Size and Surface Effects on Magnetic Properties of Fe_3O_4 Nanoparticles

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In this study, size and surface effects on temperature and frequency dependent magnetic properties of superparamagnetic Fe_3O_4 nanoparticles in a size range of 1.1-11 nm are investigated by SPR technique. We used a theoretical formalism based on a distribution of diameters or volumes of the nanoparticles following lognormal proposed by Berger et al. The nanoparticles are considered as single magnetic domains with random orientations of magnetic moments and thermal fluctuations of anisotropic axes. The individual line shape function is derived from the damped precession equation of Landau-Lifshitz. Magnetic properties of the samples were strongly temperature and size dependent. When the temperature is decreased, while the SPR line width is increasing the resonance field is decreasing. This means the anisotropy field is increasing by decreasing the temperature. At high T's the SPR line shape is governed by the core anisotropy and the thermal fluctuations. On decreasing T, as the shell spins increase their magnetic susceptibility, they produce an effective field on the core, leading to a decrease of B_r from its high T value. As the shell spins begin to order the effective anisotropy increases following its surface value more closely. So, the results can be interpreted by a simple model, in which each single-domain nanoparticle is considered as a core-shell system, with uniaxial anisotropy on the core and surface anisotropy on the shell. Also a linear microwave frequency dependence was observed. Furthermore, the blocking temperature of the particles is also increasing by the particle size.

Keywords: *SPR, superparamagnetism, spinel structure, blocking temperature, anisotropy.*

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