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Static and dynamic study of superparamagnetic $CoFe_2O_4$ nanoparticles

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Abstract – We investigate the magnetic properties of $CoFe_2O_4$ nanoparticles (D_{med} = 7.2 nm). AC susceptibility measurements of colloidal cobalt ferrite nanoparticles, as a function of temperature and frequency, reveal a prominent peak in both χ' and χ'' as a function of T (Fig.1). The peak temperature T_B of χ'' depends on frequency following the Vogel-Fulcher law. The particles exhibit superparamagnetic behavior at 300K. We observed the blocking temperature at 94K (ZFC measurements) and at 152 K (AC measurements). We present here simulations of the experimental Mössbauer spectra considering superparamagnetic relaxation, size distribution, collective excitations and particle interactions.

A superparamagnetic system is composed by magnetic monodomain nanoparticles whose atomic magnetic moments rigidly align through exchange interaction. Although many nanostructured systems (i.e., systems with particle sizes of the order of nanometers) have been reported as superparamagnetic, a lack of agreement is commonly observed between experimental data and the standard superaparamagnetic theory. These differences are usually ascribed to the intrinsic particle size distribution, anisotropy of different origins, and interactions among magnetic particles. The interparticle interactions are found to influence the energy barriers yielding an enhancement of the estimated magnetic anisotropy, $K = 1.9 \times 10^5$ J/m^3. The peak temperature T_{max} of ac susceptibility (χ'') depends on f following the Vogel–Fulcher law [$T_B = T_o + T_a / \ln(f_o/f_m)$]. The fitted value for T_o = 85 K. The particles show superparamagnetic behavior at room temperature, with transition to a blocked state at T_B ~ 94 K in ZFC and 130 K in AC susceptibility measurements (f = 10Hz), respectively, which depends on the applied field. T_f decreases with increasing DC magnetic field as evidenced by zero-field, cooled susceptibility (ZFC) studies at 200, 500 and 1000 Oe (T_f = 130, 127 and 123 K respectively) [Fig 2.]. As a typical superparamagnetic behavior, the zero-field-cooled and the field-cooled magnetizations diverge below T_f. The saturation magnetization and the coercivity measured at 4.2 K are 123.4 G and 15.7 kOe, respectively. The particle size distribution was determined by fitting a magnetization curve obtained at 295K assuming a log-normal size distribution. Mössbauer spectra obtained at higher temperatures show a gradual collapse of the magnetic hyperfine splitting typical for superparamagnetic relaxation. At 4.2 K, the Mössbauer spectrum was fitted with two magnetic subspectra with internal fields H_{int} of 490 and 515 kOe, corresponding to Fe^{3+} ions in A and B sites. We present our experimental results on Mössbauer spectroscopy and interpreted them in the light of the effect of interaction among particles

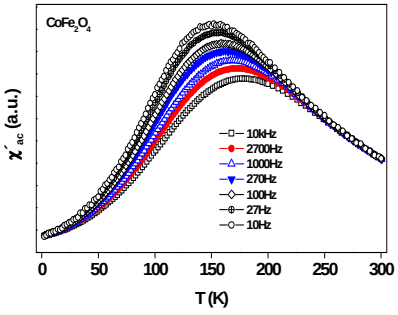

Figure 1: AC susceptibility curves (real part, χ').

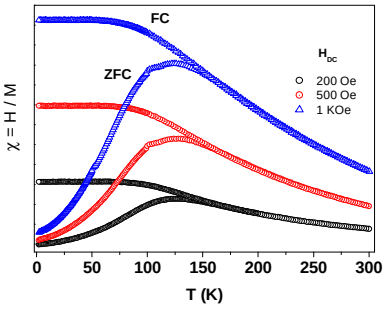

Figure 2: ZFC and FC curves.

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