Mechanical and Thermal Properties of Nanoparticle Filled Epoxy Nanocomposites

by

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ABSTRACT

One of the potential advantages of nanoparticle filled thermosets is the unique combination of mechanical properties that can be obtained. There have been several reports of improved ductility and toughness in brittle thermoset polymers due to the addition of equiaxed nanoparticles. The mechanisms leading to these improvements, however, are poorly understood. In the present study, a model system of nanoscale alumina filled bisphenol A based epoxy with two interface conditions was used to highlight the mechanisms leading to significant improvements in ductility, toughness, modulus and fatigue crack propagation resistance. It was found that the interfacial condition is critical to controlling the mechanical properties of the nanocomposites. Well-bonded APTES-Al_2O_3 (3-aminopropyltriethoxysilane treated alumina) nanoparticle filled epoxy nanocomposites showed significant improvements in tensile ductility (max 39%), fracture toughness (max 26%) and fatigue crack propagation resistance, while exhibiting an increase in modulus and maintained strength. Poorly-bonded NT-Al_2O_3 (non-treated) nanoparticle filled epoxy nanocomposites only showed improvements in fatigue crack propagation resistance and modulus. Fracture morphology and theoretical predictions were used to study the mechanisms. The key mechanism, that significantly improved the ductility or tensile toughness of the treated nanocomposites and distinguished the treated nanocomposites from the untreated nanocomposites, is crack deflection. Crack deflection occurred much more for the well-bonded nanocomposites due to the stronger particle/matrix adhesion. Furthermore, it was found that crack deflection, interfacial debonding and particle pull-out were critical for composites with a weak interface, but that a stronger interface lead to additional mechanisms of further crack deflection, plastic deformation, microcracking and as a result a further improvement in mechanical properties. In addition, higher thermal conductivity may be obtained for well-bonded nanocomposites due to a decrease in the filler – matrix thermal contact resistance through the improvement of the interface between matrix and particles. At the same thermal conductivity level of the nanoparticles, a higher aspect ratio nanoparticle provides a higher thermal conductivity value for the nanocomposite.