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Electrical conductivity of Ti substituted Ni-Zn ferrites

A. K. Ghatage*, S. H. Tamboli, R. N. Patil and R. A. Patil

Textile and Engineering Institute, Rajawada, Ichalkaranji

ABSTRACT

The electrical resistivity and seebeck coefficient measurements are carried out as a function of temperature for the system $Ni_{0.5+x}Zn_{0.5}Ti_xFe_{2-2x}O_4$ with x = 0.0, 0.2, 0.4 and 0.5. The lattice constants of the phases are evaluated from x-ray diffraction data. It is observed that the sample with x = 0 show n-type where as remaining samples show p-type at room temperature. The n-p transition takes place for the samples with x = 0.2 at 375 k and for 0.4 at 475 K and the conduction mechanism is associated with the polaron hopping.

Keywords*:* Ferrites, activation energy, resistivity, Thermoemf, polaron hopping.

INTRODUCTION

Ferrites having spinel structure are ferromagnetic and have potential applications. High electrical resistivity and relatively easy preparation make these materials widely useful for the cores of intermediate and high frequency electromagnetic devices. Ferrites have vast applications from microwave to radio frequencies [1]. Therefore their study related to electrical properties is important. Thermoelectric power and electrical resistivity are very convenient to measure and suggest the conduction phenomenon. Discussion on the electrical properties of ferrites is usually based on the band structure or carrier hopping model. In this paper we report the electrical resistivity and thermoelectric power as a function of temperature of Ti substituted Ni-Zn ferrites.

MATERIALS AND METHODS

Samples with composition $Ni_{0.5+x}Zn_{0.5}Ti_xFe_{2-2x}O_4$ with x = 0.0, 0.2, 0.4 and 0.5 were prepared using standard ceramic technique using AR grade oxides. It is mixed in proper proportions for the desired compositions and pre sintered at 850^oC for 10 hour in air. The pellets were made from the pre sintered powder. They were finally sintered at 1150 ^oC for 24 hour and furnace

cooled at the rate of 80 ^{o}C / hour. The x-ray diffraction pattern of the samples was recorded using a Philips diffractometer. This revealed that all the samples were found to be single phase spinels.

The electrical measurements were carried out by means of two probe method. Silver paste was applied on both of the flat surfaces of the pellet for good electric contacts. A low but constant voltage was applied across the sample and current through the sample was measured as a function of temperature. The activation energy was calculated from the variation in resistivity with temperature using the formula

$$\rho = \rho_0 \exp (\Delta E/KT)$$

The Seebeck coefficient α was measured as a function of temperature and composition maintaining the temperature difference of 20 ^{o}C. Details of measurement of electrical resistivity ρ and thermoelectric power are given elsewhere [2].

RESULTS AND DISCUSSION

From x-ray diffraction pattern it was observed that all the samples were single phase [3]. The lattice constants are listed in table 1. The variation of log ρ with 1/T for all the compositions is shown in figure 1(a). The activation energies were calculated for different regions. The resistivity with temperature plots show three regions with two breaks. The slope of the second region changes at temperature which is nearly equal to Curie temperature. The conduction phenomenon in the first region of lower temperature is attributed to the impurities while conduction at high temperature is due to the polaron hopping. From the activation energies noted in table 1, it is seen that the energy in I region is less than 0.15eV which decreases with increasing Ti. The activation energy is greater than 0.5 eV for the II region I e feri region. These energies are higher than the ionization energy of donors or acceptors I e 0.1 eV and hence possibility of band type conductor is ruled out. This suggests that the polaron hopping mechanism is favored.

The Seebeck coefficient α is given by the relation

$$\alpha = \Delta V/\Delta T$$

Where ΔV – voltage measured across sample,
ΔT – temperature difference across sample

Figure 1(b) shows the variation of Seebeck coefficient with temperature. It is observed that the sample with x= 0 show n type where as remaining samples show p type at room temperature. The n-p transition takes place for the samples with x = 0.2 at 375 K and for x = 0.4 at 475K, also for these two samples cusp like minima is observed at 425K and 525K respectively and afterwards α remains almost constant. The variation of Seebeck coefficient with temperature for this system shows non-degenerate semiconducting type behavior.

