ABSTRACT

The objective of the present work is to modify epoxy resin using polysulfones and bismaleimides as toughening agents in order to improve its impact behaviour, thermal, thermomechanical, dielectric and weather resistant characteristics. Bismaleimide modified polysulfone – epoxy hybrid matrices were developed using polysulfone (PS), polyethersulfone (PES) and bismaleimides namely N,N'-bis(maleimido) 4,4'-diphenylmethane (BMI-1), 1,3'-bis(maleimido) benzene (BMI-2), 3,3'-bis(maleimidophenyl)phenyl phosphine oxide (BMI-3) and 1,1'-bis (4-maleimidophenyl) cyclohexane (BMI-4) as chemical modifiers for epoxy resin. The hybrid polysulfone terminated epoxy was prepared by reacting epoxy resin with varying percentages of polysulfones (4%, 8% and 12% by weight) and the resulting products are characterized by FTIR. The hybridized polysulfone-epoxy resins were further blended with varying amounts of four different types of bismaleimides and they were cured with diaminodiphenylmethane (DDM).

The bismaleimide modified polysulfone-epoxy matrices in the form of castings were characterized by physico-chemical, mechanical (tensile strength, flexural strength, tensile modulus, flexural modulus and Izod impact strength), electrical (dielectric strength, surface resistivity, volume resistivity and arc resistance), thermal (glass transition temperature ($T_g$), thermal degradation temperature, flame retardancy, thermal ageing studies and heat distortion temperature), morphological (SEM) and water absorption properties.
FTIR spectra results confirm the chemical reaction occurred between hydroxyl group of polysulfones and oxirane ring of epoxy resin results a chemically bound hybrid polysulfone epoxy matrix resin. Further the FTIR spectra obtained for bismaleimides modified polysulfone-epoxy hybrid matrix, indicate that the homopolymerization of bismaleimides (BMIs) in the presence of epoxy resin occurred at much lower temperature range (130-140°C).

Data resulted from mechanical studies for hybrid polysulfone-epoxy matrices indicate that the incorporation of polysulfones (PS and PES) into epoxy resin increased the impact, tensile and flexural properties with increase in percentage concentration of polysulfones. This observation may be due to inherent rigid aromatic molecular structure and high elastic modulus of polysulfone. Similarly, the tensile and flexural properties of modified systems were increased with the incorporation of bismaleimides according to their percentage concentrations, which may be attributed to the formation of intercrosslinking network (ICN) between bismaleimides and epoxy systems. The values of impact strength of modified epoxy systems were decreased with increasing percentage incorporation of bismaleimide. The restricted chain mobility due to the formation of intercrosslinked network structure and hence reduced free volume may be explained for the cause of the lowering of impact strength.

The cure reaction behaviour of modified epoxy systems was studied by DSC. The increase in peak maximum temperature with increasing concentration of bismaleimides modified epoxy systems confirmed that the homopolymerization reaction of bismaleimides, which predominates over Michael addition reaction. The incorporation of polysulfones (PS and PES) into epoxy resin decreased the value of $T_g$ due to the plasticization effect
impacted by the free molecular rotation of polysulfone. However, the values of $T_g$ of modified epoxy systems were found to be increased with the incorporation of varying percentage concentrations of bismaleimides due to their rigid molecular structure. The heat distortion temperature, flame retardancy and thermal ageing characteristics of the bismaleimide modified epoxy and polysulfone epoxy systems improved significantly.

The incorporation of polysulfones into epoxy resin improved the thermal stability behaviour and enhanced the degradation temperature according to their percentage concentrations. The bismaleimides incorporation into epoxy, polysulfone-epoxy systems also enhanced the thermal degradation temperature due to the formation of intercrosslinking network between epoxy and bismaleimides and rigid heterocyclic ring structure of bismaleimides.

SEM micrographs of fractured surface of unmodified epoxy system indicated smooth, glassy and homogeneous microstructure. The micrographs of fractured surfaces of modified epoxy systems were almost similar to that of unmodified epoxy system. This indicates that there are no separate phase domains of the two components involved and also confirms the formation of homogeneous intercrosslinked network.

The incorporation of polysulfones and bismaleimides into epoxy resin decreased the water absorption behaviour due to the hydrophobic character imparted by polysulfones and bismaleimides.

The electrical properties like dielectric strength, surface resistivity, volume resistivity and arc resistance of epoxy resin were decreased with the introduction of polysulfones due to the presence of polar nature of $-\text{SO}_2$ linkage and ether linkage. The introduction of bismaleimides improved the
insulation behaviour due to the formation of intercross linking network between bismaleimides and epoxy systems, which inturn increase the crosslink density. Further, the negligible tendency to moisture absorption behaviour of bismaleimides also contributes for the improvement of insulation behaviour of epoxy and modified epoxy systems.

The formation of nanocomposites in the clay filled polysulfone modified epoxy hybrids was confirmed by a wide angle X-ray diffraction. The data obtained from mechanical, thermal, dynamic mechanical and morphological (SEM) and water absorption studies confirmed that there is a significant improvement in properties for clay filled hybrid epoxy systems when compared with those of unmodified epoxy system. The values of glass transition temperature of clay filled epoxy systems were decreased with increasing concentration of organically modified montmorillonite clay due to the decrease in crosslink density of the modified epoxy matrix. The decrease in cross link density of the matrix systems was also ascertained from the dynamic mechanical spectra. The SEM studies indicate that the clay filled polysulfone modified epoxy matrices exhibit homogeneous morphology.

Data obtained from different studies indicate that the bismaleimide modified polysulfone epoxy matrix with a composition of 12:12:100 exhibits good thermomechanical properties, electrical properties, resistance to water absorption behaviour and thermal stability. The clay filled polysulfone modified epoxy matrices of composition 05:08:100 exhibit improved thermomechanical properties. It is concluded that these modified epoxy systems can be used effectively for the development of fiber reinforced advanced composites, clay filled nanocomposites for automobile industries, marine and spacecraft applications, satellite applications, electrical and electronics applications, chemical processing industries, thermal and corrosion resistance applications for better performance and longevity.