

EPR Study of Nickel Doped Mn-Zn Ferrite Nanoparticles

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ABSTRACT

In the present work we have synthesized $Mn_{0.5-x}Ni_xZn_{0.5}Fe_2O_4$ ($x=0.0, 0.1, 0.2, 0.3$) ferrite nanoparticles by sol-gel method. The XRD patterns confirm the synthesis of single crystalline nanoparticles. The effective g-factor, g_{eff} , linewidth ΔH_{PP} , resonance field have been investigated at room temperature. Scanning electron microscopy (SEM) was used to characterize the surface morphology of the samples.

Keywords: Ferrite nanoparticles; sol-gel; XRD; SEM

I. INTRODUCTION

Ferrites are ferromagnetic materials having a spinel structure. The general chemical formula of ferrites is MFe_2O_4 where M represents divalent metallic ion like Fe, Mn, Ni, Zn, or a mixture of these. The spinel structure predicated on a face centred cubic lattice in which the sites fascinated by the cations are of two types, tetrahedral and octahedral sites [1]. This type of compounds having spinel structure exhibit a diversity of new properties which depend on the character of the cations and their site distribution through tetrahedral and octahedral sites. The electrical and magnetic properties of ferrite nanoparticles have attracted significant concentration in recent years. The properties of ferrite nanoparticles depend on method of preparation and particle size [2]. Various preparation methods have been used to synthesize ferrite nanoparticles such as sol-gel method [3], hydrothermal technique [4], ball milling [5], coprecipitation method [6]. Among these methods sol-gel method is attractive because it is simple, fast, needs cheap raw materials which consequence good homogeneity and morphology of the prepared material [7].

The properties of manganese ferrite and nickel ferrite can be changed by substitution of nonmagnetic Zn^{2+} ions which replacing Mn^{2+} ions in the A site and Ni^{2+} ions in the B site. In the substituted ferrites, Mn-Zn and Ni-Zn ferrites are commercially important class of magnetic material. Mn-Zn ferrites are the one of the most important soft ferrite which have high initial permeability, saturation magnetization and low core losses. Mn-Zn ferrites are widely used in various electronic applications such as transformers, chock coils, noise filters, recording heads, medical diagnosis etc. [8]. Ni-Zn ferrites are inexpensive magnetic materials which are useful for various technological application [9]. Ni-Zn ferrites have been used in radio frequency circuits, filters, microwave devices, antennas and transformer cores due to its high resistance and low eddy current losses [10]. Mn-Ni-Zn ferrites are technologically important materials for scientific and industrial applications. These ferrites are widely used in high frequency applications. To synthesize the ferrites with high resistivity and permeability Ni has been substituted in Mn-Zn ferrite. In this work, we investigate the influence of Ni^{2+} ions substitution on $Mn_{0.5-x}Ni_xZn_{0.5}Fe_2O_4$ ($x=0.0, 0.1, 0.2, 0.3$) ferrite nanoparticles.

II. METHODS AND MATERIAL

Nickel substituted Mn-Zn ferrite nanoparticles were synthesized by sol-gel method. Analytical grade manganese chloride, nickel chloride, zinc chloride and iron chloride were used as a starting materials. In the first, calculated amount of metal chlorides were weighed accurately and dissolved in distilled water. The solution was then heated with constant stirring and appropriate amount of ammonia solution was added to preserve the pH between 6 and 7. We added citric acid to remove the insoluble residue and ethylene glycol for homogeneity. After getting gel, it was then heated in an oven at 250°C for instinctive ignition and the slack powders were then crushed adequately. The obtained powders were then annealed at 800°C for 3 hours and sintered at 1100°C for 1 hour. The prepared samples were characterized for phase identification, crystallite size, lattice parameter, crystallite density resolution by using x-ray diffractometer. EPR spectra were recorded by using X-band Varian's (E-112) spectrometer. For morphology analysis of the samples scanning electron microscope (Hitachi-48000) was used.

III. RESULTS AND DISCUSSION

A. Structural Characterization

The sol-gel prepared ferrite nanoparticles were characterized by XRD for structural studies. The X-Ray Diffraction patterns for the samples $Mn_{0.5-x}Ni_xZn_{0.5}Fe_2O_4$ ($x=0.0, 0.1, 0.2, 0.3$) is shown in figure 1. This XRD patterns exhibit the configuration of single phase cubic spinel structure and the diffraction peaks were indexed by using JCPDS. All the experimental peaks were in good agreement with the theoretically generated one. The peaks indexed to (220), (311), (222), (400), (422), (511), (440), (531) and (622) planes correspond to cubic spinel structure. Besides the ferrite peaks, extra peaks comparable to the haematite phase has been observed in XRD pattern of the samples, haematite phase forms with large particle size [11]. The SEM photograph of the samples is

shown in figure 2. The morphology of the samples is porous and agglomerated.

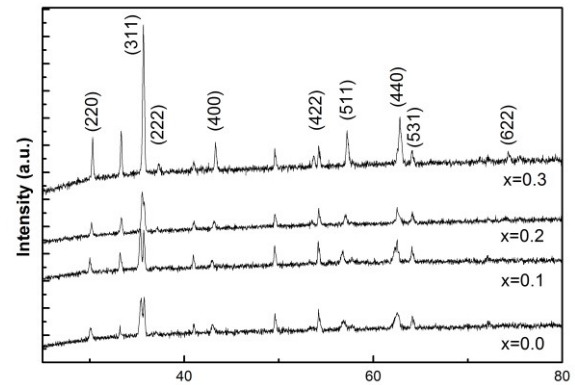


Figure 1. The X-ray diffractograms of $Mn_{0.5-x}Ni_xZn_{0.5}Fe_2O_4$ ($x=0.0, 0.1, 0.2, 0.3$).

