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Dielectric, Electric and Thermal Behavior of La^{3+} doped Co-Zn Nanoferrite

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Abstract: *Dielectric, Electric and Thermal properties of rare earth La^{3+} material doped in $Co_{0.5}Zn_{0.5}$ La_x $Fe_{(2-x)}O_4$ (where x=0.025, 0.050, 0.075, 0.100, 0.125) reaction nanocrystalline ferrites were synthesized by sol-gel auto combustion method. The electric, dielectric constant and Thermal properties were investigated. The dielectric constants and dielectric loss of the samples was observed between the 100Hz and 5 MHz. The resistivities of the prepared samples were measured from 0 Volt to 550 Volts at the constant temperature 200^0C using the Two Probe method. The Thermal properties were characterized by Thermo Gravimetric and Differential Thermal Analysis (TGDTA).*

Keywords: *Sol-gel method, Co-Zn ferrite, TGDTA, Dielectric constant.*

I. Introduction

The main advantage of sol-gel auto combustion method is an excellent combination of combustion and chemical reaction. This method has a good stoichiometric control which gives the fine nano particles [1]. Rani et al was used solution combustion method to prepare zinc substituted cobalt nanoferrite, with formula $Co_{(1-x)}Zn_xFe_2O_4$ (x = 0.0, 0.1, 0.2, 0.3, 0.4). The electric and dielectric properties were studied. The dc resistivity, dielectric constant and dielectric loss of nanoferrite was studied. The dielectric constant and dielectric loss tangent was measured in the frequency range between 1 kHz to 1MHz and found that as frequency increases, then dielectric constant and dielectric loss tangent decreases [2]. M.K. Shobana was studied synthesis of Lithium doped cobalt ferrite nanoparticles using sol–gel combustion Method. The four probe method was used for electrical properties. This paper showed that the conductivity of the ferrite sample decreased in increase of lithium concentration. The applications of such nanoferrite may be useful in microwave and high frequency devices [3]. Ping Hu-et-al was studied the Mn-Zn ferrites which were prepared by the nitrate-citrate auto combustion method. This paper mainly studied the effect of heat treatment on crystalline phase's formation and thermo gravimetric and differential thermal analysis. Mn–Zn ferrites play an important role in biomedicine as magnetic carriers for bio separation, enzymes and proteins immobilization [4]. V.V.Awati et al was studied the Cu^{+2} substituted Ni-Zn ferrite prepared by auto combustion method. This paper showed that dielectric constant and dielectric loss are the frequency dependent. While dielectric constant increases with increase in copper content. The copper has good conductivity than nickel [5]. B.A.Aldar et al was studied Ni-Co-Cd Ferrite. This paper was observed that resistivity decreases with increase in temperature. The dielectric constant also depends upon the temperature [6].The ac conductivity at various frequencies and at different temperatures was measured and found to be conductivity increases with increasing frequencies. The dispersion parameters was also obtained by graphical method of the Cole–Cole diagram and found to be in the specific temperature range [7,8]. The Ni Zn ferrite was synthesized with the help of solid state reaction techniques. The DC resistivity was measured by Two Probe Method. The DC resistivity decreases with increase in temperature. The DC resistivity is the temperature dependent [9]. The NiCuZn ferrites were synthesized by the citrate precursor method. It enhances the properties, so that NiCuZn ferrites may be used in multilayer chip inductors within RF frequency range[10]. The Er–Ni substituted strontium hexaferrite was synthesized. The dielectric constant and dielectric loss was reported as to decrease with Er–Ni substitution. This paper was recommended that such ferrites can be used in microwave devices [11].

Therefore, the present work studied the rare earth La^{3+} material substituted in Cobalt-Zinc nanoferrites were synthesized using the sol-gel auto combustion method. The behavior of Dielectric Constant, Electric and Thermal properties of Cobalt-Zinc nanoferrites was studied.

