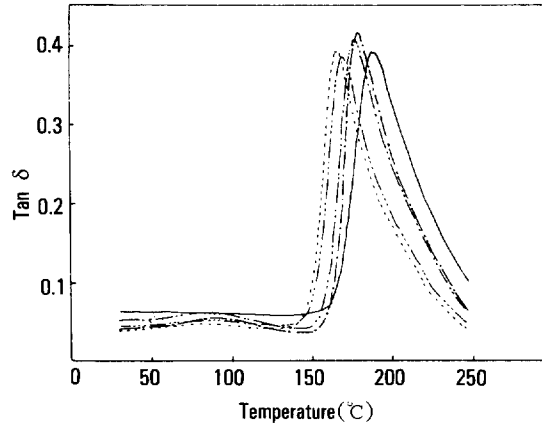

Fig. 4. The Tan δ curves of cured five epoxy blends carrying styrene moiety : A(——), B(－・－・－), C(－・・－・・－), D(－・・・－・・・－), and E(・・・・・・).

From this work, the styrene effect on the thermomechanical properties in the epoxy-styrene thermoset blends for filament winding was studied and evaluated. The thermomechanical properties (E′, E″, Tg) of the present thermoset blends were

gradually decreased as the styrene content in the resin formulations is increased. These epoxy-styrene thermoset blends were evaluated to be adequate for filament winding fabrication of high performance composite structures in the view point of thermomechanical properties.

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