ScienceDirect

Physica B: Condensed Matter
Volume 583, 15 April 2020, 412051

Effect of Zn doping on structural, magnetic and optical properties of cobalt ferrite nanoparticles synthesized via. Co-precipitation method

Deepali D. Andhare [a], Supriya R. Patade [a], Jitendra S. Kounsalye [a] [b], K.M. Jadhav [a]

Show more

Share Cite

https://doi.org/10.1016/j.physb.2020.412051
Get rights and content

Highlights

- Zn2+ substituted cobalt ferrite nanoparticles have been successfully prepared by wet chemical route.
- XRD studies confirmed the formation of cubic spinel structure.
- It's infrared, morphological, optical and magnetic properties were investigated.
- Magnetic properties were influenced significantly by nonmagnetic Zn2+ ion substitution in cobalt ferrite.
- Zn2+ ion substituted cobalt ferrite nanoparticles are desirable in biomedical applications.

Abstract

In the present work, $Co_{1-x}Zn_xFe_2O_4$ (x=0.0, 0.3, 0.5, 0.7 and 1.0) nanoparticles were prepared by chemical co-precipitation method. Prepared $Co_{1-x}Zn_xFe_2O_4$ ferrite powder was sintered at 900°C for 4h after TG-DTA thermal studies. XRD analysis revealed the single-phase cubic structure of Co–Zn ferrite nanoparticles and also studied the variation in structural parameter with increasing Zn concentration. The formation of the ferrite phase was confirmed by studying FTIR spectra. The SEM images shows the agglomeration of spherical grains due to the difference in the magnetic nature of the sample. Peaks of respective elements (Co, Zn, Fe, and O) in EDX spectra show the formation of cobalt zinc ferrite. Variation of energy band gap with increasing zinc concentration in cobalt ferrite studied by UV–Vis. Spectroscopy. The M−H loops revealed that the values of magnetic parameters such as M_S, M_r, H_c, n_B, and M_r/M_s ratio decrease with increasing Zn^{2+} content in cobalt ferrite nanoparticles.

Introduction

In recent years, the use of magnetic nanoparticles has been a vastly increased in biomedical applications. Many researchers have been focused on the improvement of magnetic nanoparticles (MNPs) as well as to improve their applicability in different areas. Investigation of ferrite nanoparticles is very much interested due to their enhanced magnetic and electrical properties [[1], [2], [3]]. Most of the applications such as Magnetic Resonance Imaging (MRI), Magnetic Hyperthermia, drug delivery, biosensors and bioimaging are depends on the magnetic properties such as spin canting effect, superparamagnetism and spin-glass-like behaviour of the magnetic nanoparticles [[4], [5], [6], [7]]. Among the various magnetic nanoparticles spinel ferrite shows excellent optical, electrical, structural and magnetic properties [8]. Spinel ferrite has general formula MFe_2O_4 (M=Zn, Co, Mn, Ni, Cu, etc.) have many applications in various field, such as biotechnology, catalysis, energy storage device, information storage system, ferrofluid technology, and electronic circuits [[9], [10], [11], [12], [13]].

M. Rahimi et al. successfully prepared PVA coated $Ni_{0.3}Zn_{0.7}Fe_2O_4$ nanoparticles by a sol-gel auto-combustion method and calculated crystallite size, as well as magnetization, were in the range 17–24nm and 16–19 emu/g respectively [14]. S. Munjal et al. Synthesized the oleic acid-coated water-dispersible $CoFe_2O_4$ nanoparticles by hydrothermal method with improved colloidal stability and also studied its applications in the biomedical field [15]. Rautet. al. synthesized the Zn substituted $CoFe_2O_4$ nanoparticles by the sol-gel auto-combustion method and reported the particle size was increased from 45 to 49nm [16]. Among the various spinel ferrites, cobalt ferrite is an important magnetic metal oxide because of its high coercivity, large magnetostrictive coefficient, and moderate saturation magnetization. The $CoFe_2O_4$ has an inverse spinel structure but when divalent metal ions such as Zn, Cd, Ni, etc. are doped in cobalt ferrite, it changes the structure of cobalt ferrite from inverse spinel to normal spinel ferrites [17]. Cobalt ferrite is the hard magnetic material and zinc ferrite is soft but the substitution of Zn^{2+} ion in cobalt ferrite reduces its hardness. Zinc substituted cobalt ferrites ($Co_xZn_{1-x}Fe_2O_4$) is one of the soft magnetic material having good chemical stability, high coercivity and highly sensitive to temperature [18]. Cobalt ferrite is generally known for its high coercivity and saturation magnetization but the substitution of non-magnetic zinc ion altered its magnetic property from ferromagnetic to superparamagnetic [19]. Magnetic material with superparamagnetic behaviour has huge applications in biomedical science.

