The effect of solution temperature on crystallite size and magnetic properties of Zn substituted Co ferrite nanoparticles

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In this work zinc substituted cobalt ferrite nanoparticles (Co0.7Zn0.3Fe2O4) have been synthesized by the coprecipitation method, using stable ferric, zinc and cobalt salts with sodium hydroxide, at different solution temperatures, from room temperature to 363 K. The cobalt–zinc ferrite crystalline phase, the particle size and the morphology of the resulting nanoparticles were studied by X-ray diffraction and transmission electron microscopy. The average crystallite size of each sample was calculated from the broadening of the most intense peak (3 1 1), using Scherrer’s formula and the results show crystallite sizes increased from 6 to 8 nm by increasing the solution temperature from room temperature to 363 K respectively. Room temperature VSM measurements show that the prepared nanoparticles have superparamagnetic behavior and did not saturate at maximum field of 8000 kA/m. The variation of AC-susceptibility of the samples with respect to temperature was measured and it was found that the blocking temperature increased from 198 to 270 K by increasing the solution temperature from room temperature to 363 K respectively. FTIR spectra of the samples have been analyzed in the frequency range 400–4000 cm−1, which also confirms the results of XRD.

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1. Introduction

Ferrite nanoparticles have found important applications in heat transfer devices, magnetic hyperthermia, drug delivery systems, medical diagnostics, biosensors, magnetic resonance imaging, microwave devices, high density information storage and ferrofluid technology [1–4]. The use of ferrites for certain applications depends on their electrical and magnetic properties, which in turn are sensitive to the preparation conditions as well as the type and amount of substitutions [5].

Nanosize ferrites can be prepared by various synthesis techniques namely high energy ball milling [6], citrate precursor [7], hydrothermal [8], coprecipitation [9,10], sol–gel [11] and other chemical methods. The magnetic properties of the ferrite nanoparticles are found to undergo changes due to superparamagnetism, surface spin effects and also with their cation distribution which depends on the method of synthesis [12,13]. Ferrites of the type AB2O4, where A and B are divalent and trivalent cations respectively, possess the spinel structure. The oxygen ions form an fcc lattice and the cations occupy the interstitial positions. There are two interstitial sites, one being the tetrahedral or A-site surrounded by four oxygen ions and the other, octahedral or B-site surrounded by six oxygen ions. The exchange interaction in spinel ferrites in which the antiparallel alignment of magnetic moments of A-site with B-site is mediated by oxygen ions is called superexchange interaction. The strength of the superexchange interaction between the cations depends on the A–O–B bond angle, which is the largest for an angle of 180°. The interesting magnetic properties, such as magnetization and Curie temperature of various ferrites have been observed to depend on the superexchange interaction strength, which is determined by the site occupancy of metal ions in the A- and B-sites [21,22]. The net magnetization is the result of the difference in the sublattice moments of the two sites, which depends upon the cation occupancy [21,22].

Ferrite nanoparticles are found to exhibit superparamagnetic behavior with their coercivity approaching zero. The critical particle size for superparamagnetism has also been calculated for various ferrites with the sizes being 14, 25 and 50 nm for CoFe2O4, Fe3O4 and MnFe2O4, respectively [14]. The blocking temperature for the superparamagnetism of the nanoparticles depends on their magnetocrystalline anisotropy. A comparative study of CoFe2O4 and MgFe2O4 with 20 nm particle size has suggested that the blocking temperature of CoFe2O4 is higher than

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