

Preparation and Magnetic Analysis of Nickel Ferrite Nanopowders Using Chemical Co-Precipitation

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ABSTRACT

Nanoparticles of pure nickel with general formula NiFe_2O_4 have been synthesized by wet chemical co-precipitation method. Room temperature X-ray diffraction (XRD) patterns were recorded for the prepared sample to confirm the single phase cubic spinel structure formation. Scanning electron microscope studies were carried out on prepared sample to study the surface morphology. The particle size obtained from XRD and SEM data is of the order of nanometer range. The lattice constant was in the reported range. The magnetic properties were investigated using pulse field hysteresis loop technique. The saturation magnetization and coercivity values were found to be greater compared to bulk counterpart.

KEYWORDS: Nanoparticles, X-ray diffraction, co-precipitation, magnetic.

INTRODUCTION

Spinel ferrites of the type MFe_2O_4 attract several researchers because of their twin property of magnetic conductor and electric insulator. These materials are widely used in the electronic and electrical industries for the fabrication of devices and components such as high density magnetic core of read/write for the high speed tapes etc. [1, 2].

In recent years there has been considerable interest in the study of the properties of nano-sized ferrite particles because of their importance in the fundamental understanding of the physical properties as well as to their proposed applications for many technological purposes [3, 4]. The unique properties of nanoparticles are in general related to the adoption of materials, crystal structure to a small (nanosize) and large surface to volume ratio.

Among the several spinel ferrites nickel ferrite is an interesting ferrite because it crystallizes either in a cubic symmetry with inverse spinel structure depending on the cation distribution among the interstitial site of a spinel structure [5, 6]. The other interesting feature of nickel ferrite is that it contains Jahn Teller ion which is responsible for interesting electrical and magnetic properties. In bulk form, nickel ferrite is a magnetic compound useful in many technological applications [7]. They can also be prepared by techniques such as wet chemical co-precipitation [8], sol-gel [9], hydrothermal synthesis [10] or microemulsion [11] at nanoscale, that can be employed in important applications such as ferro-fluid technology [12], magnetically guided drug delivery etc [13].

The magnetic properties of spinel ferrite originate from the antiferromagnetic coupling between the octahedral and tetrahedral sub lattices. The magnetization results from the difference between the magnetization of tetrahedral (A) and octahedral [B] sites. The structural, electrical and magnetic properties of chromium substituted nickel ferrite prepared in bulk form have been reported in the literature [14, 15]. However, the structural and magnetic properties of nickel ferrite prepared by wet chemical co-precipitation method are not reported much in the literature.

In this study, we report our results on structural, microstructural and magnetic properties of pure nickel ferrite nanoparticles obtained by wet chemical co-precipitation method.

MATERIALS AND METHODS

Synthesis

The sample of NiFe_2O_4 spinel ferrite was prepared by wet chemical co-precipitation technique. Iron chloride hexahydrate ($\text{FeCl}_3 \cdot 6\text{H}_2\text{O}$), nickel chloride (NiCl_2), sodium hydroxide (NaOH), and acetone were analytical grade and purchased from Merck Company.

An aqueous solution was prepared by dissolving the required weights of iron and nickel chloride in 100 ml distilled water with the fixed Fe/Ni molar ratio of 2:1. The Fe^{3+} concentration was 0.1 mol/L. The NaOH solution was used as the precipitating agent. The metal chlorides solution and the NaOH solution were added dropwise (2 mL/min) from two separate burettes into a reaction vessel containing 100 ml of distilled water, which was heated up to 40 °C with constant stirring. After 2 hours aging, the resultant precipitations were collected and

centrifuged at 5000 rpm, then washed with distilled water and acetone for several times, and finally dried in air [16].

Characterizations

The structural characterization was made through X-ray diffraction (XRD) technique in the 2θ range of 20° - 80° . The XRD pattern was recorded at room temperature using Cu-K α $\lambda=1.5406 \text{ \AA}$ radiation. Microstructural studies including evaluation of a particle size were conducted using a JEOL - JS - M840 scanning electron microscope. The magnetic measurements were carried out at room temperature using pulse field magnetic hysteresis loop tracer.

