Magnetic properties of $Zn_{1-x}Co_xFe_2O_4$ nanoparticles prepared by a hydrothermal method

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In recent years, spinel-ferrite nanoparticles have attracted much interest of the scientific community due to their potential applications in many magnetic and electronic devices, particularly microwave absorbers, active components of ferrofluids and photocatalysis. Among spinel ferrites, it has been focused on two material systems $ZnFe_2O_4$ and $CoFe_2O_4$ nanoparticles because they have high chemical stability and corrosion resistance, and excellent magneto-optical properties. To further understand these materials, we prepared $Zn_{1-x}Co_xFe_2O_4$ (x = 0-1) nanoparticles (NPs) by using a hydrothermal method, and then investigated in detail their structural characterization and magnetic properties. The analyses of X-ray diffraction (XRD) patterns and Raman scattering spectra indicated all the samples crystallized in a cubic-spinel structure (the space group $Fd3m$) with the lattice parameter $a \approx 8.4$ Å. Average crystallite sizes obtained from the XRD linewith by using the Scherrer equation are about 16-22 nm, which are close to the particle sizes of ~20 nm determined from scanning-electron-microscopy images. Magnetization measurements versus temperature, $M(T)$, in the magnetic filed H = 100 Oe indicate the ferromagnetic-to-paramagnetic phase transition temperate (T_C, the Curie temperature) $Zn_{1-x}Co_xFe_2O_4$ NPs increases from ~600 K for x = 0 to ~815 K for x = 1. The features of the $M(T)$ curves also indicate inhomogeneities in magnetization of the samples in the FM region. At room temperature, we found that both the saturation magnetization (M_s) and coercive force (H_c) increase with increasing Co content in $Zn_{1-x}Co_xFe_2O_4$, in which M_s = 60~72 emu/g, and H_c = 100~500 Oe. These results reflect that the Co doping into zinc-ferrite NPs improve remarkably the magnetic property, making them more helpful for practical applications. In this work, additionally, based on analyzing the initial magnetization curves, $M(H)$, recorded around the T_C, we also assess the magnetic-entropy change and critical behaviors in order to figure out magnetic-interaction mechanisms taking place in the samples.