

MORPHOLOGY DEVELOPMENT AND FRACTURE PROPERTIES OF TOUGHENED EPOXY THERMOSETS

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(ABSTRACT)

The phase separation process of a rubber modified epoxy system during cure was analyzed by a model developed on the basis of a thermodynamic description of binary mixture and constitutive equations for nucleation and growth rates. As epoxy resins are cured, rubber molecules are precipitated from the epoxy matrix to a non-equilibrium composition due to the decrease in the configurational entropy and the increase in the viscosity with conversion. If phase separation takes place in a metastable region, this model can monitor the changes of rubber compositions in both phases as well as the changes in the number and size of rubber particles upon conversion of polymerization. The particle size distribution at the completion of phase separation was also calculated. The effect of cure temperature on the final morphologies of a rubber modified epoxy system was discussed.

The computed particle size distributions for piperidine and diaminodiphenyl sulfone cured systems showed good agreements with experimentally measured values. Depending on the activation energy for viscous flow of the epoxy matrix relative to that for the polymerization, the particle size distribution may show bimodal or unimodal distribution. The size of rubber rich phase increases to a maximum and then decreases with an increase in cure temperature. However, due to limitations of temperature range to probe in an actual experiment, one may observe only either decreasing or increasing particle size as cure temperature increases. The number of rubber particles per unit volume increases for the DGEBA/DDS/ETBN system as cure temperature increases in the temperature range of 30 °C to 220 °C.

Fracture toughness of cured DGEBA/DDS/ETBN system was analyzed in terms of morphologies generated by the temperature variation. Since the volume fraction of rubber particles did not change with cure temperature, the critical stress intensity factor did not vary significantly with cure temperature as expected. However, increases in cure temperature produced smaller but more numerous particles. The critical stress intensity factor normalized by the number density of particles exhibited dependence on the radius of particles to the third power. On the other hand, the critical stress intensity factor normalized by the radius of particles showed a linear dependence with respect to the number density of particles.