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Preparation and Electrical Conductivity of Ni-Mg Ferrites

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ABSTRACT
Electrical conductivity of Ni-Mg ferrites of various compositions were investigated from room temperature to well beyond the curie temperature bytwo probe method.. Plots of conductivity versus temperature increases ith increasing temperature. On the basis of these results an explanation for the conduction mechanism in Ni-mg mixed ferrites is suggested
Keywords: Ni-Mg ferrites, Electrical conductivity, Hopping Mechanism, Curie temperature

I. INTRODUCTION

As per the present authors knowledge no information is available on electrical conductivity studies of mixed Ni-Mg ferrites in the literature. Moreover, there is need for thorough study of electrical conductivity studies of magnesium substituted nickel ferrites as a function of composition and temperature. The results of such study are presented in this communication.

II. EXPERIMENTAL

Mixed Ni-Mg ferrites have been prepared by the double sintering ceramic technique[1-3]. Specimens of the Ni – Mg ferrites having the chemical formula $Ni_{1-x}Mg_xFe_2O_4$ where x = 0.2, 0.4, 0.6 and were prepared by double sintering ceramic technique using Nio – 99% pure (AR Grade) MgO – 99% pure (AR Grade) and Fe_2O_3 – 99.999% pure (AR Grade) have been used in the preparation of these ferrites. The chemicals are weighed correct to the milligram and mixed intimately in a medium of acetone by milling in a ball mill using steel balls of one inch diameter. The ball milling is done for about 80 hrs to obtain a fine particle size of the order of about 10 microns, and to ensure an homogenous mixing of all the four ingredients. The mixture is then put in a china dish and dried thoroughly in an oven at 100^0C for about 6 hours, in order to remove the traces of acetone. After getting the fine powder it is pressed into acylindrical discs by applying 10 tons/sq.inch with the help of hydraulic press. The cylindrical discs are pre-sintered for 4 hours in air at a temperature of about 800^0C.

The pre-sintered specimens are crushed to powder in a steel mortar and the powder is again milled in a steel container with acetone as a medium for about 80 hours. The mixture is dried in an oven for about 6 hours at a temperature of about 100^0C. A binder is used to avoid the breakdown of the samples while handling at a later stage. The binder forms 1.5 percent of the mass of samples. The powder is then pressed in the shape of cylindrical bars having a dia of 1 cm and 2 cm of thickness by applying a hydraulic pressure of 10 tonns/sq.inch. The most important stage of the preparation of the ferrites is final sintering. The pressed samples are then kept on a fire-brick having a number of ‘v’ shaped grooves. This prevents the bending of the bars during the process of sintering. To distribute the uniform temperature the fire-brick is kept in the center of the furnace. The raising temperature of the furnace is regulated at the rate of 100^0C/hour up to 800^0C and thereafter at a rate of 50^0C/hour till the final temperature is reached. The specimens are kept at the final sintering temperature 1200^0C for 4 hours, the sintering atmosphere being air. After sintering process the furnace is cooled at the same rate as that of heating. Following this procedure, polycrystalline ferrites with the following compositions are prepared.

Ni-Mg ferrite system:
(1) $Ni_{0.8}Mg_{0.2}Fe_2O_4$
(2) $Ni_{0.6}Mg_{0.4}Fe_2O_4$
(3) $Ni_{0.4}Mg_{0.6}Fe_2O_4$
(4) $Ni_{0.2}Mg_{0.8}Fe_2O_4$

III. RESULTS AND DISCUSSION

The electrical conductivity (σ) of the ferrites under investigation has been computed using the formula.

$$\sigma = \frac{I\ t}{V\ A}$$

Where, ‘I’ is the current passing through the specimen in amperes, ‘V’ is the voltage applied to the specimen in volts, ‘t’ is the thickness of the sample in cm and ‘A’ denotes the area of the sample in sq.cm. The conductivity cell is shown in Fig1.

Measurement of Curie Temperature

The Curie temperatures for the ferrite specimens under investigation have been determined by using a simple experimental method (Fig 2)set up in this laboratory. The ferrite specimen is made to attach itself to a bar magnet due to the magnetic attraction and the combination is suspended inside a furnace the temperature of which can be varied up to 1000^0C. As the temperature of the system is increased, at a particular temperature the specimen is found to drop down when the ferrite specimen loses its spontaneous magnetization and becomes paramagnetic. This temperature is taken as the approximate Curie point of the specimen. The temperature of the specimen is measured by a chromel-alumel thermocouple inserted in the furnace.

