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Synthesis and Characterization of Nickel Doped Iron Oxide Nano Particles

Abbas Adeel[1], Arshad Javid Muhammad [1],Ahtisham Anjum[2], Sardar Sikandar Hayat[3], Muhammad Sultan[1]

1 Department of Basic Sciences, University of Engineering & Technology, Taxila,Pakistan .47050
1 MS Scholar , Department of Basic Sciences, University of Engineering & Technology, Taxila,Pakistan.47050;.
2 Functional materials Lab, Department of Phyiscs, Air University, PAF Complex E-9, Islamabad. Pakistan.
3 De pa r t me n t o f Phy si c s, Fa cu lt y of B asi c andA ppl ie d S ci en c es , In t e rna ti ona l Is la mi cU ni v er si ty , H-1 0, I sl a mab ad, Paki sta n
** Correspondence:Dr.Muhammad Arshad Javid, Department of Basic Sciences, University of Engineering & Technology, Taxila,Pakistan .47050*

Abstract
The objective of this work is to synthesize and characterization ofnickel ferrite to improve the magnetic saturation. For structural analysis, XRD was revealed that Ni-doped Fe_2O_4have a cubic spinal structure. From XRD data, the grain size of $NiFe_2O_4$ was observed to be (17.12 nm) after 20 wt.% Ni-dopedFe_2O_4, and its further increases up to19.36 nm for 40 wt.% $NiFe_2O_4$, respectively. The XRD pattern confirmed that doping of Ni metal incresed the grain size of nanoparticles. SEM was performed to study the morphology of prepared samples. EDX was performed to confirm the elemental analysis. Saturation magnetization (Ms) was improved with concentration of dopant material Ni(20 wt.% , 40 wt.%)in magnetic nanoparticles. In conclusion, this study demonstrate the very easy way of synthesis of Ni doped iorn oxides nanoparticles for magnetic material applications

Keywords: *Nickel ferrites; Magnetic nanoparticles; VSM , Magnetic sacturation*

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I. Introduction

Magnetic nanoparticles were significantly studied for biomedical researchsuch as drug delivery, hyperthermia in cancer,protein separation, biosensing and magnetic resonance imaging (MRI)[1, 2],[3]. Since the late 1990s, iron oxide-based nanoparticle contrast agents have been explored and clinically used as T2 -weighted contrasts agents. They compose magnetic nanoparticle core and biocompatible coating material, preventing aggregation and sedimentation and allowing high biological tolerance [4]. Recently, researchers have focused on nickel ferrite nanoparticles as MRI contrast agents due to their high magnetic susceptibility, biocompatibility, biodegradability and nontoxicity characterisitics[5]. Several studies have investigated the nickel-based nanoparticles as an alternative to gadolinium for reducing the risk of toxicity [6]. Nickel metal also possesses a high spin quantum number and proton exchange kinetics [7]. MRI has several blessings over unique imaging modalities due to excessive spatial selection, amazing clean tissue evaluation and non-utilization of radioisotopes. Paramagnetic gadolinium complexes are commonly used as MRI contrast agent[8]. However, gadolinium-based complexes have low sensitivity and have toxic outcomes that incorporate nephrogenic systemic fibrosis (NSF) [9].

In thisresearch work, nickle dopped iorn oxidenanoparticle have been synthesied using co-pericipitation method to enahnce the saturation magnetization of mgnetic nanoparticles .

II. Experimental

Ferric chloride hexahydrate ($FeCl_3.H_2O$), ferrous chloride tetra-hydrate ($FeCl_2.H_2O$), nickel chloride hexahydrate ($NiCl_2.H_2O$) and ammonium hydroxide (NH_4OH) were usedfor the preparation of Fe_3O_4 and $NiFe_2O_4$ superparamagnetic nanoparticles using co-precipitation method. Distilled water was used as a solvent to remove the impurities in the final product. [3]. First, the solution of $NiCl_2.6H_2O$ was prepared in distilled water and stirrered for 1 hourat at 50℃ approximately. Then the solution of $FeCl_2.4H_2O$was prepared in the distilled water and stirrered for 1 hour at 50 ℃. Then solutions of $NiCl_2.6H_2O$ and $FeCl_2.4H_2O$ were mixed

with continuous stirring at 60 ℃. Then NaOHwas added drop wise upto pH 10. Oleic acids were added in the same solution as a capping agent and surfactant. The precipitation was washed out with distilled water and dried in the oven at 60 ℃ for 8 hours.

