Toughening of Epoxy Resins using 3-Layer Particles prepared by Emulsion Polymerisation

R.J. Day, P.A. Lovell and D. Pierre

Polymer Science and Technology Group, Manchester Materials Science Centre
University of Manchester and UMIST, Grosvenor Street
Manchester, M1 7HS, United Kingdom

This paper describes the preparation of a series of three-layer core-shell particles using sequential emulsion polymerisation, and the effect of the particles upon the mechanical properties of a DGEBA epoxy resin. The particles were specially designed for toughening epoxy resins and comprised a glassy core (diameter between 100 and 370 nm) based upon poly(methyl methacrylate), a rubbery layer (diameter between 280 and 470 nm) based upon poly(n-butyl acrylate) and a glassy outer layer based upon poly(methyl methacrylate) with epoxy- or acid-functionality derived from glycidyl methacrylate or methacrylic acid respectively. The overall particle diameters were between 300 and 500 nm. The glassy core and the rubbery layer were crosslinked using allyl methacrylate which also provided graftlinking between the layers. The outer glassy layer was not crosslinked but was grafted to the rubbery layer.

Transmission electron microscopy of the cured resin/particle blends showed that a good particle dispersion was achieved in almost all of the blends.

Tensile testing was carried out on the blends, and introduction of the particles led to an approximately linear decrease of both Young's modulus and yield stress with increasing particle content. Transmission electron microscopy of failed tensile specimens revealed that deformation bands were formed which ran between the particles at angles of 60-90 ° to the tensile axis. Cavitated rubber particles were also observed. Real-time small-angle X-ray scattering with tensile testing showed that particle cavitation occurred just prior to yielding of the epoxy resin matrix.

Fracture testing effects of particle surface chemistry, diameter and morphology upon the toughness of the blends. Non-functional particles provided significantly lower toughening than those of similar size and morphology with epoxy functionality.