RESEARCH ARTICLE   **OPEN ACCESS**

Study of Electrical and Dielectric properties of Zn doped Ni-Cu Ferrite

Padampalle AS [1]*, Suryawanshi AD[2], Suryawanshi DD[3], Patil SS[4] and Gurav SK[5]

[1]Department of Physics, S. C. S. College, Omerga, 413606 (M. S.) India,[2]Department of Physics, B. J. College, Ale (Pune) 412411 (MS) India.[3]Department of Chemistry, B. S. S. College, Makani, 413606(MS) India.,[4]Department of Physics, S C College Junnar (Pune) 412411 (MS) India.,[5]Department of Physics, S. M. P. College Murum, 413606 (M.S.) India

Email: aspadampalle@yahoo.com

ABSTRACT

Ni-Cu-Zn ferrite is prepared by sol-gel autocombustion method using metal nitrates and citric acid. The information of single phase formation was confirmed by X-ray diffraction and lattice constant and particle size is evaluated. The electrical resistivity has been studied as a function of temperature. Dielectric constant; Dielectric loss and loss tangent were studied at fixed frequency 1KHz and varying temperature.

Keywords: Nanocrystalline; DC resistivity; dielectric constant; ferrite;

INTRODUCTION

Ferrites which have many applications at microwave frequencies are very good dielectric material. Ferrites have high electrical resistivity, low dielectric loss and chemical stability. Nanocrystalline material ferrites have many applications in making cores of audio frequency and high frequency transformers, chokes, permanent magnets, microwave absorbers, wave guides and chlorine gas sensors, high density information storage, color imaging, bioprocess, medical diagnosis, electromagnetic wave absorption, etc. Multi layer chip indicator (MLCI) has recently been developed as one of the key surface mounting devices [1].

Due to their reduced sizes, the nanocrystalline materials passes novel and improved properties in comparison to bulk materials, which have been extensively used in electronic devices for high frequency telecommunications [2]. Very fine ferrite particles can be produced by the chemical co-precipitation and sol–gel methods [3–5]. Several researchers have reported the synthesis of Ni-Zn ferrites using different techniques like, ceramic [6], hydrothermal [7], combustion [8], co-precipitation [9], spark plasma sintering [10], micro emulsion [11] and ball milling etc. The size and shape of the ferrite particles are dependent on the synthesis process. Sol-gel autocombustion method is a simple process, which offers a significant saving in time and energy consumption over the traditional methods.

In this paper, we prepare Cu doped Ni-Zn ferrite and studied electrical and dielectric properties. The study of dielectric properties gives valuable information on the behavior of localized electronic charge carriers leading to greater understanding of mechanism of dielectric polarization in ferrites.

METHODOLOGY

Nanocrystalline spinel ferrite $Ni_{0.7-x}Cu_xZn_{0.3}Fe_2O_4$ where x= 0.0 to 0.5 were prepared by sol-gel autocombustion method using metal nitrates and citric acid. Citric acid $C_6H_8O_7$, ferric nitrate $Fe(NO_3)_3.9H_2O$, nickel nitrate $Ni(NO_3)_2.6H_2O$, zinc nitrate $Zn(NO_3)_2.6H_2O$ and copper nitrate $Cu(NO_3)_2.3H_2O$ were used as raw materials with molar ratio of metal nitrates to citric acid 1:3. All nitrates and citric acid were dissolved in distilled water and stirred continuously. During the constant stirring ammonia solution was added drop wise to adjust PH 7; the solution was heated at 100°C to transform into gel. The gel burnt in a self propagating combustion manner until all gels were completely burnt to form ashes. The as-prepared powder was ground using a mortar and pestle, and then calcined in muffle furnace at 500⁰Cfor 5h and cooled slowly to room temperature. The X-ray diffraction patterns of the ferrite samples were taken in our laborites using Regaku Miniflex II diffractometer with Cu Kα radiation (λ= 1.54056 Å) in the range of 2θ from 20° to 80°. Dc electrical resistivity was measured by using two probe methods. Dielectric properties as a function of temperature were studied with fixed frequency I KHz using LCRQ meter.

RESULTS AND DISCUSSION

3.1. XRD:
The X-ray diffraction pattern of $Ni_{0.7-x}Cu_xZn_{0.3}Fe_2O_4$ ferrite for x= 0.0 and 0.1 is as shown in Fig.1. All the peaks could be indexed with cubic spinel ferrite structure showing that all the samples were formed in single phase and were well crystalline in nature. By knowing the values of interlplanar distance (d) and Miller indices (hkl) lattice parameter *a* calculated by using formula, $[a=d(h^2+k^2+l^2)^{1/2}]$. The value of lattice parameter increases by increasing Cu^{2+} ions. This increase in lattice parameter is due to increase in ionic radii of Cu^{2+} (0.72A°) as compared to ionic radii of Ni^{+2} (0.69A°). The value of lattice parameter is as shown in table 1. The FWHM of the most intense peak is used to get average particle size using scherrer's equation,

