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Impedance Spectroscopy of Copper Substituted Nickel Ferrite Nan particles

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Abstract: Copper substituted Nickel ferrite ($Cu_xNi_{1-x}Fe_2O_4$) nanoparticles with different values of x (x=0.1,0.2,0.3,0.4,and0.5)havebeenpreparedbysol-gelauto-combustion method.Allthesampleswereannealedat600 ^{0}Cfor3hourstoachieve crystal structure of spinel ferrite. Dielectric properties were studied through impedance analyzer and effect of frequency on the different parameters such as tangent loss, dielectric constant, imaginary dielectric constant, real impedance, complex impedance, electric modulus and complex electric modulus have been studied in this paper.

Keyword: Spinal ferrite, Nickel Nan particles, Sol-gel Method, Dielectric Properties.

1. INTRODUCTION

Spinel ferrites have been focused widely because of simple to achieve and used in advanced and modern allocations (El-Sayed, 2009) (Mathur, *et al.*, 2008). The helpful properties of the spinel ferrites depend on the chemical composition, preparation of samples, sintering temperature, nature of substituted elements and their composition. Spinal ferrites have face centred cubic crystal structure with general formula of AB_2O_4 wherestructure A represents tetrahedral sites and B is octahedral (Dias, and Moreira 1997).

Cu^{2+} is the divalent transition element which substituted basically at tetrahedral A-site depending upon the atomic radii of the replaced element (Roumaiah, 2008). (Krupicka and Novak, 2002) Among the all spine structures, nickel ferrite have been broadly utilized as a part of various types of attractive inductors, and electrical devices, for example, inductors, heads, refrigeration and attractive sound imaging. Ni-Cu doped ferrites nanoparticles have good material properties due to which can be used to find the electrical properties for advanced a.lications. The electrical conductivity of spinel ferrites is of prime importance as it gives good conductive system

(Patil, *et al.*, 1991). In this way an efficient review of the electrical conductivity of the mixed Ni-Cu ferrite structure from room temperature to well past Curie temperature was attempted. Nan composite materials broadly cover a substantial scope of frameworks, for example, one-dimensional, two-dimensional, three-dimensional and formless materials made of certainly distinguishing parts and merged at the nanometer measure. These material s are broadly utilized from the last seven decays. Currently, the utilization of the ferrite materials develops and, proceeding with scaling down pattern in electrical building. There is a need to create unique technique to prepare the ferrite nonmaterial's. In addition, Various researchers have developed the techniques to prepare nickel based ferritenanop articles .(Kamigaito 1991) have presented a detailed review on the nanocrystal line Nickel ferrite particles forx=0tox=1 and coerdoped Nickelferrite forx=0.05,0.08,0.1. They were prepared these samples using wet chemical co-precipitation strategy. The particles were observed to show a spinel structure with sizes ranging from 21–51nm.The confirmation fthespinelcubic structure with high level of crystallinity of arranged ferrites was achieved. (Song *et al.*, 2011) prepared the Nano-sized Ni-Cuferritesnanop articles by sol-gel auto combustion method and have studied impact of fuel proportion in auto-combustion procedure on the auxiliary, attractive and dielectric properties. (Anilkumar *et al.*, 2009) prepared Ni-Cunanop articles by sol-gelau to burning method. From that mentioned analysis, the prepared ferritesnanop articles have the effect of substitution of NionCu. The increased in grain size with increase with Ni element was observed. Consequently increment of surface area with increasing the concentration of Ni was investigated. Larger surface is responsible for high coercive field of these ferrites. Ni^{2+} replaces Fe^{3+} in both [A] and [B] site diminishes the immersion polarization. The surface impact of Nickel particles diminishes immersion of charge. In this paper, co.er substituted Nickel ferrite nanoparticles have been prepared through sol-gel auto-combustion method.

