Study of the Electrical Properties Of Manganese-Copper Ferrites.*

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ABSTRACT

A series of mixed ferrites, $Mn_xCu_{1-x}Fe_2O_4$ with x= 0.0,0.1,0.2,0.3,0.4, 0.5, 0.6, 0.7, 0.8,1.0. were fabricated by solid state reaction technique. The crystalline structure and dielectric properties of the samples were investigated. All the samples show cubic spinel structure and lattice parameter increases with the increasing manganese content. The dc resistivity was found to be increasing with an increasing substitution of manganese ions. Higher values of resistivity make these ferrites more suitable for high frequency applications. Dielectric constant and dielectric loss tangent are found to be decreasing with an increase in frequency. Possible mechanism responsible for the results is discussed in this paper.

Keywords : Mn-Cu ferrite, resistivity, Dielectric constant.

1 Introduction

In the early days of electrical industry, the need for the magnetic materials was served by iron and its magnetic alloys. However, with the advent of higher frequencies, the standard techniques of reducing eddy current losses, using lamination or iron cores were, no longer efficient or cost effective. This realization stimulated a renewed interest in magnetic insulators as first reported by S.Hilpert in Germany in 1909.

It was readily understood that if the high electrical resistivity of oxides could be combined with desired magnetic characteristics, a magnetic material would result that was particularly well suited for high frequency operation. Ferrites are ferrimagnetic oxide consisting of ferric oxides and metal oxides. On the basis of crystal structure ferrites are grouped in to three classes namely hexagonal ferrite, garnet and spinel ferrite. The spinel ferrites are widely studied because of their numerous applications in several fields. Spinel ferrites have some special properties compared with other magnetic materials. One of these is the high value of electrical resistivity and the other is low eddy current losses. These properties make them ideal for use at microwave frequencies. Hence the electrical properties of spinel ferrites have become very important. The dielectric properties of ferrites are dependent upon several factors including the method of preparation, chemical composition and grain size. This aroused considerable interest in the low frequency range (10^1 – 10^7 Hz) dielectric behavior of ferrite. Among the many researchers involved in this type of studies, the prominent one are Koops[1], Iwanchi et.al[2], Rezlescu[3]. A number of researchers[4,10] have studied properties of such ferrites. The objective of present work is to investigate the dielectric properties of $Mn_xCu_{1-x}Fe_2O_4$ ferrite system. The result of resistivity, dielectric constant and dielectric loss are reported in this paper.

2 Experimental Techniques

The spinel ferrite system $Mn_xCu_{1-x}Fe_2O_4$ with variable composition (x=0.0,0.1,0.2,0.3,0.4,0.5,0.6,0.7,0.8,1.0) were prepared by solid state reaction technique. The sample were prepared using dry method involving solid state reaction of metal oxide, copper oxide, manganese oxide and Fe_2O_4 (99.99%) pure supplied by Merk Germany. The weight percentage of the oxides to be mixed for various samples was calculated by using following formula:

$$\text{Weight \% of oxide} = \frac{\text{M.Wt.of oxide x required of the sample}}{\text{Sum of Mol.Wt. of each oxide in a sample.}}$$

The required amount of each oxide was weighed using electronic balance having an accuracy of 10^{-4} gms. The weighed amount of oxides of manganese, copper and Fe_2O_4 were grounded and mixed homogeneously to a fine powder. The prepared samples were dried and dried powder was pressed into disc shapes. The disc shape samples were prefired at 1000^0 C for 48 hrs and finely sintered at 1150^0C for 4 hrs and samples were then air quenched.

Formation of ferrite was confirmed by Philips analytical X-ray diffractometer using CuKα radiation. Crystal structure was determined from XRD data. The measurement of electrical resistivity was carried out with varying compositions. The variation with dielectric constant and dielectric loss was measured in the range 10^1 Hz to 10^7 Hz with LCR meter by two probe methods.

3 Result and Discussion

The XRD patterns are shown in Fig 1 for $Mn_xCu_{1-x}Fe_2O_4$ sintered at 1150^0C and it can be seen that the samples confirms the formation of cubic spinel structure.

