Structural and optical study of $CoFe_2O_4$, $NiFe_2O_4$ NanoParticle Synthesized via Hydrothermal synthesis

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Abstract:

The Cobalt ferrite nanoparticles (CFN), Nickel ferrite nanoparticles (NFN) were prepared through the hydrothermal synthesis method. The X-ray diffraction (XRD) pattern, Fourier transforms infrared spectroscopy (FTIR), Transmission Electron microscopy (TEM), and field emission scanning electron microscopy (FESEM) used to study structural and surface properties for the CFN and NFN samples.). The FESEM image shows the morphology with stone-like particles with agglomeration between particles. The TEM images reflect the nano size of the particle with the strong attraction between the particle and this type of nature useful in memory device applications. The FTIR and UV-Visible spectroscopy techniques were used to study the optical properties of Cobalt and Nickel ferrite nanoparticles. The FTIR gave the conformation of spinel configuration by the arrangement of octahedral and tetrahedral stretching spinel characteristic modes of frequencies The energy band gap values 1.4eV and 1.6 eV for the CFN and NFN particles found from UV-Visible spectroscopy.

Keywords: Hydrothermal technique, Transmission electron microscopy, UV-visible spectroscopy

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1. Introduction

The magnetic ferrite particles common formula AB_2O_4 where 'A' represent tetrahedral site occupied with Fe^{3+} cations and B divalent metal elements (M= Cu, Mn, Mg, Co, Ba) indicates octahedral site. The wide range of applications of ferrites is extensively used by magnetic materials as they having various kinds of properties to lead a variety of applications. The ferrite characteristic properties are high electrical resistivity, saturation magnetization and permeability can change usually by selecting proper materials [2]. These Ferrite materials are used in various applications like in the field of electronic devices, microwave devices, memory devices (RAM, ROM, Hard disk, magnetic tapes), humidity sensors, and biomedical applications [2]. When the micro size of ferrites particles is converted into the nano-size their properties also change widely. However, the synthesis of nanoparticles put together the challenge to get the required physical properties. Hence, many synthesis techniques were practiced to get resourceful properties. Commonly used synthesis techniques are co-precipitation, polyol method, hydrothermal thermal method, sol-gel technique, citrate gel, and salvo thermal, techniques…etc [3]. Compare to all preparation techniques the hydrothermal technique is efficient and effective to prepare the magnetic nanoparticles [4]. The physical properties could depend on the sintering temperature soaking time, pH of the solution [5-8] by modification of the surface, structural, magnetic properties of nano ferrite particles and strongly affected the size of particles as well as purity of the samples [9]. The pH of the precursor's mixer can be the accomplished factor that can change the reaction of the synthesis processes [10].

Comparing to all of the other magnetic ferrites the Co and Ni ferrites are good electric and magnetic and magneto-electric nature, whereas most parts studied in material science. The bulk and nanostructures of Nickel, cobalt ferrite, and its mixers prepared by various researches through

different preparation methods and exceptional preparation conditions like soaking time, sintering temperature [11] and pH conditions [12], etc…Nickel ferrite and cobalt ferrite nanoparticles are multifunctional and technically widely used soft magnetic ferrite with ferromagnetic nature. The ferrite characteristics like lower eddy current loss, stable thermal stability needed for the high radiation applications. The superparamagnetic nature is an important property of the nickel ferrite it helps some biomedical applications like drug delivery, cancer treatment applications, and cobalt ferrite's high saturation magnetization values lead to memory device purpose; viewing to this facts Nickel ferrite and cobalt ferrites were got impressive importance in the engineering and technology. In this connection, the authors are interested to study the basic properties such as Structural, morphological, and optical properties with the help of X-Ray diffraction, FESEM, TEM, FTIR, UV- Visible spectroscopy characterization techniques.

