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Synthesis and Design of Magnetic Parameters by Ti doping in Cobalt Ferrite Nanoparticles for Nanoelectronics Applications

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Abstract

In the present study, we report thesynthesis of cobalt ferrite nanoparticles using well known sol-gel auto combustion technique and design of magnetic parameters by titanium (Ti^{4+}) doping. Cobalt ferrite is a promising candidate for magnetic recording, data storage and other nanoelectronics applications. The samples with generic formula $Co_{1+x}Ti_xFe_{2-2x}O_4$ (x=0.00, 0.10, 0.30 and 0.50) were prepared in thenanocrystalline form using the standard sol-gel autocombustion technique by taking citric acid as a fuel. The prepared nanoparticles were characterized by X-ray diffraction (XRD) technique and scanning electron microscopy (SEM) technique to know the phase and morphology respectively. The XRD patterns confirm the monophase cubic spinel structure of the samples and particle size obtained by Scherrer's formula was around 25 nm indicating the nanocrystalline nature of the prepared samples. The microstructural studies were investigated through scanning electron microscopy (SEM) technique. SEM confirmed the homogeneous and well-defined surface morphology in nano range. A careful designing and optimization of magnetic parameters are achieved by tetravalent non-magnetic Ti^{4+} doping in cobalt ferrite nanoparticles. The obtained magnetic parameters are useful for nanoelectronics applications.

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*Keywords:*Co-Ti Ferrite;Magnetic Materials; Hysteresis; XRD.

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1. Introduction

Ferrites having high electromagnetic performance, high saturation magnetization, high Curie temperature with low eddy current losses makes them much applicable in many fields. Cobalt ferrite (CFO) crystallizes in an inverse spinel structure with the space group of Fd-3m. The inverse spinel structure of cobalt ferrite is represented by $(Fe)^{A}[CoFe]^{B}\ O_4$. Recently, a considerable attention has been paid towards the structural, magnetic and electrical properties of some divalent (Zn) or trivalent (Al, Cr) or tetravalent (Mn, Zr) metal ion doped spinel ferrites (cobalt, nickel, and Zinc ferrite)[1-5]. Developing the devices for high frequency and electronic applications based on metal doped Co ferrites is clearly dependent upon the essential knowledge of thestructural and magnetic behavior of these materials. Cobalt ferrite and substituted cobalt ferrite has emerging technological applications such as ferrofluid, sensors, catalyst, heat transfer, radar absorbing material, magnetic data storage etc because of their high Curie temperature (T_C), high saturation magnetization and less economical price. The properties of cobalt ferrite are predominantly governed by substituting divalent, trivalent and tetravalent ions. In cobalt ferrite substitution of Zn^{2+}, Al^{3+}, Sn^{4+} etc. was studied by many researchers and found that the substituted cobalt ferrite have a huge amount of applications in many technological fields especially in nanoelectronics [6-8]. The substitution of nonmagnetic tetravalent Ti^{4+} ion in cobalt ferrite leads to interesting results which are useful in many technological applications such as electronic devices and memory cores [9, 10]. In literature, to the best of our knowledge very few reports are available on Ti^{4+} substituted cobalt ferrite in bulk form [11-13].

In the recent years, nanoscience and nanotechnology havegreat impact on many materials as these materials exhibit superior properties compared to the bulk materials. Cobalt ferrite is also prepared in nanosized form by various wet chemical methods which include co-precipitation, hydrothermal, sol-gel etc [14-17]. Among these methods, sol-gel auto combustion technique is unique and advantages over the other as it produce nanosized particles at low temperature. The method is most economical and does not require any large setup. In the literature, reports on Ti^{4+} substituted cobalt ferrite nanoparticles are not available to the best of our knowledge. The substitution of Ti^{4+} ions may reduce the magnetic properties of cobalt ferrite as it is nonmagnetic in nature and occupy theoctahedral site. The saturation magnetization, coercivity, remenance magnetization, remenance ratio, Curie temperature etc magnetic properties are of cobalt ferrite are very much important from the point of view of their application. The modification of the properties can be achieved by synthesis methods as well as by doping different ions of different valency. With this view in mind, it was decided to synthesize Ti^{4+} substituted cobalt ferrite nanoparticles and to investigate their structural, morphological and magnetic properties as a function of Ti^{4+} doping concentration. In the present work, the sol-gel method [6], which is a solution method capable of forming the ferrites at relatively lower temperatures, has been used for the preparation of $Co_{1+x}Ti_xFe_{2-2x}O_4$. Furthermore, it is aimed to investigate its suitability in the field of nanoelectronics and other emerging applications of nanotechnology. Here, we report our results on synthesis, structural and magnetic properties of Ti^{4+} doped cobalt ferrite.

2. Experimental

2.1. Synthesis

Ti^{4+} substituted cobalt ferrite nanoparticles of chemical formula $Co_{1+x}Ti_xFe_{2-2x}O_4$ (x=0.00, 0.10, 0.30 and 0.50) were synthesized by using sol-gel auto combustion method. AR grade chemicals such as tetrabutyl titanate ($C_{16}H_{36}O_4Ti$), cobalt nitrate ($Co(NO_3)_3 9H_2O$), ferric nitrate ($Fe(NO_3)_3 9H_2O$) as oxidants and citric acid ($C_6H_8O_7{\cdot}H_2O$) as a fuel were used. The metal nitrates to fuel ratio were chosen as 1:3 by adopting the propellant chemistry []. Ethanol (C_2H_6O) was used as a solvent to dissolve tetrabutyl titanate while ammonia solution was used to adjust the pH at 7. The reaction was carried out at temperature 90°C. The details of sol-gel auto combustion synthesis method are reported in our previous report [18, 19]. The as-prepared powder was sintered at 650°C for 6h to remove any impurity of nitrate remained and for well crystal growth. The sintered powder was used for structural, morphological and magnetic characterizations.