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STRUCTURAL BEHAVIOR AND INITIAL PERMEABILITY STUDY OF Ni-CuFERRITE

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Abstract: In present work polycrystalline soft spinel ferrite samples having the general chemical formula $Ni_{1-x}Cu_xFe_2O_4$ (with x = 0.0, 0.4 and 0.8) have been prepared by standard ceramic technique. The formation of single phase cubic spinel structure of all the samples was characterized by X-ray diffraction technique. The values of lattice constant determined from XRD data found to increase as copper content x obeying Vegard's Law. The initial permeability μ_i was measure and it is found that μ_i increases with Cu substitution. Curie temperature measured through permeability versus temperature plot.

Keywords: X-ray diffraction, Initial Permeability, Curie temperature.

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1. Introduction

Several mixed metal oxides with iron oxide as their main component having the formula MFe_2O_4 have been investigated and found to have interesting structural, electrical and magnetic properties. Due to their remarkable electrical and magnetic properties they are used in many technological applications [1]. Spinel ferrites are commercially important materials because of their excellent electrical and magnetic properties. Interesting physical and chemical properties of ferrites arises from ability of these compounds to distribute cations amongst the available tetrahedral (A) site and octahedral [B] site and magnetic A-A, B-B and A-B interactions. Ferrites are generally classified into two groups, hard ferrites and soft-ferrites. Ferrites for which coercive field is small are termed as soft ferrites. Polycrystalline ferrites which have many applications in microwave frequencies are very good dielectric materials. The basic structural and magnetic properties of spinel ferrite are depends upon several factors such as method of preparation, preparative parameters and preparative conditions, nature, type and amount of dopant [2-6].

Extrinsic property such as permeability losses even depend on microstructure as well as sintering condition [7]. Among the spinel ferrites, the inverse type is particularly interesting due to its high magneto-crystalline anisotropy, high saturation magnetization, and unique magnetic structure. Nickel ferrite ($NiFe_2O_4$) is an inverse spinel with cubic structure shows ferrimagnetism that originates from magnetic moment of anti-parallel spins between Fe^{3+} ions at tetrahedral sites and Ni^{2+} ions at octahedral sites [8]. Spinel ferrites are important in several applications, hence studies of structural, electrical, magnetic and other properties of spinel ferrites are very essential [9, 10]. The interest in these materials is sustained till date because of their applications in the field of drug delivery, multilayer chips, magnetic recording, sensors, catalysts, etc. [11-13].

The substitution of divalent, trivalent and tetravalent ions in spinel ferrites leads to diversification in various properties. The properties ofspinel ferrites can be modified by substituting the various kinds of cations. In the literature, many reports are available on the structural, electrical and magnetic properties of Zn, Cd, Al, Cr, Ti,Mn substituted spinel ferrites [14, 15].

Nickel ferrites ($NiFe_2O_4$) and substituted nickel ferrites have been the subject of extensive investigation because of their high-frequency application. Copper ferrite ($CuFe_2O_4$) is a distinguished among other spinel ferrites by fact that it under goes structural phase transition accompanied by reduction crystal symmetry to tetragonal due to cooperative Jahn-Teller effect. However there are differences about the phase transition temperature of Copper ferrite [16, 17]. Copper ferrite is random spinel ferrite and possesses tetragonal structure. Both nickel and copper ferrite is important from the point ofview of their applications. Abnormal thermal, magnetic and dielectric properties of Cu-containing ferrite have been reported[18, 19].

In this paper we report our results on initial permeability of mixed Nickel-Copper spinel ferrite.

2. Experimental Technique

A series of polycrystalline spinel ferrites of the chemical composition $Ni_{1-x}Cu_xFe_2O_4$ (x = 0.0, 0.4 and0.8) were prepared using the standard ceramic method. A.R. grade NiO, CuO and Fe_2O_3 oxides in appropriate molar proportions were used for the preparation of ferrite. The compositions of these ferrites are shown in Table 1.

Table 1

Chemical composition of various components of $Ni_{1-x}Cu_xFe_2O_4$ system in mole percentage.

Composition X	NiO	CuO	Fe_2O_3
0	50	00	50
0.4	30	20	50
0.8	10	40	50

The oxides were mixed thoroughly and wet ground by using an agate mortar. First pre-sintering of powder was carried out at 1225K for 12 hr followed by a slow cooling. The sintered powder is again reground and sintered at 1375K for 12 hr. To measure the initial permeability toroids of outer diameter 2 cm and inner diameter 1 cm are prepared. The prepared samples were characterized by X-ray powder diffractometer (model PW 3710) using Cu-K_α radiation (λ = 1.5405Ǻ) in the 2θ range 20^0-80^0.The initial permeability as a function of temperature was measured for 1 KHz frequency. Toroidal cores were used for the inductances measurements because the toroidal core can provide potentially the greatest band width since it has no residual gap and proper winding gives minimal leakage inductance.

