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# A Study of Electrical and Magnetic Properties of $La^{+3}$ Substituted Ni-Zn Ferrites

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***Abstract:*** *Ferrites, which are a class of magnetic oxide compounds that contain Iron oxide as a major component, have found a large number of applications in various electronic and communication devices. The ferrite system $Ni_xZn_xFe_{2-y}O_4$ ; x=0.50, y=0.00, 0.05, 0.10, 0.15, 0.20.and 0.25 is prepared by solid state route method. Influence of La substitution in the prepared samples (Ni-Zn ferrites) enhances the electrical and magnetic properties. The Curie temperature, Saturation Magnetization values are found to decrease with La concentration. The variation in Curie temperature can be explained on the basis of exchange interactions. The density of samples is low up to y=0.10 and then increases gradually with the increase of dopant content. The value of Dielectric constant slowly increases initially up to y=0.10 and then increases sharply at higher La concentration. The variation of dc resistivity as function of temperature for the concentration of La at y=0.00, 0.05, 0.10, 0.1, 0.20, 0.25 was studied.*
***Keywords:*** *Ferrite, density, Saturation Magnetization, Curie temperature, dielectric constant, Resistivity.*

## I. Introduction

Ferrites which are class of magnetic oxide compounds that contain Iron oxide as a major component, have found number of applications in various electronic and communication devices. Ni-Zn ferrite is of greater commercial application in the electromagnetic interfaces known as EMI, which is used in hard disk drives in laptops. Generally ferrites have high resistivities ($10^{11}$ ohm-cm)[1] as compared to metals. The electronic conduction in ferrites is mainly due to hopping electrons between the ions of the same element present in more than one valence state distribution randomly over crystallographically equivalent lattice sites [2]. The electrical resistivity of ferrites drops exponentially with rising temperature. It has been since the investigators of Blechschmidt[3]in 1938 ,that ferrites have high dielectric constants at low frequencies which exhibited dimensional resonance effects[4]. Higher values of dielectric constants are due to interfacial polarization [5].

In a ferrite we can observe transition from ferromagnetic to paramagnetic state as temperature increasing. Although there are few reports on different properties of Ni-Zn ferrite a systematic investigation about electrical properties on Ni-Zn ferrite to understand general properties. Hence in this communication we are reporting electrical and magnetic properties of Ni-Zn ferrites synthesized by solid state method.

## II. Experimental

The following ferrite ceramic compositions are processed through the standard conventional ceramic route [6-7] with small changes. The starting materials are analytical reagent grade Nickel oxide, Zinc oxide, iron oxide and Lanthanum oxide with the purity of 99.9%.

1. $Ni_{0.50}\ Zn_{0.50}\ Fe_2O_4$
2. $Ni_{0.50}\ Zn_{0.50}\ Fe_{1.95}\ La_{0.05}\ O_4$
3. $Ni_{0.50}\ Zn_{0.50}\ Fe_{1.90}\ La_{0.10}\ O_4$
4. $Ni_{0.50}\ Zn_{0.50}\ Fe_{1.85}\ La_{0.15}\ O_4$
5. $Ni_{0.50}\ Zn_{0.50}\ Fe_{1.80}\ La_{0.20}\ O_4$
6. $Ni_{0.50}\ Zn_{0.50}\ Fe_{1.75}\ La_{0.25}\ O_4$

The quantities of the reagents required for each composition were calculated. The initial ingredients were thoroughly mixed in correct proportions and dry ground for 5 hours using agate mortar and pestle and wet ground for 5-6 hours in the presence of methyl alcohol to improve the homogeneity. The resulting mixture was pre sintered in air at $800^0$c for 6 hours. This pre sintered ferrite was again grounded for few hours added 5%PVA (Poly Vinyl Alcohol) as a binder and pressed into disk shaped pellets at a pressure of 5 tons per square inch using a hydraulic press. These disk shaped pellets placed on a platinum foil and sintered in air at $1100^0$c for 10 hours. These sintered samples were polished inorderd to remove any oxide formed on the surface of the sintered disks during sintering at high temperatures, and these samples were painted with air dried silver paste and heated at $600^0$c for 1 hour to establish good electrical contact.

