Electrical properties of silicon substituted Co–Zn Spinel Ferrite

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Abstract- Spinel ferrites with general formula $Co_{0.7+x}$ $Zn_{0.3}$ Si_x Fe_{2-2x} O_4 (for x = 0.0 to 0.4) were prepared by standard double sintering ceramic method. Electrical properties of the present spinel system were studied by means DC and AC resistivity measurements. Both DC resistivity ρ_{dc} and AC resistivity ρ_{ac} are found to increase with increase in Si concentration from x = 0.0 to 0.1 and then they decrease with increase in Si concentration from x = 0.2 to 0.4. AC resistivity ρ_{ac} of all the samples is found to increase at lower temperature and then it decreases with increase in temperature.
Keywords: spinel ferrite, Electrical Properties, hoping

1) INTRODUCTION

Ferrites have wide range of applications due to their interesting electrical and dielectric properties. The electrical properties of ferrites depend upon chemical composition, Methods of preparation and sintering temperature [1,2].

The electrical conductivity in ferrites can be explained on the basis of Verway mechanism [3]. The study of dielectric properties of ferrites produces valuable information on the behavior of electronic charge carriers leading to greater understanding of the mechanism of dielectric polarization. It is reported that incorporation of Si in $CoFe_2O_4$ necessitates adjustment of both Co^{2+} and Fe^{3+} ions [4]. The present work reports effect of Si substitution on DC and AC resistivities of Co-Zn ferrite.

2) EXPERIMENTAL

Five samples of the ferrite system $Co_{0.7+x}$ $Zn_{0.3}$ Si_x Fe_{2-2x} O_4 (for x = 0.0 to 0.4) were prepared by the double sintering ceramic method using AR grade oxides CoO, ZnO, SiO_2 and Fe_2O_3. The XRD patterns of all the samples were recorded using CuKα radiation on a Pw710 diffractometer.

The electrical resistivity as a function of Si concentration was measured using a two probe method for all samples in the form of pellets. AC electrical resistivity, as a function of temperature was measured using Aplab made LCR-Q meter at fixed frequency of 1KHz.

3) RESULTS AND DISCUSSION

3.1 XRD ANALYSIS

Analysis of the XRD patterns revealed that all the samples have a single phase cubic structure. Comparing the calculated and observed X-ray intensity ratios I_{220}/I_{400} and I_{400}/I_{422} and using site preference of various ions, the cation distribution of the present system can be written as

For x = 0.0 $(Zn_{0.3}\ Fe_{0.7})^A\ [Co_{0.7}\ Fe_{1.3}]^B$

For x=0.1 to 0.4

$(Co_{0.05}\ Zn_{0.3}\ Si_{0.05+y}\ Fe_{0.6-y})^A\ [Co_{0.75+y}\ Si_{0.05}\ Fe_{1.2-y}]^B$

Where x = 0.1 + y , y = 0.0, 0.1, 0.2, 0.3

3.2 DC RESISTIVITY

The values of DC resistivity (ρ_{dc}) of the present system with varying Si concentration at fixed temperature of 500 K are shown in Table-1. It is evident that dc resistivity increase with increases in Si concentration from x = 0.0 to 0.1 and then it decreases with increase in x form x = 0.2 to 0.4. Due to complex structural composition of these ferrites, the conduction mechanism can be attributed to a combination of several processes. Fe^{2+} ions are formed due to partial reduction of small fraction of Fe^{3+} to Fe^{2+} ions due to volatilization of Zn at elevated firing temperature during sintering process [5]. In the present system, $2Fe^{3+}$ ions are replaced by Si^{4+} ions and Co^{2+} ions. Also CoO has an affinity for oxidation resulting in the formation of Co^{3+} ions. So increasing resistivity of the system with increase of Si content up to x = 0.1 may be due to electron – hole compensation.

The decrease in dc resistivity ρ_{dc} with increase of Si content from x = 0.2 to 0.4 may be attributed to the presence of larger number of cobalt ions on B-site, which favor the hoping mechanism between Co^{2+} and Co^{3+} ions. Thus P-type i.e. hole hoping between Co^{2+} and Co^{3+} ions is predominant conduction mechanism in the present system containing higher concentration of cobalt. These observations are consistent with the earlier reported results [6,7] according to which the presence of Co^{2+} ions on B site lowers the resistivity.

3.3 AC RESISTIVITY

Table- 1 shows variation of AC resistivity ρ_{ac} with variation of Si concentration. Similar to DC resistivity, AC resistivity is found to increase with increase in Si concentration from x = 0.0 to 0.1 and then it decreases for higher concentration of Si. Only difference is that the AC resistivity values are smaller than DC resistivity values.

Fig.1 shows plots of log ρ_{ac} against reciprocal of temperature. It is evident that for all samples of the present system, ρ_{ac} is found to increase initially with temperature (up to about 350K) and then the characteristic variation of ρ_{ac} follows the typical semiconducting behavior i.e. it decreases with increase in temperature. The anomalous variation of ρ_{ac} resistivity at lower temperature (up to 350K) may be due to ionic drift current. The variation of ρ_{ac} with temperature can be attributed to current due to electrons in conduction band, current due to electron hoping and ionic drift current [8]. The present results indicate that contribution from ionic drift current is more predominant in the anomalous region of ρ_{ac} plots. The ionic contribution becomes negligible at higher temperatures and ρ_{ac} resistivity becomes entirely electronic.

