Magnetocapacitance in Fe_3O_4@SiO_2 nanocomposite

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Nowadays, there is a growging interest in materials in which their dielectric constant can be modified by the application of a magnetic field [1]. Unluckily, relatively few compounds display such a magnetocapacitive (MC) behavior and many efforts have been devoted in the last years to search for new alternatives.

Recently, several authors have reported magnetocapacitive response in magnetic nanoparticles systems such as ε-Fe_2O_3 [2], $MnFe_2O_4$ and γ-Fe_2O_3 [3]. Therefore, nanoparticle technologies open a new route to obtain materials with such a behavior.

In this contribution, we study the influence of the SiO_2 coating on the dielectric and magnetocapacitive response of one of the most studied magnetic compounds among the iron oxides: the magnetite, Fe_3O_4. This compound is a very well known material that shows a ferrimagnetic transition around T_C ~ 850 K and nearly full spin polarization at room temperature [4], both properties of great potential for applications in giant magnetoelectronic and spin-valve devices.

For this purpose, the Fe_3O_4 nanoparticles (ϕ~ 20 nm) that constitute the cores were prepared following the solvothermal method described by Pinna et al. [5], and the Fe_3O_4@SiO_2 core-shell nanocomposites (Figure 1) were synthesized using the Stöber method [6]. The obtained samples were morphologically and structurally characterized by means of X-ray powder diffraction, scanning electron microscopy and transmission electron microscopy. Its complex dielectric permittivity, $\varepsilon_r = \varepsilon_r' - i\varepsilon_r''$, was measured as a function of frequency ($20 \leq \nu$ (Hz) $\leq 10^6$) and temperature ($90 \leq T$ (K) ≤ 300). Dielectric measurements as a function of a magnetic field, H_{max}= 0.5 T, were aditionally performed in the temperature range $200 \leq T$ (K) ≤ 300.

The frequency dependent behavior of the two materials are compared in Figure 2. As it can be seen the dielectric constant shows higher values in the case of the Fe_3O_4 nanoparticles, even if those of the core-shell nanocomposite do not decrease so markedly with frequency. Very interestingly in the coated sample the loss tangent has decreased as compared to the uncoated sample by at least a factor of 10 (Figure 3).

Moreover, a magnetocapacitive (MC) response is observed at room temperature in the Fe_3O_4 nanoparticles, MC= $[\varepsilon'_{r(H=0.5T)} - \varepsilon'_r(_{H=0T})]/\varepsilon'_{r(H=0T)}$~ 6 %, that slighly decreases, but maintains values ~ 1 % in the case of the Fe_3O_4@SiO_2 nanocomposite.

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References:

[1] G. Catalan, *Appl. Phys. Lett*. **88** (2006) 102902.
[2] M. Gith, C. Frontera, A.Roig, J. Fontcuberta, E. Molins, *Nanotechnology* **17** (2006) 687.
[3] G. Lawes, R. Tackett, O. Masala, B. Adhikary, R. Naik, R. Seshadri, *Appl. Phys. Lett*. **88** (2006) 687.
[4] J. M. D. Coey, A. E. Berkowitz, Ll. Balcells, F. F. Putris, F. T. Parker, *Appl. Phys. Lett.* **72** (1998) 734.
[5] N. Pinna, S. Grancharow, P. Beato, P. Bonville, M. Antonetti, M. Niederberger, *Chem. Mater*. **17** (2005) 3044.

[6] W. Stöber, A.Fink, E. Bohn, *J. Colloid Interface Sci.* **26** (1968) 62.

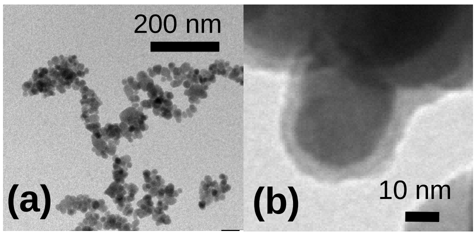

Figure 1. TEM micrographs of: (a) the Fe_3O_4 nanoparticles, (b) the $Fe_3O_4@SiO_2$ core-shell composite (thickness of the SiO_2 nanocoating ~ 6 nm).

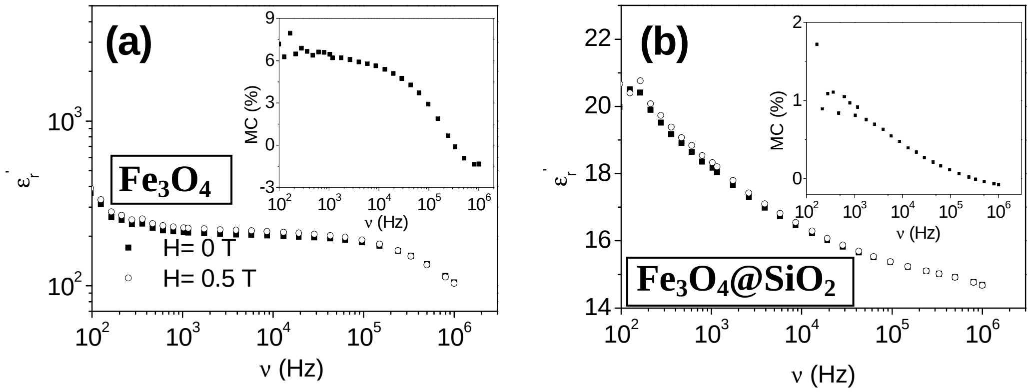

Figure 2. Frequency (ν) dependence of the dielectric constant (ε'_r) for: (a) Fe_3O_4 nanoparticles and (b) $Fe_3O_4@SiO_2$ nanocomposite, measured at T= 295 K in the absence and presence of magnetic field.

Inset on Figures 2a and 2b: Magnetocapacitive effect, where $MC=[\varepsilon'_{r(H=0.5T)}-\varepsilon'_r(_{H=0T})]/\varepsilon'_{r(H=0T)}$.

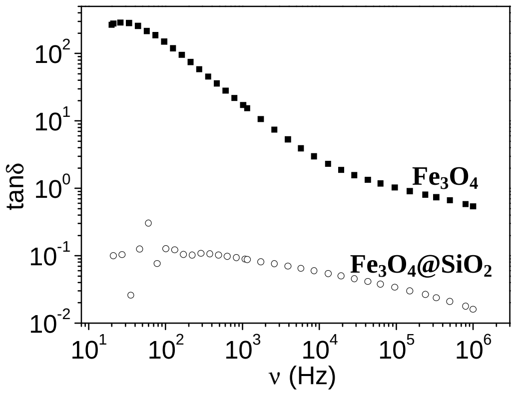

Figure 3. Plot of the loss tangent (tanδ) versus frequency ($20\leq \nu$ (Hz) $\leq 10^6$) corresponding to both the Fe_3O_4 nanoparticles and the $Fe_3O_4@SiO_2$ nanocomposite measured at T= 300 K.