Iran Polym J (2015) 24:399–410
DOI 10.1007/s13726-015-0332-5

ORIGINAL PAPER

Toughening of dicyandiamide-cured DGEBA-based epoxy resins using flexible diamine

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Received: 9 September 2014 / Accepted: 19 March 2015 / Published online: 31 March 2015

Abstract This study has examined the toughening of dicyandiamide-cured diglycidyl ether of bisphenol-A (DGEBA)-based epoxy resin with a flexible diamine. Eight different formulations were prepared by mixing DGEBA resin with a mixture of two curing agents of dicyandiamide (Dicy) and flexible polyoxypropylene diamine (Jeffamine D-400) in the presence and the absence of Monuron as an accelerator. The effect of curing agents on the curing behavior of epoxy systems was studied using differential scanning calorimetry (DSC). The fracture surfaces of the tensile test samples were examined by scanning electron microscopy (SEM). The DSC results showed that the reaction between Jeffamine and epoxy resin occurred within a much wider range of temperatures than the reaction of Dicy in the presence of accelerator. The tensile strength of the modified epoxies was much higher than the tensile strength of samples cured by one curing agent alone, due to the synergistic effect of the former. The tensile modulus of all samples was approximately equal and the Izod notched impact strength remained fairly constant up to 60 % Jeffamine and then increased beyond this amount. The fracture toughness increased as the Jeffamine content increased. All samples containing Jeffamine showed greater elongation-at-break. This behavior was a confirmation that Jeffamine increased the flexibility and toughness of Dicy-cured epoxy resin, even at 20 % Jeffamine content. The glass transition temperature (T_g) for epoxy resin containing 100 % Dicy (116 °C) was higher than that containing 100 % Jeffamine (73 °C). SEM observation showed a homogeneous phase with no phase separation and that the crack area increased as the content of the flexible curing agent increased.

Keywords Epoxy resin · DGEBA · Dicy · Flexible diamine · Toughening

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Introduction

Epoxy resins are one of the most important classes of thermosetting polymers. These resins are used as surface coatings, adhesives and engineering composites, and in construction, automotive, and aerospace industries. They possess numerous attractive properties, including high chemical and corrosion resistance, good mechanical and thermal properties, outstanding adhesion to various substrates, low shrinkage upon curing, good electrical insulating properties, and the ability to be processed under a variety of conditions [1–3]. Their brittleness and poor resistance to crack growth, however, are major drawbacks, which significantly limit their use in applications requiring high impact and fracture strength. The inherent brittleness of cured epoxy resins can be decreased by increasing the fracture toughness of the epoxy systems with minimum sacrifice of their thermo-mechanical properties [4, 5].

Various approaches have been used to enhance the toughness of epoxy resins, including chemical modification of the epoxy backbone, lowering the cross-link density of the matrix by increasing the molecular weight of the epoxy monomers, decreasing the functionality of the curing agents, and incorporation of a dispersed toughener phase in the cured epoxy matrix or inorganic fillers into the neat resin [6, 7]. The second phase includes liquid