Effect of Concentration of Mg^{2+} ion and temperature variation on resistivity of Mg-Mn Ferrites prepared by Chemical Co-precipitation Method.

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Abstract: Electrical properties of $Mg_xMn_{1-x}Fe_2O_4$ (x = 0.00, 0.01, 0.03, 0.05, 0.07) ferrites prepared by chemical co-precipitation method were studied by the variation of the concentration of Mg^{2+} ion and temperature on dc resistivity of prepared samples. Resistivity decreased with increase in temperature in all prepared samples. Addition of Mg^{2+} ion concentration results in increase in resistivity which can be explained on the basis of decrease in conduction by blocking the Verwey's hopping mechanism.

Introduction

An ideal ferrite with all its characteristics properties improved and is capable of covering a complete spectrum of applications is impossible to prepare. It is found that on substitution of impurity ions a few properties improved but some of other is adversely affected. Therefore, a compromise has to be made in improving one property at the expense of other by substituting suitable ions in various ferrites. The properties of ferrites are highly sensitive to the type and amount of impurity. A number of workers have studied the effect of divalent, trivalent, tetravalent impurities on their magnetic properties [1-4]. The Mg–Mn ferrites prepared by the chemical co-precipitation techniques have been studied by several workers [5-8]. These ferrites highly suitable for memory and switching circuits in digital computers and phase shifters as they have characteristic rectangular hysteresis loop, The electrical properties of the Mg–Mn ferrites can be upgraded by preparing these ferrites by various preparation methods. The aim of present investigations is to study the variation in dc resistivity with respect to temperature and concentration iof Mg^{2+} ions using two probe method.

Experimental details

All the compositions of nanocrystalline $Mg_xMn_{1-x}Fe_2O_4$ (x = 0.00, 0.01, 0.03, 0.05, 0.07) system were prepared from Merck Germany GR grade chemicals viz. $Mg(NO_3)_2.6H_2O$, $Fe(NO_3)_3.9H_2O$, $Mn(NO_3)_2.6H_2O$ and aqueous NH_3 (Merck India, 30%). The samples were prepared using stoichiometric quantities of $Mg(NO_3)_2{\cdot}6H_2O$ and $Fe(NO_3)_3{\cdot}9H_2O$ then dissolving them separately in 100mL deionized water and adding simultaneously into a flask containing 200mL deionized water. Ammonia solution was added drop wise till the pH value 10 was attained. The solution was continuously stirred by a magnetic stirrer for 1 h and aged at room temperature overnight. The precipitates were filtered and washed with deionized water and then dried at 120 ^oC for 16 h in a hot air oven. The dried samples were calcined at 950^{o}C in air in a tube furnace programmed at a fixed heating rate of 5^{o}C/min for 8 h. The Mn doped derivatives of $Mg_xMn_{1-x}Fe_2O_4$system were also prepared by adding the appropriate stoichiometric quantities of dopant salt $Mn(NO_3)_2.6H_2O$ and following the same procedure as stated above. Electrical properties like dc resistivity were studied for the prepared samples using two probe method (Kiethley Electrometer Model 610 C)**.** The resistance R of the sample was calculated by measuring the slope of I verses V curve. The resistivity ρ was then calculated by using the well known relation:

$$\rho = R.\ A/d \qquad (1)$$

where A is the area of cross section and d is the thickness of pallets.

Results and Discussion:

The variation of log ρ as function of the concentration, of the Mg^{2+} ions is shown in Fig. 1. It shows that dc resistivity of the prepared ferrites increased from 1.9 x 10^4 ohm-cm to 9.8 x 10^4 ohm-cm as the concentration of Mg^{2+} ions increased from x= 0.01 to 0.07

respectively. It can be explained on the basis that, during the sintering process, the Fe^{3+} ions get partially reduced to Fe^{2+} ions which resulted in the presence of small amount of Fe^{2+} ions in the sample. Also Mn^{2+} ions react with Fe^{3+} ions to form Mn^{3+} ions and Fe^{2+} ions according to following reaction:

$$Mn^{2+} + Fe^{3+} \rightarrow Fe^{2+} + Mn^{3+}$$

The presence of Fe^{2+} -- Fe^{3+} and Mn^{2+} -- Mn^{3+} ion pairs of same elements but of different valency states present at equivalent crystallographic sites result in an increase of conduction due to hopping of electrons in $MnFe_2O_4$. The addition of diamagnetic Mg^{2+} ions in place of Mn^{2+} ions limit the degree of conduction by blocking Verwey's hopping mechanism which resulted in increase of resistivity. The hopping of electrons between the ions of same element present in more than one valence state distributed randomly over crystallographic equivalent lattice point is the main mechanism behind the conduction in ferrites [9]. The probability of hopping taking place is greatest at octahedral sites as com[pared to tetrahedral sites because the distance between B-B sites in spinel ferrites is smaller than the distance between A-A sites which is still smaller than distance between A-B sites, as the hopping probability depends upon (i) the separation between the ions and (ii) activation energy. The phonon assisted electron tunneling on crystallographic equivalent octahedral sites is the possible mechanism given by Srivastava and Srinivasana for electron transport [10]. The conduction may also arise as a result of substitution of cation of high resistivity by a cation of low resistivity [11]. Fig 2 shows that with increase in temperature, the resistivity decreased in all prepared samples. This decrease in resistivity with temperature is attributed to the semiconducting nature of ferrites [12].

