Study of magnetic and structural properties of ferrofluids based on Cobalt-Zinc ferrite nanoparticles

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Abstract

Ferrofluids are colloidal systems composed of a single domain of magnetic nanoparticles with a mean diameter around 10 nm, dispersed in a liquid carrier. Magnetic $Co_{(1-x)}Zn_xFe_2O_4$ (x = 0.25, 0.50, 0.75) ferrite nanoparticles were prepared via co-precipitation method from aqueous salt solutions in an alkaline medium. The composition and structure of the samples were characterized through Energy Dispersive X-ray Spectroscopy and X-ray diffraction, respectively. Transmission Electron Microscopy studies permitted determining nanoparticle size; grain size of nanoparticle conglomerates was established via Atomic Force Microscopy. The magnetic behavior of ferrofluids was characterized by Vibrating Sample Magnetometer; and finally, a magnetic force microscope was used to visualize the magnetic domains of $Co_{(1-x)}Zn_xFe_2O_4$ nanoparticles. X-ray diffraction patterns of $Co_{(1-x)}Zn_xFe_2O_4$ show the presence of the most intense peak corresponding to the (311) crystallographic orientation of the spinel phase of $CoFe_2O_4$. Fourier Transform Infrared Spectroscopy confirmed the presence of the bonds associated to the spinel structures; particularly for ferrites. The mean size of the crystallite of nanoparticles determined from the full-width at half maximum of the strongest reflection of the (311) peak by using the Scherrer approximation diminished from (9.5 ± 0.3) nm to (5.4± 0.2) nm when the Zn concentration increases from 0.21 to 0.75. The size of the Co-Zn ferrite nanoparticles obtained by Transmission Electron Microscopy is in good agreement with the crystallite size calculated from X-ray diffraction patterns, using Scherer's formula. The magnetic properties investigated with the aid of Vibrating Sample Magnetometer at room temperature presented super-paramagnetic behavior, determined by the shape of the hysteresis loop. In this study, we established that the coercive field of $Co_{1-x}Zn_xFe_2O_4$ magnetic nanoparticles and the crystal and nanoparticle sizes determined by X-ray Diffraction and Transmission Electron Microscopy, respectively, decrease with the increase of the Zn at%. Finally, our magnetic nanoparticles are not very hard magnetic materials given that the hysteresis loop is very small and for this reason $Co_{(1-x)}Zn_xFe_2O_4$ nanoparticles are considered soft magnetic material.

Keywords: Chemical coprecipitation synthesis, Ferrofluids, nanoparticles, single domain, spinel structure, super-paramagnetism.

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Figures

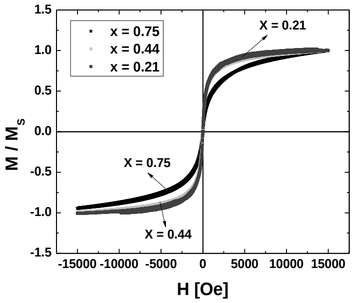
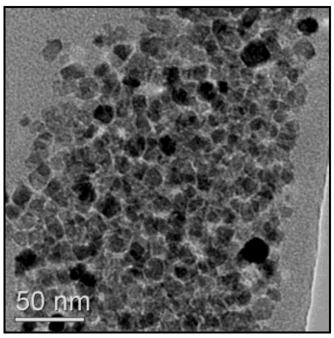
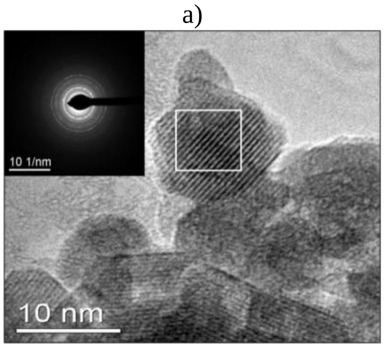


Fig. 1. M vs. H hysteresis loop of $Co_{(1-x)}Zn_x\mathit{Fe_2O_4}$ magnetic ferrofluid as a function of Zn concentrations at room temperature.



a)



b)

Fig. 5. HRTEM images of $Co_{0.79}Zn_{0.21}Fe_2O_4$ nanoparticles at two different scales: a) 50 nm, b) 10 nm.