2. Experimental Technique

The hydrothermal technique is used for the synthesis of nickel and cobalt ferrite nanoparticles. Co $(NO_3)_2.6H_2O$, Nickel nitrate: Ni $(NO_3)_2.6H_2O$ and Iron nitrate Fe $(NO_3)_3.9H_2O$ are taken as precursors all chemicals are AR grade elements and mixed as per calculations to synthesize $CoFe_2O_4$, $NiFe_2O_4$ magnetic nanocomposites by adding the sodium hydroxide (NaOH) to the mixer of nitrates the resultant solution changes into brown color to maintain pH is 13. Then After two hours, the perfect stirred solution was moved into Teflon coated steel autoclave after two hours of stirring of solution completely. Then the autoclave closed tightly for deposition of the Hot air oven for 24 hours taken as soaking time and temperature of the oven is 423K. Finally, reacted nanoparticle composition was kept in the oven for 373K to sintering. The rotor is sed make the samples as powder later the powder of Nickel ferrite and Cobalt ferrite powder type sample can be

used for the various characterization techniques XRD, FESEM and TEM, UV-Visible spectroscopy, FTIR.

3. RESULT AND DISCUSSION

3.1. XRD Study

Figure.1 illustrates the x-ray diffraction spectra of $CoFe_2O_4$, $NiFe_2O_4$ MNPs synthesized through hydrothermal synthesis. The structural parameters lattice parameter, crystallite size; volume found using formulae reported in previous articles the calculated values are revealed in table [12].

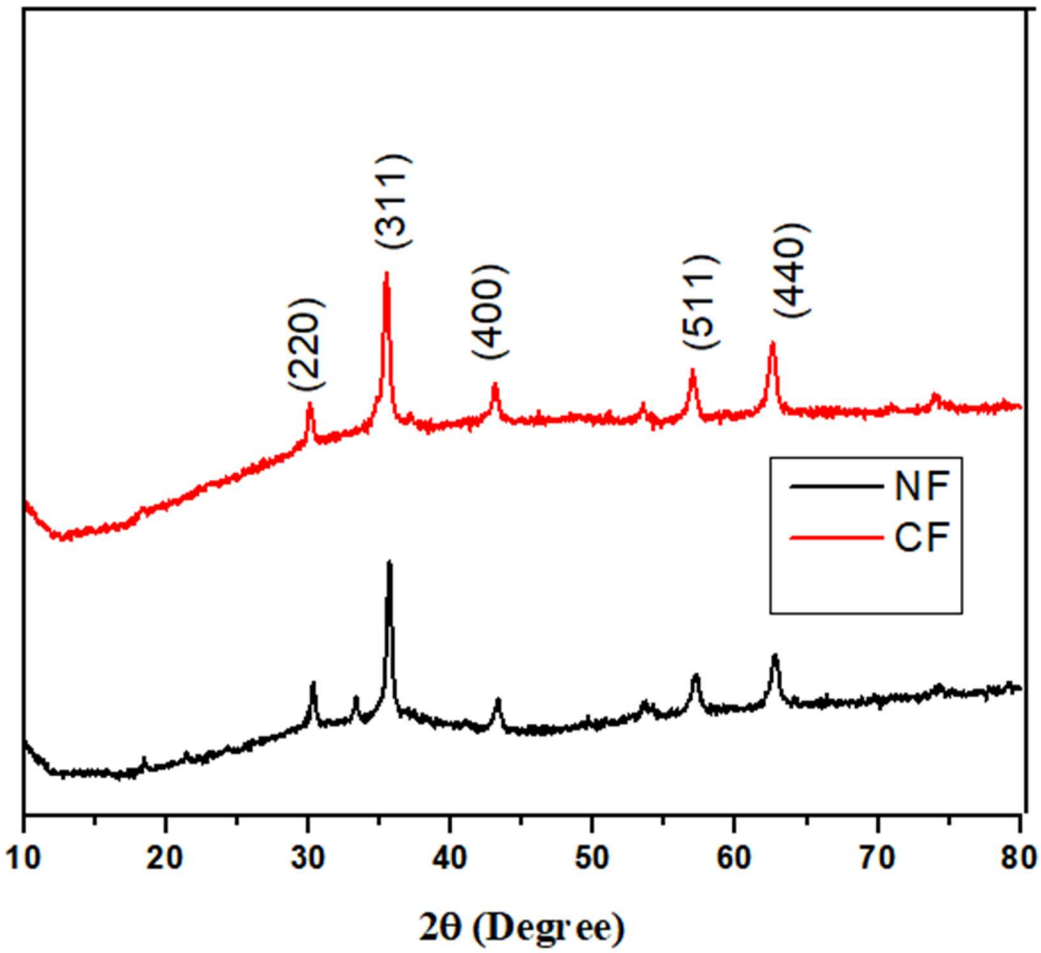

Figure.1. XRD pattern of Cobalt ferrite (CF) and Nickel ferrite (NF)

