Research Article

Improved Magnetic Properties of Ni-Zn Nano Ferrites by Using *Aloe vera* Extract Solution

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ABSTRACT

$Ni_xZn_{1-x}Fe_2O_4$ (x = 0.25, 0.45) ferrite nanoparticles were prepared by a modified sol-gel method using high purity metal nitrates and aloe vera plant extracted solution. Using of aloe vera extract simplifies the process, provide an alternative process for a simple and economical synthesis of nanocrystalline ferrite. The structural characteristics of calcinated sample of $Ni_xZn_{1-x}Fe_2O_4$ (x = 0.25, 0.45) ferrite nanoparticles were determined by X-ray diffraction (XRD), fourier transform infrared spectroscopy (FT-IR) and transmission electron microscopy (TEM). The prepared samples have spinel structure. From XRD we observed that particle size decreases with increasing Ni content. All the prepared samples have spinel structure with particle size of 23.0 nm-31.7 nm. Nano size of the particles was confirmed by TEM measurement. FTIR spectral analysis helps to confirm the formation of spinel structure in ferrite samples. Magentization measurements were obtained at room temperature by using vibrating sample magnetometer (VSM) , which showed that the calcinated samples exhibited magnetic behavior.

Keywords: Sol-gel, Aloe-vera, Synthesis, Magnetic properties, Electron microscopy , Vibrating sample magnetometer.

INTRODUCTION

$Ni_xZn_{1-x}Fe_2O_4$ (x = 0.25, 0.45) ferrites are soft magnetic material is mostly used as various inductance components, such as magnetic cores of filters, transformers, deflection, antenna, video magnetic heads and magnetic heads of multiple path communication and so on. Furthermore, the material has also brought potential applications in magnetic liquid absorbing materials. With rapid development of electronic information industries such as communications and computer networks,the size of electronic apparatus and equipments is miniaturized.[1-9] Demand for electronic components with high density, light weight, thin type and fine performance is greatly increasing, which accelerate the demand for soft magnetic ferrites with high performance and thus contributes to the development of soft magnetic ferrites on the direction of higher frequency and lower power consumption.[10-15] Ferrite particles in nano scales can be produced by soft chemical methods, such as co-precipitation, sol-gel and hydrothermal synthesis.[16-20] Among other established synthesis methods, simple and cost effective routes to synthesize nanocrystalline Ni-Zn ferrite by utilization of cheap ,non-toxic and environmentally benign precursors are still the key issue.

In this present work, we report for the synthesis of nanoparticles of Ni-Zn ferrite by simple method using metal nitrates and aloe vera extract solution as a precursors. The samples were characterized by, XRD, FT-IR and TEM. The magnetic properties of prepared nanoparticles were investigated by vibrating sample magnetometer (VSM).

MATERIALS AND METHODS

Materials

All materials were of analytical grade and were used without further purification. Distilled water was used in all experiments.

Synthesis of $Ni_xZn_{1-x}Fe_2O_4$ ferrite nanoparticles

In this study, the $Ni_xZn_{1-x}Fe_2O_4$ ferrite nanoparticles was synthesized by the modified sol-gel method. In this study either $Zn(NO_3)_2.6H_2O$ or $Ni(NO_3)_2.6H_2O$ mixed with Fe $(NO_3)_2.9H_2O$ were used as the starting materials. In a typical procedure, 60 ml of aloe vera plant extract, instead of toxic organic polymers, was mixed with 40 ml distilled water under vigorous stir until homogenous solution was obtained. According to this formula $Ni_xZn_{1-x}Fe_2O_4$ (x = 0.25, 0.45) each metal nitrate was added slowely to the aloe vera solution under vigorous stirring for 2 hours to obtain a well – dissolved solution. Then the mixed solution was evaporated by heating on the hot plate at 100^{0}C under vigorous stirring for several hours until a dried precursor was obtained. The dried precursor was crushed into powder using mortar and pestle. The dried precursor then was calcinated in a muffle – furnace at 700^{0}C for 2 hours .

Particle characterization

The X- ray diffraction (XRD) patterns of the samples were recorded on a PANalytical X'Pert PRO X-ray diffractometer using Cu Kα radiation (λ = 0.15406 Å). The

crystallite size of nanocrystalline samples was measured from the line broadening analyses using Debey-Schherer formula after accounting for instrumental broadening (Equation 1):

$$D_{XRD} = 0.89 \lambda / \beta \cos \theta \quad .....(1)$$

Where λ – wavelength of X-ray radiation used in Å , θ is the diffraction angle, β is the full width at half maximum (FWHM) in radians in the 2θ scale, D_{XRD} is the crystallite size in nm [22].

