Nanofilled Epoxy Adhesive for Structural Aeronautic Materials

Abstract

The focus of this study is to design new nano-modified epoxy adhesives using carbon nanofillers such as carbon nanotubes, carbon nanofibers and exfoliated graphite. Kinetic analysis, transport properties, dynamic mechanical properties and electrical properties have shown to be a powerful means for understanding molecular structure and phase composition of the formulated nanocomposites. Kinetic analysis, performed by using an advanced iso-conversional method and the Kamal's model-diffusion controlled respectively, has shown which, in epoxy resin, based on the tetrafunctional epoxy precursor N,N′-tetraglycidyl methylene dianiline-(TGMDA) hardened with 4,4-diaminodiphenyl sulfone (DDS), the introduction of the diluent decreases particularly the activation energy of secondary amine-epoxy reaction. The inclusion in the resin of one-dimensional fillers does not lead to big differences in the curing kinetics behaviour with respect to the raw epoxy. An increase in the activation energy is found in the case of highly exfoliated graphite. It is likely due to a reduction of free molecular segments of the epoxy network entrapped inside self-assembly structures. Transport properties have shown that, using a non-stoichiometric amount of hardener, the chemical structure of epoxy mixture exhibits unique properties concerning the water sorption for which the Equilibrium Concentration of Water is reduced up to a maximum of 30%. Dynamic mechanical analysis have shown that the nanoparticles are responsible of a more mobile phase, in the structure of the resin, determining an additional glass transition at lower temperature with respect to the main glass transition temperature. The fraction of the more mobile phase is strictly related to the amount and nature of the nanofiller and to the amount of the hardener, in fact, using a non-stoichiometric amount of hardener, also the electrical properties are improved further. The adhesive formulations based on epoxy/nanostructured carbon forms are used to obtain both adhesive and adherents to order to evaluate the adhesion properties with different joint configurations (tensile butt joint and single lap joint). The inclusion of carbon nanofillers inside the epoxy adhesive caused a significant improvement in the bond strength of the joints, changing the failure mode of joints in single lap joint shear tests. Finally, the conductive adhesive carbon nanotubes based, have been modified, by introduction of an elastomer, to order to obtain high performance in the configuration lap shear strength (LSS) with adherents in carbon fiber reinforced plastics (CFRP) used in aeronautic field. A correct combination of elastomer and carbon nanotubes, has allowed obtaining a conductive adhesive with high performance.