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Synthesis of Nickel Ferrite and Cobalt doped Nickel Ferrites of NixCo1−xFe2O4 (x =0,0.2,0.4,0.6,0.8, 1.0) of single-phase well-crystallized Nano sized particles by hydrothermal method

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Abstract:
The synthesis and characterization of Ni ferrite Co doped - nanomaterials. NixCo1−xFe2O4(x =0,0.2,0.4,0.6,0.8, 1.0) Research can explore different synthetic routes such as sol-gel, co-precipitation, hydrothermal, and microwave-assisted methods to achieve nano sized Co-Ni ferrite Co- doped particles with controlled properties. advanced characterization techniques such as X-ray diffraction (XRD), transmission electron microscopy (TEM), and magnetic measurements can provide insights into the crystal structure, morphology, and magnetic properties of Ni ferrite Co- doped nanomaterials. Tuning magnetic properties: Co-Ni ferrite Co doped - nanomaterials exhibit superior magnetic properties such as high saturation magnetization, coercivity, and magnetic anisotropy, which can be tuned by controlling the dopant concentration, particle size, and synthesis conditions. Research explore the effect of these parameters on the magnetic properties of Ni ferrite Co- doped nanomaterials and optimize them for specific applications. Application-specific studies Ni ferrite Co- doped nanomaterials have shown great potential in various applications such as magnetic data storage, microwave devices, sensors, and catalysis. Future work can focus on the application-specific studies of Ni ferrite Co doped - nanomaterials to underst and their performance in real-life scenarios.

Key Words: Ni ferrite Co doped – nanomaterials, sol-gel, co-precipitation, hydrothermal, X-ray diffraction (XRD), transmission electron microscopy (TEM).

Introduction

the research work Nickel Ferrite and Cobalt doped Nickel Ferrites of single-phase well-crystallized Nanosized particles of$Ni_xCo_{1-x}Fe_2O_4$(x =0,0.2,0.4,0.6,0.8, 1.0) were successfully synthesized via well-known hydrothermal method at a relatively low temperature (100 ◦C) for 24 hrs. The structural and magnetic properties were examined with the help of X - ray diffraction and vibrating sample magneto meter characterization technique. The present study displayed the result of Co doping on structural and magnetic properties of $Co_xNi_{1-x}Fe_2O_4$ (x =0.2, 0.4, 0.6, 0.8) nanoparticles synthesized by hydrothermal method. XRD analysis confirmed that these nanomaterials come under the family of inverse spinel ferrites of single phase spinel cubic structure and lattice parameter varied between 8.22 nm to 8.41nm [1]. It is found that on increasing the Co doping concentration the crystallite size (D) also increases with it. On increasing Co doping concentration the increase of crystallite size may be happened due to the Co^{2+} ions larger sizeas compared to Ni^{2+} ions. It was also observed that the synthesized samples exhibits more crystalline structure on increasing the doping concentration of Co and has been examined by FESEM - EDX study, confirmed that all the elements are present in the samples as per stoichiometric ratio at x = 0.2, 0.4, 0.6 and 0.8. Moreover, the study of FTIR an alysis confirms that the synthesized nanoparticles have spinel cubic structure and show two fundamental bands, v_1 and v_2 corresponding to the tetrahedral and octahedral complexes respectively in the frequency range of 4000–400 cm^{-1}. The band, v_1, shifts towards the higher frequency site from 468 cm^{-1} to 470 cm^{-1} while the band v_2 shifts towards the lower frequency site from 603cm^{-1}to596$cm^{-1}$with increasing of Co concentration. Further more, it was confirmed that the optical properties such as tetrahedral and octahedral vibrations of the sample from the FTIR characterization analysis and the spinel nature of ferrites were observed as the spectra detecting tetrahedral and octahedral modes of vibrations at 600 cm^{-1} and 480 cm^{-1} respectively [2, 3].