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Experimental Procedure

In the present work, ferrite nanoparticles having the general formula $Ni_{1-x}Cu_xFe_2O_4$ (x=0.1, 0.2,0.3,0.4,0.5) were prepared by sol-gelauto combustion method. The chemical used inthis experiment a research based with no impurity. The chemical were chose nasnickel nitrate ($Ni(NO_3)_2 \cdot 6H_2O$), ferricnit rate ($Fe(NO_3)9H_2O$), ($Cu(NO_3)_2 \cdot 6H_2O$) were mixed in distilled water with molarity ratio f1: 2 depending upon the formula. The citricacid was selected on the basis of metal nitrate. The ratio of molarity of metal nitrate to citric acidwasselectedas1: 2. The solution was strongly stirred during heating from room temperature to 80^0 C and kept for 3 hours. The solution moved toward becoming viscous material and solis converted to gel. The solvent was evaporated form the solution when heating at 200° Cona hot plate with continuous stirring. The gel was converted into soft powder. The samples were grinded into mortar and pestle to obtain the fine particles. The samples were then annealed at 600°C for 3 hour to achieve the crystalline nature of spinel ferritenanop articles.

2. RESULTS AND DISCUSSION

The impedance spectroscopy is a reasonable procedure to explore the electrical properties of materials. It can be utilized to concentrate the impedance conduct of substance and can be broke down by the perfect circuit show with discrete electrical segment. The impact of tangent loss, dielectric constant, and imaginary dielectric constant have been examined for each prepared sample, these properties of all specimens is measured in the frequency range of 600Hz to 1MHz.

The tangent loss was calculated form the given formulas

$\tan\delta = 1/(2\pi f R_p C)$ (1)

In above formula, "f" represents the frequency, "Rp" represents the parallel resistance of the pellets and "C" represents the capacitance of the pellets. The frequency depending dielectric loss, also called tangent loss is measured in the range 600Hz to 1MHz as shown in Figure 1. From the figure, we conclude that the tangent loss is decreased by increasing the value of frequency. For all the samples the dielectric loss is reduced by increasing the co.er substitution in the manganese nanoparticles because loss factor is depending upon the electrical conductivity of the material. The graph shows the maximum loss is observed at lower frequency range. This shifting of the peaks suggests that the dipole-dipole interaction is stronger at lower frequency range (Patange *et al.*, 2009).

To determine the dielectric constant, the given formulas was used as

$\varepsilon' = Cd/A\varepsilon_o$ (2)

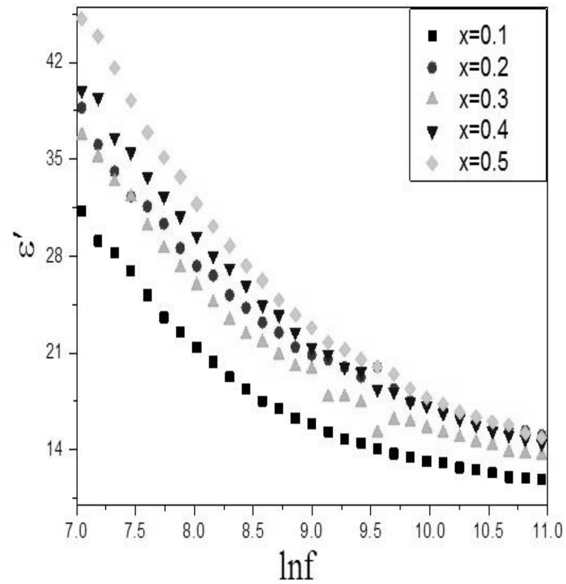

Fig.1: Frequency dependent tangent loss with different values co.er substitution in nickelferrite

Where "d" is the thickness of the pellet, "A" is the area of the pellet and "ε_o" is the permittivity in free space whose value is 8.85x10-12F/m. The frequency dependent dielectric constant is measured in the range 600Hz to 1MHz and observed that the dielectric constant is exponentially decreased with increasing frequency and at high frequency it remains same, as shown in **(Fig. 2).** These varieties in the co.er substituted Nickel ferrite tests were seen because of space charge polarization. As indicated by Maxwell and Wagner two layer show, the space charge polarization is because of the in homogeneous morphology of the material. In the recurrence extend, the dielectric constant is at first exponentially diminish at lower recurrence go while at higher qualities it changes so little, consequently, becomes independent of frequency. This variety is clarified on the premise of space charge polarization which is delivered because of higher conductivity stage in the grain limits and restricted because of social occasion of charges in the region of electric field. The changing electric field will assembled the charge bearers in similar tomahawks which take limited time. Be that as it may, at the specific recurrence this marvel does not occur and this outcomes the diminishing in dielectric steady (Singh, *et al.,* 2012).