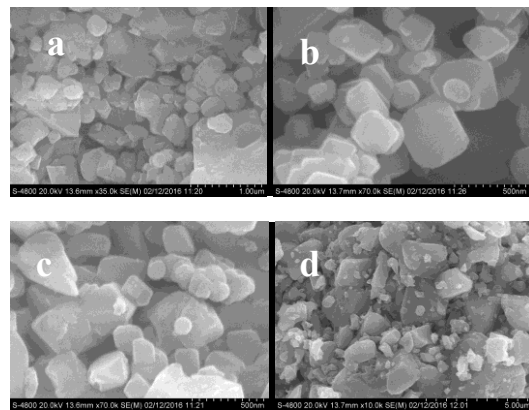


Figure 2. SEM photographs of $Mn_{0.5-x}Ni_xZn_{0.5}Fe_2O_4$ ferrite nanoparticles, (a) $x=0.0$, (b) $x=0.1$, (c) $x=0.2$, (d) $x=0.3$.

B. EPR Study

The EPR spectra of $Mn_{0.5-x}Ni_xZn_{0.5}Fe_2O_4$ ($x=0.0, 0.1, 0.2, 0.3$) were recorded at 9.1 GHz at room temperature. The EPR is important for exploring the magnetic properties of ferrite nanoparticles at high frequency since the resonance arises from the interaction among spin and electromagnetic waves. All the EPR spectra were analysed to acquire the values of different parameters such as linewidth (ΔH_{pp}), resonance field (B) and g-value using Lorentzian distribution function and the values are presented in table 1. The g-value is deliberated by the relation [12].

$$g = h\nu/\beta H$$

Where, h is a Planck's constant, ν is the microwave frequency, β is Bohr magneton and H is the magnetic field at the resonance.

Table 1. EPR parameters of $Mn_{0.5-x}Ni_xZn_{0.5}Fe_2O_4$ ($x=0.0, 0.1, 0.2, 0.3$)

Ni Content (x)	Linewidth (ΔH_{PP}) Gauss	Resonance Field (B) Gauss	g-value
0.0	1180	2930	2.22
0.1	1680	2340	2.78
0.2	1780	2190	2.97
0.3	1820	2230	2.92

G. S. Shane et al. [13] reported the decrease in spin-spin relaxation time constant with increase in nickel ion concentration. The decrease in spin-spin relaxation time is accredited to the decrease in electron motion and weakening of superexchange interaction and strengthening dipole interaction with increase in nickel ion substitution. The strong dipole interactions contribute a large linewidth (ΔH_{PP}) and g-value. It has been observed that the linewidth (ΔH_{PP}) increases with the increase in nickel substitution. This is probably due to increasing dipolar interaction through cations and oxygen ions [14].

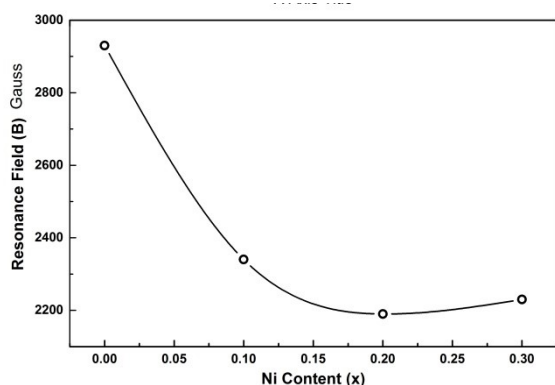


Figure 3. Variation of Resonance Field with Ni content.

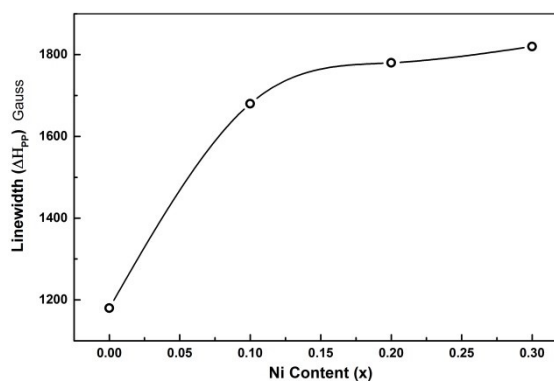


Figure 4. Variation of Linewidth (ΔH_{PP}) with Ni content.

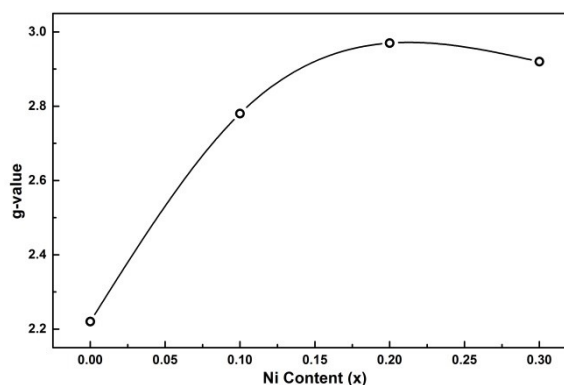


Figure 5. Variation g-value with Ni content.

IV. CONCLUSION

We have investigated structural and magnetic properties of sol-gel prepared $Mn_{0.5-x}Ni_xZn_{0.5}Fe_2O_4$ ($x=0.0, 0.1, 0.2, 0.3$) ferrite nanoparticles. The linewidth increases with increase of nickel ion concentration which is due to leading dipole-dipole interactions. It has been observed that g-value increases by Ni substitution from 2.22 to 2.97. This can be interpreted by spin-spin and spin lattice relaxation.

V. REFERENCES

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