Further FESEM, as well as TEM images clearly showed that the particles have size and morphology in nanoscale range. The M-H curve obtained from VSM used for the estimation of magnetic properties such as coercivity, remanence magnetization, saturation magnetization and squareness ratio. On increasing doping concentration of cobalt the saturation magnetization (M_s) firs decreases up to x = 0.4 and then increases afterwards as observed from hysteresis loop drawn from VSM study. The reduction of saturation magnetization (M_s) value is attributed to the domination of spin canting effect initiated by prominent secondary phase found in the sample. The increase in the saturation magnetization (M_s) value is attributed to Co^{2+} ions high magnetic moment that replace the Ni^{2+} ions in octahedral (B) sites and decreasing the effect of secondary hematite phase [4]. Similarly, Coercivity (H_c) value also depends on the particles size and magnetization [5]. The observed coercivity (H_c) value of the prepared sample at x = 0.6 concentration is larger than the samples at x = 0.4 and 0.8 concentration. This is because of inverse relation of coercivity(H_c) with particle size and magnetization [1, 5, and 6]. Further increased value of remnant magnetization (Mr) and coercivity (H_c)with doping concentration is due to distribution of Co^{2+} ions in sites B having positive K [3]. The widening of hysteresis loop indicates the increasing of hardness of hydrothermally prepared CNF nanoparticles. The energy band gap of Nickel ferrite and Cobalt ferrite nanoparticles from UV-Visible Spectroscopy studies were found as 1.9 eV and 2.63 eV. The energy band gap of synthesized CNF nanoparticles was found to be increased from 1.9 eV to 2.63 eV with the increasing of doping concentration of cobalt. Ferrites have large applications in various fields because of their large coercivity, high magnetic flux and contain large magnetic permeability in a magnetically saturated state which turns them to store strong magnetic fields than the iron itself. They can be used as Giant Magneto Resistance (GMR) based sensors, e- spintronic devices, magnetic RAM, Information storage devices and other novel gadgets [7].Soft ferrites are also used in the core of magnetic memories, inductors, transformers, and microwave components [8, 9]. Modern applications of ferrite nanoparticles include gas sensing [10], catalytic application [11] and high density magnetic storage media [12, 13].

Scope of Future Work

Cobalt doped nickel ferrite nanomaterials have been the subject of extensive research due to their potential applications in various fields such as catalysis, magnetic data storage, microwave devices, sensors, and biomedical applications. That is why Cobalt-doped nickel ferrite (Co-Ni ferrite) nanomaterials have attracted significant attention in recent years by their unique physical and chemical properties, which make them suitable for various applications. The scope of future work in this area is broad and includes several directions,

Synthesis and characterization: One of the most important areas of future work is the synthesis and characterization of Co-Ni ferrite nanomaterials. Researchers can explore different synthetic routes such as sol-gel, co-precipitation, hydrothermal, and microwave-assisted methods to achieve nanosized Co-Ni ferrite particles with controlled properties. Moreover, advanced characterization techniques such as X-ray diffraction (XRD), transmission electron microscopy (TEM), and magnetic measurements can provide insights into the crystal structure, morphology, and magnetic properties of Co-Ni ferrite nanomaterials. Tuning magnetic properties: Co-Ni ferrite nanomaterials exhibit superior magnetic properties such as high saturation magnetization, coercivity, and magnetic anisotropy, which can be tuned by controlling the dopant concentration, particle size, and synthesis conditions. Researchers can explore the effect of these parameters on the magnetic properties of Co-Ni ferrite nanomaterials and optimize them for specific applications. Application-specific studies: Co-Ni ferrite nanomaterials have shown great potential in various applications such as magnetic data storage, microwave devices, sensors, and catalysis. Future work can focus on the application-specific studies of Co-Ni ferrite nanomaterials to understand their performance in real-life scenarios. For example, researchers can study the effect of Co-Ni ferrite nanomaterials on the microwave absorption properties of polymer composites or investingate their catalytic activity in different chemical reactions. Composite materials: Co-Ni ferrite nanomaterials can be combined with other materials to form composite materials with enhanced properties. Future work can focus on the synthesis and characterization of Co-Ni ferrite-based composite materials and their performance in various applications such as energy storage, water treatment, and biomedical applications.

