ScienceDirect

Solid State Communications
Volume 360, 1 February 2023, 115016

Low temperature synthesis of In doped cobalt ferrite and investigations of structural, magnetic and dielectric properties

Shakti Bajaj [a], Deepali D. Andhare [b], Swapnil A. Jadhav [b], Sangita Shinde [a]

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https://doi.org/10.1016/j.ssc.2022.115016
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Highlights

- $CoFe_{2-x}In_xO_4$ ferrite has been synthesized by sol-gel auto-combustion method.
- Structural and magnetic properties of ($CoFe_{2-x}In_xO_4$, x = 0.00, 0.02, 0.04, 0.06, 0.08 and 0.10) materials were studied.
- The dielectric constant decreases with In^{3+} doping.
- The variation of dielectric loss (ε‘’) as a function of frequency.

Abstract

The present paper deals with the low temperature synthesis of In^{3+} doped cobalt ferrite ($CoFe_{2-x}In_xO_4$, x = 0.00, 0.02, 0.04, 0.06, 0.08 and 0.10) using sol-gel auto-combustion method operated at low temperature. The prepared samples were well characterized for crystal structure and phase purity using X-ray diffraction technique which shows the formation of single-phase cubic spinel structure. The FE-SEM images of the typical samples show the well formation of spherical grains of average grain size 36 nm. The particle size determined from TEM histogram is found to be 35 to 32 nm. M−H plot recorded at room temperature reflects that the saturation magnetization overall decreases with doping due to the decreasing A-B interaction. The real and imaginary part of dielectric constant varies exponentially with frequency. The dielectric constant decreases with In^{3+} doping.

Introduction

Magnetic oxides systems like ferrites are the ferrimagnetic oxides with twin properties of electrical insulator and magnetic conductor [1,2]. These materials have large number of applications on the basis of their remarkable properties such as high electrical resistivity, low eddy current losses, high saturation magnetization, high permeability etc [3]. Ferrite finds applications in several fields such as transformer core, antenna rod, data storage, sensors, catalyst etc. Ferrite materials have been studied for last seven to eight decades for their structural, electrical, magnetic, optical and other properties [4]. These properties of ferrite are tunable as per the need and are sensitive to various parameters like method of preparation, nature and type of dopant, synthesis parameter etc.

Recently, ferrites in nanocrystalline form have gained much importance because of their unique superior properties as compared to bulk ferrite. The nanocrystalline ferrites have greater surface area as compared to their volume, greater reactivity, greater homogeneity, high stability etc [5]. The wet chemical methods like sol-gel autocombustion method, co-precipitation, hydrothermal, microemulsion, are now a days commonly used for the synthesis of nanocrystalline ferrite [6,7]. These methods are simple, low cost and operates at low temperature (approximate 60 °C–120 °C and therefore are of great interest to many researchers. The modification in these methods can bring large variation in the properties of ferrite. The nanocrystalline ferrite have been used currently in the field of medical science, agriculture, environmental, sensors, catalyst etc [8]. The magnetic nanoparticles of ferrite show superparamagnetic nature with enhanced magnetic properties. Being a magnetic material, it can be easily separable and can be used many times as a catalyst in several organic reactions [9]. The bandgap of the nanocrystalline ferrite is optimum to be used in photocatalytic application for the degradation of various industrial dyes. Thus, the ferrites with nanocrystalline nature are of prime importance to many researchers and technologist [10].

On the basis of crystal structure ferrites are grouped into spinel ferrite, rare earth garnet and hexagonal ferrite. The spinel ferrite is very much interesting and widely studied material [11]. The spinel ferrite shows large number of application as compared to the other types of ferrites. Compared to the garnet and hexagonal ferrite, the crystal structure of spinel ferrite is very simple. The general chemical formula of spinel ferrite is MFe_2O_4, where M stands for the divalent metal ions. The crystal structure possesses cubic spinel symmetry with space group Fd3m. The spinel ferrite has two interstitial sites namely tetrahedral (A) and octahedral [B] in which various ions can accommodate as per their site preference energy and size [12].