III. Results and Discussion

3.1. XRD anylysis

XRD pattern for Ni-doped iron oxide $Ni_{0.2}Fe_{2.8}O_4$and $Ni_{0.4}Fe_{2.6}O_4$. was shown in Figure 1. Diffracting peaksof all prepared samples were depicted in Figure 1 at $2\theta = 29.94°, 35.57°, 37.13°, 43.32°, 47.33°, 54.11°, 57.21°$ and $62.95°$with miller indices $(220), (311), (222), (400), (331), (422), (333)$, and (440) respectively.

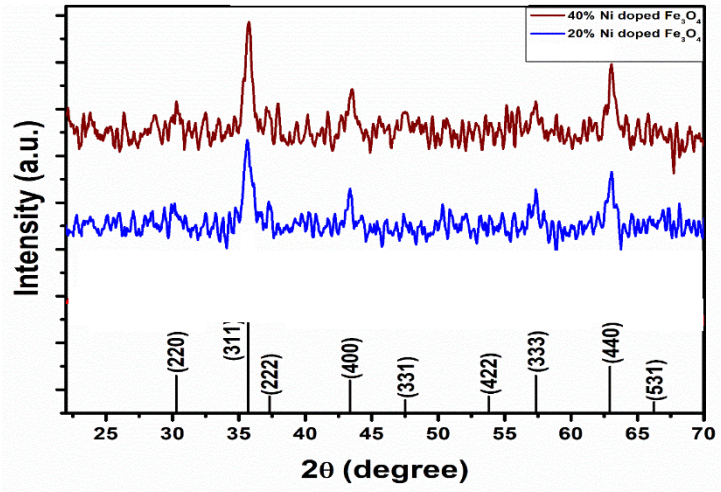

Figure 1. XRD pattern of $NiFe_2O_4$.

The XRD diffraction peaks of the $Ni_{0.2}Fe_{2.8}O_4$ (S2), and $Ni_{0.4}Fe_{2.6}O_4(S_3)$, belongs to the FCC structure, which can be well-matched with (JCPDS) card no (00-010-0325). Diffraction peaks and their sharpness define the degree of crystallinity.There are no other extra secondary phases, suggesting that the ions of $Ni^{2+}$are entirely diffused into the A-site which is Fe^{2+}in Fe_3O_4. For the calculation of the lattice parameter following relation was used:

$$\boldsymbol{a = d_{hkl}(\sqrt{h^2 + k^2 + l^2})} \quad (1)$$

$$\boldsymbol{n\lambda = 2dsin\theta} \quad (2)$$

For the calculation of crystallite size following equation was used:

$$\mathbf{D} = \frac{\mathbf{K\times\lambda}}{\mathbf{\beta\times cos\theta}} \quad (3)$$

Where D represents the crystallite size of the diffraction peak, K represents the shape factor of the particles which is 0.9, λ is the wavelength of the radiation has the value 1.54 Å, β is the full width at half maxima of the diffraction peak, and θ is the corresponding Bragg's diffraction angle.

Table 1. *Average grain size* $NiFe_2O_4$

Sr. No	*Material*	*Grain Size* (nm)
2	$Ni\text{-}Fe_2O_4(20\%\ wt)$	17.12
3	$Ni\text{-}Fe_2O_4(40\%\ wt)$	19.36

3.2. SEM analysis

The surface morphology of Ni-doped $Fe_2O_4$was studied through SEM model Instrument JSM-5910, Japan at 20.0 kV. SEM confirmed that particles are sphericalin shape and most of them are in flask shape [10]. The density of the particles was also increased with the increase in the concentration of Ni in Fe.

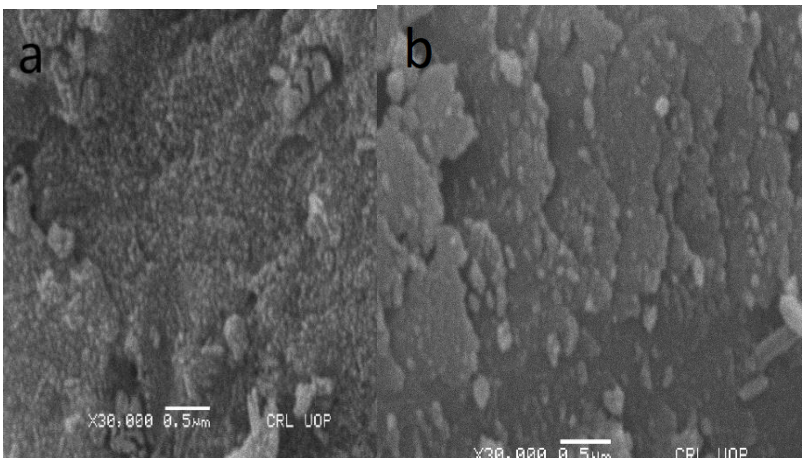

Figure 2. SEM of Ni-doped Fe_3O_4 **(a)**20% Ni − doped $Fe_2O_4$and **(b)**40% Ni − doped Fe_2O_4