II. Material And Method

The sol-gel auto combustion method was used for the synthesis of $Co_{0.5}Zn_{0.5}$ $La_xFe_{2-x}O_4$ (Where x=0.025, 0.050, 0.075, 0.100, 0.125) nanoparticles. Ferric nitrate ($Fe(NO_3)_3.9H_2O$), Zinc nitrate ($ZnNO_3{\cdot}6H_2O$), Cobalt nitrate ($CoNO_3{\cdot}6H_2O$), Citric acid ($C_6H_8O_7$), Ammonium hydroxide solution

(NH_4OH) were used. All AR grade nitrates and chemicals were used. The Citric acid acts as a fuel. The stoichiometric ratio proportion was used for the synthesis. All chemicals was dissolved in distilled water and were stirred till to get the homogeneous solution. The ammonium hydroxide was added drop by drop for pH =7 throughout the stirring process. This chemical solution was stirred constantly for 3 to 4 hours at 100 $^{\circ}$C to get sol. This sol becomes a viscous gel after half an hour and auto-combustion takes place. The Cobalt-Zinc nanoferrite powders were prepared and this powder was sintered at 600 $^{\circ}$C for 4 hours.

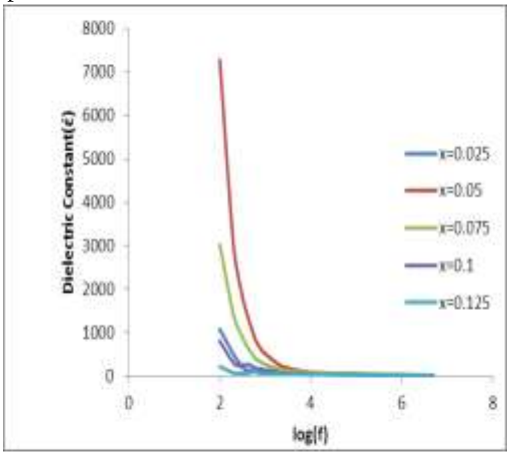
III. Results And Discussion

3.1 Dielecric Constant (ε) and Dielecric Loss (Tan δ):

The dielectric constant was calculated using the formula

$$\varepsilon = Cd/\varepsilon_0 A$$

Where C=capacitance in farad, d=thickness in meters, A= cross sectional area of pellet and ε_0 – permittivity of free space.



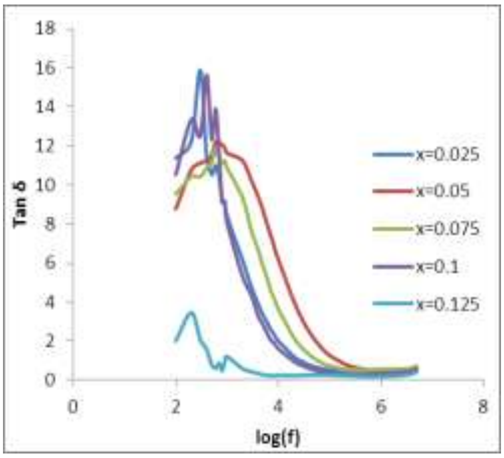


Fig.1: Variation of Dielectric Constant (ε) with log(f) **Fig.2:** Variation of Dielectric Loss (Tan δ) with log(f)

The dielectric constants (ε) of the prepared ($Co_{0.5}Zn_{0.5}La_xFe_{2-x}O_4$) (where x = 0.025, 0.050, 0.075, 0.100 and 0.125) nanocrystals was measured between the 100Hz and 5 MHz. Fig.1 shows that the dielectric constant decreases as the frequency increases, this indicates that normal behavior of magnetic material.

The dielectric loss (Tan δ) of the prepared ($Co_{0.5}Zn_{0.5}La_xFe_{2-x}O_4$) (where x = 0.025, 0.050, 0.075, 0.100 and 0.125) nanocrystals was measured between the 100Hz and 5 MHz. Fig.2 shows that dielectric loss (Tan δ) versus log (f) graphs. From graphs, it is observed that dielectric loss decreases with increase in frequencies after the initial peaks obtained at approximately 600 – 700 Hz. Hence it is the abnormal behavior of the dielectric loss.

3.2 D.C. Resistivity:

The dc resistivity (ρ) of the prepared ($Co_{0.5}Zn_{0.5}La_xFe_{2-x}O_4$) (where x = 0.025, 0.050, 0.075, 0.100 and 0.125) nanocrystals was measured by Two Probe method. The dc resistivity was calculated by the formula

$$\text{Resistivity } (\rho) = AR/L \text{ Ohm-m}$$

The resistivity was observed between the voltage 0 Volt and 550 Volts at constant temperature 200^0C. The resistivity of the prepared ($Co_{0.5}Zn_{0.5}La_xFe_{2-x}O_4$) (where x = 0.025, 0.050, 0.075, 0.100 and 0.125) nanocrystals decreases with the voltage increases after 100 Volts shown in Fig.3. The decrease in resistivity may be due temperature.