Particle Morphology

The particle morphology was examined by transmission electron microscopy (HITACHI model, H-7500). For the TEM observations, powders were supported on carbon-coated copper grids which were ultrasonically dispersed in ethanol.

Magnetic measurements

Room temperature magnetic measurements were carried out using a Lakeshore viberating sample magnetometer (VSM) and parameters like specific saturation magnitization (Ms), corecive force (Hc) and remanence (Mr) were evaluated.

Spectral measurements

FTIR spectra were recorded for dried samples of $Ni_xZn_{1-x}Fe_2O_4$ (x = 0.25, 0.45) with an Perkin – Elmer FTIR spectrometer. The dried samples were in KBr matrix, and spectra were measured according to transmittance method.

RESULTS AND DISCUSSION

XRD Aanalysis

XRD can be used to characterize the crystallinity of nanoparticles and it gives the average diameters of all the nanoparticles. The fine particles were characterized by XRD for structural determination and estimation of crystallite size. XRD pattern were analyzed. All experimental peaks were matched with theoretically generated one and indexed. The XRD patterns of all the samples were shown in Fig.1.

Figure 1. shows the powder X-ray diffraction pattern of $Ni_xZn_{1-x}Fe_2O_4$ (x=0.25, 0.45) nanoferrites which were calcinated at 700^{0}C for 2 hours. The XRD pattern confirmed single phase cubic spinel structure in all the samples. The crystallite size was calculated from XRD data by using Scherrer's formula . The average crystallite size has been found between 23.0 nm to 31.7 nm for all nanosamples of this series as shown in table 1. It shows the formation of spinel ferrite phase in all the samples. The broad XRD line indicates that the ferrite particles are in nano size. The crystallite size for each composition are calculated from XRD line width of the (311) peak using Scherrer's formula.[21] The average crystallite size decreases from 31.7 nm to 23.0 nm when the partial substitution of Ni increases (x = 0.25 to x = 0.45).

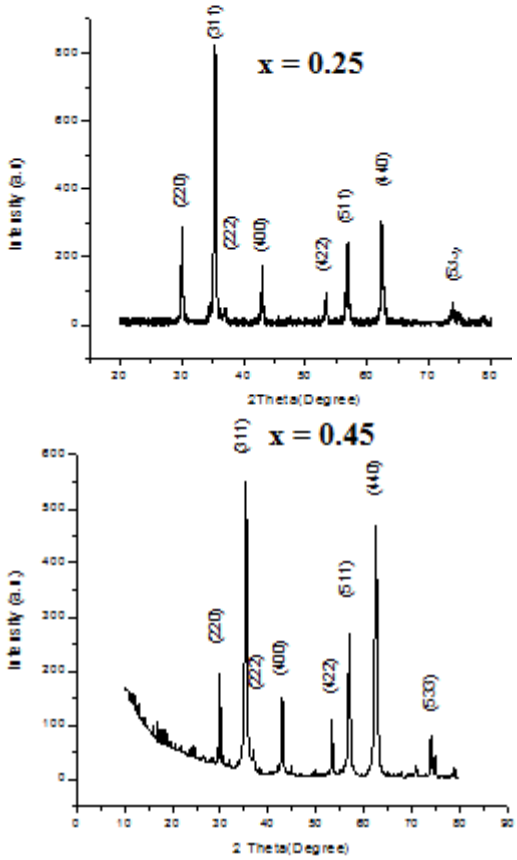

Figure 1: X- Ray Diffraction spectra of $Ni_xZn_{1-x}Fe_2O_4$ (x= 0.25, 0.45) nanoferrites calcinated at 700^{0}C for 2 hours

Such a decrease in the value of the particle size for series is expected because replacement of Zn^{2+} ion of larger radius, by Ni^{2+} ions of smaller size. The values of the particle size, lattice constant as deduced from X-ray data are given by Table 1. The lattice constant was found to decreases from 8.359 to 8.344 Å with increase in Ni concentration as shown in Table.1. This is due to the fact that replacement of larger Zn^{2+} cation of larger radius, by smaller Ni^{2+} cations, causing a shrinkage in the unit cell dimensions of the spinel lattice. Therefore as the concentration of Ni^{2+} ions increases, the lattice constant decreases. The strongest reflection comes from the (311) plane. Which denotes the spinel phase. All the compositions had a spinel structure.

Table 1: Crystallite size, lattice constant and unit cell volume for $Ni_xZn_{1-x}Fe_2O_4$ (x =0.25, 0.45) nanoferrites calcinated at 700°C for 2hours

Ni Concentration(x)	Crystallite Size (D) (nm)	Lattice constant (Å)	Unit Cell Volume a^3 (Å)
0.25	31.7	8.359	584.067
0.45	23.0	8.344	580.928

The peaks indexed to (200), (311), (400), (422), (511) and (440) planes of a cubic unit cell, corresponds to cubic spinel structure. The calculated lattice constant (Å), identified the sample to be cubic spinel.