Cobalt ferrite is a unique spinel ferrite exhibiting highest magnetic and electrical properties as compared to the other spinel ferrites. On account of their magnetic properties cobalt ferrite is considered as hard ferrite. The crystal structure of cobalt ferrite is inverse [13]. In literature, several studies are reported on the cobalt ferrite nanoparticles in pure and substituted form [[14], [15], [16]]. Very few reports are available on the synthesis and investigation of electrical and magnetic properties of indium doped cobalt ferrite. The present chapter of the thesis reports the synthesis of indium doped cobalt ferrite with generic formula $CoFe_{2-X}In_XO_4$ using glycine assisted sol-gel autocombustion method and results of structural, morphological, magnetic, electrical and dielectric properties investigated through standard techniques.

Section snippets

Materials

The metal nitrates such as ferric nitrate ($Fe(NO_3)_3·9H_2O$), cobalt nitrate ($Co(NO_3)_2·6H_2O$), indium nitrate ($In(NO_3)_3·xH_2O$) and fuel as glycine ($C_2H_5NO_2$) was utilized for the fabrication of indium doped cobalt ferrite nanoparticles. The pH of the solution was adjusted by using liquid ammonia (NH_3). The analytical grade chemical reagents utilized in these studies and were employed without additional purification. Distilled water was used throughout the experiment.…

Synthesis of $CoFe_{2-x}In_xO_4$ nanoparticles

The indium (In) doped cobalt…

X-ray diffraction (XRD)

The X-ray diffraction patterns of indium (In) doped cobalt ferrite are shown in Fig. 1. The XRD technique was used to investigate the crystal structure and for the determination of various structural parameters. The study of X-ray diffraction pattern suggests that the reflections present are sharp and intense. All these reflections are indexed to (220), (311), (222), (400), (422), (511) and (440) planes. These planes are included in cubic structure [17]. No extra peaks other than the mentioned…

Conclusions

The conclusions of the present study are as under.

In^{3+} doped cobalt ferrite with the chemical formula $CoFe_{2-x}In_xO_4$ (x=0.00, 0.02, 0.04, 0.06, 0.08 and 0.10) were prepared with nanocrystalline nature using sol-gel autocombustion method. The single phase, homogeneous and cubic structure formation of all the samples was verified for all samples through X-ray diffraction analysis. The sample with x=0.1 shows extra peak of a-Fe_2O_3. The lattice constant increases with increasing In^{3+} content x.…

Author statement

All the persons who meet the authorship criteria are listed as authors for this manuscript, as all of them have a sufficient contribution to the present scientific work.

Shakti Bajaj: Writing the manuscript in detail. Conducting the experimental analysis and collecting complete data.; Deepali D. Andhare: Providing idea regarding the experimental analysis; Swapnil A. Jadhav: Help for correcting the manuscript.; Sangita Shinde: Help in analyse of characterization work and correcting the manuscript.…

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.…

Acknowledgements

One of the authors Shakti Bajaj is thankful to Punyashlok Ahilyadevi Holkar Solapur University, Solapur for providing XRD data, IIT Madras for providing VSM data, S. M. Patange Shri Krishna Mahavidyalaya Gunjoti for providing dielectric parameters.…

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References (25)

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Adv. Colloid Interface Sci. (2019)

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Structural, electrical, magnetic and dielectric properties of rare-earth substituted cobalt ferrites nanoparticles synthesized by the co-precipitation method
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Acta Biomater. (2013)

M.T. Rahman *et al.*
Structural characteristics, electrical conduction and dielectric properties of gadolinium substituted cobalt ferrite
J. Alloys Compd. (2014)

S.B. Ogale *et al.*
Functional Metal Oxides: New Science and Novel Applications
(2013)

G.F. Dionne
(2009)

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