M. Ben Ali et al. successfully prepared Co–Zn ferrites nanoparticles by the Sol-Gel method and average particle size was increased from 11 nm to 28nm [20]. M. Madhukara Naik et al. reported that the $Zn_{1-x}Co_xFe_2O_4$ nanoparticles prepared by the combustion method and calculated particle size are in the range 21 nm–12nm [21]. Magnetic nanoparticles are synthesized by various synthesis techniques such as sol-gel auto-combustion, micro-emulsion, hydrothermal technique, and forced hydrolysis method [22]. But the co-precipitation method is broadly used for the synthesis of spinel ferrite nanoparticles due to its number of good points like it is a time-consuming method, cost-effective, simple to do and reliable, etc. [23]. The chemical co-precipitation method produces a homogeneous powder with maximum yield and does not require any organic fuels like citric acid etc. Thus, in the present study, we have synthesized $Co_{1-x}Zn_xFe_2O_4$ with x value 0, 0.3, 0.5, 0.7, and 1 nanoparticles by co-precipitation method. Aim of the present work is to study the effect of Zn substitution on thermal, structural, magnetic, optical, morphological and elemental properties of Co–Zn ferrite nanoparticles investigated by TG-DTA, XRD, VSM, UV–Vis. Spectroscopy, SEM, and EDX respectively.

Section snippets

Materials and methods

$Co_{1-x}Zn_xFe_2O_4$ ferrite nanoparticles with x=0.0, 0.3, 0.5, 0.7 and 1 were synthesized by the co-precipitation method. Analytical grade cobalt chloride hexahydrate ($CoCl_2·6H_2O$), zinc chloride ($ZnCl_2$), ferric chloride ($FeCl_3$) and sodium hydroxide (NaOH) were used as raw materials. Nanoparticles prepared by co-precipitating aqueous solutions of $CoCl_2·6H_2O$, $ZnCl_2$. and $FeCl_3$. Initially, the solutions of $CoCl_2·6H_2O$, $ZnCl_2$, and $FeCl_3$ were mixed in their respective stoichiometric amounts (7 ml of 1 M…

Thermo - Gravimetric and Differential thermal analysis (TG-DTA)

TG-DTA was performed under a nitrogen atmosphere in such a way that temperature varies from 23 °C to 1200 °C with heating rate 20 °C/min. According to TG–DT analysis (Fig. 1) it is clear that the removal of water, decomposition of metal hydroxide and formation of spinel ferrite can be completed below 900 °C temperature [24]. Three different weight losses exhibit in the TGA curve and DTA curve shows two endothermic and one exothermic peak corresponding to each weight loss [25]. First weight loss …

Conclusion

$Co_{1-x}Zn_xFe_2O_4$ ferrite nanoparticles with x value 0.0, 0.3, 0.5, 0.7 and 1were successfully synthesized by co-precipitation method. $Co_{1-x}Zn_xFe_2O_4$ (x=0, 0.3, 0.5, 0.7, and 1) nanoparticles possess single-phase cubic spinel structure was confirmed by XRD analysis. The crystallite size increases with increase Zn substitution in prepared samples were observed from the XRD study. Structural parameters such as lattice constant and X-ray density increase with increasing zinc concentration. Two main…