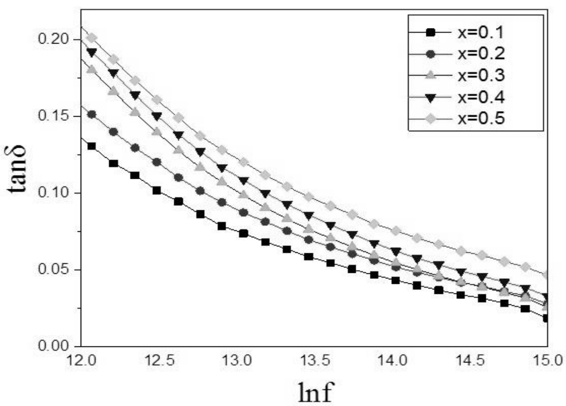

Fig. 2: Frequency dependent real part of the dielectric constant with different values co.er Substitution in nickel ferrite

The imaginary part of the dielectric constant was calculated using the following
Formula
$\varepsilon'' = \varepsilon' \tan\delta$(3)

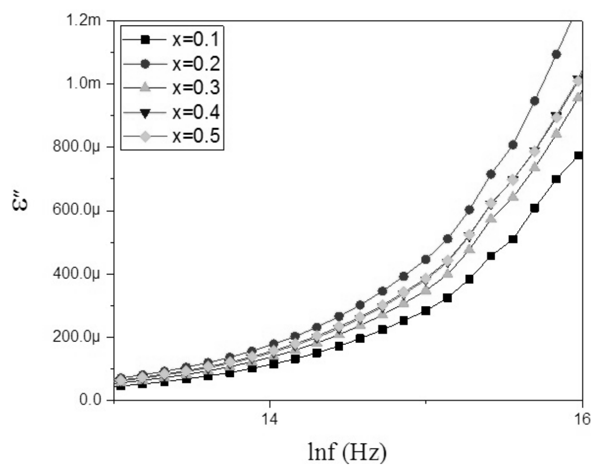

Fig.3: Frequency dependent imaginary part of the dielectric constant with different values Co.er substitution in nickel ferrite

The impedance of the material is actually based on the real and imaginary part was calculatedForm the formulas

$Z` = Rs$ (4)
$Z'' = 1/2\pi fCp$(5)

"Rs" represents the resistance in series of the pallets. Equation 5 determines the imaginary impedance of the pallets where "Z''" represents imaginary impedance, "f" stands for frequency a.lied on the pallets and "Cp" is the capacitance of the pallets. Impedance spectroscopy is the suitable technique to understand the electrical properties of the substance; such as conductivity, dielectric and relaxation characteristics. All the samples of Ni1-xCuxFe2O4 NPs (0.0≤x≥0.5) sintered at 600ºC for 3hrs. The variation of impedance loss with increasing frequency pretends to the conduction mechanism due to the ho.ing of electrons, which is directly related to the frequency of a.lied electric field. The reduction in the curve explains the increase in the conductivity with increase in frequency (Gopalan *et al.*, 2008) It also found that the real part of impedance loss (Z') is increased by the Cu2+ concentration. This behavior is explained on the space charge polarization in the substance. The merger at higher frequencies is due to the release of space charges. The complex impedance loss (Z'') is observed as shown in Figure at the lower frequency range which is due to the major contribution of the grain and whereas grain boundary resistance while conduction is negligible. The observed peak pretends to the dominating of grain boundary resistivity on the conductivity while the conductivity is ignorable at the grain boundary (Farea *et al.*, 2008).

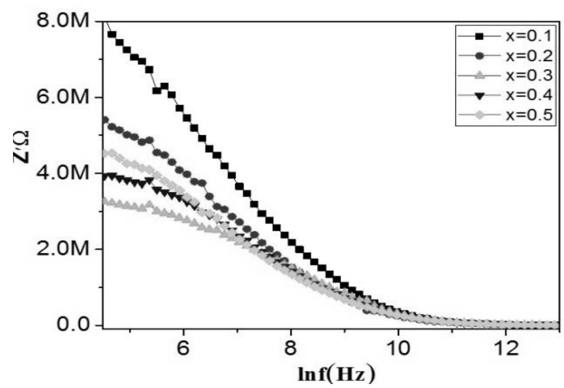

Fig.4: Frequency dependent real impedance loss with different values co.er substitutionin nickel ferrite.