CONCLUSION

1) Increase in dc resistivity up to Si content x = 0.1 is due to electron – hole compensation.
2) Decrease in dc resistivity for Si content x $\geq$ 0.2 is due to hoping mechanism between Co^{2+} and Co^{3+} ions.
3) Anomalous variation of ac resistivity at lower temperature is due to ionic drift current.

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REFERENCES

[1] B.P. Ladgaonkar, C.B. Kolekar, P. N. Vasambekar, A.S.Vaingankar, Ind. J.Eng. Mater. Sci. 7 (2000) 419.
[2] A.S. Vaingankar, S.G. Kulkarni, M.S. Sagare J. Phys. France 7 (1997) C 1 – 155.
[3] E.J.W. Verwey, P.W. Haaijmann, E.C. Romeyn, G.M.Van Oosterhont, Philips Res. Rep. 5 (1950) 173.
[4] S.S. Shinde, K.M. Jadhav, Mater Lett. 37(1998) 63-67.
[5] Van Uitert L.C. Proc. IRE (USA), 1294 (1956)1303.
[6] A.B. Devale, D.K. Kulkarni, J. Pure and Appl. Phys. 16(1978) 697.
[7] R. Satyanarayana, S.R. Murthy, T.S. Rao and M.D. Rao, J. Less. Commun. Metals, 86 (1982) 115.
[8] R.H.J. Waldron, Appi. Phys. (USA), 43(1972)1186.

Table 1-DC and AC resistivity of $Co_{0.7+x}\ Zn_{0.3}\ Si_x\ Fe_{2-2x}\ O_4$

Composition x	DC resistivity ρ_{dc}	AC resistivity ρ_{ac}
0.0	1.31×10^6	1.26×10^5
0.1	3.53×10^6	6.31×10^5
0.2	1.61×10^6	5.01×10^5
0.3	0.34×10^6	1.26×10^5
0.4	0.07×10^6	0.63×10^5

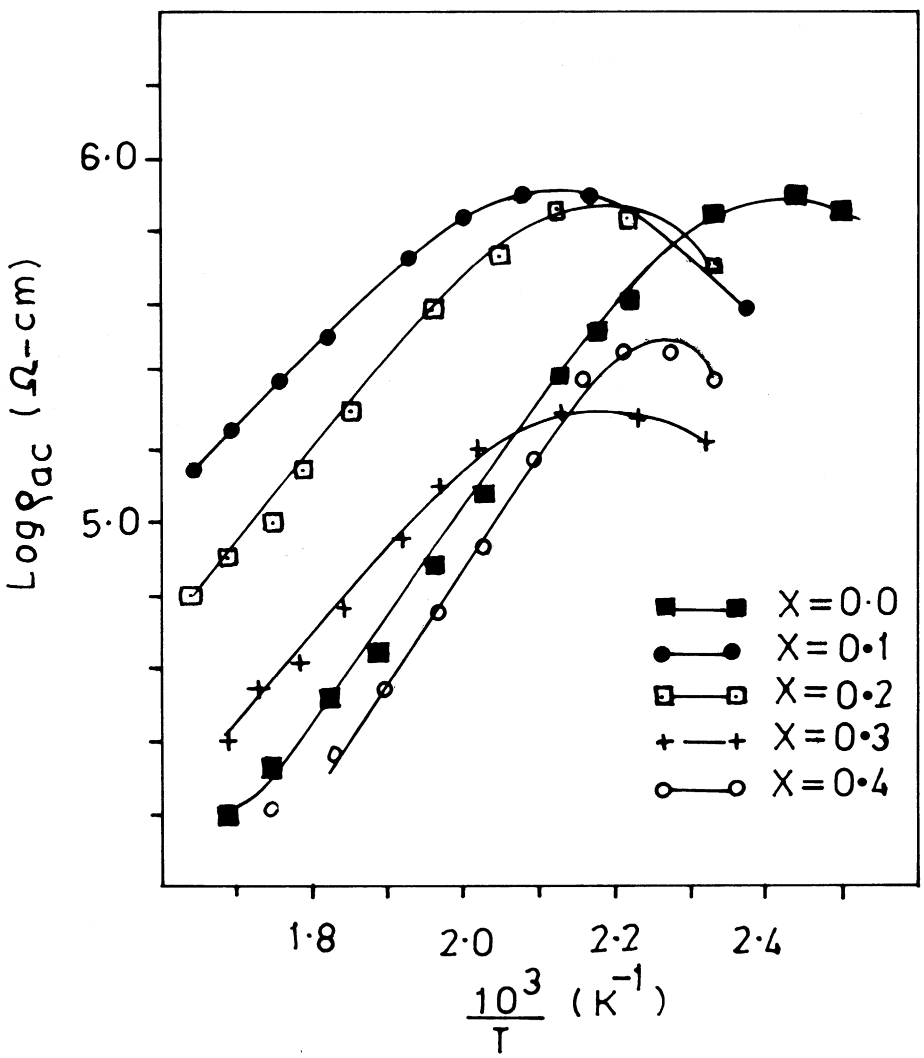

Fig. 1- Variation of log ρ_{ac} with reciprocal of temperature