Credit author statement

1. Study conception and design: **K. M. Jadhav**.

2. Acquisition of data: **Deepali D. Andhare, Supriya R. Patade**.

3. Analysis and interpretation of data: **Deepali D. Andhare, Supriya R. Patade, Jitendra S. Kounsalye, K. M. Jadhav**.

4. Drafting of manuscript: **Deepali D. Andhare, Supriya R. Patade, Jitendra S. Kounsalye, K. M. Jadhav**.

5. Critical revision: **Deepali D. Andhare, K. M. Jadhav**.…

Declaration of competing interest

No conflict of interest.…

Acknowledgements

The Author (Miss. Deepali D. Andhare) is thankful to Dr. V. Ganesan, Ex-centre director of UGC-DAE consortium for scientific research, Indore, India for providing UV–Vis spectroscopy measurement facilities. Authors are grateful to Dr. Alok Banerjee centre director of UGC-DAE consortium for scientific research, Indore, India for providing vibrating sample magnetometer (VSM) measurement facilities and also thankful to Dr. D. M. Phase and Dr. V. K. Ahire scientist UGC-DAE consortium for scientific …

Recommended articles

References (38)

G.R. Gordani *et al.*

Enhanced magnetic properties of substituted Sr-hexaferrite nanoparticles synthesized by co-precipitation method
Ceram. Int. (2014)

S. Alone
Chemical synthesis, structural and magnetic properties of nano-structured Co–Zn–Fe–Cr ferrite
J. Alloys Compd. (2011)

M. Rahimi
The effect of polyvinyl alcohol (PVA) coating on structural, magnetic properties and spin dynamics of Ni0. 3Zn0. 7Fe2O4 ferrite nanoparticles
J. Magn. Magn Mater. (2013)

S. Munjal
Water dispersible CoFe2O4 nanoparticles with improved colloidal stability for biomedical applications
J. Magn. Magn Mater. (2016)

A. Raut
Synthesis, structural investigation and magnetic properties of Zn2+ substituted cobalt ferrite nanoparticles prepared by the sol–gel auto-combustion technique
J. Magn. Magn Mater. (2014)

R.S. Yadav
Magnetic properties of Co1− xZnxFe2O4 spinel ferrite nanoparticles synthesized by starch-assisted sol–gel autocombustion method and its ball milling
J. Magn. Magn Mater. (2015)

A. Amri
Developments in the synthesis of flat plate solar selective absorber materials via sol–gel methods: a review
Renew. Sustain. Energy Rev. (2014)

A. Bardhan
Low temperature synthesis of zinc ferrite nanoparticles
Solid State Sci. (2010)

Z. Tianshu
Ethanol-sensing characteristics of cadmium ferrite prepared by chemical coprecipitation
Mater. Chem. Phys. (1999)

M. O'Donnell

Structural analysis of a series of strontium-substituted apatites
Acta Biomater. (2008)

View more references

Cited by (141)

Bioinspired ferromagnetic NiFe<inf>2</inf>O<inf>4</inf> nanoparticles: Eradication of fungal and drug-resistant bacterial pathogens and their established biofilm
2024, Microbial Pathogenesis

Show abstract

Green synthesized manganese-doped cobalt ferrite photocatalysts for light driven degradation of dye and optoelectronic studies
2024, Ceramics International

Show abstract

The effect of apple pectin agent on the structural, magnetic, and optical properties of cobalt ferrite nanoparticles synthesized by the auto-combustion sol-gel method
2024, Materials Chemistry and Physics

Show abstract

Investigation on structural, morphological, optical, magnetic properties of CdO-CoFe<inf>2</inf>O<inf>4</inf> nanocomposites and their photocatalytic application
2024, Optik

Show abstract

Rare earth-doped mixed Ni–Cu–Zn ferrites as an effective photocatalytic agent for active degradation of Rhodamine B dye
2024, Journal of Rare Earths

Show abstract

Controlling magnetic and surface properties of cobalt ferrite nanoparticles: A comparison of co-precipitation and solvothermal synthesis methods
2024, Solid State Sciences

Show abstract

View all citing articles on Scopus

View full text