Study of Electrical Properties of Ni Substituted Mg-Cu-Zn ferrites Synthesized by Molten Salt Route

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Abstract :

A polycrystalline $Mg_{0.25-x}Ni_xCu_{0.25}Zn_{0.5}Fe_2O_4$ with X= 0.15, and 0.20 system have been synthesized by molten salt method and studied by using x-ray diffraction (XRD) technique and transports characteristics. The XRD data confirms the formation of single phase cubic spinal structure. The temperature dependent of d.c. electrical resistivity of two samples were studied by two-probe method. The increases in resistivity increases as Ni content X increases. The result in reduction of Fe^{2+} ions that may be formed during preparation, therefore, the electron exchange between the iron –iron ions at B-site is reduced and hence the resistivity increases was reported in the present study.

Keywords : Mg-Cu-Zn ferrite, XRD, Resistivity etc.

I. INTRODUCTION

The interest in ferrite emerges from their versatile applicability in radio to microwave frequency region. Ferrites have low conductivity greatly influences the dielectric and magnetic behavior [1]. The polycrystalline ferrites which have many application at microwave frequencies are very good dielectric materials. The electrical and dielectric properties of ferrites are dependent on various factors like method of preparation, sintering temperature, sintering atmosphere, sintering time and chemical composition [2]. The reduction of Fe^{3+} to Fe^{2+} takes place without disturbing the lattice configuration. The electrical transport properties of ferrites provide information suitable for the specific application of ferrite in electrical and electronic device. High electrical resistivity and low eddy current losses at high frequencies make them widely usable for the cores of high frequency electromagnetic devices [3, 4]. Electrical switching in ferrites was reported by Yamashiro [5] in polycrystalline thermally treated bulk copper ferrite. Similar reports are presented for copper ferrite by Vaingankar [6]. The purpose of the present work is to study the electrical properties of Ni substituted Mg-Cu-Zn ferrite as a function of temperature.

II. EXPERIMENTAL

The samples of Ni substituted ferrite having the generic formula $Mg0.25_{-x}Ni_xCu_{0.25}Zn_{0.5}Fe_2O_4$ with X= 0.15 and 0.20 have been synthesized by molten salt method. Both samples were characterized by x-ray diffraction technique (XRD) to confirm the phase purity of the prepared samples.

The temperature dependence of d.c.electrical resistivity of all the samples of the series $Mg_{0.25-x}Ni_xCu_{0.25}Zn_{0.5}Fe_2O_4$ under investigation was studied by two-probe method. The sample was held in specially electrodes. Silver paste was applied on the two surfaces of the circular pellet for good ohmic contact. The whole assembly is placed in a furnace. The temperature of the sample was measured by chromel-alumel thermocouple with an accuracy of +5k. The temperature of the furnace was controlled by digital temperature controller. A slow rate of change in temperature was maintained throughout the experiment. The measurement was carried out from room temperature to beyond Curie temperature, in the step of 10k.

The resistivity ρ_{dc} of all the samples was calculated from dimension and resistance of the pellet by using the relation,

$$\rho_{dc} = \frac{\pi r^2 R}{t}\ \Omega\ \text{cm}$$

Where, r is radius of pallet, t is thickness of pallet and R is resistance of the pallet. The conductivity ($\sigma = 1/\rho$) of all samples were measured by the following formula;

Where, ρ is resistivity calculated by previous equation

III. RESULTS AND DISCUSSION

All the samples under investigation were characterized by x-ray diffraction technique at room temperature. The XRD pattern shows the presence of all the reflection belonging to cubic spinal structure. The analysis of XRD pattern revealed the formation of single phase cubic structure. Figure 1 shows the XRD spectra of 0.15 composite and figure 2 shows the XRD spectra of 0.20 composite respectively. Both spectrum shows cubic behavior with nanocrystalline materials and 0.15 composite particle size is 45nm and 0.20 composite particle size is 49nm respectively.