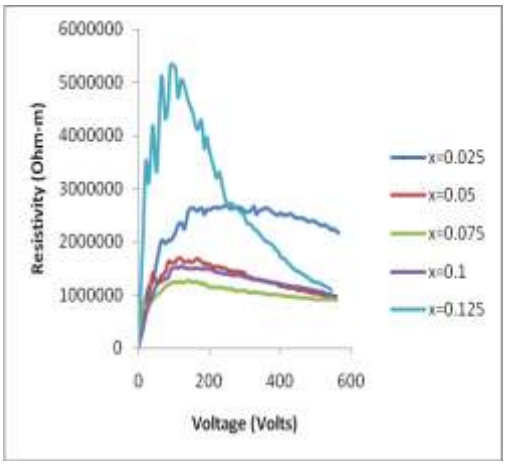


Fig.3: Variation of Resistivity with Voltage

3.3 Thermal Properties:

The prepared nanoparticles were characterized by Thermo Gravimetric and Differential Thermal Analysis (TGDTA). Fig.4 shows that TG curve, as temperature increases then continuous weight loss.

Fig.5 shows that initially voltage increases as temperature increases up to 250^{0}C. Between temperature 250^{0}C and 400^{0}C, the voltage remains constant. After temperature 400^{0}C, voltage decreases it may be due to the weight loss.

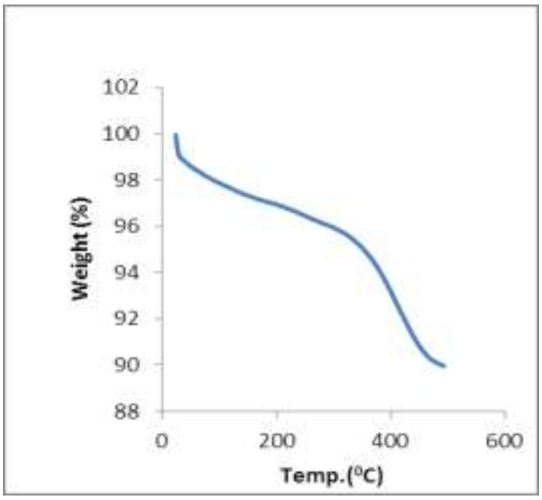


Fig. 4: TGDTA of $Co_{0.5}Zn_{0.5}\ La_xFe_{2-x}O_4$(x=0.05)

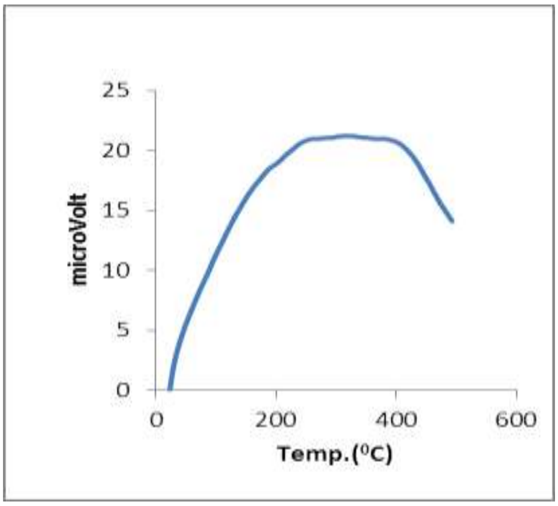


Fig. 5: TGDTA of $Co_{0.5}Zn_{0.5}\ La_xFe_{2-x}O_4$(x=0.05)

IV. Conclusions

The rare earth La^{3+} material doped in $Co_{o.5}Zn_{0.5}\ La_xFe_{2-x}O_4$ (where x=0.025, 0.050, 0.075, 0.100, 0.125) reaction nanocrystalline ferrites were synthesized by sol-gel auto combustion method successfully. The dielectric constant (ε) decreases with the increase in frequencies, this gives the normal behavior of magnetic material. The dielectric loss decreases after the initial peaks obtained at approximately 600 – 700 Hz with increase in frequencies, this gives the abnormal behavior of the dielectric loss. The resistivity of the prepared nanoferrite decreases with the voltage increases after 100 Volts. The decrease in resistivity may be due temperature. The continuous weight loss with increase in temperatures is shown in TGDTA graph.

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