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

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ABSTRACT
NiₓZn₁₋ₓFe₂O₄ (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 synthesize of nanocrystalline ferrite. The structural characteristics of calcined sample of NiₓZn₁₋ₓFe₂O₄ (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. Magnetization 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
NiₓZn₁₋ₓFe₂O₄ (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. 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. Ferrite particles in nano scales can be produced by soft chemical methods, such as co-precipitation, sol-gel and hydrothermal synthesis. 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 NiₓZn₁₋ₓFe₂O₄ ferrite nanoparticles
In this study, the NiₓZn₁₋ₓFe₂O₄ ferrite nanoparticles was synthesized by the modified sol-gel method. In this study either Zn(NO₃)₂.6H₂O or Ni(NO₃)₂.6H₂O mixed with Fe (NO₃)₂.9H₂O 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 NiₓZn₁₋ₓFe₂O₄ (x = 0.25, 0.45) each metal nitrate was added slowly 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°C under vigorous stir 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°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 Debye-Scherrer formula after accounting for instrumental broadening (Equation 1):

\[
D_{\text{XRD}} = \frac{0.89 \lambda}{\beta \cos \theta} \quad \text{.....................................}(1)
\]

Where \( \lambda \) – wavelength of X-ray radiation used in Å , \( \theta \) is the diffraction angle, \( \beta \) is the full width at half maximum (FWHM) in radians in the 2θ scale, \( D_{\text{XRD}} \) 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 vibrating sample magnetometer (VSM) and parameters like specific saturation magnetization (Ms), corecive force (Hc) and remanence (Mr) were evaluated.

**Spectral measurements**

FTIR spectra were recorded for dried samples of \( \text{Ni}_x \text{Zn}_{1-x} \text{Fe}_2 \text{O}_4 \) ( \( x = 0.25, 0.45 \) ) 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 Analysis**

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 \( \text{Ni}_x \text{Zn}_{1-x} \text{Fe}_2 \text{O}_4 \) ( \( x =0.25, 0.45 \) ) nanoferrites which were calcinated at 700°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.\(^\text{21}\) The average crystallite size decreases from 31.7 nm to 23.0 nm when the partial substitution of Ni increases ( \( x = 0.25 \) to \( x = 0.45 \) ).

**Table 1**: Crystallite size, lattice constant and unit cell volume for \( \text{Ni}_x \text{Zn}_{1-x} \text{Fe}_2 \text{O}_4 \) ( \( x =0.25, 0.45 \) ) nanoferrites calcinated at 700°C for 2hours

<table>
<thead>
<tr>
<th>Ni Concentration((x))</th>
<th>Crystallite Size (D) (nm)</th>
<th>Lattice constant (Å)</th>
<th>Unit Cell Volume (a^3) (Å)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.25</td>
<td>31.7</td>
<td>8.359</td>
<td>584.067</td>
</tr>
<tr>
<td>0.45</td>
<td>23.0</td>
<td>8.344</td>
<td>580.928</td>
</tr>
</tbody>
</table>
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 °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$_x$Zn$_{1-x}$Fe$_2$O$_4$ (x = 0.25, 0.45) nanoferrites calcinated at 700°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, especially ferrites. The highest one, ($\nu_1$), generally observed in the range 580–600 cm$^{-1}$, is caused by the stretching vibrations of the metal at tetrahedral site, M$_{tetra}$↔O. The lowest band ($\nu_2$) usually observed in the range 430–400 cm$^{-1}$, correspond to M$_{octa}$↔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. The weak absorption broad band at 3400 cm$^{-1}$ represents a stretching mode of H$_2$O 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$_x$Zn$_{1-x}$Fe$_2$O$_4$ (x= 0.25, 0.45) nanoferrites calcinated at 700°C for 2hours](image)

![Figure 3: FTIR spectra of Ni$_x$Zn$_{1-x}$Fe$_2$O$_4$ (x= 0.25, 0.45) nanoferrites calcinated at 700°C for 2 hours](image)
Magnetic measurements

From the hysteresis curve one can get information such as saturation magnetization (Ms), coercivity (Hc), remanant magnetization (Mr) and squareness ratio (Mr/Ms) for a given sample. The magnetic properties of the Ni$_{x}$Zn$_{1-x}$Fe$_2$O$_4$ (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$_{x}$Zn$_{1-x}$Fe$_2$O$_4$ (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. Calculated values of saturation magnetization (Ms), coercivity (Hc), remanent magnetization (Mr) and squareness ratio for Ni$_{x}$Zn$_{1-x}$Fe$_2$O$_4$ (x=0.25, 0.45) nanoferrites at 700°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.

Table 2: Calculated values of saturation magnetization (Ms), coercivity (Hc), remanent magnetization (Mr) and squareness ratio for Ni$_{x}$Zn$_{1-x}$Fe$_2$O$_4$ (x=0.25, 0.45) nanoferrites at 700°C for 2 hours.

<table>
<thead>
<tr>
<th>Ni concentration (x)</th>
<th>Magnetic properties</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Saturation magnetization (Ms)(emu/gm)</td>
</tr>
<tr>
<td>0.25</td>
<td>53.2</td>
</tr>
<tr>
<td>0.45</td>
<td>59.2</td>
</tr>
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</table>

CONCLUSION

Nanocrystalline Ni$_{x}$Zn$_{1-x}$Fe$_2$O$_4$ 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 temperature at 700°C for 2 hours. XRD pattern confirms the synthesis of fully crystalline single phase Ni-Zn nano ferrites. The particle 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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