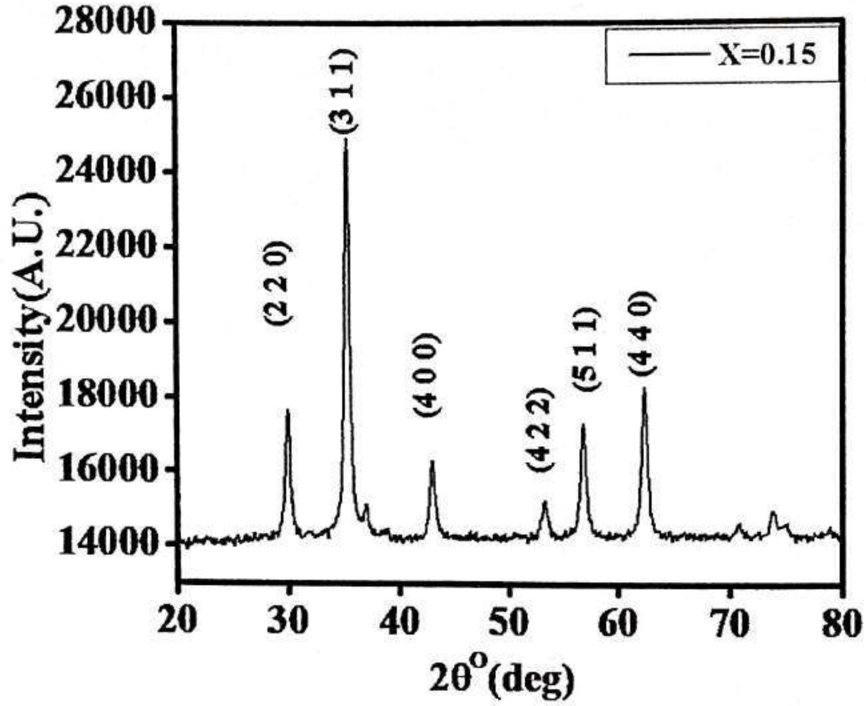

Figure 1:- XRD spectra of 0.15 composite.

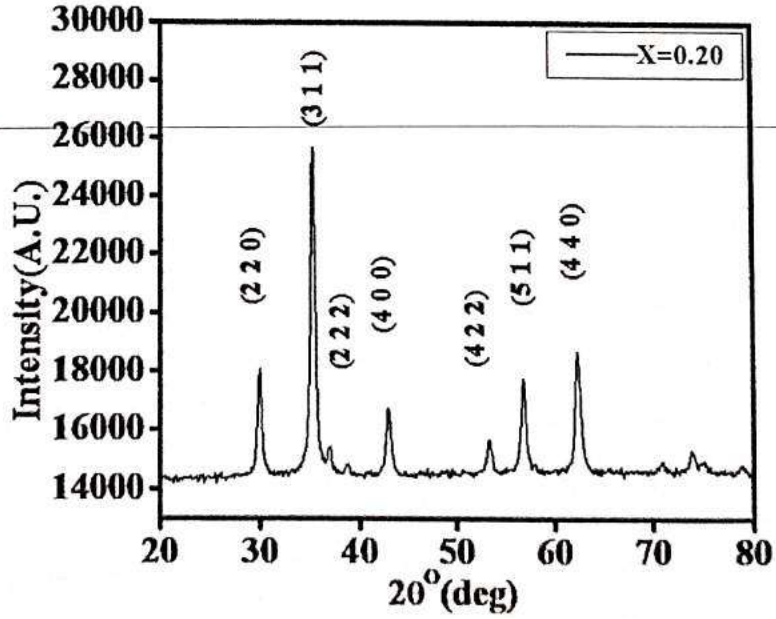

Figure 2:- XRD spectra of 0.20 composite.