The **density** of sintered ceramic samples was determined by Archimedes principle. The D.C.Resistivity of processed compositions under investigation were carried out by two terminal method. It was calculated by using the Conductivity cell. The resistivity was calculated by using the relation $\rho = RA/l$, where A is area of cross section, R is Resistance. The Resistivity is generally changed by impurities substitution in basic ferrites [8]. The measurements of **Curie temperature** are carried out by using the technique [9] of attaching a small piece of ferrite material to the lower end of an iron rod attached to an electromagnet. The temperature was measured using Cr-Al thermocouple. The capacity and the **dielectric loss** of ferrite materials were measured at room temperature using LCR meter. The dielectric constant was calculated [10] using the following formula $\mathcal{E} = d.C/\mathcal{E}_0 A$, where $\mathcal{E}_0$ is the free space permeability, 'A' is the area 'd' is the thickness of the sample. The saturation magnetization was measured using the pendulum method described by Rathonev and Snoek[11]. The magnetic moment per unit volume is equal to

$M=K(\omega^2- \omega_0^2)/V$, where 'M' is the saturation magnetization, 'K' represents a constant of the system and can be obtained by using standard sample of known magnetization, here '$\omega$' and $\omega_0$ are the pendulum frequencies with and without ferrite sample respectively.

## III. Results And Discussions

**Density:** Densities of the prepared compositions have been calculated. The variation of densities can be observed from TableI.

**Table I: Density variation with the La content**

| La Content | Density |
|---|---|
| 0.00 | 4.76 |
| 0.05 | 4.6 |
| 0.10 | 4.5 |
| 0.15 | 4.8 |
| 0.20 | 4.91 |
| 0.25 | 4.95 |

Fig.1 shows the variation in density with the variation of Lanthanum dopant concentration and it is clear from the figure that the density is low Upto 0.10 and then increased gradually with the increase of dopant content. The highest density is observed to be 4.95 $gm/cm^3$ which were found to be in good agreement with reported value of 4.88 $gm/cm^3$ for similar compositions as shown in table I.

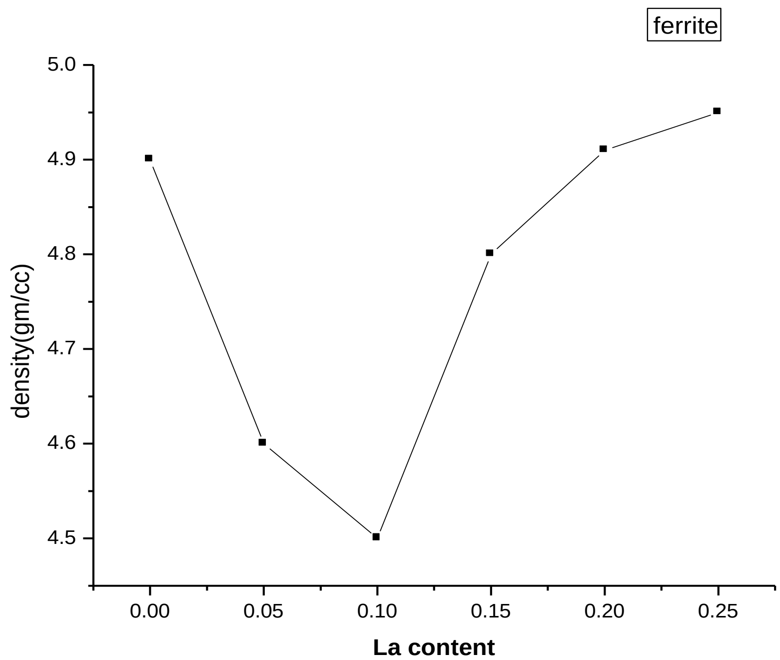


**Fig.1 Density variation with La Concentration**

**Resistivity:** The variation of Resistivity with the as a function of temperature for $La^{+3}$ substituted different compositions have been calculated and show in the Table II.

