Toughening of epoxy matrices with reduced single-walled carbon nanotubes and the effect of the resin stoichiometry

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Negatively charged (reduced) SWCNTs (r-SWCNTs) obtained upon reduction with alkali metal naphthalides react readily at room temperature with epoxide-containing moieties. This surface modification allows better SWCNT dispersion and improves affinity with epoxies. The physical properties of a tridentate epoxy (MY0510, triglycidyl p-aminophenol) were evaluated upon addition of r-SWCNTs. Direct integration of r-SWCNTs by solution processing can improve the toughness and fracture toughness ($K_{IC}$) by 118% and 40%, respectively, without compromising important properties like modulus and glass transition temperature ($T_g$). Our studies with stoichiometric and off-stoichiometric ratios of epoxide to amine hydrogen (1:0.8, 1:1 and 1:1.1 molar ratios) showed that the $K_{IC}$ values of the unmodified resin increased with the amount of hardener. As expected, $T_g$ decreases and a slightly lower storage modulus is obtained by the addition of more hardener. The molar ratio 1:0.8 provides the best overall properties for the unmodified resin in agreement with the manufacturer’s recommended ratio of epoxy to hardener. However, the SWCNT modified nanocomposites showed a different trend, with the 1:1 molar ratio considerably outperforming the other two stoichiometries studied and showing a larger improvement in mechanical properties and $T_g$ with the incorporation of r-SWCNT. The results obtained for composites prepared at different stoichiometric ratios suggest that the formation and structure of the softer interface depends on the stoichiometry of the epoxy.