Effect of Nickel Substitution on Structural and Magnetic Properties of Novel Polyol route Synthesized Cobalt Ferrite

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Abstract

Nanocrystalline $Ni_xCo_{1-x}Fe_2O_4$ ($1.0 \geq x \geq 0$) ferrites were prepared by polyol route. Formation of single phase cubic spinel structure for all the compositions was confirmed from their X-ray diffraction patterns. These ferrite samples existed as crystalline nanoparticles of about 10-20 nm size as observed from Transmission Electron Microscopy technique. The magnetic studies indicated that, the ferrimagnetic behavior increases with nickel substitution.

Keywords: Polyol method, X-ray diffraction, nanostructures, magnetic materials, infrared spectroscopy

Introduction

Among various classes, nanoferrites are very common, most diverse and possess richest class in terms of physical, chemical and structural properties. Nanoferrites are being intensively studied due to their interesting physico-chemical properties as well as various promising applications such as microelectronic circuits, dielectrics, sensors, magnets and catalysts[1-6]. The interesting physical and chemical properties of ferrospinels arise from their ability to distribute the cations among available tetrahedral (A) and octahedral (B) sites. Among various oxides, transition metal oxides with iron oxides as their main component have attracted the attention of physicists and technologists, since these are magnetic semiconductors suitable for use in microwave devices.

In a spinel structure, the distribution of cations on A and B sites depends on their nature of ions, charge distribution and site preference amongst tetrahedral and octahedral sites. $CoFe_2O_4$ possesses inverse spinel structure having wide range of applications and degree of inversion depends upon the heat treatment. It has high coercivity and moderate saturation magnetization[7]. Recently, considerable effort has been made on the surface modification of nanoparticles and the preparation of different type of metal oxides. Various methods are available for the synthesis of metal oxides such as microwave refluxing[8], sol-gel[9], hydrothermal[10,11] co-precipitation[12], citrate-gel[13] and spray pyrolysis[14] etc.

The selection of appropriate synthetic procedure often depends on the desired properties and final applications. Among these synthesis techniques, polyol method has several advantages over others for preparation of nanosized metal oxides as the process begins with a relatively homogeneous mixture and involvement of low temperature conditions resulting in a uniform ultrafine porous powder[15]. In our previous work[16], this method was employed to obtain improved powder characteristics, more homogeneity and narrow particle size distribution, thereby influencing structural, electrical and magnetic properties of ferrites. In this communication, we report preparation of nanosized cobalt substituted Ni ferrites by polyol method.

Material and Methods

$Ni_xCo_{1-x}Fe_2O_4$ ($1.0 \geq x \geq 0$) ferrites system has been synthesized by polyol-mediated route. High purity (AR grade) nickel nitrate, cobalt nitrate and iron nitrate were used as raw materials. The stiochiometric amounts of individual metal nitrates were dissolved in doubly distilled deionized water to get a clear transparent solution. The solution ($25cm^3$) was mixed with $25cm^3$ of ethylene glycol and refluxed at 373K for 1 h. Sodium hydroxide (molar ratio, Sodium /cation = 2.5) was dissolved in $25cm^3$ of water and mixed with $25cm^3$ ethylene glycol and this solution was added to the clear solution containing the precursor ions in water and ethylene glycol mixture. This mixture was then refluxed at 453K for 4 h to get the precipitate of the oxide.

The precipitate obtained was separated by centrifugation, washed with acetone and ethyl alcohol followed by drying in an oven at 363K for 5 h. After drying, this powder was then sintered at 773 K for 4 hrs. The sintered powders were granulated and using 2 % polyvinyl alcohol as a binder were uniaxially pressed at a pressure of 8 ton/cm^2 to form pellet specimens.

Characterization technique: Thermal analysis of the unsintered $CoFe_2O_4$ ferrite sample was carried out from the curves of TG-DTA. Stability of the dry complexes was checked by scanning the thermogram in the temperature range of 10-1000 ^oC in static air at the flow rate of 10 ^0C/min. The phase formation of the sintered samples was confirmed by X-ray diffraction studies (Philips PW-1710 X-ray diffractometer with CuKα radiation λ=1.57058Å). Particle size was measured using a transmission electron microscope (TEM) (Philips, CM200, operating voltages 20–200 kV). Magnetic study was carried out by using B-H loop traces