**Table II: Variation of resistivity of La concentrations as a function of Temperature**

| S.NO | 1/T X$10^{-3}$ | Log ρ values at various La concentrations | | | | | |
|---|---|---|---|---|---|---|---|
| | | 0.0 | 0.05 | 0.10 | 0.15 | 0.20 | 0.25 |
| 1 | 21 | 1.2 | 1.25 | 1.3 | 1.4 | 1.5 | 1.6 |
| 2 | 22 | 1.3 | 1.4 | 1.4 | 1.4 | 1.5 | 1.6 |
| 3 | 23 | 1.5 | 1.6 | 1.5 | 1.5 | 1.6 | 1.7 |
| 4 | 24 | 1.6 | 1.6 | 1.6 | 1.6 | 1.7 | 1.8 |
| 5 | 25 | 1.65 | 1.7 | 1.6 | 1.7 | 1.8 | 1.9 |
| 6 | 26 | 1.7 | 1.8 | 1.7 | 1.7 | 1.8 | 1.9 |
| 7 | 27 | 1.77 | 1.85 | 1.9 | 1.8 | 1.8 | 2 |
| 8 | 28 | 1.82 | 1.95 | 2 | 2 | 1.9 | 2.1 |
| 9 | 29 | 1.9 | 2 | 2.1 | 2.1 | 2.1 | 2.2 |
| 10 | 30 | 2 | 2.1 | 2.2 | 2.3 | 2.2 | 2.4 |

Fig.2 shows the variation of Resistivity as a function of temperature for the prepared samples. It has been observed the increase in resistivity for the prepared compositions from the table II. The increase in resistivity is because of formation of Layers of $La_2O_3$ and the change in resistivity values due to hopping mechanism [12] in all the samples.

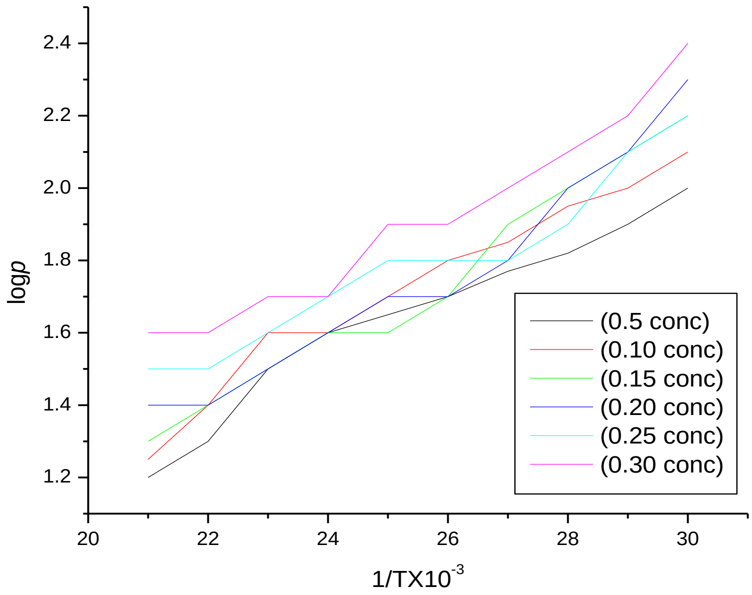


**Fig.2 : log ρ Vs 1/T at various $La^{+3}$ substituted concentrations**

**Curie Temperature:** Variation of Curie temperature with the $La^{3+}$ concentration have been calculated and indexed in the table III. The Curie temperature has been observed as decreasing with the increase of Lanthanum concentration. The change in Curie temperature can be explained on the basis of exchange interactions. The non- magnetic $La^{3+}$ dopant replaces the iron ions, which prefer to occupy B-sites [13]. The obtained value of Curie temperature for pure composition i.e., $Ni_{0.5}$ $Zn_{0.5}$ $Fe_2O_4$ is $370^0$c which is almost in agreement with the reported value of $380^0$c [14].

