TOUGHENED EPOXY NANOCOMPOSITES BASED ON SURFACE ENGINEERED NANOFILLERS

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by

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ABSTRACT

Epoxy resin is an important thermosetting matrix with good stiffness, thermal resistance, chemical resistance and long pot life period. On the other hand, cured epoxies are highly brittle, which limits their utility in many composite applications. The incorporation of nanofillers into epoxy matrix is gaining significant interest in the structural composite application, where strength, stiffness, durability, lightweight, design, and process flexibility are required such as in aerospace and automobile industry. The inherent brittle nature of the epoxy matrix can be improved by the incorporation of nanofillers in the matrix. The realization of nanofiller reinforced epoxies with high toughness requires a homogeneous dispersion and strong interfacial interaction between the nanofiller and the polymer matrix. Generally nanoparticles have a tendency for agglomeration because of the weak van der Waals force of attraction. Surface modifications of nanofillers are an effective way to improve interfacial interaction between the nanofillers and the epoxy matrix, which in turn leads to better filler dispersion, and enhanced mechanical performance in the nanocomposites. The main objective of this research work is to study the influence of geometry and surface modification of nanofiller on the morphology, mechanical, thermal and viscoelastic properties of the epoxy composite system. We focus our work to develop epoxy systems with high toughness as well as mechanical strength.

Glycidyl polyhedral oligomeric silsesquioxane (POSS) was used as a crosslinking agent to prepare a new organic–inorganic hybrid material from carboxyl terminated poly(acrylonitrile-co-butadiene) (CTBN). Differential Scanning Calorimetry (DSC) at different heating rates in the presence and absence of catalyst, triphenyl phosphine (TPP), was conducted to investigate the curing kinetics. The curing mechanism of POSS-CTBN system followed an autocatalytic model.

A novel hybrid epoxy nanocomposite has prepared using CTBN as modifier, glycidyl POSS as nanofiller and diaminodiphenyl sulfone (DDS) as curing agent. We have carried out a comparison of the properties of the hybrid systems with POSS/epoxy nanocomposites and CTBN/epoxy blends. Fracture toughness measurement showed 59 % improvement in K_{IC} for 2.5 phr POSS/epoxy composites as compared to neat epoxy, whereas only 38 % improvement was observed for hybrid composite. A decrease in toughness for the hybrid composite was observed due to the occurrence of high crosslink density created by octa-functional POSS particles near rubber particles which might have reduced the rubber particle size and this in turn, causes the toughening capability of soft rubber particles.

The surface of multi-walled carbon nanotubes (MWCNTs) were modified by grafting with CTBN and hydroxyl terminated poly(ethersulfone) (PES). Incorporation of PES and CTBN grafted MWCNTs in epoxy matrix composites imparted tremendous improvement in fracture toughness when compared to pristine and acid modified MWCNT/epoxy composites (125 % improvement for 0.3 wt% MWNCT-g-PES and 119 % improvement for 0.3 wt% MWNCT-g-CTBN compared to neat epoxy) in addition to the improvement in mechanical characteristics. The mechanism of fracture behavior revealed that crack deflection, pullout of nanotubes, debonding of MWCNTs and bridging mechanism were responsible for the improvement in fracture toughness of the composites.

The effect of surface modification of graphite oxide (GO) on the thermo-mechanical properties of epoxy composites was investigated. CTBN grafted GO and polyethylenimine (PEI) grafted GO were successfully synthesized. Partial reduction of GO was observed during functionalisation with CTBN and PEI. The mechanical properties of the epoxy system showed an excellent improvement by the addition of polymer functionalized GOs. The surface morphology revealed improved interfacial bonding between the filler/matrix. Therefore, polymer functionalized GO modified composites were able to carry higher level of loading during fracture. The viscoelastic properties also showed drastic improvement in modulus and T_g. This improvement in T_g is due to the hindered polymer chain mobility near the filler/matrix interface. The improvement in modulus and T_g was further confirmed by the quantitative analysis of the constrained region.

TiO_2-derived nanowires were prepared by a simple hydrothermal synthesis using commercial TiO_2 powder. The TiO_2(B)-NWs showed the highest mechanical properties and analogous thermal properties compared to TiO_2 nanoparticle. The optimum properties of this system are attributed to the particle shape or particle dimension that has been described by the aspect ratio wherein the elongated filler shows the highest aspect ratio hence improving the bonding between resin and filler. TiO_2/epoxy composite showed little effect on fracture toughness, but TiO_2 nanowires increased toughness significantly. The TiO_2(B)-NWs incorporated into the epoxy matrix effectively disrupted the development of crack growth and prevented crack propagation.