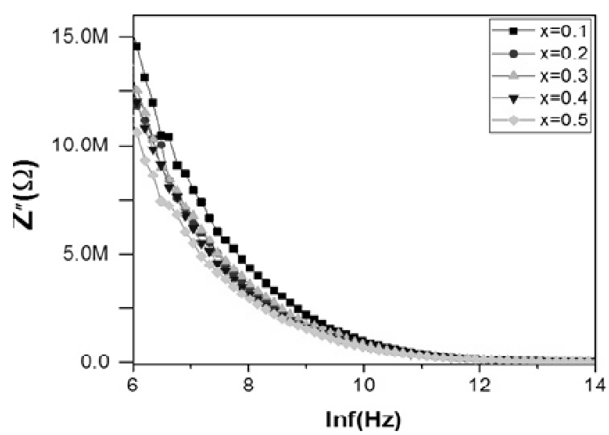

Fig.5: Frequency dependent imaginary part of impedance loss with different values co.ersubstitution in nickel ferrite.

Equation 6 is used to calculate imaginary modulus of the pallets while equation 7 determinesthe modulus of the pallets in which "M"" stands for imaginary modulus and "tanδ" represents tangent loss or dielectric loss..

M"=2πfCpZ`(6)
M`= M"/ tanδ (7)

The real part of electric modulus of co.er substituted ($Ni_{1-x}Cu_xFe_2O_4$) nanoparticle is observed in figure which reveals exponentially increment in the electric modulus at lower frequencies lies in the range 7 KHz to 11 KHz for all samples. The real part of electric modulus is dependent of co.er substitution in the lower frequency range. The concentration dependency is saturated and become uniform at higher frequency range.

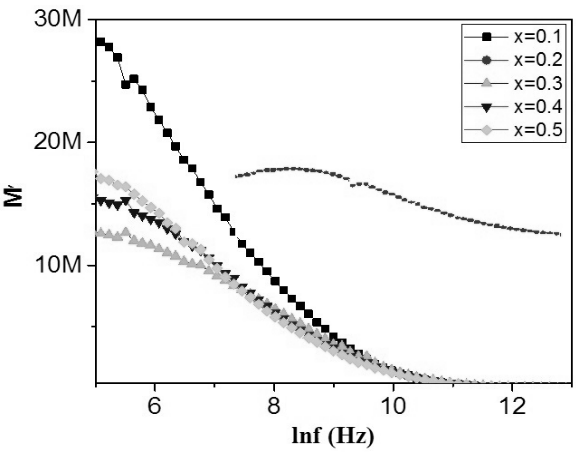

Fig.6: Frequency dependent imaginary part of impedance loss with different values co.er Substitution in nickel ferrite

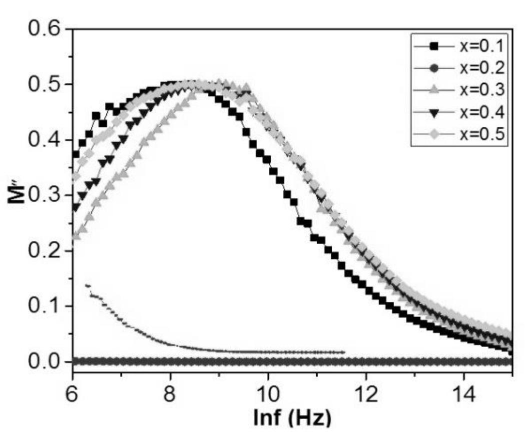

Fig.7: Frequency dependent imaginary part of Modulus with different values co.er Substitution in nickel ferrite

3. CONCLUSIONS

In this report, Cu substituted $NiFe_2O_4$ powders were prepared by the solgel auto combustion technique. The crystallinity was achieved with annealing of temperature at 600 ^{0}C for three hrs. The dielectric loss and the spectrum loss patterns show the reduction in as the frequency of a.lied electric field increase. These phenomena have been explained on the basis of space-charge polarization in the light of Maxwell-Wagner two layers model. The imaginary part of impedance indicated only one semicircle which shows the dominance of grain and the conduction of grain boundary is negligible. The real part of impedance has been found to increasing substitution of Cu^{2+} concentration as well as frequency which suggest the reduction in conductivity.

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