ABSTRACT

The aim of present study is to improve the thermal, mechanical, electrical and surface properties of epoxy, benzoxazine and unsaturated polyester resin based organic matrices by hybridization with nano-sized inorganic fillers to obtain nanocomposites meeting the requirements of high performance applications. The inorganic fillers such as POSS (polyhedral oligomeric silsesquioxane), Graphene Oxide and SBA-15 (Santa Barbara Amorphous) were synthesized using appropriate reaction conditions and their molecular structures were confirmed using FTIR and NMR spectroscopic analysis. The organic-inorganic hybrid nanocomposites were prepared by reinforcing the synthesized fillers with the matrices cured using different curatives. The developed composites were characterized and discussed.

Three structurally different diamines namely bisphenol- A based ether diamine, octane diol based ether diamine, and capron based diamine were synthesized and characterized using FT-IR, $^1$H-NMR and $^{13}$C-NMR spectra. These diamines were used to cure DGEBA epoxy resin. Epoxy resin was reinforced with NH$_2$-POSS in different weight percentages (1%, 3% and 5% wt) to obtain epoxy nanocomposites and characterized with FTIR spectroscopy. Data obtained from thermal, mechanical, dielectric and surface studies were compared with those of neat epoxy matrix cured with diamino diphenyl methane (DDM). The capron based diamine cured epoxy matrix shows better improvement in tensile strength and impact strength of 39.8% and 137.0% respectively than those of neat epoxy cured with diamino diphenyl methane (DDM). The value of contact angle ($91.3^\circ$) obtained for the capron based diamine cured epoxy composites infers that the epoxy matrix becomes hydrophobic nature. Data obtained from different studies suggest
that the capron diamine cured epoxy matrix can be used in the form of coatings, encapsulants, sealants for different industrial and engineering applications for better performance and improved longevity.

Graphene oxide was synthesized using modified Hummers method and confirmed with FTIR, XRD and Raman spectral analysis. Flexible hybrid nanocomposites with high k dielectric and UV resistant behaviour have been developed and studied using capron toughened epoxy resin with different weight percentages (wt%) of graphene oxide (GO) and confirmed with FTIR spectroscopy. The data obtained from thermal, dielectric, mechanical and radiation resistance and morphological studies infer that the graphene oxide reinforced composites show improved properties. Among the wt% of GO, 0.7 wt% graphene oxide reinforced nanocomposite possesses a higher value of dielectric constant. 1wt% GO reinforced nanocomposites shows highest retention of tensile strength (93.35%) with graphene morphology, even after 168 h UV exposure proves that 2D graphene network serves as a passive protective layer against UV radiation. High dielectric behaviour and efficient retention of strength properties suggest that the flexible and light weight hybrid nanocomposite materials developed in the present work can be used as potential capacitor in microelectronic components for satellites operating at low earth orbit. The TEM morphology further supports the uniform dispersion of graphene oxide into the capron toughened epoxy matrix.

Allyl terminated benzoazine and thiol terminated polyhedral oligomeric silsesquioxane (SH-POSS) were synthesized and their molecular structures were confirmed by FTIR, $^1$H NMR, $^{13}$C NMR and $^{29}$Si NMR spectroscopy. The hybrid materials were developed by mixing benzoazine with different weight percentages of SH-POSS (10, 30 and 50wt %) in chloroform solution. The hybrid SH-POSS blended benzoazine is photo irradiated using UV (365nm) lamp with varying time intervals (0 to 150 min)
and the representative spectral changes involved in the photolysis of samples were analysed by UV-visible spectroscopy. The photo initiated samples were subjected to thermal curing. The photo initiated followed by thermally cured samples was subjected to thermal dielectric, UV-transmittance and surface free energy studies. Data obtained from the above studies indicate that the photopolymerised 50 wt% POSS-PBZ composite exhibits the higher thermal, UV-shielding and hydrophobic behaviour and lower value of dielectric constant than those of other weight percentages of SH-POSS incorporated composites.

Mesoporous silica (SBA-15) was synthesized and functionalised with vinyltriethoxysilane (VTES). The surface functionalization of SBA-15 was confirmed by FTIR spectroscopy and TGA analysis. The surface functionalized SBA-15 (VSBA-15) with varying weight percentages (1, 3, 5 and 7 wt %) was incorporated into the unsaturated polyester resin to develop UP/VSBA-15 nanocomposites and their molecular structure was confirmed with FTIR spectroscopy. The morphology of the developed composites were analysed with XRD and TEM analysis. Data resulted from different studies, it was inferred that the 7wt% of VSBA reinforced UP composites possesses the higher thermal stability, lower value of dielectric constant and lower surface free energy than those of other VSBA-15/UP composites.

A new type of benzoxazine was synthesized using caproamine with cardanol and its molecular structure was confirmed by FTIR and NMR spectroscopy. The graphene reinforced epoxy-polybenzoxazine (Bz-g/Ep) nanocomposites were prepared by incorporating varying weight percentages of graphene and benzoxazine to epoxy resin. The developed nanocomposites were confirmed with FTIR spectroscopy. SEM, TEM and XRD data ascertain the existence of uniform and homogeneous morphology of the developed composites. The 20 wt% Bz-g/Ep composite shows better improvement in the
values of tensile strength and impact strength of 39.8% and 137.0% respectively than those of neat epoxy matrix and other weight percentages of Bz-g/Ep composites. The value of contact angle (91.3°) obtained for the 20 wt% Bz-g/Ep composite infers that the epoxy matrix becomes hydrophobic nature. Data obtained from different studies suggest that Bz-g/Ep composites developed in the present work can be used in the form of coatings, encapsulants, sealants for different industrial and engineering applications.

Hybrid composites were developed using different matrix viz epoxy, benzoxazine, unsaturated polyester and reinforced with functionally terminated POSS derivatives, graphene oxide, SBA-15 and graphene and cured with structurally modified amine curatives at appropriate conditions and then characterized with different analytical techniques. Data resulted from different studies indicate that these hybrid materials can be used in the form of coatings, films, sealants, encapsulants, adhesives, matrices and composites for varying range of industrial and engineering uses including microelectronic applications for better performance with enhanced longevity.