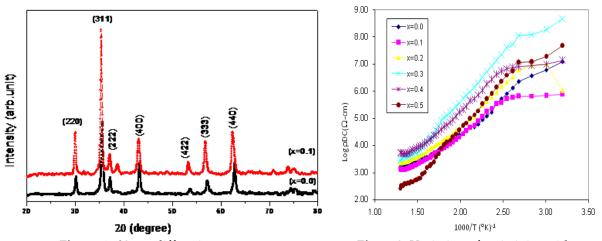$$t = \frac{0.9\lambda}{\beta\cos\theta}$$

Where, λ the wavelength of x-ray radiation (Cu Kα, 1.54056 Å), β is full width at half of the intensity maximum of plane in radian and t is diameter of crystal particle. The crystallite size of the as-burnt powder estimated from the X-ray. Peak broadening of the diffraction peak is 40 nm to 80 nm. This shows that the synthesized powder has nano-sized crystallites.
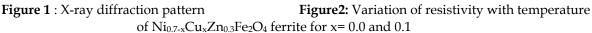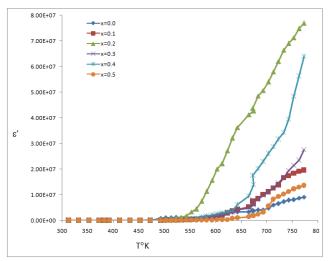
3.2 D. C. electrical resistivity:
The variation of logρ with 1/T the sample is shown in Fig.2. Form figure, it can be noted that the resistivity decreases with increasing temperature. The ferrites show semiconducting behavior. The decrease in resistivity may be attributed to facts that existence of Fe^{3+} in B-site. It is well known that the conductivity of ferrite depends upon the ratio of Fe^{3+} to Fe^{2+}, since this ratio decreases with increasing composition, then resistivity should exhibits a continuous decrease with increasing composition. The breaks in resistivity plots denote two regions of conductivity and temperature corresponding to the break is Curie temperature of the samples confirmed. The lower temperature region

below Curie temperature corresponds to the ordered ferromagnetic region with low activation energy while the higher temperature region above Curie temperature corresponds to a paramagnetic region with comparatively high activation energy [12]. The value of Curie temperature is shown in table1. It represents that as composition increases Curie temperature decreases.

Table 1: Variation of Lattice parameter and particle size for $Ni_{0.7-x}Cu_xZn_{0.3}Fe_2O_4$ ferrite for (x= 0.0 to 0.5).

Compositions X	Lattice Constant a in(A°)	Particle size t (nm)	Curie temp. (T_c) in (°K)
0.0	8.3654	40.23	735
0.1	8.3979	47.28	702
0.2	8.4012	55.13	684
0.3	8.4067	67.34	664
0.4	8.4108	72.51	700
0.5	8.4154	79.31	665

Figure 1 : X-ray diffraction pattern of $Ni_{0.7-x}Cu_xZn_{0.3}Fe_2O_4$ ferrite for x= 0.0 and 0.1

Figure2: Variation of resistivity with temperature

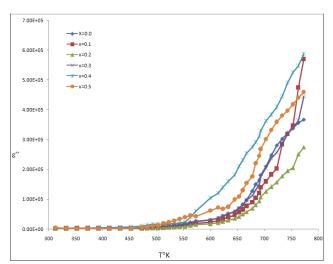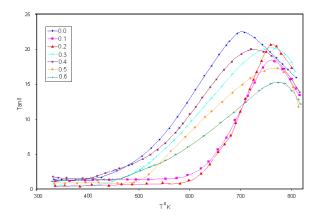**Figure 3:** Variation of dielectric constant with temp of Ni0.7-xCuxZn0.3Fe2O4 ferrite for (x= 0.0 to 0.5)

Figure 4 Variation of dielectric constant with temp of $Ni_{0.7-x}Cu_xZn_{0.3}Fe_2O_4$ ferrite for (x= 0 to 0.5)

http://www.irjse.in

Figure 5: Variation of loss tangent with temperature of $Ni_{0.7-x}Cu_xZn_{0.3}Fe_2O_4$ ferrite for (x= 0.0 to 0.5).

3.3 Dielectric Properties:

The variation of dielectric constant (ε'), dielectric loss (ε'') and loss tangent ($\tan\delta$) as a function of temperature at a fixed frequency 1 KHz is as shown in Fig. 3, 4 and 5 respectively. From figures, it is observed that dielectric constant (ε'), dielectric loss (ε'') and loss tangent increases gradually with an increasing temperature. This increase is due to polarization in ferrites has largely attributed to the presence of Fe^{2+} ions which give rise to heterogeneous spinel structure. Since Fe^{2+} ions are easily polarisable, the larger the number of Fe^{2+} ions the higher would be dielectric constant [13]. The electric hopping between Fe^{2+} and Fe^{3+} ions and hole hopping between Ni^{2+} and Cu^{2+} on B-sites are responsible for electric conduction and dielectric polarization. As Cu ion substation increases replacing Ni ions some Fe ions will be forced to migrate from B to A sites [14-15].

CONCLUSION

In Cu-doped Ni-Zn ferrite, the resistivity is found to be decrease with increasing temperature for all samples. The ferrites show semiconducting behavior. The dielectric constant, dielectric loss and loss tangent are increases with increasing temperature. This increase in dielectric constant with increasing temperature is due to local displacement of electrons in the direction of electric field which determine the polarization process.

Conflicts of interest: The authors stated that no conflicts of interest.

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