Conclusion

Samples prepared using co-precipitation method were studied for electrical properties like variation in dc resistivity with respect to concentration of Mg^{2+} ion in $Mg_xMn_{1-x}Fe_2O_4$ (x = 0.01, 0.03, 0.05, 0.07) and temperature. Resistivity initially decreased upto x = 0.01 and then increases with the concentration of substituted Mg^{2+} ions. This observed variation have been explained on the basis of limiting the degree of conduction by blocking Verwey's hopping mechanism. The resistivity of prepared sample also decreased with increase in temperature.

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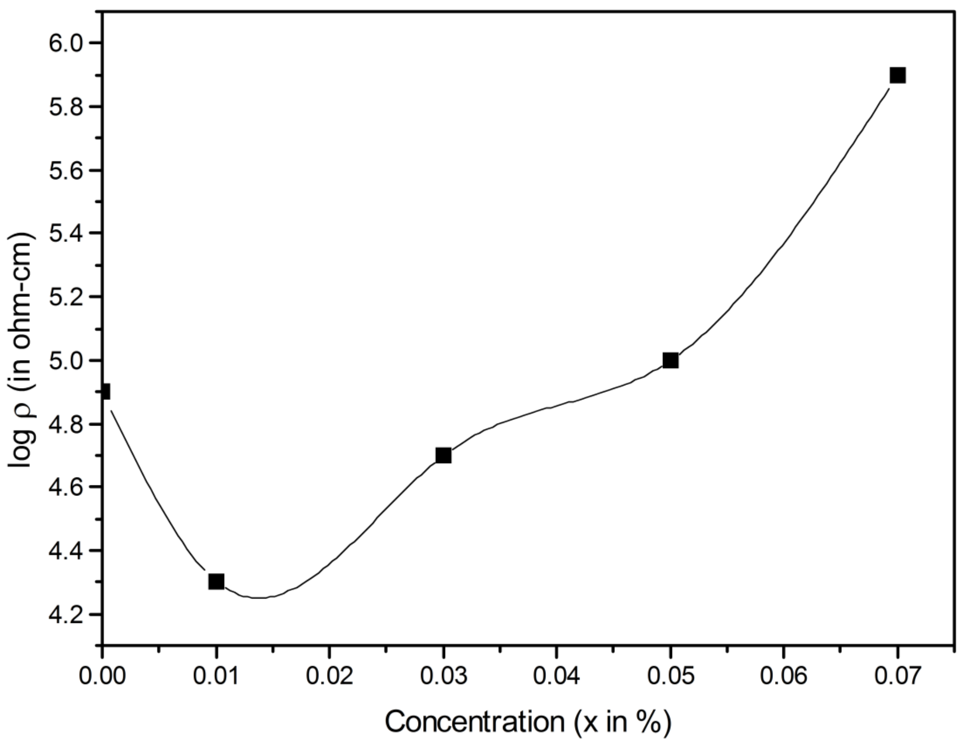

Figure 1. Variations of log ρ with concentration of Mg^{2+} ions in $Mg_xMn_{1-x}Fe_2O_4$ ferrites at 150^oC

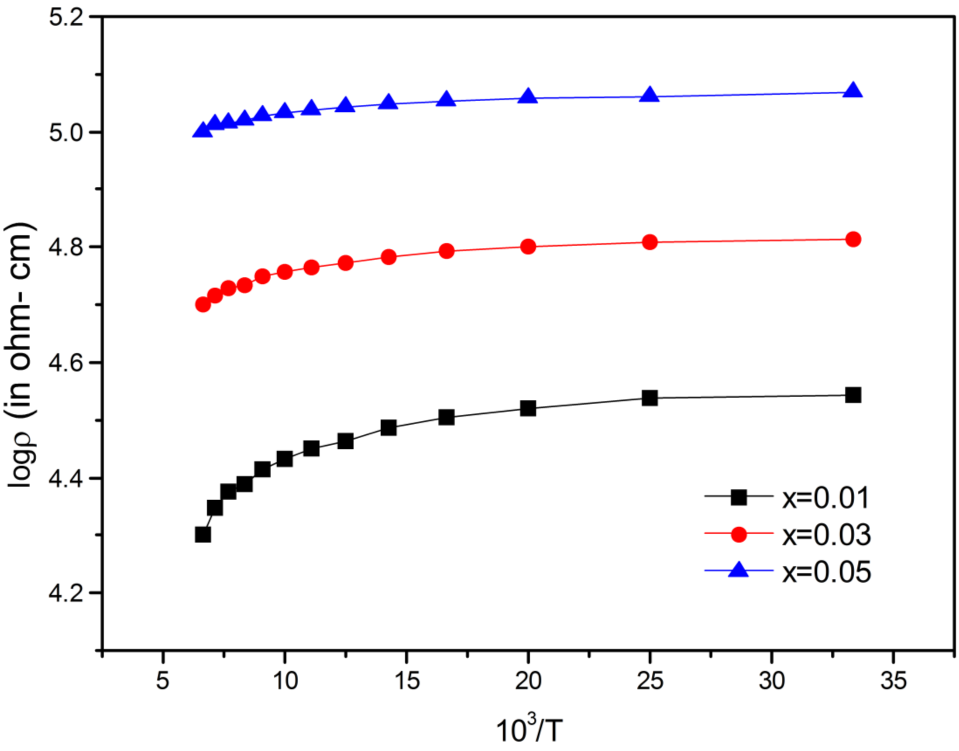

Figure 2: Variations of log ρ with 1000/T in $Mg_xMn_{1-x}Fe_2O_4$ (x= 0.01, 0.03, 0.05) ferrites