Transmission electron microscopy

The morphology and structure of the prepared ferrite samples calcinated at 700 ^{0}C were investigated by TEM techniques as shown in Fig.2. The results indicate that the samples prepared by sol-gel method are almost uniform in both morphology and particle size distribution. A close inspection would reveal the presence of particles showing the spherical in shape. The particle sizes decreased with increasing Ni concentration. Mean particle size from TEM image is in good agreement with the crystallite size measured from X-ray line (311) broadening using scherrer' s formula. This is lower than the particle size of nanoferrites prepared by other chemical method.

Fourier transform infrared analysis (FT-IR) measurements

The FTIR spectra of the $Ni_xZn_{1-x}Fe_2O_4$ (x = 0.25, 0.45) nanoferrites calcinated at 700^{0}C for two hours were shown below in figure 3. The spectrum was recorded in the range 400 cm^{-1}up to 4000 cm^{-1}.Two main broad metal–oxygen bands are seen in the infrared spectra of all spinels, specially ferrites. The highest one, (v_1), generally observed in the range 580–600 cm^{-1}, is caused by the stretching vibrations of the metal at tetrahedral site, $M_{tetra}\leftrightarrow O$. The lowest band ($v_2$) usually observed in the range 430–400 cm^{-1}, correspond to $M_{octa}\leftrightarrow O$. This difference in the spectral positions is expected because of the difference in the Fe^{3+}- O^{2-} distance for the octahedral and tetrahedral compounds. This is confirmed from fourier transform Infrared spectroscopy (FTIR) that the structure remains cubic spinel after nickel substitution in zinc nanoferrites .[22-24] The weak absorption broad band at 3400 cm^{-1} represents a stretching mode of H_2O molecules. The weak band around 1340 cm^{-1}-1600 cm^{-1} corresponds to the H-O-H bending and corresponds to the molecular water absorbed or incorporated into the crystalline lattice. In all samples a very small impurity peak is observed around 2918-2920 cm^{-1} . This may be due to C-H stretching bond.

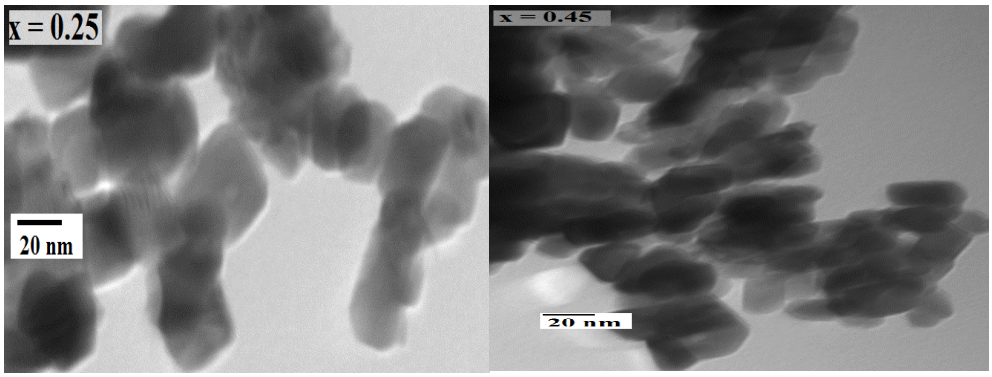

Figure 2: TEM image for $Ni_xZn_{1-x}Fe_2O_4$ (x= 0.25, 0.45) nanoferrites calcinated at 700^{0}C for 2hours

