Synthesis and Properties of Different Concentration of Zinc Substituted In Nickel Ferrite

K S R Murthy¹*, M.Chaitanya Varma¹, Dasari Madhava Prasad¹ and GSVRK Choudary²

¹ Department of Physics, GIT, GITAM University, Visakhapatnam- 530045, India
² Department of Physics, Bhavan's Vivekananda College BVB, Sainikpuri, Secunderabad 500094, India.

Abstract: The Ni₀.₅Zn₀.₅Fe₂O₄ & Ni₀.₇Zn₀.₃Fe₂O₄ was prepared through precursor route and sintered at 1000°C. The XRD conforms the sample nature with spinel structure with out additional peaks. The parameter such as crystallite size, porosity, magnetization and resistivity was estimated for the samples showing the effect of zinc substitution on various properties such as magnetic properties, Curie temperature and permeability.

Introduction to Ferrites:

Different dopants are used for substitution in nickel ferrites are most investigated ferrites for wide applications under different frequency condition [1-6]. The stability of the nickel with ferrite with doping of zinc and its effect of particle size, resistivity and magnetization was studied [1-2]. The substitution of different dopants in Ni-Zn ferrite such as magnesium or copper resulting modification and improvement of many properties [3,5]. Hence, Ni-Zn ferrites are matter of great interest for many researchers for system exhibits resistivity, magnetization and temperature stability up to Curie temperature under different frequency conditions. Therefore, we are investigating zinc substitution in Nickel ferrite for different concentration x=0.3 and x=0.5 and understanding the magnetic and curie temperature variation occurs in the system.

Experimental:

Nickel (II) nitrate, Zinc (II) nitrate and Iron (III) were taken as initial ingredients through stoichiometric rations. Using precursor route [1-2, 5-6], Ni₀.₅Zn₀.₅Fe₂O₄ & Ni₀.₇Zn₀.₃Fe₂O₄ samples were synthesized. The samples were initial was annealed at 400°C and using polyethylene glycol in 5 wt%, pellets and toroids in order to study the magnetic and electrical properties. The samples in form of pellets and toroids were sintered at 1000°C in muffle furnace having the soaking time 1 hour. The room temperature magnetization of the filament was measured using a VSM (EG&GPAR-4500 Model) with an applied magnetic field in the range of 20 kOe. The variation of inductance (L) with temperature was measured using LCR-02 Impedance analyzer at the small voltage of 1mV at a frequency of 1 kHz. Curie temperature for this composition has been measured from the change in the slope of the inductance versus temperature graph. The resistivity measurements was measured using Digital Nano-ammeter model DNM-121 for certain temperature range.

Results and discussions:

Characterization of samples using X-ray diffraction verifies the spinel structure of the Nickel zinc ferrite for different zinc dopants substitution. Spinel structure was confirmed using peak index information from Joint Committee for Powder Diffraction Structure (JCPDS) file with card no. 52-0278. The obtained figure conforms and shows the spinel nature without any impurities or secondary phases. Lattice constant was calculated for each composition by analyzing the XRD patterns and using Nelson-Riley function. The lattice constant can be obtained from a = d√h²+k²+l² [7-8]. Nelson-Riley function indicates the error involved in the calculation of lattice constant. The value of the lattice constants for zinc variation in Nickel ferrite is tabulated in table 1. Higher zinc concentration with radii of 0.82 Å replaces nickel matrix with radii of 0.78 Å resulted expansion of unit cell resulting increase in lattice parameter as shown in table 1. The higher porosity observed is the result of this expansion showing the decrease in bulk density. The X-ray density value is depended on the lattice parameter showing the decrease as increase of lattice parameter is observed.
The average crystallize size for the samples are estimated and tabulated in table 1. The crystallize size was calculated using Sherrer formula using the experimental data obtained from observed X-ray diffraction patterns by constructing a non-linear least squares fit obeying pseudo-Voigt function.

\[ D = \frac{k \lambda}{\beta \cos \theta} \]

Here k is Scherrer factor (0.9), \( \lambda \) is the wavelength of X-rays during the time of recording the diffraction patterns (here \( \lambda = 1.5406 \ \text{Å} \)), \( \beta \) is the line broadening of a diffraction peak at angle \( \theta \). The lower particle size was observed higher zinc concentration sample due to obstruction of crystal growth by zinc during crystal growth as reported elsewhere[9].

