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Original research article

Effect of Cd^{2+} doping on structural, morphological, optical, magnetic and wettability properties of nickel ferrite thin films

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Abstract

$Ni_{1-x}Cd_xFe_2O_4$ ($0.0 \leq x \leq 1.0$ in step of 2) spinel ferrite thin films have been synthesized by spray deposition technique. The prepared films were characterized by X-ray diffraction, Raman spectroscopy, Scanning Electron Microscopy, UV–vis spectroscopy, Photoluminescence and contact angle measurement studies. The analysis of XRD pattern reveals broad peaks exhibiting a single phase cubic spinel structure. The crystallite size obtained from Scherrer's formula varies between 8–24 nm confirming the nanocrystalline nature. Metal cation active vibration modes, metal oxygen stretching and bending vibrations were confirmed through the Raman analysis. The FE-SEM shows that the formation of spherical agglomeration and grain size are found to be in the range of 19–38 nm. The elemental compositions of the prepared thin films were studied by EDS. The energy band gap decreases from 1.86 to 2.11 eV with increase in Cd^{2+} content x calculated by using UV–vis data. The Photoluminescence study showed the characteristic near-band-edge emission of presently investigated films samples at around 710 nm. All films are hydrophilic in nature conformed by contact angle measurement.

Introduction

In the recent years, due to miniaturizing technology many devices like memory, spintronics, and other multifunctional devices have rapidly developed [[1], [2], [3], [4], [5]]. Many magnetic structures with nanoscale dimensions plays important role in the development of new devices [[6], [7], [8], [9], [10]]. The ferrites have more attention due to their electrical resistivity and magnetic properties where as high frequencies devices application [11,12]. On account of the trend for smaller size of electronic apparatus and their potential applications of magnetic materials, which is due to the fabrication of ferrite thin films [[13], [14], [15]]. Ferrite thin films with high resistivity are used for the insulators, circulators, gyrators in microwave devices, microwave integrated circuits etc. which are supposed to replace the surface mounted devices (SMD) in near future [16,17]. The spinel type of magnetic materials is commonly used in magnetic devices and electronic due to their magnetic losses and high permeability. Nowadays many researcher and scientists focused on the spinel ferrite thin film because their many application in various field such as technology, hyperthermia, water purification, biomedical application [[18], [19], [20]]. Among the different types of ferrites strongly correlated spinel oxides of MFe_2O_4 (M = divalent metal ion, e.g. Co, Ni, Cu, Cd etc.) structure, which are commonly known as spinel ferrites. Among the ferrite properties, which are depend on their physical properties of size and surface effects to the bulk materials. Among the various spinel type ferrites, nickel ferrite ($NiFe_2O_4$) is considered as important ferrites used for different technological applications, humidity sensor, gas sensing and supercapacitors [21]. The nickel ferrite has low eddy current, catalytic behaviour, high stability and low conductivity as well as abundance in nature which is due to the exhibiting excellent ferromagnetic properties [22]. Nickel ferrite can also exhibit spin glass like behaviour which is one of the important characteristics that leads to many interesting behaviour like shifting hysteresis loops, anomalous relaxation dynamics and high field irreversibility [23]. $NiFe_2O_4$ thin film with spinel structure of great interest due to their high resistivity, high magnetic permeability, and low losses, producing the for the high-frequency. Nickel ferrite in pure and substituted form is technologically important magnetic material and has been subject of interest for many scientist and technologist [24]. The Cadmium ferrite is a non-magnetic materials and Cd^{2+} substituted nickel ferrites are prepared in the nanoscale they show tunable magnetic behavior. Cadmium ferrite ($CdFe_2O_4$) and zinc ferrite ($ZnFe_2O_4$) both possesses spinel structure in which Cd^{2+} and Zn^{2+} ions occupy tetrahedral (A) site and all the Fe^{3+} ions occupy octahedral [25] sites. The important magnetic, electric and other properties of the nickel ferrite are affected by the composition, amount and type of substitution, preparation

techniques, cation distribution etc. [26]. The substitution of cadmium in spinel ferrite enhances the magnetic properties like saturation magnetization as reported in the literature [25,27]. In the literature, cadmium substituted nickel ferrite in bulk and nano powder form have been studied by many researchers because of its wide applications in antenna rods, recording heads, microwave devices etc. [[28], [29], [30], [31]]. However, no reports are available on systematic investigations of structural, morphological, optical, wettability and magnetic properties of Cd^{2+} substituted $NiFe_2O_4$ thin films deposited by chemical spray technique. Spray pyrolysis technique is a unique technique which produces uniform, homogeneous and nanostructured thin films. Apart from this, the method is simple and cost effective over the other deposition techniques like sputtering, pulse laser deposition, dip coating process etc. [32].

In the present work, Cd^{2+} substituted $NiFe_2O_4$ thin films having the general chemical formula $Ni_{1-x}Cd_xFe_2O_4$ (where x = 0.0–1.0 in step of 0.2) were produced by spray pyrolysis technique by optimizing all the necessary parameters. The structural, morphological, optical wettability and magnetic properties were investigated and results are presented here.

Section snippets

Materials

The AR grade cadmium nitrate ($Cd(NO_3)_2 \cdot 6H_2O$), nickel nitrate ($Ni(NO_3)_2 \cdot 4H_2O$) and ferric nitrate ($Fe(NO_3)_3 \cdot 9H_2O$) were used as starting materials. The glass substrates carefully dipped in chromic acid at 1 h. These glass slides cleaned in the ultrasonic bath for 30 min and acetone used for the surface of glass; were used as glass substrate.…

Synthesis of thin films

The all AR grade nitrates are dissolved in double distilled water. The total solution was sprayed by using chemical spray set up on the cleaned glass…

X-ray diffraction

The X-ray diffraction technique was employed to evaluate the structural properties of Cd^{2+} substituted nickel ferrite ($Ni_{1-x}Cd_xFe_2O_4$ thin films as shown in Fig. 1 **(a)**. XRD pattern show well defined reflections which could be indexed as (220), (311), (222), (511), (440) and (533). The presence of all these peaks confirms the development of the cubic spinel structure. A close examination of the XRD pattern indicates that, the reflections shifted towards lower 2θ angle with increase in Cd^{2+}…

Conclusions

The present work reports successful spray deposition of Cd^{2+} substitution $NiFe_2O_4$ ferrite thin films with chemical formula $Co_{1-x}Cd_xFe_2O_4$ (x = 0.0, 0.2, 0.4, 0.6, 0.8 and 1.0) on preheated glass substrates. XRD analysis confirmed the formation of single phase cubic spinel structure with crystallite sizes ranging in between 8–24 nm. The lattice constant and X-ray density was found to be increased with increase in cadmium doping. The FE-SEM analysis confirmed the spherical grain morphology with…

CRediT authorship contribution statement

H.J. Kardile: Investigation, Methodology, Data curation, Formal analysis, Writing - original draft. **Sandeep B. Somvanshi:** Investigation, Methodology, Data curation, Formal analysis, Writing - original draft, Writing - review & editing. **Apparao R. Chavan:** Investigation, Methodology, Data curation, Formal analysis, Writing - original draft. **A.A. Pandit:** Writing - original draft. **K.M. Jadhav:** Conceptualization, Supervision, Writing - original draft, Writing - review & editing.…

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.…

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References (54)

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