The d.c. electrical resistivity was studied as a function of temperature from room temperature to beyond curie temperature using two probe method. The resistivity and conductivity values measured at room temperature for $Mg_{0.25-x}Ni_xCu_{0.25}Zn_{0.5}Fe_2O_4$system are given in table 1.

X	R Ω x10^6	(ρ_{dc}) Ω.cmx10^5	σ Ω.(cm)$^{-1}$x10^{-6}
0.15	1.96	3.61	2.78
0.20	2.068	3.85	2.54

Table1:- Variation of resistance (R) and specific resistance (ρ_{dc}) at room temperature of $Mg_{0.25-x}Ni_xCu_{0.25}Zn_{0.5}Fe_2O$system

It can be seen from Table1. That the values of electrical resistivity are 3.61x10^5 Ω and 3.85 x10^5 Ω increases continuously with increases in Ni content. The increases in resistivity may be due to the presence of number ofFe^{3+} ions at octahedral B-site. In the present case according to cation distribution data Ni^{2+} ions are occupied at tetrahedral A-site leading to more Fe^{3+} ions at octahedral B- site. The dependence of resistivity of 0.15 and 0.20 compositions is show in figure 3 and figure 4 respectively.

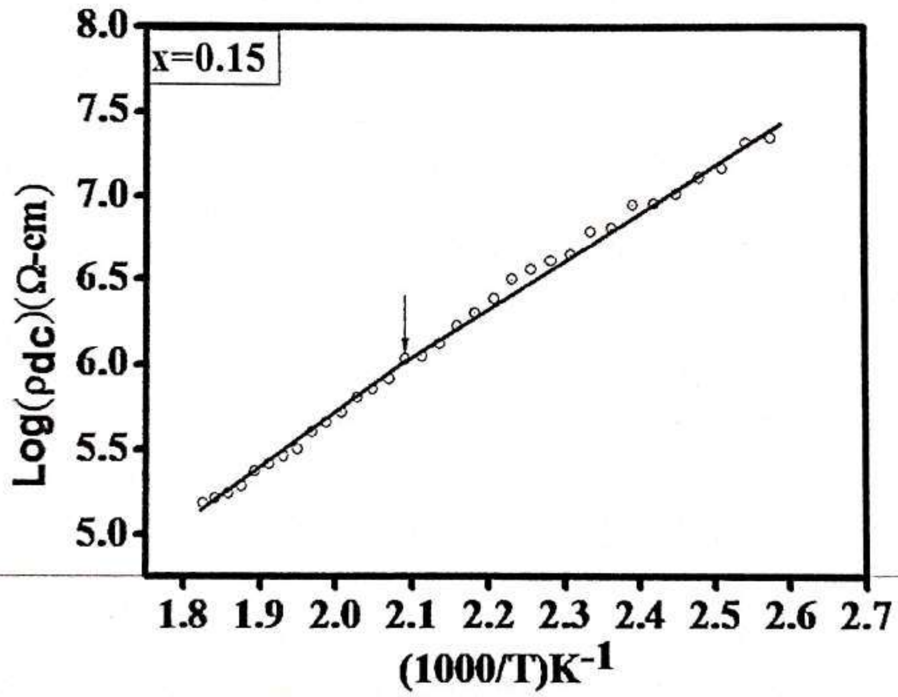

Figure 3:-The dependence of resistivity of 0.15 compositions.