**Table III : variation of Curie Temperature for the $La^{+3}$ substituted concentrations**

| La Content | Curie Temperature |
|---|---|
| 0.00 | 370 |
| 0.05 | 365 |
| 0.10 | 353 |
| 0.15 | 339 |
| 0.20 | 305 |
| 0.25 | 270 |

The diamagnetic Lanthanum causes a decrease of magnetic interaction among the A and B sub lattices, which has been gradually seen in Curie temperature as shown in the fig.3

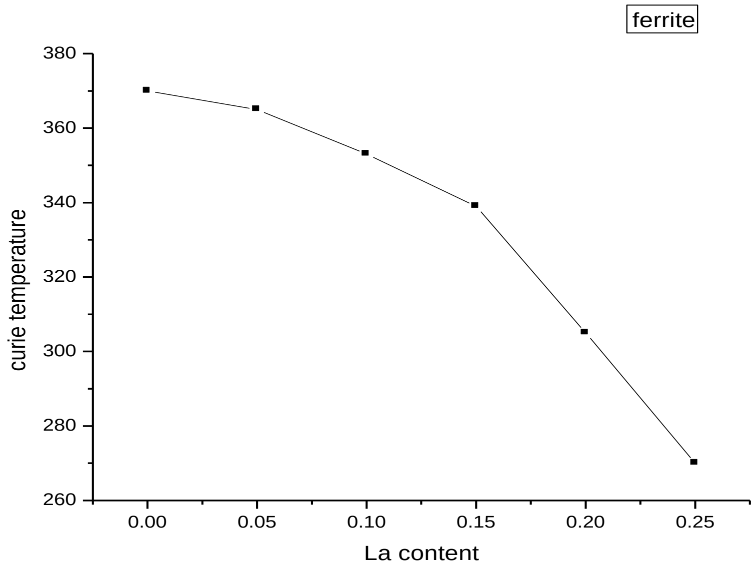


**Fig 3: Variation of Curie temperature with La content**

**Dielectric constant:** The variation of dielectric constant for the different concentrations of La content calculated and shown in the table IV. It is found that the value of dielectric constant slowly increased initially up to a Lanthanum content of x=0.10 and then increases sharply thereafter at higher Lanthanum concentrations

**Table IV: variation of dielectric constant at different $La^{+3}$ concentrations**

| La Content | Dielectric Constant |
|---|---|
| 0.00 | 18200 |
| 0.05 | 18650 |
| 0.10 | 19100 |
| 0.15 | 32500 |
| 0.20 | 40500 |
| 0.25 | 44300 |

It is very clean from the values of dielectric constant as shown in fig.4, that the dielectric constant of the material increases by three orders in magnitude

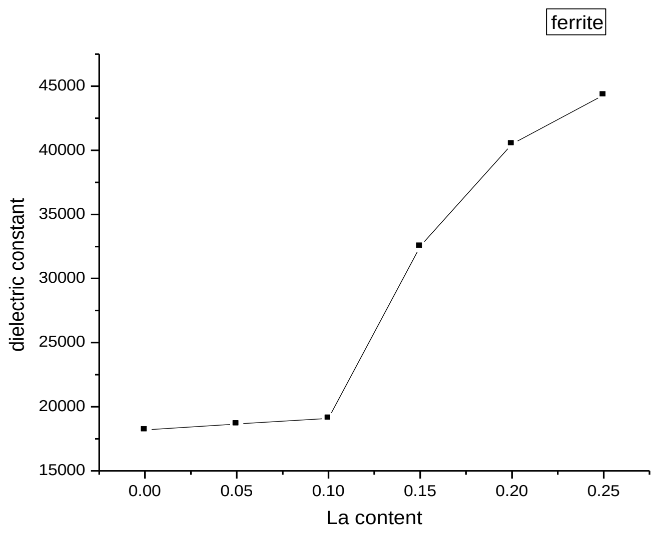


**Fig.4 Variation of Dielectric constant with La content**

**Dielectric loss:** Dielectric loss have been calculated and shown in the tableV. Variation in Dielectric loss with increasing lanthanum concentrations is presented.

**Table V: Dielectric loss for different concentrations of $La^{+3}$**

| La Content | Dielectric loss |
|---|---|
| 0.00 | 0.035 |
| 0.05 | 0.028 |
| 0.10 | 0.030 |
| 0.15 | 0.031 |
| 0.20 | 0.030 |
| 0.25 | 0.031 |

It is evident from the fig.5 that the dielectric loss decreased in the beginning and then increased with the increase of Lanthanum concentration. The trend observed in the present study which is in agreement with the reported behavior.