3.3. ***Vibrating Sample Magnetometer (VSM)***

Magnetic properties of prepared samples such as saturation magnetization were measured at room temperature using Dexing Magnet Tech Co, Model (VSM-100), China. Ni-doped Fe_2O_4 nanoparticlesdid not depicted hysteresis curve. This saturation magnetization confirmed that all the samples have superparamagnetic behavior in nature. The magnetization curve showed high saturation magnetization and low coercive force. The saturation magnetization was increased from 48.96 $emu/cm^3$to 126.7 emu/cm^3. The total magnetic moment of the system is increased and therefore the magnetization of the system also increases. There is no detectable change observed in coercive field values that are 0.0094 and 0.0095 T for 20% Ni-doped Ni and 40% Ni-doped ferrite, respectively.

Where H_c represents the coercive field and M_s shows saturation magnetization, while anisotropy constant value K depends upon the concentration of dopant material. It means that the anisotropy constant of the system increases with the increasing content of Ni.

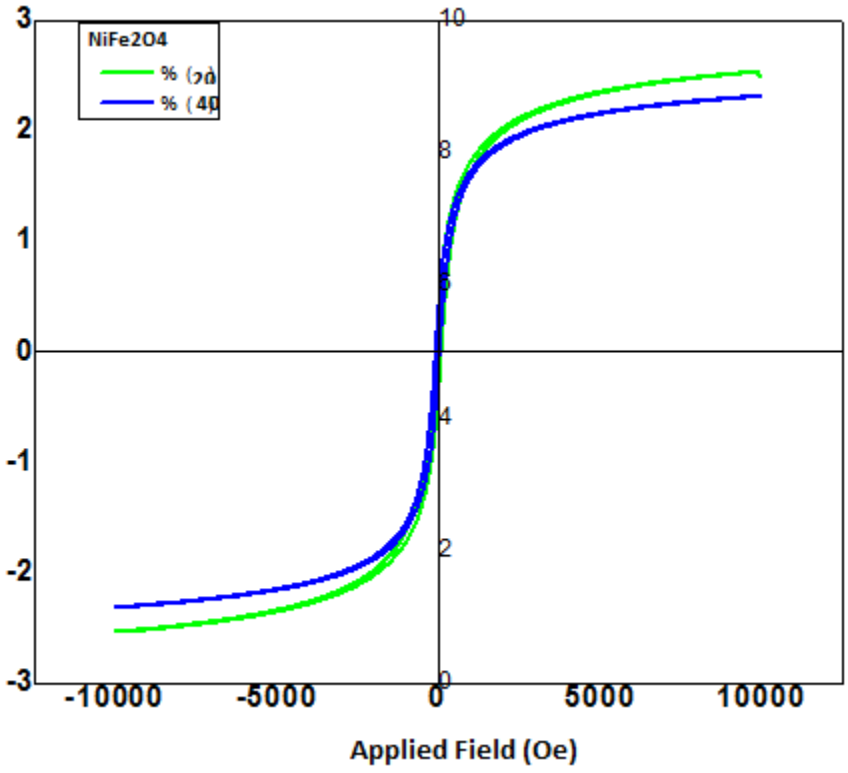

Figure 3. M-H loop for Ni-doped Fe_2O_4

IV. Conclusions

In this study, Ni-doped iron oxides nanoparticleswere prepared using co-precipitation method at room temperature. The structural conformation was done with XRD which exhibit spinal cubic structure of magnetic nanoparticles. The surface morphology of samples revealed that particles depicted the flat surface and have negligible agglomeration in SEM analysis. The saturation magnetization for $NiFe_2O_4$wasenahnced 115.55,to 126.7 emu/cm^3 after Ni dopping with 20wt. %and 40 wt. % Ni, respectively. Therefore ,this study concludes that nickel ferrites may be used in magnetic technology to enahnce its magnetic saturation .

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Conflicts of Interest

Declare conflicts of interest or state "The authors declare no conflict of interest."

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