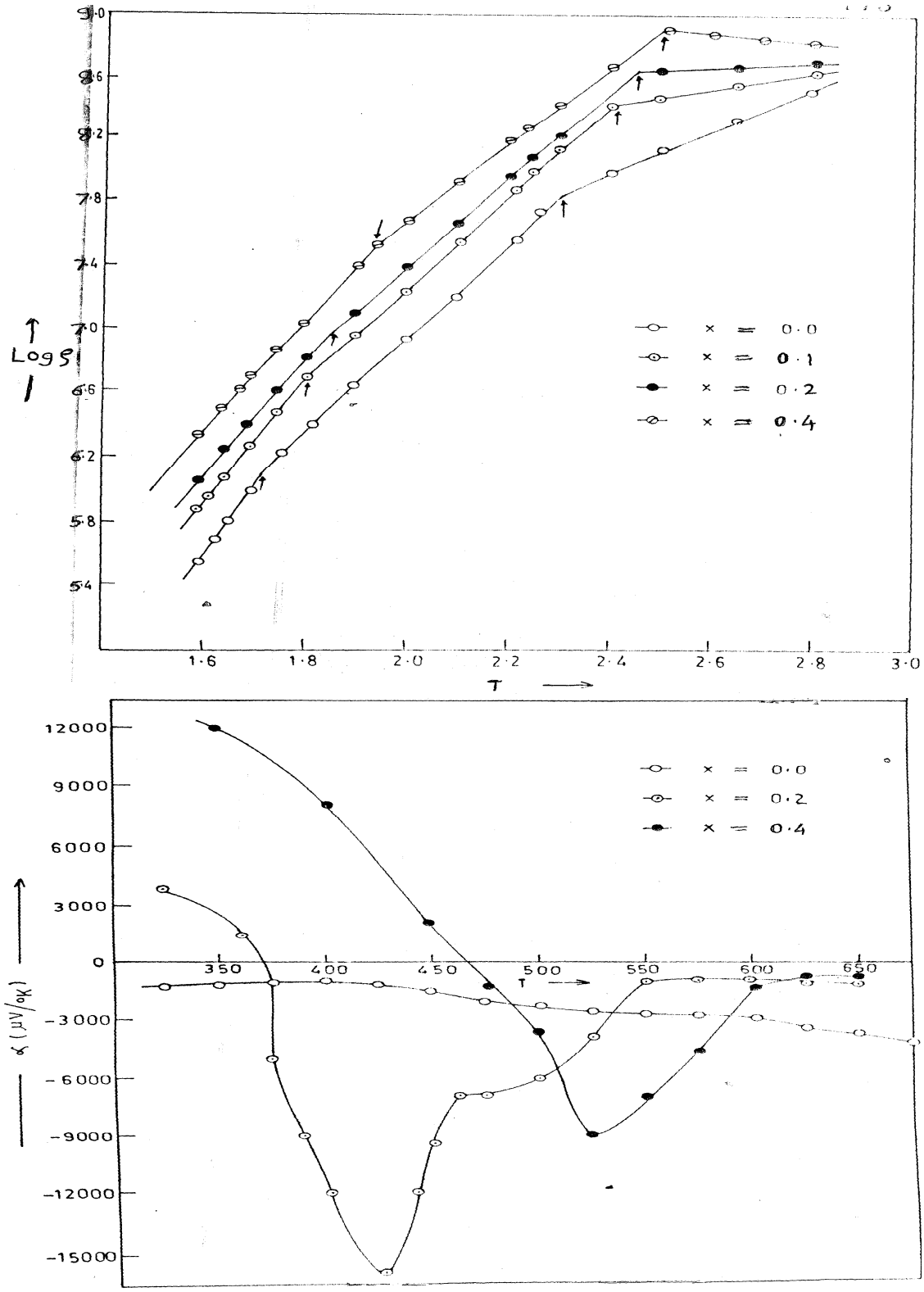

Figure 1: (a) variation of resistivity with temperature and (b) variation of thermo emf with temperature

Table 1: Lattice constants, activation energies from conductivity and mobility of given samples.

Content (x)	Lattice Parameter (A^o)	Activation energy from conductivity ΔE_1 (eV)	Activation energy from conductivity ΔE_2 (eV)	Activation energy from mobility (eV)
0.0	8.390	0.16	0.57	0.41
0.2	8.399	0.12	0.56	0.40
0.4	8.399	0.04	0.53	0.38
0.5	8.396	0.02	0.52	0.37

The predominant conduction in Ni-Zn ferrites is due to presence of Ni ions in the octahedral sites [4], favoring the mechanism as $Ni^{2+} + Fe^{3+} \leftrightarrow Ni^{3+} + fe^{2+}$. In $Ni_xFe_{3-x}O_4$ system it is observed that as x becomes larger than one. Ni^{2+} becomes Ni^{3+} in order to maintain charge neutrality and continues to stay at octahedral site, also NiO has affinity for oxidation resulting in the formation of Ni^{3+} ions. Therefore in the present system the concentration of Ni increases with increasing Ti concentration. According to cation distribution studied by neutron diffraction, all the Ni ions situate at B-site. Hence the possibility of formation of Ni^{3+} is more. Therefore, the conduction at B-site may be due to two types of carriers. $Fe^{2+} \leftrightarrow Fe^{3+}$ (n type) [5] and $Ni^{2+} \leftrightarrow Ni^{3+}$ (p-type). The possibility of the occurrence of hopping conductivity in ferrites has been developed in literature considering the small polaron model [6]. Hence electrical conduction in these ferrites is due to small polaron hopping mechanism. The mobility values are calculated using Seebeck coefficient and resistivity data. The activation energies of mobility are given in table 1. The activation energy from mobility is slightly lower than that measured from resistivity. This can be regarded as the confirmation of the fact that the conduction is due to polaron hopping. This supports the results of Simsa and Andrejev [7].

CONCLUSION

For the present studied system, the conduction in the first region of lower temperature is due to the impurities while the conduction at higher temperature is due to the polaron hopping mechanism. The sample with x = 0 is of n type and remaining are p-type at room temperature. The p-n transition takes place at higher temperature. The variation of Seebeck coefficient with temperature for this system shows non-degenerate semiconducting type of behavior.

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