Study of Dielectric and Electric properties of La$^{3+}$ Doped Ni-Zn Nanoferrite

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**ABSTRACT**

The rare earth La$^{3+}$ material substituted in Nickel-Zinc nano ferrite was synthesized by sol-gel auto combustion method. The dielectric and electric properties of the Ni$_{0.5}$Zn$_{0.5}$ La$_x$Fe$_2$O$_4$ nanoferrite where ($x=0.025$, 0.050, 0.075, 0.100, 0.125) were studied. The dielectric constant and dielectric loss was observed with the variation in frequencies. The a. c. resistivity was observed with the increase in Lanthanum concentration. The dc resistivity of Ni$_{0.5}$Zn$_{0.5}$ La$_x$Fe$_2$O$_4$ nanoferrite was observed with increase in Lanthanum concentration.

**Keywords:** Sol-gel method, Ni-Zn nano ferrite, dielectric constant, dielectric loss, dc resistivity, a. c. resistivity.

**INTRODUCTION**

The Al$^{3+}$ and Cr$^{3+}$ doped Co-Ni spinel ferrites was successfully synthesized by the sol gel auto combustion method. The dielectric parameters decrease due to the doping of the nickel, aluminum and chromium ions in the cobalt ferrites. Such ferrite has the applications in the high frequency and electromagnetic wave absorbing devices due to the high dc resistivity [1]. The sol gel auto combustion method has the excellent mixture of the combustion and chemical gelation route. The sol gel auto...
combustion method has the good stoichiometric ratio and gives the ultrafine nanoparticles. The Lanthanum substituted in Nickel ferrite [2]. The cadmium substituted nickel- cobalt nanoferrite was synthesized by standard double sintering ceramic method. The resistivity was decreases with increase in cadmium content. The dielectric constant decreases as frequency increases. The AC conductivity increases as increase in frequency [3]. The Ni-Zn ferrite was prepared using the solid state reaction method. As temperature increases then the DC resistivity also decreases and DC resistivity was obtained by Two Probe Method [4]. The Zinc doped cobalt ferrite was successfully prepared by the solution combustion method. The electric and dielectric properties of Zinc doped cobalt ferrite were studied and it was found that dielectric constant and dielectric loss decreases as frequency increases [5]. The Cu⁺⁺doped Ni-Zn ferrite was synthesized by auto combustion method. It was reported that that dielectric constant and dielectric loss are depends on the frequency. The dielectric constant increases as copper content increases [6]. The Ni₁₋ₓCdₓFe₂O₄ ferrite was obtained by the sol gel auto combustion synthesis Method. Gel auto combustion takes place. The fine powder of NiₓLa₀.₅₋ₓCdₓFe₂₋ₓO₄ nano ferrite was obtained. The Ni₀.₅ Zn₀.₅ LaₓFe₂₋ₓO₄ ferrite was synthesized by sol-gel auto combustion synthesis Method.

RESULT AND DISCUSSION:

Dielectric Properties:
The dielectric constant (ε) was calculated using the formula

\[
\varepsilon = \frac{C \cdot t}{E_0 \cdot s}
\]

Where

- \(C\) = capacitance in farad,
- \(t\) = thickness in meters,
- \(C\) = cross sectional area of pellet and
- \(\varepsilon_0\) = permittivity of free space.

The dielectric constants (ε) of the Ni₀.₅ Zn₀.₅ LaₓFe₂₋ₓO₄ where \((x=0.025, 0.050, 0.075, 0.1, 0.125)\) nanoferrite was synthesized by sol-gel auto combustion synthesis Method.

MATERIALS AND METHODS:

All chemicals such as Ferric nitrate \((Fe \cdot (NO_3)_3 \cdot 9H_2O)\), Nickel nitrate \((Ni \cdot (NO_3)_2 \cdot 6H_2O)\), Zinc nitrate \((Zn \cdot (NO_3)_2 \cdot 6H_2O)\), Citric acid \((C_6H_8O_7)\), Ammonium hydroxide \((NH_4OH)\) was used in high purity AR grade. The stoichiometric ratio proportion of all nitrates and citric acid was used. All nitrates were added in distilled water and stirred till to obtain the homogeneous solution. To maintain \(pH=7\), the ammonium hydroxide solution was added drop by drop during the stirring process. The Citric acid was used as a Fuel. This solution was stirred constantly for 3 to 4 hours to obtain sol at temperature 100°C. When a viscous brown gel was formed, then the auto combustion takes place. The fine powder of Ni₀.₅ Zn₀.₅ LaₓFe₂₋ₓO₄ nano ferrite was synthesized by sol-gel auto combustion synthesis Method.
The AC resistivity is maximum at x=0.075. The AC resistivity is varying with the increase in Lanthanum concentration.

![Graph of Dielectric Constant (ε) with log(f)](image1)

**Fig.1:** Graph of Dielectric Constant (ε) with log(f)

![Graph of Dielectric Loss (Tan δ) with log(f)](image2)

**Fig.2:** Graph of Dielectric Loss (Tan δ) with log(f)

![Graph of Concentration (x) with AC Resistivity](image3)

**Fig.3:** Graph of Concentration (x) with AC Resistivity

**Electric Properties:**

The dc resistivity ($\rho$) of the Ni$_{0.5}$Zn$_{0.5}$La$_x$Fe$_{2-x}$O$_4$(where $x = 0.025, 0.050, 0.075, 0.100$ and $0.125$) nanoferrite was obtained by Two Probe method. The dc resistivity was calculated by the formula

$$\text{DC Resistivity (}\rho) = \frac{\text{AP} \times \text{R}}{\text{L}}$$

Where,

- AP = Surface area of the pellet,
- R = Resistance of the sample,
- L = Length of the pellet

It was found that the DC resistivity of the Ni$_{0.5}$Zn$_{0.5}$La$_x$Fe$_{2-x}$O$_4$ nanoferrite at 200°C increases as Voltage increases and shown in **Fig.4**. The electric properties of the nanoferrite were decided by the cation distribution. The DC conductivity increases up to $x=0.05$ and decreases after $x=0.05$ at 200°C, which is shown in **Fig.5**.

![Graph of dc Resistivity with Voltage at 200°C](image4)

**Fig.4:** Graph of dc Resistivity with Voltage at 200°C

![Graph of dc conductivity with concentration (x) at 200°C](image5)

**Fig.5:** Graph of dc conductivity with concentration (x) at 200°C
CONCLUSION

The Ni$_{0.5}$Zn$_{0.5}$ La$_x$Fe$_2$O$_4$ nanoferrite where (x=0.025, 0.050, 0.075, 0.100, 0.125) were synthesized successfully by the sol gel auto combustion method. The dielectric constant of all samples decreases as increase in the frequency; this indicates the normal behavior of magnetic material. The dielectric loss of all samples decreases with increase in frequencies after some initial peaks. It shows that the abnormal behavior of the dielectric loss at specific frequencies. The AC resistivity is fluctuating with the increase in Lanthanum concentration. The DC resistivity of all nanoferrite samples at 200°C increases with increase in Voltage. The DC conductivity decreases after x=0.05 at 200 °C.

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