The resistivity measured for the current samples shows the decrease in resistivity and an increase in activation energies for higher zinc concentration as shown in table 1. The semiconducting nature of the samples shows hopping nature of electrons which varies due to different concentration of zinc resulting different activation energies. The resistivity is said to be resultant contribution from non ferrimagnetic and

<table>
<thead>
<tr>
<th>Property</th>
<th>Ni_{0.7}Zn_{0.3}Fe_{2}O_{4}</th>
<th>Ni_{0.5}Zn_{0.5}Fe_{2}O_{4}</th>
</tr>
</thead>
<tbody>
<tr>
<td>Obtained Values</td>
<td>Obtained Values</td>
<td></td>
</tr>
<tr>
<td>Density bulk (g/cc)</td>
<td>4.4</td>
<td>4.3</td>
</tr>
<tr>
<td>Porosity (%)</td>
<td>18.22</td>
<td>19.33</td>
</tr>
<tr>
<td>Crystallite size (nm)</td>
<td>46.602</td>
<td>30.71</td>
</tr>
<tr>
<td>Lattice constant (Å)</td>
<td>8.3757</td>
<td>8.396</td>
</tr>
<tr>
<td>Resistivity (ohm-cm)</td>
<td>3.01x10^6</td>
<td>6.69x10^5</td>
</tr>
<tr>
<td>Activation energy (eV)</td>
<td>0.455</td>
<td>0.733</td>
</tr>
<tr>
<td>Magnetization (Emu/gm)</td>
<td>66.30</td>
<td>67.04</td>
</tr>
<tr>
<td>Curie temperature (°C) at 1 kHz</td>
<td>385</td>
<td>100</td>
</tr>
</tbody>
</table>
ferrimagnetic conductive core. Lower grain creates a trend mismatch between the energy states among the grains and acts like barrier for the flow of electrons [10].

The variation of saturation magnetization with zinc concentration is given in table 1. From the figure 2, it shows that the hysteresis loops have soft magnetic nature, an ideal feature with characteristic narrow loops and low loss. The observed values of magnetization are higher values of than values reported elsewhere [11]. The increase in magnetization with small increase in zinc can be understood on the basis of spin disorder and effect of particle size. As zinc is substituted, it dilutes the magnetic contribution from iron from A sites as zinc replaces iron. The contribution from B sites is mainly from Nickel which has 2.3 $\mu_B$ while as Zinc 0 $\mu_B$ [12]. The magnetization is algebraic sum of magnetic moments in individual lattices for which A-B are strongest [13]. The effect of particle size cannot be ignored as reduction of particle size is observed. The increase in magnetization when compared to zinc x=0.3 and x=0.5 is due to spin canting effect occurs due to B-B interactions which explains the higher magnetization values [14-15]. Table1 also shows the Curie temperature for both the samples suggesting the permeability nature of the specimen. Curie temperature falls drastically falls from 385°C to 100°C suggesting the role of zinc in weakening the exchange interaction among the lattices. The magnitude of the curie temperature depends on the concentration of Ni$^{2+}$ and Zn$^{2+}$ in the spinel structure [16].

**Conclusion:**

Zinc substituted Nickel ferrite was synthesized and annealed at 1000°C. The phase formation was conformed from XRD shows the single phase morphology in the samples. The crystallite size decreases with increase of zinc shows the effect if zinc. Decreases of resistivity and increase of activation energy was observed by zinc substitution in nickel. Magnetization increases slightly for higher zinc concentrations suggesting the canting effects caused within the system.

**References:**


![Figure 2: Room temperature hysteresis loop for Zinc doped Nickel samples.](image-url)