207b Al_2O_3-Reinforced Epoxy Composites with Enhanced Fracture Toughness: a Sem, Rheology and Mechanical Study

Laura M. McGrath, Joseph L. Lenhart, and Richard Parnas

Epoxy composites have found wide applications due to their exceptional mechanical properties and production ease, but are limited by low fracture toughness. To gain a better understanding of the effect of both filler and epoxy matrix variables on the fracture toughness, we have investigated the effect of particle size, size distribution and molecular weight of the diamine in a series of novel epoxy composites based on alumina (Al_2O_3), bisphenol A diglycidyl ether (DGEBA) and diamines with a poly(propylene oxide) (PPO) backbone. The effect of various structural parameters such as the diameter of Al_2O_3 (2, 5, 10, 18 and 26 μm) and the molecular weight of PPO diamines (Mn = 230, 400 and 2000) was studied by combination of rheological experiments and scanning electron microscopy (SEM), while the fracture toughness was quantified via K_{Ic}, the stress intensity factor. K_{Ic} increased with the inclusion of Al_2O_3 for all systems and typically doubled at 50% (v/v) Al_2O_3. Unexpectedly, a larger than 6-fold increase in K_{Ic} was observed for the DGEBA-230/18μm- Al_2O_3 system. The particle size in the ranges investigated did not affect fracture toughness, while incremental toughening decreased with increasing Al_2O_3 volume fraction. Except for the DGEBA-230/18μm- Al_2O_3 system, an increase in fracture toughness was observed with increasing Mn of the diamine. Dynamic torsional shear rheology demonstrated that Tg was not significantly affected by particle size or loading, while the storage modulus increased with Al_2O_3 volume fraction. SEM corroborates these observations and provides additional details on the micromechanical behavior at the crack tip giving support to the theory of crack-front-bowing observed for other rigid inorganic/polymer particle composites. These results demonstrate a very promising avenue towards a dramatic increase in fracture toughness.