Nucleation of the electroactive β-phase, dielectric and magnetic response of poly(vinylidene fluoride) composites with Fe_2O_3 nanoparticles

J. Gutiérrez[1], A. Lasheras[1], J.M. Barandiarán[1] , R. Gonçalves2,3, P.M. Martins2, C. Caparrós2, M. Benelmekki[2], G. Botelho[3] and S Lanceros-Mendez[2,4]

[1]Departamento de Electricidad y Electrónica, Facultad de Ciencia y Tecnología, Universidad del País Vasco UPV/EHU, P. Box 644, E-48080, Bilbao, España
[2]Departamento de Física and [3]Departamento de Química da Universidade do Minho, Campus de Gualtar, 4710-057 Braga, Portugal
[4]INL-International Iberian Nanotechnology Laboratory, 4715-330 Braga, Portugal
jon.gutierrez@ehu.es

Abstract

We present the synthesis of iron oxide magnetic nanoparticles (IOMNPs) and their inclusion in a poly(vinylidene fluoride) (PVDF) matrix with the objective to produce IOMNPs/PVDF multiferroic nanocomposites [1]. A co-precipitation technique was used to produce IOMNPs with an average size distribution of the order of the 15 nm of diameter. These IOMNPs were studied and characterized by X-ray diffraction (XRD), dynamic light scattering (DLS) and transmission electron microscopy (TEM) (see Fig. 1).

IOMNPs/PVDF composites were prepared by a solution method and melt crystallization crystallize in the electroactive phase of the polymer, being the β-phase fraction proportional to the ferrite content. Increasing concentration of the IOMNPs nucleates the piezoelectric β-phase of the polymer, decreases the degree of crystallinity and increases the melting temperature of the polymer matrix leading to electroactive materials with large potential for sensor and actuator applications. The crystallization of this phase is attributed to electrostatic interactions of the polymer chains with the nanoparticles. The room temperature dielectric constant and the melting temperature of the nanocomposites increase with increasing IOMNP content, whereas the degree of crystallinity and the a.c. conductivity decrease (see Fig. 2). The slight decrease of the a.c. conductivity of composites respect to the pure PVDF polymer (this difference being larger for lower frequencies) is attributed to the lower ionic mobility within the polymer matrix due to charge trapping around nanoparticles, mainly due to strong interfacial interactions.

Both missing coercivity and the shape of the hysteresis loop represent an evidence for quasi-superparamagnetic behavior for room IOMNPs/PVDF composites (see Fig. 3). That behavior is also evidenced from the FC and ZFC dependences of the magnetization vs. temperature. From those ZFC–FC measurements it is also inferred that the nanoparticles inside the polymeric matrix behave as magnetic monodomains. The overall electrical and magnetic characteristics of the IOMNPs/PVDF nanocomposites lead to materials with large potential for sensor and actuator applications.

References

[1] R. Gonçalves, P.M. Martins, C. Caparrós, P. Martins, M. Benelmekki, G. Botelho, S Lanceros-Mendez, A. Lasheras, J. Gutiérrez and J.M. Barandiarán, Journal of Non-Crystalline Solids, **361** (2013) 93-99, and references therein.

Figures

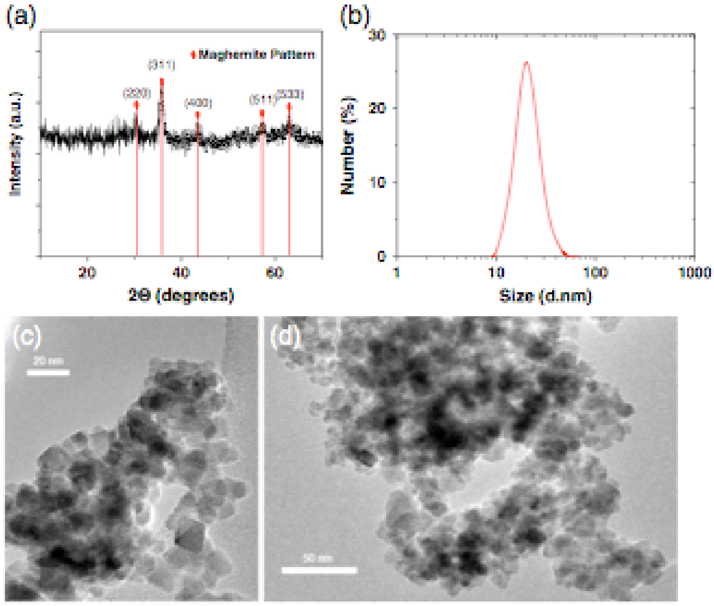

Figure 1. Nanoparticle characterization by (a) X-ray diffraction, (b) DLS and (c) and (d) TEM.

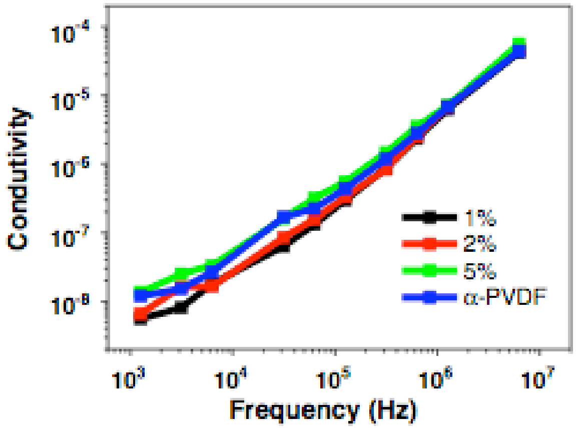

Figure 2. Conductivity obtained for the different IOMNP content on nanocomposite films, at different frequencies..

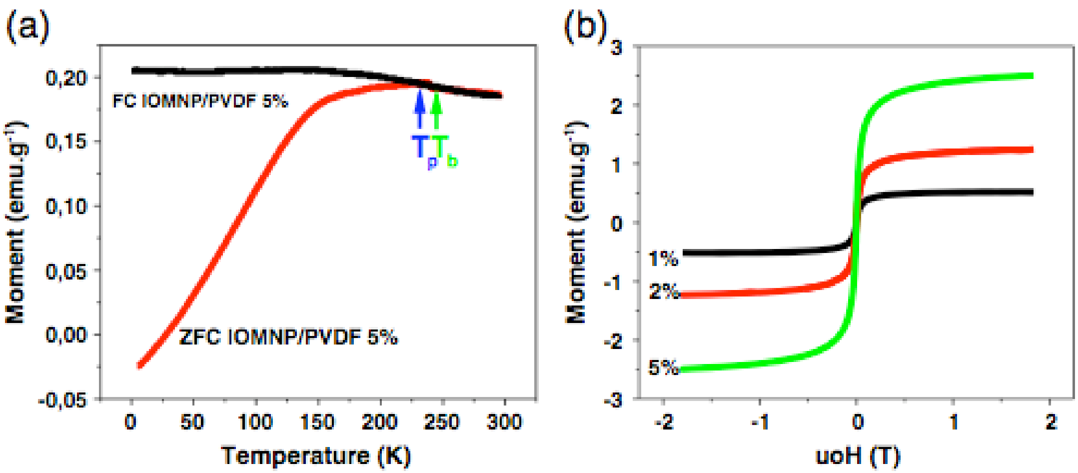

Figure 3. (a) ZFC–FC low field (100 Oe) magnetization curves for IOMNP/PVDF 5%w/w nanocomposite. (b) Room temperature hysteresis for IOMNP/PVDF nanocomposites with different ferrite contents