3. Results and Discussion

The structural characterization of all the samples of spinel ferrite system $Ni_{1-x}Cu_xFe_2O_4$ was carried out using X-ray diffraction technique. Results indicate that these oxides crystalline with a single spinel cubic structure. Fig.1 shows the typical X-ray diffraction (XRD) pattern of $Ni_{1-x}Cu_xFe_2O_4$ (for x = 0.4) spinel ferrite system.

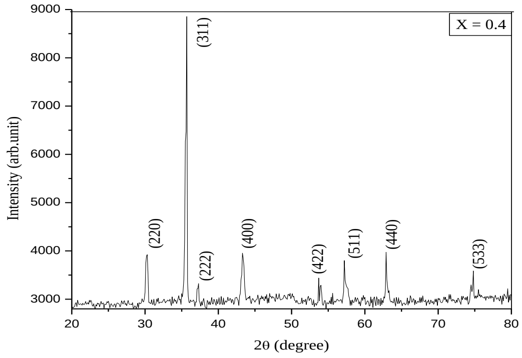

Fig. 1: XRD patterns of $Ni_{1-x}Cu_xFe_2O_4$ for x = 0.4

The XRD patterns indicates that all the composition exhibits single phase cubic spinel structure and exclude the presence of any secondary phase. The Braggs reflection observed in XRD pattern are intense and sharp. The XRD pattern shows the reflections (220), (311), (222), (400), (422), (511), (440) and (533) belonging to cubic spinel structure. The analysis of XRD pattern reveals the formation of single phase cubic spinel structure. No extra peak has been detected in the XRD pattern.Using XRD data the inter planer spacing (d) was calculated using Bragg's law and the values of lattice constant (a) of all the samples was calculated by the relation [20];

$$a = d_{hkl}\left(h^2 + k^2 + l^2\right)^{\frac{1}{2}} \qquad \ldots 1$$

where, a is the lattice constant,

d is inter planer spacing and

(h k l) is the Miller indices.

The values of lattice constants are given in the Table 2.From Table 2 it is observed that lattice constant increases with Cu substitution. The increase in lattice constant is related to the difference in ionic radii of copper and nickel. In the present case, nickel ions with ionic radii 0.69 Ǻ are replaced by copperions of ionic radii 0.72 Ǻ, and hence lattice constant of the Ni-Cusystem increases with increasing copper content x.

The initial permeability (μ_i) was obtained by measuring inductance of the toroid using LCR-Q meter and was calculated using the following relation.

$$L = 0.0046N^2 h\mu_i Log_{10}\left(\frac{d_2}{d_1}\right)$$

where, d_2 is the outer diameter,

d_1 is the inner diameter,

L is inductance in micro-Henry,

h is the height in inches,

μ_i is initial permeability and

N is number of turns of wire.

The variation of permeability μ_i was measured as a function of temperature. The plot of permeability versus temperature for typical sample x = 0.4 is shown in Fig. 2. It is observed from permeability versus temperature plot that permeability increases slowly as temperature increases and attains a maximum value. Thereafter, permeability suddenly falls down. The curve exhibits tailing effect. Using these plots Curie temperature of all the samples was also obtained.

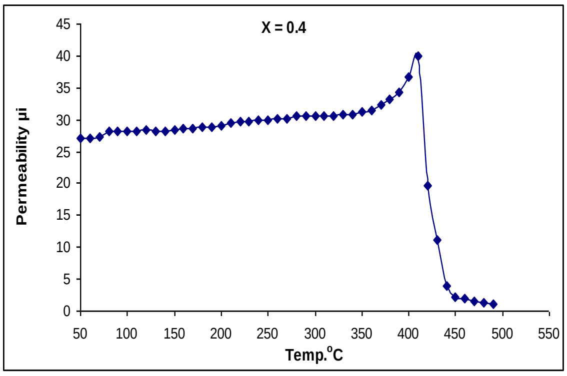

Figure 2: Permeability versus temperature plot.

The values of initial permeability for all the samples were calculated and the values are presented in table 2. It can be seen from table 2 that initial permeability increases with copper substitution.

Table 2: Lattice Constant (a), Initial Permeability (μ_i) and Curie Temperature (T_C).

x	a (Å)	μ_i	T_C (K)
0.0	8.3259	24.38	823
0.4	8.3555	23.55	753
0.8	8.3912	42.86	693

Similar variation in permeability with composition was observed in other well-knownspinel ferrite [21].

4. Conclusions

The single phase nature of all the samples of Ni-Cu spinel ferrite was confirmed by X-ray diffraction analysis. Curie temperature obtained using permeability data. The initial permeability values are affected much by copper substitution.

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