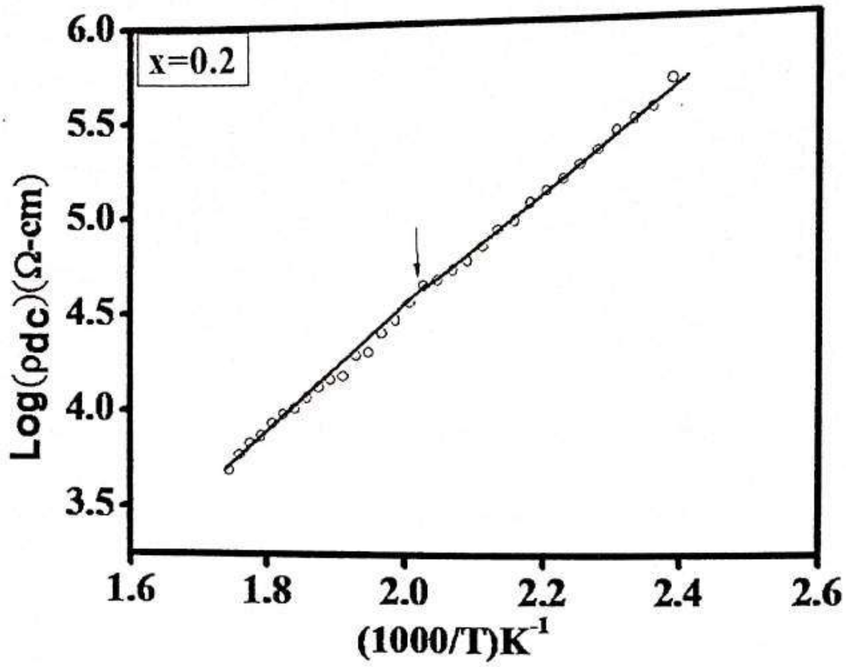

Figure 4:-The dependence of resistivity of 0.20 compositions.

The resistivity as a function of temperature is also studied. Fig.3 shows the variation of log ρ versus 1000\T for typical composition x=0.15 It can be seen from figure that d.c. resistivity decreases with the increases of temperature, indicating the semi-conducting nature of the ferrite system. Each sample shows a break near the Curie temperature which is attributed to the from ferromagnetic region to paramagnetic region.

Using the resistivity plots the activation energy in ferromagnetic and paramagnetic region was calculated and the values of activation energies are tabulated in Table2.

X	Activation energy (eV)		ΔE (eV)	Tc (°C)
	Ferro	Para		
0.15	0.46	0.70	0.24	184
0.20	0.49	0.73	0.24	201

Table.2. Variation of activation energy in Ferromagnetic and paramagnetic region of $Mg_{0.25-x}Ni_xCu_{0.25}Zn_{0.5}Fe_2O$ system.

It is well known that the electron and polaron hoping between Fe^{2+} / Fe^{3+}, Cu^{2+}/Cu^{1+} ions, with the activation energy 0.2ev is responsible for conduction in mixed ferrite [7]. The lower activation energy in ferrimagnetic region is attributed to the magnetic ordering due to the due to the decrease in concentration of current carriers [8].

The electrical conductivity in ferrites can be explained on the basis of the verway de Bore Mechanism [9], i.e. exchange of electrons between ions of the same element that are present in more than one valance state distribution randomly over equivalent crystallography lattice states i.e. $Fe^{3+} \leftrightarrow Fe^{2+}$.

The substitution of Ni^{2+} ions reduces Fe^{3+} ions at tetrahedral A-site by (1-x) and increases Zn^{2+} ions reduces Fe^{3+} ions at tetrahedral A-site by (1-x) and increases Ni^{2+} ions by x. the presence of Cu^{2+} ions at octahedral B-site reduces concentration of Fe^{3+} ions at octahedral B-site . The may result in reduction of Fe^{2+} ions that may be formed during preparation, therefore, the electron exchange between the iron-iron ions at B-site is reduced and hence the resistivity increases . The present values of activation energy suggest that the hopping of smaller polaron is responsible for the conduction in the present samples.

CONCLUSION

The electrical resistivity measurement shows that the resistivity increases with composition for Nickel substituted Mg-Cu-Zn ferrite. The electrical logarithm of resistivity versus temperature plots of Nickel substituted Mg-Cu-Zn ferrite. The conduction mechanism can be explained on the basis of polaron as activation energy values are found to be less than 0.2ev. The particle size of 0.15 and 0.20 compositions are 45nm and 49nm respectively. It has confirmed that both nanomaterials are cubic spinal structure.

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