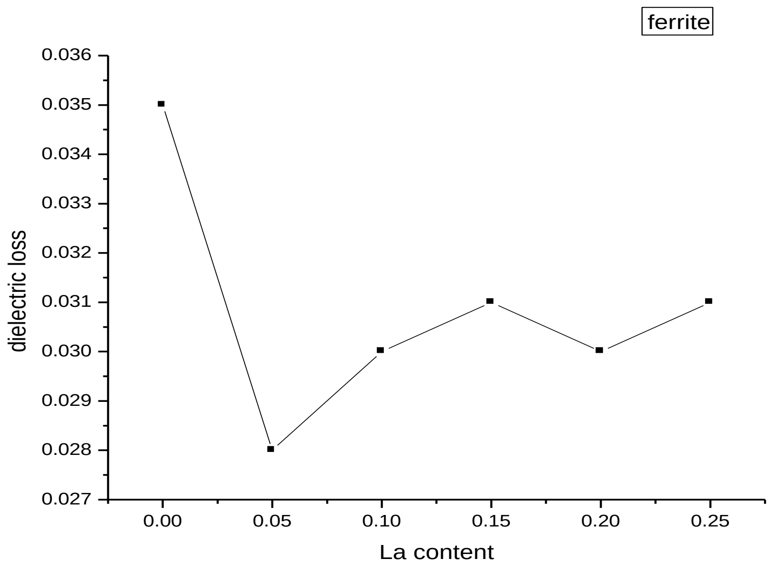


**Fig.5:** variation of dielectric loss with la content

**Saturation magnetization:** the studies on saturation magnetization with the variation of dopant content are carried and calculated as shown in the table vi.

**Table.vi: variation of saturation magnetization of la content.**

| La Content | Saturation Magnetization(emu/gm) |
|---|---|
| 0.00 | 72 |
| 0.05 | 64 |
| 0.10 | 61 |
| 0.15 | 55 |
| 0.20 | 48 |
| 0.25 | 41 |

The change in Saturation Magnetization with dopant concentration is given in fig.6. The gradual decrease in saturation magnetization is observed with the La content. The variation of Saturation Magnetization can be explained on the basis of exchange interaction of cataions like $Fe^{+3}$-$O^{-2}$-$Fe^{+3}$.The obtained value for basic composition is 71emu/gm which is almost reported value [15].And further it is observed a systematic decrease in Saturation Magnetization in all samples due to addition of La Content.

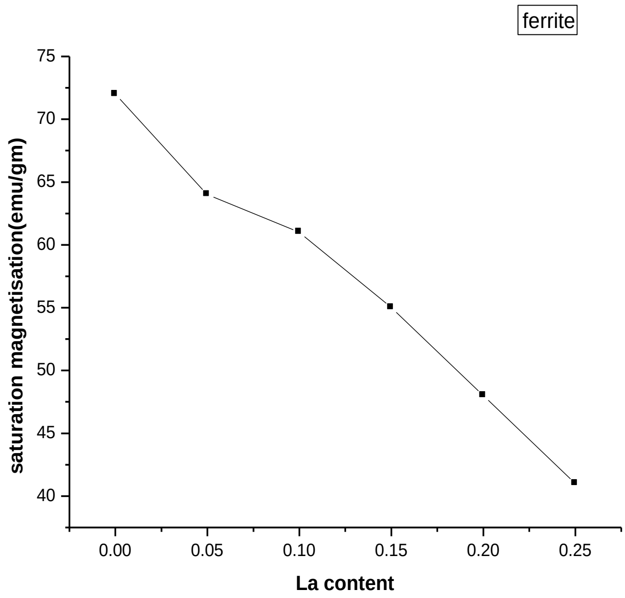


**Fig.6: Variation of Saturation Magnetization with La content**

## IV. Conclusions

Samples of $Ni_{0.5}Zn_{0.5}$ $Fe_2O_4$ has been successfully synthesized using solid-state route method. It is observed that the electrical properties like dielectric constant and dielectric loss changes with increasing La concentration. The d.c. resistivity changes with respect to temperature. Magnetic properties like Curie temperature and Saturation magnetization also changes with increasing La content.

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