Table1.gives the values of electrical conductivity at room temperature. The values of electrical conductivity decreases with the increase of Mg content. Among all the ferrites the specimen with composition $Ni_{0.2}$ $Mg_{0.8}Fe_2O_4$ exhibits lowest value of electrical conductivity (σ = 8.12 x $10^{-8}ohm^{-1}cm^{-1}$) or highest value of electrical resistivity (ρ =1.23x10^6 ohm.cm)

The temperature dependence of electrical conductivity of mixed Ni-Mg ferrites has been investigated from room temperature to well beyond the Curie temperature. Plots of conductivity Log (σ T) verses temperature (10^3/T) for Ni-Mg ferrites are shown in Fig 3 and 4.

Table 1 - Electrical Conductivity data of Ni-Mg ferrites

S. No.	Ferrite Composition	Electrical Conductivity (□) $Ohm^{-1}cm$
1	$\mathbf{Ni_{0.8}Mg_{0.2}Fe_2O_4}$	**1.52x10^{-5}**
2	$\mathbf{Ni_{0.6}Mg_{0.4}Fe_2O_4}$	**4.86x10^{-6}**
3	$\mathbf{Ni_{0.4}Mg_{0.6}Fe_2O_4}$	**6.84x10^{-7}**
4	$\mathbf{Ni_{0.2}Mg_{0.8}Fe_2O_4}$	**8.12x10^{-8}**

It can be seen from the figures that value of log (σT) increases with increasing temperature up to Tσ(K). Beyond Tσ(K) change of shape has occurred.

The variation of the Curie temperature T_c(K) with magnesium composition is shown fig 5. it can be noted from the figure that the value of T_c(K) decreases with increase of magnesium content. The decrease of Curie temperature with increase of magnesium content can be explained on the basis of the number of magnetic ions present in the two sub-lattices and their mutual interactions. As Fe^{3+} ions are gradually replaced by magnesium ions, the number magnetic ions being decrease at both sides, which also weakens the strength of AB exchange interactions of the type Fe_A^{3+}-O^2-Fe_B^{3-} Thus the thermal energy required to offset the spin alignment decrease, thereby decreasing the Curie temparatue. A similar decrease of the T_c (K) with the composition was also observed by Zaki[1] in case of Mg-Zn ferrites and Ravinder and Latha in Mn-Zn [2] ferrites.

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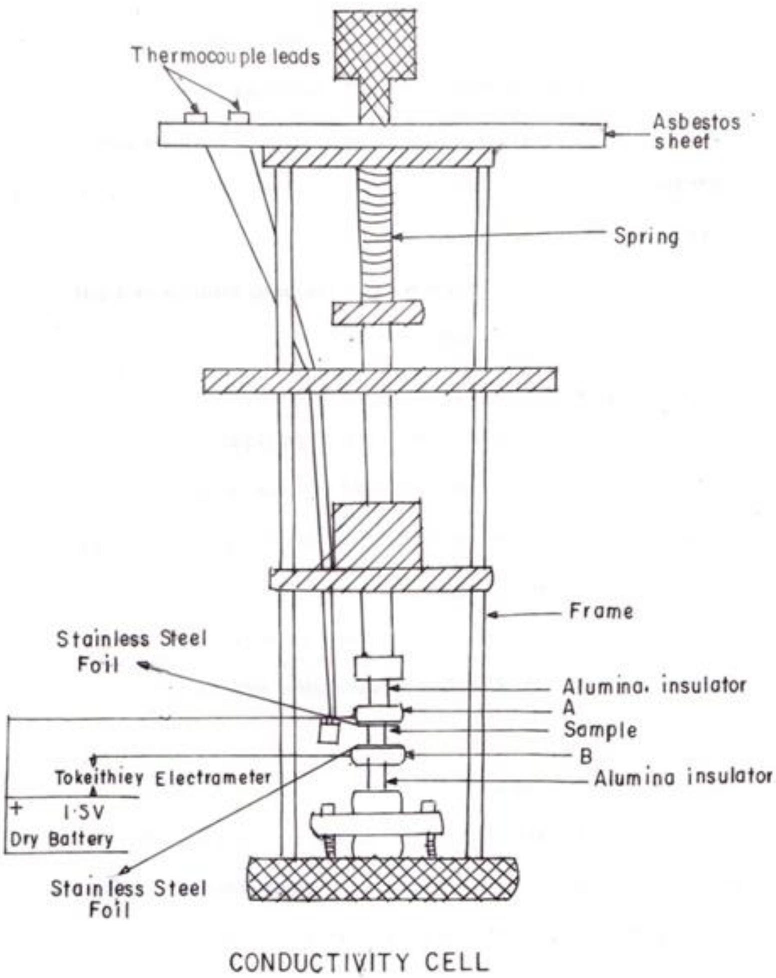

