Magnetocapacitive response in Fe_3O_4 nanoparticles

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There is a renewed 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 nanoparticle systems such as ε-Fe_2O_3 [2], $MnFe_2O_4$ and γ-Fe_2O_3 [3], and ferroelectric and magnetic nanocomposites [4]. Therefore, nanoparticle technologies open a new route to obtain materials with such a behavior.

In this contribution, we report the dielectric and magnetocapacitive response of the magnetic nanoparticles of magnetite, Fe_3O_4. This compound is a very well known material that shows a ferrimagnetic transition around $T_C \sim 850$ K and a charge localization around $T_v \approx 120$ K (the so-called Verwey transition). Also, it shows magnetoresistance at room temperature [4].

The Fe_3O_4 nanoparticles (ϕ~30 nm) were synthesized following the solvothermal method described by Pinne et al. [5]. The obtained sample was 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 ($20 \leq \nu(\text{Hz}) \leq 10^6$) and temperature ($90 \leq T(\text{K}) \leq 300$). Dielectric measurements as a function of a magnetic field, $H_{max} = 0.5$ T, were additionally performed in the temperature range $200 \leq T(\text{K}) \leq 300$.

The variation of the dielectric constant (ε'_r) and the dielectric loss ($\tan\delta$) as a function of temperature reveal interesting features as the Verwey transition takes place (see Figure 1): the dielectric constant drops abruptly while a peak appears in $\tan\delta$, results that suggest a coupling between the charge condensation and the dielectric response.

In addition, we have found a magnetocapative response at room temperature and under a relative moderate magnetic field, $MC = [\varepsilon'_{r(H=0.5T)} - \varepsilon'_{r}(_{H=0T})] / \varepsilon'_{r(H=0T)} \approx 6\%$ under H = 0.5 T (Figure 2).

References:

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Figures:

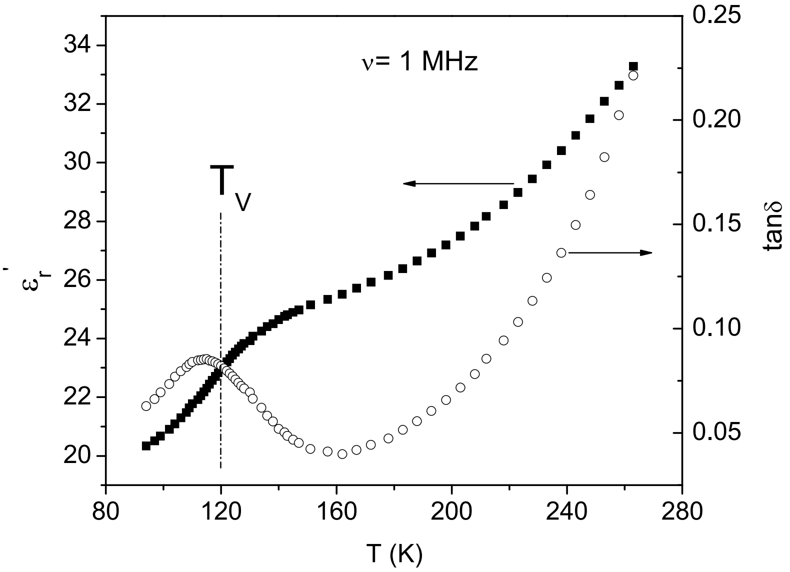

Figure 1. Temperature dependence of the dielectric constant (ε'_r) and dielectric loss (tanδ) measured at ν = 1 MHz.

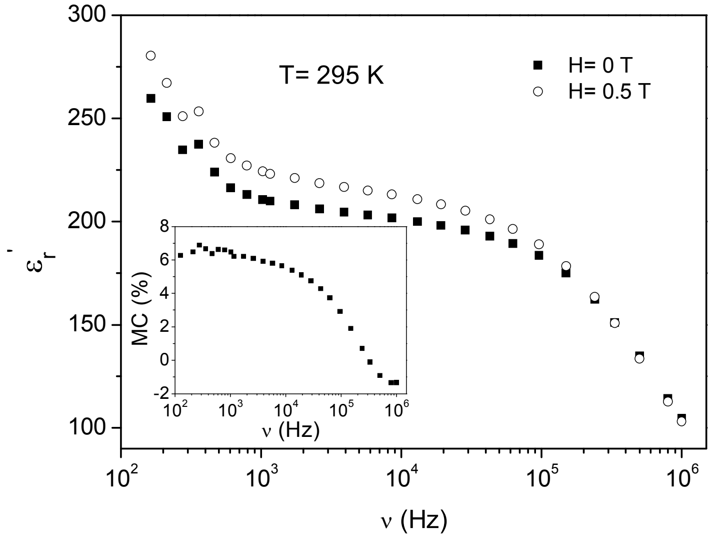

Figure 2. Influence of the magnetic field (H) in the frequency (ν) dependence of the dielectric constant (ε'_r) measured at T = 295 K. Inset: Magnetocapacitive effect, where MC = $[\varepsilon'_{r(H=0.5T)} - \varepsilon'_r(_{H=0T})] / \varepsilon'_{r(H=0T)}$.

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