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Study of the structural and magnetic properties of $Co_{(1-x)}Zn_xFe_2O_4$ nanoparticles in ferrofluids

J. Lopez[1*], L. F. González[2], J. Prado, G. Zambrano[1], M. E. Gómez[1]

(1) Thin Film Group, Universidad del Valle, Cali, Colombia. e-mail: javierlo21@gmail.com
(2) Chemistry Analytical Laboratory, Universidad del Valle, Cali, Colombia.
* Corresponding author.

Abstract – Magnetic $Co_{(1-x)}Zn_xFe_2O_4$ (x = 0.25, 0.50, 0.75) ferrite nanoparticles less than 10nm, were prepared by co-precipitation method. 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 $CoFe_2O_4$. Magnetic properties investigated with the aid of a VSM at room temperature presented a superparamagnetic behavior, determined by the shape of the hysteresis loop. Finally, our magnetic nanoparticles are not very hard magnetic materials since the hysteresis loop is very small and for this reason $Co_{(1-x)}Zn_xFe_2O_4$ nanoparticles are considered as soft magnetic.

Magnetic nanoparticles offer some attractive possibilities in biomedicine. The use of magnetic particles with nanometer size has expanded its applications in fields such as biomedicine, which has been proposed, for example, as an alternative therapy and localized for treatment of malignant tumours, where the nanoparticles are injected directly into the tumour. When this fluid is placed in an alternating magnetic field, the nanoparticles generate heat and destroy the tumour. An effect to take into account, for medical applications, that these materials must be biocompatible. [1,2]. Magnetic fluids are colloidal systems composed of single domain of magnetic nanoparticles with a mean diameter of around 10 nm dispersed in a liquid carrier. In the present work, magnetic $Co_{(1-x)}Zn_xFe_2O_4$ ferrite nanoparticles were prepared by co-precipitation method from aqueous salt solutions in an alkaline medium. The powder samples were characterized by XRD, Vibrating Sample Magnetometer VSM, Fourier Transform Infrared Spectroscopy (FTIR) and EDS studies. X-ray diffraction pattern of $Co_{(1-x)}Zn_xFe_2O_4$ at Zn concentration of x = 0.25, shows the presence of the most intense peak corresponding to the (311) crystallographic orientation of the spinel phase of $CoFe_2O_4$, which presents a shift to the position of the Zn Fe_2O_4 phase, when the Zn concentration increases from x = 0.25 to x = 0.75 (Figure 1). On the other hand, the mean size of the crystallite of nanoparticles determined from the full-width at half maximum (FWHM) of the strongest reflection of the (311) peak by using the Scherrer approximation, diminished from 9.5 ± 0.3 to 5.4± 0.2 nm when the Zn concentration increases from 0.25 to 0.75, respectively. In these conditions, the lattice parameter of the $Co_{(1-x)}Zn_xFe_2O_4$ decreases from 8.393659 ± 0.002358 to 8.443995 ± 0.001774 Å, similar to the lattice parameters of $CoFe_2O_4$ (8.3919 Å) and $ZnFe_2O_4$ (8.4411 Å), respectively (Figure 2). Magnetic properties of $Co_{(1-x)}Zn_xFe_2O_4$ investigated with the aid of a VSM at room temperature presented a superparamagnetic behavior, determined by the shape of the hysteresis loop (Figure 3), and strongly dependent on the Zn concentration and the particle size. In this case, the coercivity exhibits a maximum when the partial substitution of cobalt ferrite with zinc is minimum. Finally, our magnetic nanoparticles are not very hard magnetic materials since the hysteresis loop is very small and for this reason $Co_{(1-x)}Zn_xFe_2O_4$ nanoparticles are considered as soft magnetic.

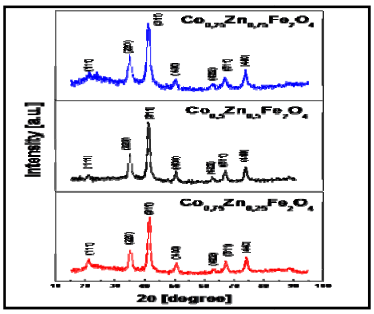

Figure 1: X-ray diffraction patterns of $Co_{(1-x)}Zn_xFe_2O_4$ powders at different Zn concentrations.

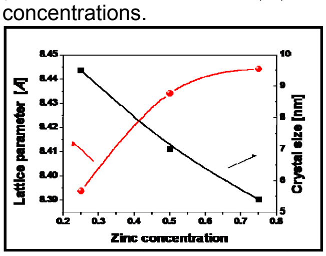

Figure 2: Variation of the lattice parameter and the crystal size at different Zn concentrations.

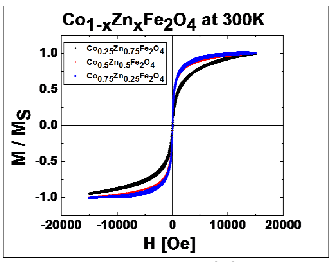

Figure 3: M vs. H hysteresis loop of $Co_{(1-x)}Zn_xFe_2O_4$ magnetic ferrofluid at different Zn concentrations.

References

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