Thermal and dielectric characterization of polymer nanocomposites incorporating ferromagnetic nanoparticles

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Abstract

Organic–inorganic nanocomposites combine the advantages of the inorganic materials (mechanical strength, electrical and magnetic properties and thermal stability) and the organic polymers (flexibility, dielectric strength, ductility and processibility), in one constructional element, producing new technological possibilities [1]. Due to their good magnetic and electrical properties, ferrites are used predominately in different areas of electronics such as low-level applications, power applications, and Electro-Magnetic Interference (EMI) suppression. The wide range of possible geometries, the continuing improvements in material characteristics and their relative cost-effectiveness make ferrite components the choice for both conventional and innovative applications [3].

In the present study, series of nanocomposite systems consisting an epoxy resin as matrix and five different magnetic iron oxides nanoparticles (YIG, $ZnFe_2O_4$, Fe_3O_4, $BaFe_{12}O_{19}$ and $SrFe_{12}O_{19}$) as reinforcing phase, have been prepared and studied, varying the filler content. Specimens' morphology was assessed via Scanning Electron Microscopy (SEM). The thermal properties were investigated by Thermogravimetric Analysis (TGA) and Differential Scanning Calorimetry (DSC) and the mechanical characterization was conducted via Dynamic Mechanical Thermal Analysis (DMTA). The dielectric analysis was carried out by means of Broadband Dielectric spectroscopy (BDS).

Experimental data revealed an enhancement in both the thermomechanical and dielectric properties as expressed by the increasing values of storage modulus and the real part of dielectric permittivity respectively. The achieved increase varies with filler type and optimum performance corresponds to different reinforcing material at different levels of filler content. Relaxation phenomena arising in polymer composites are related to the polymer matrix and the presence of filler. For all nanocomposites, a relaxation attributed to the glass to rubber transition of the polymer matrix was identified by the DMA, DSC and BDS measurements. The characteristic temperature of this transition (T_g) can increase, decrease or remain constant depending on the matrix-inclusions interactions which can be attractive, repulsive or neutral respectively [4]. Two additional relaxation mechanisms were recorded in the dielectric analysis: the reorientation of small polar side groups of the polymer chain and interfacial polarization due to the accumulation of free charges in the interface between the nanoinclusions and the polymer matrix.

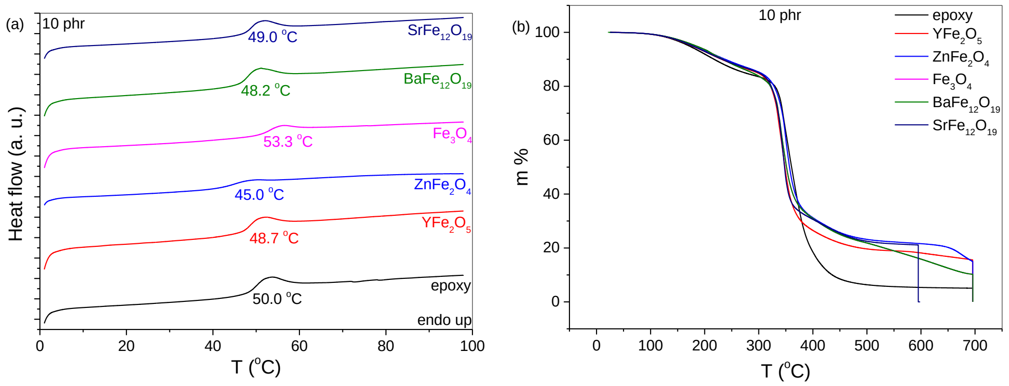

Figure 1. (a) DSC *and* ***(b)*** TGA thermographs for all examined systems with 10 phr filler concentration.

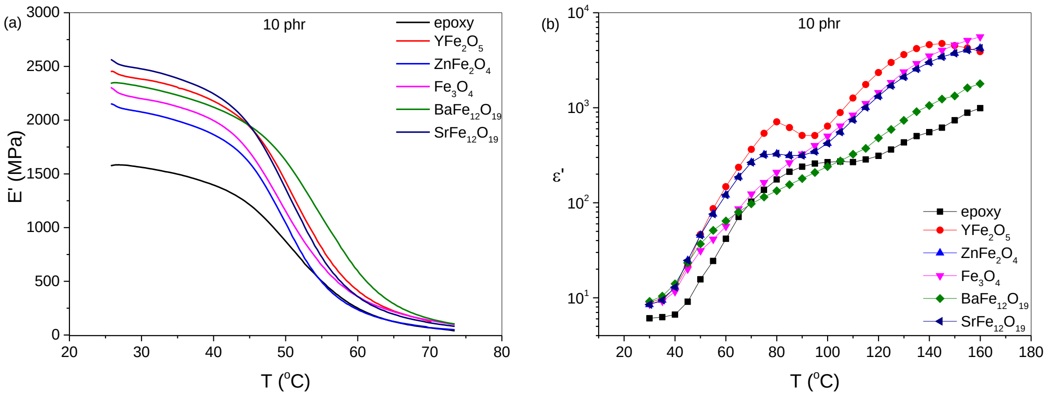

Figure 2. (a) *Storage Modulus and* ***(b)*** real part of dielectric permittivity, at 0.1Hz, as a function of temperature, for all examined systems with 10 phr filler concentration.

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