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ORIGINAL PAPER

Toughening modification of cyanate ester with amino-terminated polyoxypropylene

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Abstract
An amino-terminated polyoxypropylene (DA2000) was used to modify a bisphenol A-type cyanate ester resin (BADCy). A series of BADCy/DA2000 resins with different DA2000 contents were prepared and investigated by mechanical tests, dynamic mechanical analysis (DMA) and scanning electron microscopy (SEM). The results of mechanical tests demonstrated that the addition of DA2000 improved the bending and tensile strength of the modified resins. Compared with those of pure BADCy, the K_{IC} and G_{IC} values of the modified resins increased, indicating an improvement in toughness of the resin system. The DMA curves of modified resins showed that the storage moduli dropped with the increase in temperature and the T_g values decreased with the increase in modifier content. Simultaneously, the moduli showed different changing trend at different temperature stages, indicating the existence of phase separation, which was also demonstrated by the fracture morphologies. At 20 wt% of DA2000 content, the fracture surface showed its characteristic strong ductile tear. Based on the above results, it was concluded that the $–NH_2$ groups of DA2000 reacted with the –OCN groups of triazine ring to form flexible segments, which were embedded into the main chains of the curing network; the distance between the triazine rings increased, the cross-link density decreased and the yield deformation of the system was enhanced. Meanwhile, DA2000 reacted with BADCy monomers to form linear macromolecular chains, which interpenetrated into the network matrix, and enhanced the plastic deformation of the system. The formation of flexible segments, low cross-link density and the yield and plastics properties led to toughened cyanate ester (CE) resins.

Keywords Cyanate ester resin · Modification · Mechanical properties · Morphology · Phase separation

Introduction

Cyanate ester resins (CE) are one of the most important thermosetting resins. This series of resins possesses many outstanding properties including excellent mechanical properties, high glass transition temperature, superior dielectric properties, low water absorptivity, good thermal stability and adhesive properties [1–3]. They are widely used in high-tech fields such as aerospace, microwave communication and surface mounting technology (SMT) [4–6]. Besides many advantages, the further applications of CE are restricted by the structural brittleness originating from high cross-link density, which ultimately leads to poor resistance to crack propagation and high internal residual stress [1].

Commonly, block copolymerization is considered as an effective method for toughening of CE resins. The cross-link density and network structure can be lowered using copolymerization between the monofunctional CE molecules and the modifiers containing active end groups. Hydroxy-terminated oligoester or polyethers and carboxyl-terminated polymers or polyols have been reported as modifiers up to now. For example, a hydroxy-terminated oligoester, poly (butylenes glycol adipate) (PBGA), was introduced into the poly (bisphenol A) cyanurate (PCy) network. The introduction of PBGA did not drastically reduce the thermal characteristics of the PCy network, while the impact properties were improved significantly [7]. Hydroxyl-terminated polyethers (PEth), polyoxypropylene glycol (PPG) and polyoxytetramethylene glycol (PTMG) were also used to modify CE resins [8, 9]. The influence of each modifier on the polycyanurate chemical

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