Table.1 Structural property of CFN NFN particles

x	CFN	NFN
a (nm)	8.11	8.22
D (nm)	18.92	19
V(nm^3)	533.412	555.412
υ_1(cm^{-1})	580	575
υ_2(cm^{-1})	475	470
Eg (eV)	1.4	1.6

3.2 FESEM and TEM study

The morphology of the cobalt ferrite and Nickel ferrite nanoparticles are checked with the help of well-known morphology techniques Field emission scanning electronic microscopy (FESEM) and Transmission electron microscopy (TEM). The surface morphology and size orientation were verified $CoFe_2O_4$ and $NiFe_2O_4$ from obtained micrographs as shown in figure.2. The FESEM images reflected the small aggregation of nanoparticles with condensed agglomeration among the surfaces of the particles of Nickel ferrite then cobalt ferrites. The huge surface energy of Nickel ferrite was responsible for the large agglomeration in nickel ferrites. The TEM images of prepared nanoparticles are depicted in figure.3. The TEM images of cobalt ferrite and nickel ferrite appear as square shapes clearly with partially stretched particles to be small. However, in the nanoscale (50 nm magnification) TEM images show agglomeration in the sample indicate the strong magnetic nature of the particles. The average size of CFN and NFN was found to be 15 nm and 18 nm respectively [13-15].

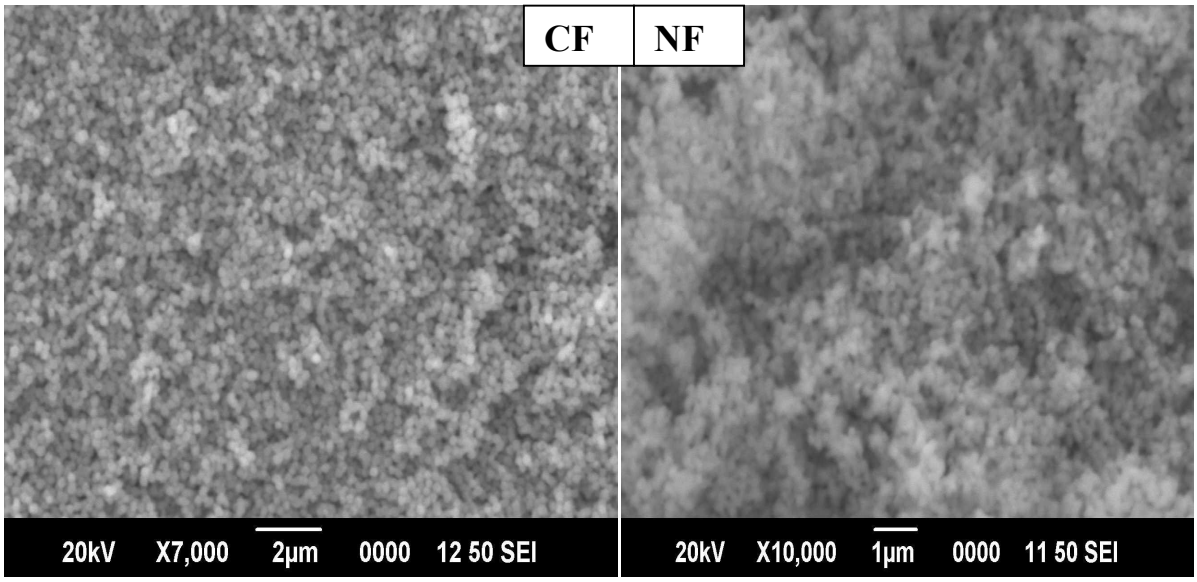

Figure.2. FESEM micrographs of Cobalt ferrite (CF) and Nickel ferrite (NF) nanoparticle