Overall, the future scope of work in cobalt doped nickel ferrite nanomaterials is vast and offers numerous exciting opportunities for researchers to explore the potential applications of these materials in different fields.

The results of this study suggest that there are grounds for claiming that the structural factor can be improved as it is related to the nature of the dopant. With an increase in density similar to this, the magnetic properties of samples of cobalt ferrite could be improved with an increase in the magnetostriction. The magnetic factor is related to the fact that the easy axes of magnetization are arranged in different directions in each magnetic domain. The future step in this approach would be the development of magnetic properties to achieve super paramagnetism by doping with more than one dopant and by controlling the sintering operations that is to cause the alignment of the easy axes of magnetization of these particles.

Conclusions

Nano $Ni_{0.2}Mg_{0.8-x}Zn_xFe_2O_4$ferrites are prepared using sol-gel method at low calcinated temperatures successfully. The important conclusions obtained are as follows.

- The Prepared Nano $Ni_{0.2}Mg_{0.8-x}Zn_xFe_2O_4$having spinel cubic structure and lattice parameter is varying from **8.337 A^0 to 8.420 A^0.**
- The nano ferrites having crystallite size from**5nm–69.4nm.**
- The **EDS** spectra confirms the presence of elements Ni,Mg,Zn,Fe and O.
- The direct band gap of the nano ferrites is FTIR Study indicates the formation of **M-O bonds** and prominent frequency bands corresponding to Tetrahedral and Octahedral sites present in the ferrites.
- The ferrites prepared at the calcination temperature 450 ^{0}C having enhanced magnetic properties compared to the ferrites prepared at the calcination temperatures 400 ^{0}Cand 500 ^{0}C.
- The prepared ferrites having the influence of atoms at octahedral sites and the experimental magnetic moments strongly influences by cationic distributions.
- The susceptibility studies of the ferrites preparing showing the ferro to para magnetic behaviour above the magnetic transition temperatures.
- Thehighε'~163.1(at1MHz) was noticed at x=0.2content calcined at 500^{o}C.
- The $\ln\zeta_{ac}$-T^{-1} plots showed the decrease of activation energies in both high and low temperature regions.
- The frequency and temperature dependence of dielectric modulus and impedance parameters showed the space charge effect and relaxation dynamics, further the prepared ferrites show non-Debye relaxations.
- The Nyquist plots (Cole-Cole plots) of ferrites prepared also confirms the non-Debye relaxations. Most of the electrical conduction mechanism is due to grains rather than grain boundaries.

Applications

- The prepared nano $Ni_{0.2}Mg_{0.8-x}Zn_xFe_2O_4$ ferrites at 450 ^{0}C having the applications in the optoelectronic and photocatalysis applications.
- The enhanced magnetic properties of the ferrites calcinated at 400^{0}C,450^{0}C & 500^{0}C having applications in the soft magnetic applications.
- Theferritespreparedat500^{0}Cwith(x=0.2)havinghighdielectricconstantcanbe used for the high charge storage applications.
- The optical and dielectric properties of show that these ferrites prepared can be usedin semiconducting applications also.

Future scope of the work

The optical, magnetic, dielectric and impedance properties of nano ferrites are strongly influenced by the preparation methods, calcination temperatures and cationic distribution. Hence by adopting different preparation mechanism and sintering temperatures these nano $Ni_{0.2}Mg_{0.8-x}Zn_xFe_2O_4$ (x = 0.0,0.2,0.4,0.6,0.8) ferrites may be used for modern nano technology applications such as target drug delivery, high energy storage applications, soft magnetic applications, magnetic resonance imaging (MRI) technology etc.

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Conflict of Interest:

The author has no conflict of interest regarding the research.

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