Figure 1 – Conductivity cell

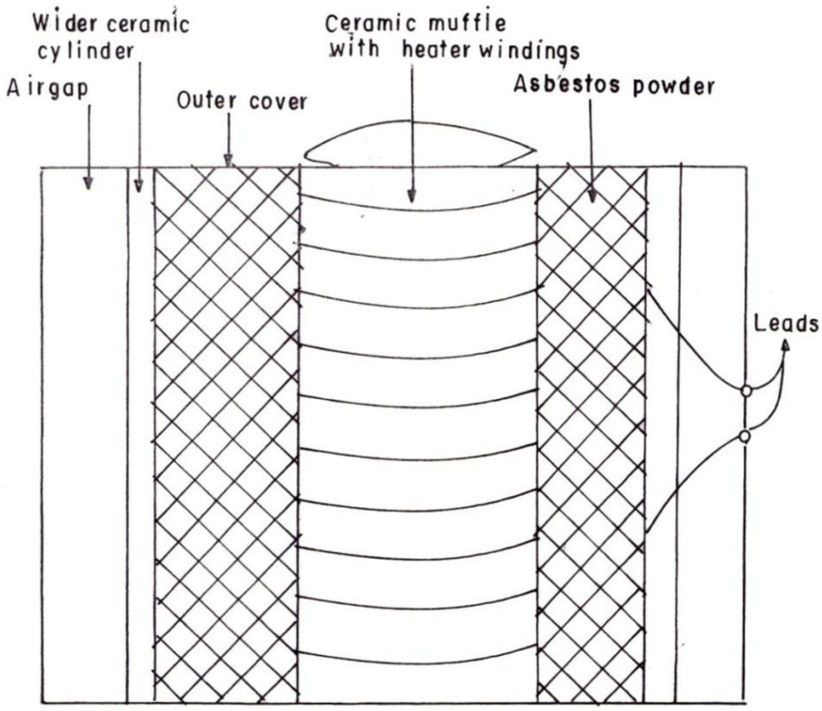

Figure 2 – Furnace

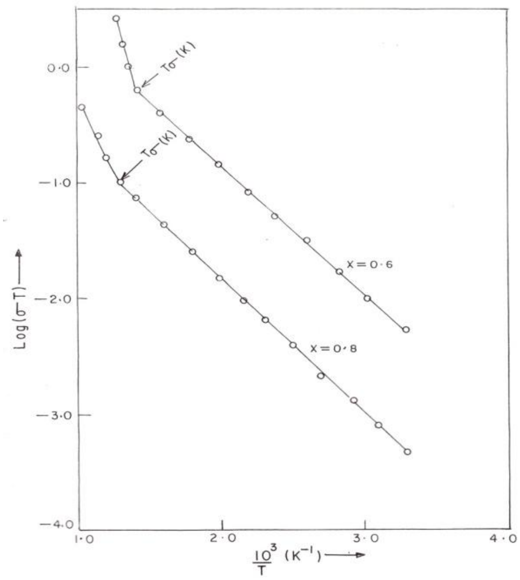

Figure 3 – Electrical conductivity Vs Temperature

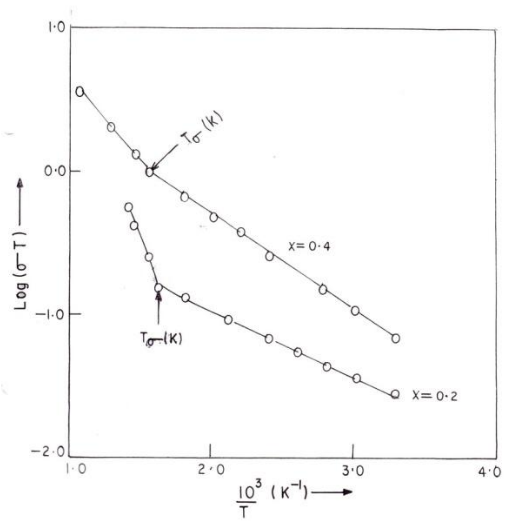

Figure 4 – Electrical conductivity Vs Temperature

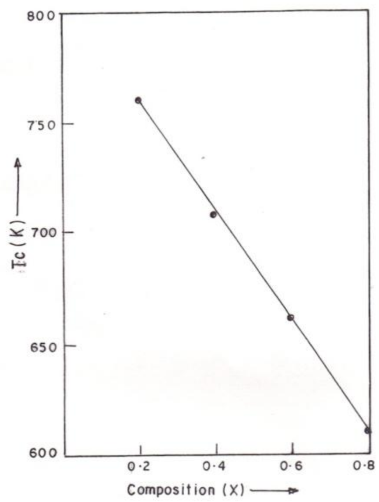

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Figure 5 – Curie temperature Vs Composition