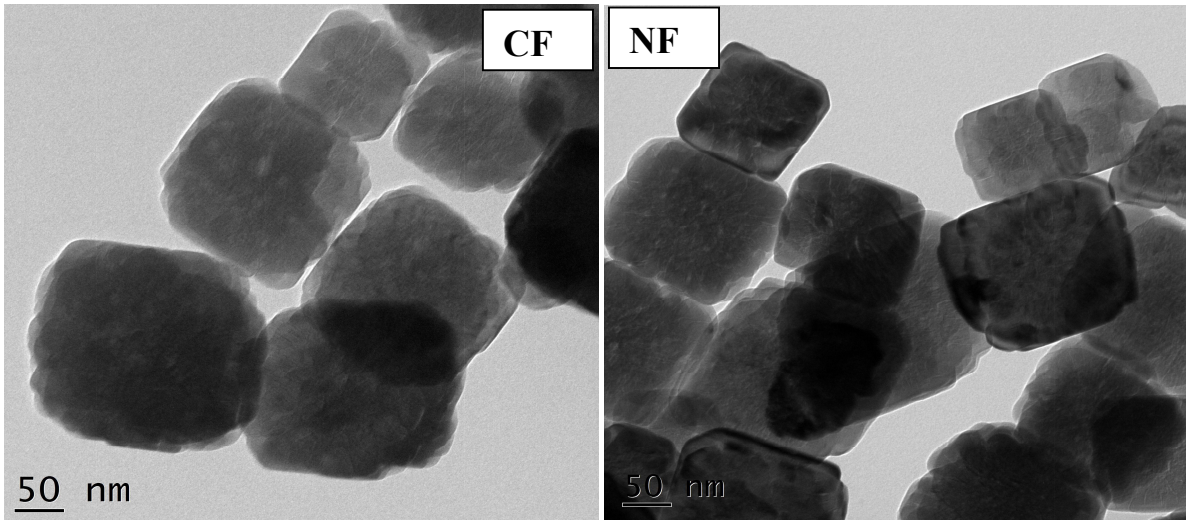

Figure.3. TEM nano graphs of Cobalt ferrite (CF) and Nickel ferrite (NF)

3.3. FTIR spectra

The FTIR spectra were obtained as a function of wavenumber and transmittance as shown in the figure.5 The spinel nature of ferrites observed as the spectra detecting tetrahedral and octahedral modes of vibrations at the 580cm^{-1} and 480cm^{-1} [16-17]. These similar studies were reported by babu et.al [18] to get spinel characteristic vibration. The octahedral and tetrahedral modes vibrations are found from spectra and tabulated in table.1.

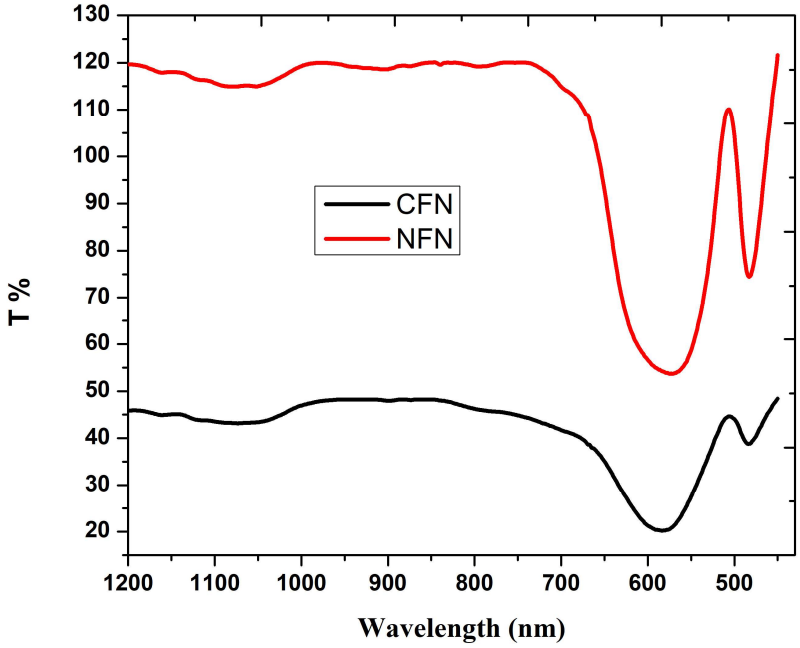

Figure.4. FTIR spectra of the CF and NF particles

3.4. UV-Visible spectroscopy

The optical properties of synthesized Nickel ferrite and cobalt ferrite nanoparticles were estimated using diffused reflectance phenomena of UV-Visible spectroscopy. The absorption spectra for the CFN and NFN particles presented in figure.6 clears the range absorption between 300 nm to 500nm. The Tauc plot was drawn based on the DRS spectra are shown fig. The values $(\alpha h\upsilon)^2$ and $h\upsilon$ are calculated as per the Kubelka-Munk method, The absorption coefficient α was found using the relation $\alpha = (1-R)^2/2R$ where R is the diffusion reflectance [19]. The energy bandgap from Tauc plots was found as 1.4 eV and 1.6 eV for Copper ferrite and Nickel ferrite nanoparticles from fig.6, this type of optical behavior is observed by Thomas et.al [20].