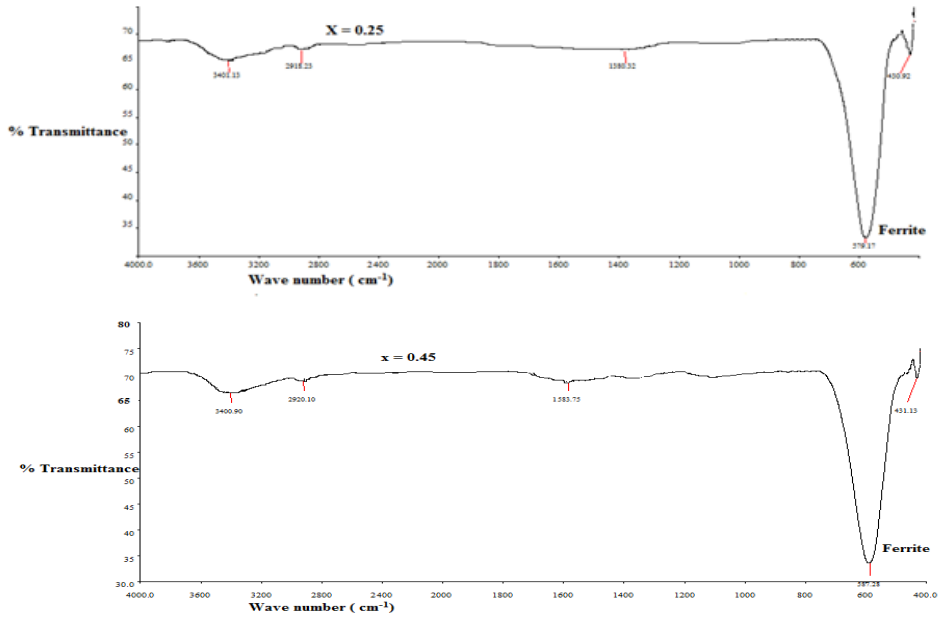

Figure 3: FTIR spectra of Ni_x $Zn_{1-x}Fe_2$ O_4 (x= 0.25, 0.45) nanoferrites calcinated at 700^{0}C for 2 hours

Magnetic measurements

From the hysterestis curve one can get information such as saturation magnetization (Ms), coercivity (Hc), remanance magnetization (Mr) and squareness ratio (Mr/Ms) for a given sample. The magnetic properties of the $Ni_xZn_{1-x}Fe_2O_4$ (x=0.25, 0.45) nanoferrites powder sample can be determined at room temperature using vibrating sample magnetometer (VSM) with applied field up to 30,000 Oe. Figure 4. shows the variation of magnetization with applied field for all $Ni_xZn_{1-x}Fe_2O_4$ (x=0.25, 0.45) nanoferrites.

The hysteresis curve (Figure 5) recorded at room temperature shows very low coercivity and remanence. Nanoferrites do not attain saturation in applied field .[25-29] Calculated values of saturation magnetization (Ms), coericivity (Hc), remanent magnetization (Mr) and squareness ratio for Ni_xZn_{1-x} Fe_2O_4 (x=0.25, 0.45) nanoferrites at 700^{0}C for 2 hours as shown in table 2. The reduced values of the Mr/Ms ratio shows a powder ferrite behaviour, within the magnetization field, closer to the superparamagnetic one.

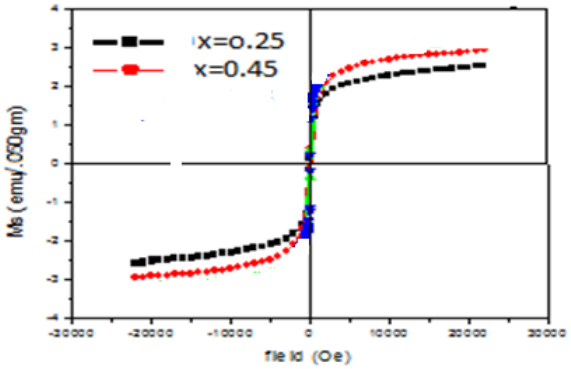

Figure 4: Variation of magnetization with applied field at room temperature for Ni_xZn_{1-x} Fe_2O_4 (x=0.25, 0.45) nanoferrites at 700^{0}C for 2hours.

Table 2: Calculated values of saturation magnetization (Ms), coericivity (Hc), remanent magnetization (Mr) and squareness ratio for $Ni_xZn_{1-x}Fe_2O_4$ (x=0.25, 0.45) nanoferrites at 700°C for 2 hours.

Ni concentration (x)	Magnetic properties			
	Saturation magnetization (Ms)(emu/ gm)	Coercivity (Hc) (Oe)	Remanent magnetization (Mr)(emu/ gm)	Squareness ratio (R= Mr/Ms)
0.25	53.2	13.0	08.8	0.16
0.45	59.2	16.4	09.6	0.17

CONCLUSION

Nanocrystalline $Ni_xZn_{1-x}Fe_2O_4$ ferrites with varying x were synthesized by a simple solution route using high purity nitrates and aloe vera plant extract solution. Form XRD, FTIR spectra and TEM analysis, it is indicated that the crystalline spinel ferrite can be obtained using calcination temperatue at 700^{0}C for 2 hours. XRD pattern confirms the synthesis of fully crystalline single phase Ni-Zn nano ferrites. The particle size size of nanocrystalline spinel ferrite calculated from FWHM of XRD (311) peak and in good agreement with TEM result. The room temperature M-H hysteresis curve show that the particles are super paramagnetic at room temperature. This work demonstrates the use of a simple synthetic method using cheap precursors of Aloe vera plant extract provides high – yield nanosized ferrites with well crystalline structure and uniform particle sizes, energy saving, high purity, no reaction with containers which increases purity, no pH adjustment, environmental friendly .

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