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ORIGINAL PAPER

Morphology and properties of nanostructured epoxy blends toughened with epoxidized carboxyl-terminated liquid rubber

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Abstract A liquid carboxyl-terminated butadiene acrylonitrile (CTBN) rubber was epoxidized using hydrogen peroxide and formic acid, and the epoxidized CTBN (ECTBN) rubbers with different degrees of epoxidation were used to toughen the epoxy resin. The effects of epoxidation degree on the morphology and mechanical and thermal properties of the ECTBN/epoxy blends were then investigated. It was shown that the CTBN particles dispersed in the matrix in micro-scale, presenting sea–island structure, and the blends were opaque, whereas the ECTBN particles dispersed in nano-scale in the ECTBN/epoxy blends, forming nanostructure, and the blends presented good transparency. The glass transition temperatures of the blends decreased with rubber content or epoxidation degree. The mechanical properties of the ECTBN/epoxy blends and the traditional CTBN/epoxy blends were measured and compared, and better balanced properties were observed for the ECTBN/epoxy blends. After the addition of ECTBN, the impact strength and the tensile strength of the blends increased 2.3 and 1.6 times, respectively, and elongation-at-break was about 4 times that of the neat epoxy resin. In particular, the Young's modulus improved or at least retained after the addition of ECTBN, being considerably higher than that of the CTBN-modified blends. Based on the morphology observations by SEM and TEM, the toughening mechanisms were discussed, and the excellent optical and mechanical properties of the ECTBN-modified blends could be attributed to the nanostructure formation and strong interfacial interactions.

Keywords Epoxidized liquid rubbers · Structure–property relations · Nanostructured polymers · Morphology · Mechanical properties

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Introduction

Epoxy resins are widely used as coatings, structural adhesives, electrical materials, and advanced composite materials in many applications, because of their excellent mechanical, thermal, and electrical properties and chemical resistance. However, epoxy resins are inherently brittle and poorly resistant to crack propagation, thereby limiting their wide applications, particularly in some fields requiring high-strength performance [1–3]. To overcome these problems, modifiers are incorporated to toughen the thermosetting matrix; the used modifiers include liquid rubber [4–6], preformed rubber particles [7–9], inorganic rigid particles [10–12], thermoplastics [13, 14], and amphiphilic block copolymers [15–17].

Although modification with reactive liquid rubbers is one of the most frequently used methods to toughen epoxy resins, the improvement in toughness is inevitably accompanied with the disappearance of transparency and significant loss in tensile modulus and tensile strength, which can be ascribed to the micron-sized rubber particles in the epoxy matrix and the weak interfacial interaction [2, 18, 19].