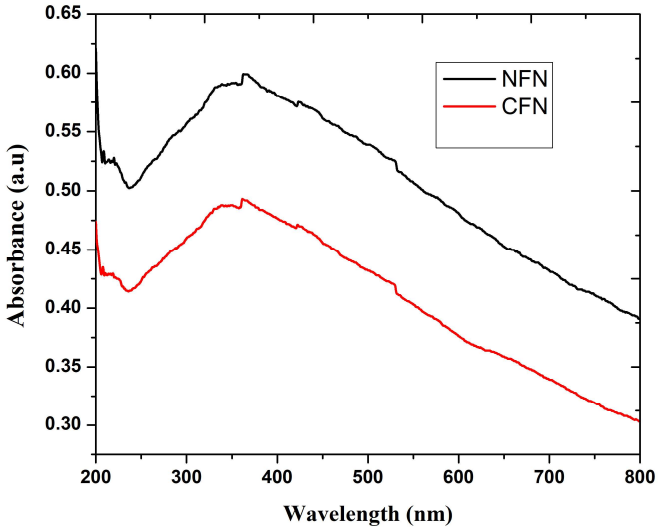

Figure.5. absorption spectra of Cobalt ferrite (CF) and Nickel ferrite (NF) nanoparticles

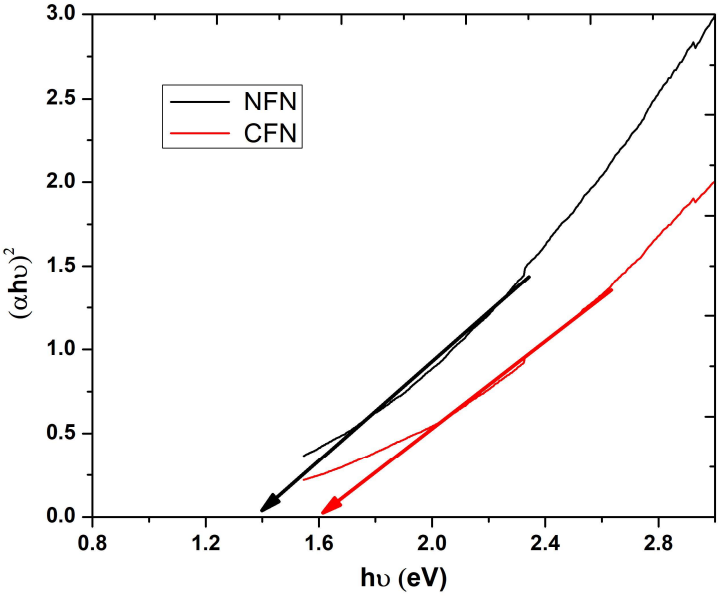

Figure.6. Energy band gap estimation of Cobalt ferrite (CF) and Nickel ferrite (NF) nanoparticles

4. Conclusion

In this work Cobalt ferrite, Nickel ferrite nanoparticle prepared via hydrothermal synthesis. The structural properties evaluated using x-ray diffraction studies. Moreover, the FTIR analysis shows the synthesized nanoparticles have a spinel structure. Also, FESEM, as well as TEM images, show morphology clearly and particle size found in the nano range. Furthermore, the optical properties such as tetrahedral and octahedral vibrations of the sample from the FTIR and energy bandgap 1.4eV and 1.6eV for Nickel ferrite and Cobalt ferrite nanoparticles were revealed from UV-Visible spectroscopy studies.

5. Acknowledgment

The authors express their thanks to the Department of Physics, Sri Krishnadevaraya University, Anantapuramu, for providing laboratory facilities to carry out the present research work. The financial support was rendered by the UGC under SAP [NO.F 530/5/DRS-II/2016(SAP I).and Department of Science and Technology under FIST [SR/FST/PSI-116/2007], New Delhi, are gratefully acknowledged.

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