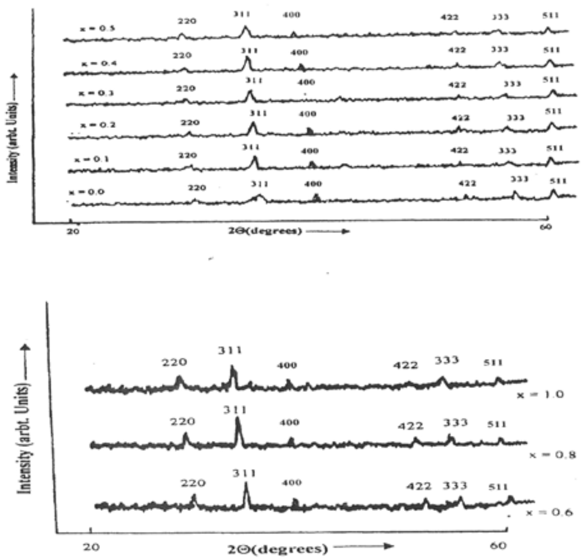

Fig. 1. XRD patterns of $Mn_xCu_{1-x}Fe_2O_4$.

It is observed that the lattice parameter increases with the increase of manganese contents in accordance with Vegard's Law.

Table [1] shows the variation of the electrical resistivity with concentration. The value of resistivity [Log ρ (Ω-Cm)] lies between 8.40 and 8.65.

Table 1
Room Temperature Resistivity (ρ) of MnxCu 1-xFe2O4 Ferrites.

Concent. (x)	Log ρ (Ω-Cm)
0.0	8.40
0.1	8.45
0.2	8.46
0.3	8.47
0.4	8.48
0.5	8.50
0.6	8.52
0.8	8.60
1.0	8.65

The addition Mn ion limits the degree of conduction by blocking the Verway hopping mechanism which results in increase of resistivity. This indicates that they can be used as insulator at room temperature. The variation of dielectric constant with frequency at room temperature is shown in fig.3.

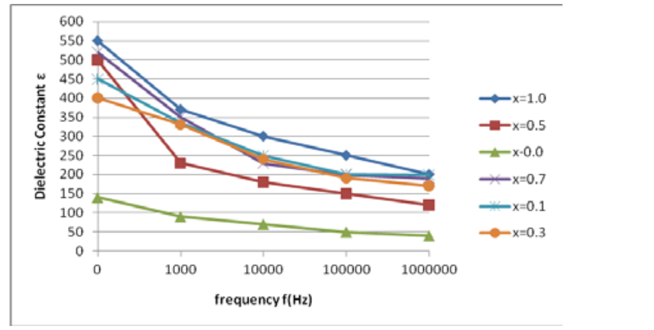

Fig.3. Variation of dielectric constant with frequency for $Mn_xCu_{1-x}Fe_2O_4$.

This behaviour of dielectric may be explained quantitatively by the fact that the mechanism of the polarization process in ferrite is similar to that of the conduction process. The electron hopping (Fe^{2+}+Cu^{2+} ↔ Fe^{3+}+Cu^{1+} and Fe^{2+}+Mn^{2+} ↔ Fe^{3+} +Mn^{1+}) one obtains local displacements of electrons in the direction of the applied field, these displacement determine the polarization of ferrites. It is known that the effect of polarization is to reduce the field inside the medium. Hence the dielectric constant is decreased as the frequency is increased. This variation in dielectric constant is in consistent with the Koop model[1].The Fig.4 shows the variation of dielectric loss tangent with frequency at room temperature.

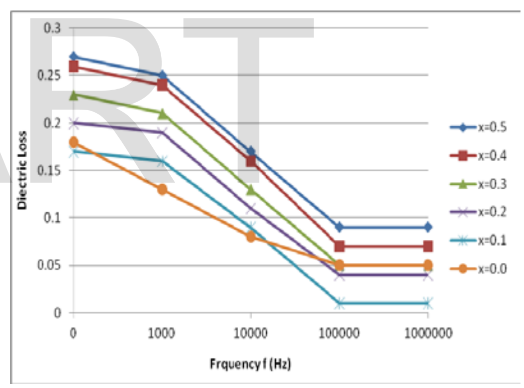

Fig.4. Variation of dielectric loss with frequency for $Mn_xCu_{1-x}Fe_2O_4$

The reason for low dielectric loss is the higher value of resistivity. It is observed that the dielectric loss decreases rapidly with the increase of frequency and attains nearly constant value at higher frequencies. It is established that there is strong correlation between the conduction mechanism and dielectric behavior of ferrites as observed by Iwanchi.

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