RESULTS AND DISCUSSION

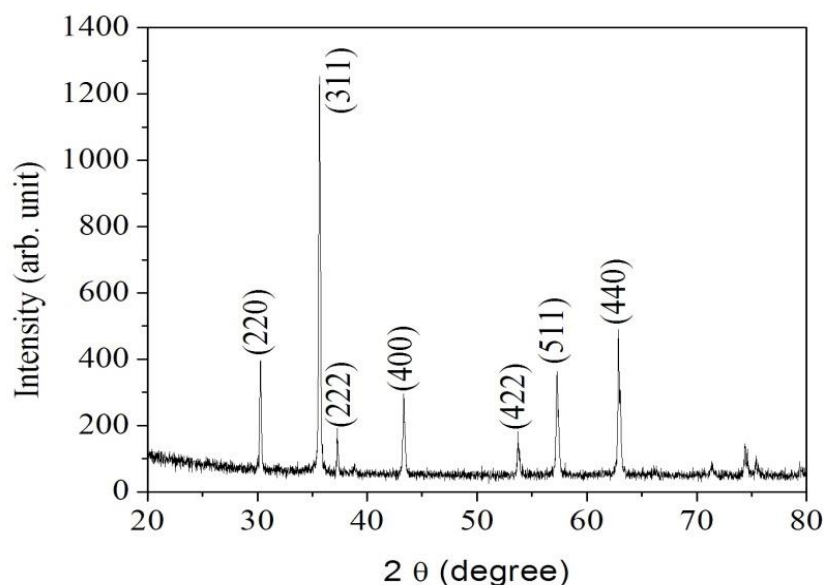


Fig. 1 X-ray diffraction pattern for NiFe₂O₄ nanoparticles

Fig.1 shows the X-ray diffraction (XRD) pattern of NiFe₂O₄ nanoparticles. All the Bragg reflections have been indexed, which confirms the formation of cubic spinel structure in single phase. The Bragg's reflections are found to be sharp and intense. The values of lattice parameter calculated from interplanar spacing (*d*) values and Miller indices are given in table 1. The value of lattice parameter is found to be 8.232 Å. The present value of lattice parameter of nickel ferrite is in good agreement with the reported value [17-19]. The average crystallite size was determined from the measured width of the diffraction using Scherrer formula [20]. The particle size obtained from XRD data is found to be 37 nm.

Table 1. Lattice constant, X-ray density and crystallite size from XRD data

Structural Parameters	Values
Lattice constant (a)	8.232 Å
X-Ray density (ρ_x)	5.302 g/cm ³
Crystallite Size (t)	37 nm

Scanning electron micrograph (SEM) of the prepared sample is shown in Fig. 2.

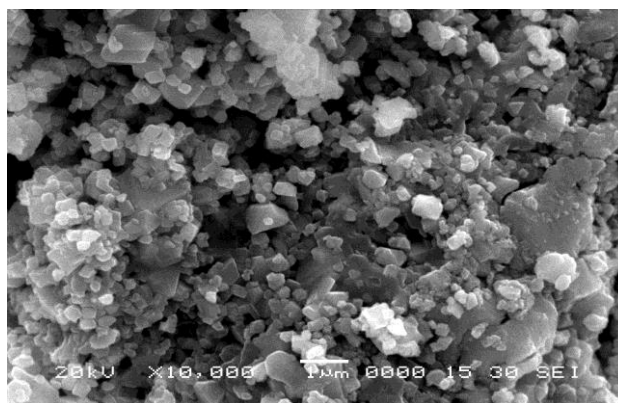


Fig. 2. SEM image of NiFe₂O₄ nanoparticles

It can be observed that the grains are in nanometer range. The micrograph reveals dense microstructure with developed grains along with few pores.

Fig. 3 shows the magnetization (M) versus field (H) image plot of NiFe₂O₄ nanoparticles.

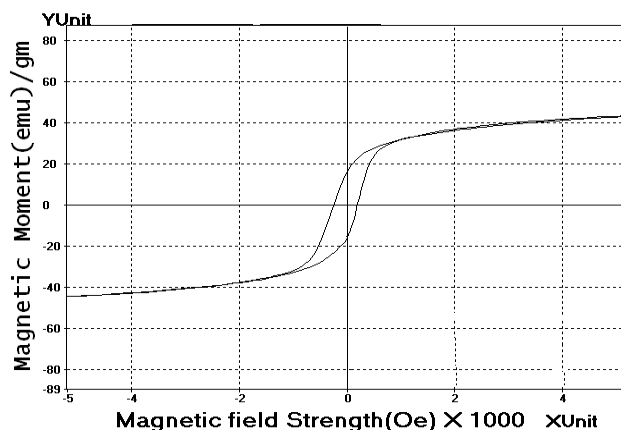


Fig. 3. Hysteresis loop for NiFe₂O₄ nanoparticles

These plots are used to evaluate saturation magnetization (M_s), remanence magnetization (M_r) and coercivity (H_c). The values of these magnetic parameters are given in table 2. The saturation magnetization values (M_s) are used to calculate magneton number n_B are given in table 2. The observed variation in magneton number was also studied by Neel's theory [21]. According to Neel's theory the magneton number is the difference of magnetic moment of B sub lattice and A sub lattice respectively

$$i.e. n_B = M_B - M_A \quad (1)$$

The calculated value of magneton number is also given in table 2.

Table 2. Magnetic parameters of NiFe₂O₄

Magnetization Parameters			Magneton number 'η _B ' (μ _B)	
Mr (emu/gm)	Ms (emu/gm)	Hc (Oe)	Cal.	Obs.
19.84	43.16	221.35	1	0.90

CONCLUSION

Nickel ferrite (NiFe_2O_4) nanoparticles were successfully obtained by wet chemical co-precipitation method. The single phase formation of the nickel spinel ferrite system was confirmed by X-ray diffraction method. The lattice constant was in the reported range. Microstructural analysis showed grains in nanometer regime. The values of saturation, remanence magnetization and coercivity show ferrimagnetic nanocrystalline nature and are enhanced than that of bulk particles.

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