Structural Integrity and Thermomechanical Response of Fe_3O_4/Carbon Nanotubes/Epoxy Resin Hybrid Nanocomposites

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Polymer matrix nanocomposites with conductive and/or semiconductive nanoinclusions are mostly employed in electrical and magnetic applications. Increasing the conductive filler content results in a gradual alteration of composite's conductivity and at a critical reinforcing phase concentration an abrupt increase of a few orders of magnitude appears in conductivity. This critical concentration is also known as percolation threshold. The presence of semiconductive nanoparticles within the polymer strengthens the dielectric response of the insulating matrix, while the magnetic inclusions induce magnetic properties to the composites. Dispersing nanoparticles in a polymer matrix can be considered as a distribution of nanocapacitors, where energy can be stored and retrieved. The simultaneous presence of semiconductive-magnetic and conductive nanofillers in a polymer matrix, results in a hybrid multifunctional system, where dielectric, electrical and magnetic properties are adjustable by controlling the type and the amount of the fillers [1,2]. A significant drawback for the applications of these hybrid systems can be their mechanical performance under both static and dynamic loading.

In the present study, a set of hybrid nanocomposites consisted of an epoxy resin as matrix and magnetite (Fe_3O_4) nanoparticles, multiwall carbon nanotubes (MWCNTs) as reinforcing phases was fabricated and studied, with filler content as a parameter. Systems' morphology was assessed via Scanning Electron Microscopy (SEM). Their thermomechanical characterization was conducted via Dynamic Mechanical Analysis (DMA) and their structural integrity via static tensile tests. Thermal properties were assessed via Differential Scanning Calorimetry (DSC) and Thermogravimetric Analysis (TGA). SEM images revealed fine nanodispersions in all cases, with limited and small clusters in the high filler content specimens. The presence of MWCNTs appears to be beneficial to both electrical behaviour and mechanical properties of the nanocomposites. On the contrary, the increase of the magnetite nanoparticles content, besides the effect of reinforcing the dielectric and magnetic performance, has a detrimental influence on the mechanical response of the systems. Glass to rubber transition temperature, as determined via the DMA tests, seems not to vary significantly with the reinforcing phases' content.

Optimum multifunctional performance, considering in tandem the thermal, electrical, magnetic and mechanical responses is derived by compromising positive and negative influences of fillers, upon every type of properties and accounting the requirements of a specific application.

References

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