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# Magnetic Properties and Initial Permeability Studies of Spinel Ferrite

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**A B S T R A C T**

Polycrystalline soft ferrite samples having the chemical formula Ni1-xCuxFe2O4 with x=0.0, 0.4 and 0.8 was synthesised by standard double sintering ceramic method. The samples were characterized by X-ray diffraction technique. X-ray diffraction study of composition confirms the formation of single-phase cubic structure. Bulk density (dB) of the investigated sample was measured using Archimedes Principle. The lattice parameter, X-ray density, particle size of these samples has been calculated using XRD data. Magnetization measurements were carried out using pulse-field hysteresis loop technique at room temperature. The saturation Magnetization obtained from pulse field magnetization technique decreases with Cu substitution x. The initial permeability $\mu_i$ was measured and it is found that $\mu_i$ increases with Cu substitution. Curie temperature measured through permeability versus temperature plot.

***Keywords :*** *X-ray density, Lattice constant, Initial Permeability, Magnetization.*

## 1. Introduction:

Ferrites are magnetic oxide materials with semiconducting nature, which are of great technological importance since they possess combined high resistivity along with highly useful magnetic properties. They are applicable in many magnetic devices due to their low electrical conductivity as compared to that of other known magnetic materials [1]. Ferrites are generally classified into two groups, hard ferrites and soft-ferrites. Ferrites for which coercive field is small are termed as soft ferrites. Several mixed metal oxides having the formula MFe2O4 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. Polycrystalline ferrites which have many applications in microwave frequencies are very good dielectric materials. The basic structural and magnetic properties of spinel ferrite are depending 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's that originates from magnetic moment of anti-parallel spins between $Fe^{3}+$ ions at tetrahedral sites and $Ni^{2}+$ ions at octahedral sites [8]. Nickel ferrites 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 $CuFe_2O_4$ [9, 10]. Copper ferrite is random spinel ferrite and possesses tetragonal structure. Both nickel and copper ferrite is important from the point of view of their applications.

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

## 2. Experimental Technique

Polycrystalline specimens of $Ni_{1-x}Cu_xFe_2O_4$ (x = 0.0, 0.4 and 0.8) were prepared by standard ceramic technique using analytical reagent grade oxides. Compounds were accurately weighed in molecular weight percentage with a single pan balance. The compositions of these ferrites are shown in Table 1. The mixed powders were wet ground and pre-sintered at 950 $^0$ C for 24 hours. The sintered powder is again re-ground and pelletized. Polyvinyl alcohol was used as a binder in making circular pellets of 10mm diameter and 2 -3mm thickness. To measure the initial permeability toroids of outer diameter 20mm and inner diameter 10 mm are prepared. The pellets were finally sintered in muffle furnace for 1180$^0$ C for 24 hours and then slowly cooled to the room temperature. The prepared samples were characterized by X-ray powder diffractometer (model PW 3710) using Cu-$K_\alpha$ radiation ($\lambda$ = 1.5405Å) in the 2θ range 20$^0$-80$^0$. The magnetic properties were studied using pulse field hysteresis loop technique at room temperature. Curie temperature of the sample was determined through loria techniques.

**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 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

### 3.1 XRD analysis

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 crystallizes 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.

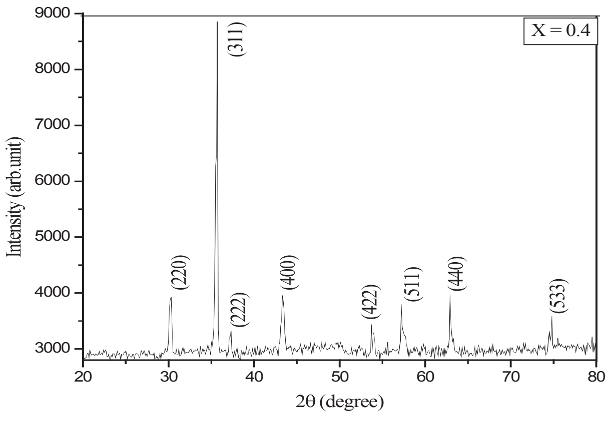


**Fig. 1: XRD patterns of $Ni_{1-x}Cu_xFe_2O_4$ for x = 0.4**

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.

### 3.2 Magnetization

The hysteresis loops are used to obtain magnetic parameters like saturation magnetization ($M_s$) and coercivity ($H_c$) remnant magnetization ($M_r$). It is observed from M-H loop that, the saturation magnetization ($M_s$) decreases with copper content x. The decrease in saturation magnetization is due to the replacement of $Ni^{2+}$ ions of high magnetic moment (2μB) by small magnetic moment $Cu^{2+}$ ions (1μB). The values of saturation magnetization ($M_s$) of all samples are listed in Table 2. The magneton number (nB) of all the samples was calculated with the help of saturation magnetization value ($M_s$) obtained from hysteresis loop.

$$n_8 = \left[ \frac{Mol.\ weight\ x\ M_2}{5585} \right]$$

The values of magneton number are given in Table 2. The values of Curie temperature are given in Table 2. It can be observed that, Curie temperature decreases with copper content x.

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

$$L = 0.0046 N^2 h \mu i \mathrm{Log} \left[ \frac{d_2}{d_1} \right]$$

where, d2 is the outer diameter,
d1 is the inner diameter,
L is inductance in micro-Henry,
h is the height in inches,
μi is initial permeability and
N is number of turns of wire.

The variation of permeability μi was measured as a function of temperature. The plot of permeability versus temperature for typical sample x = 0.8 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.

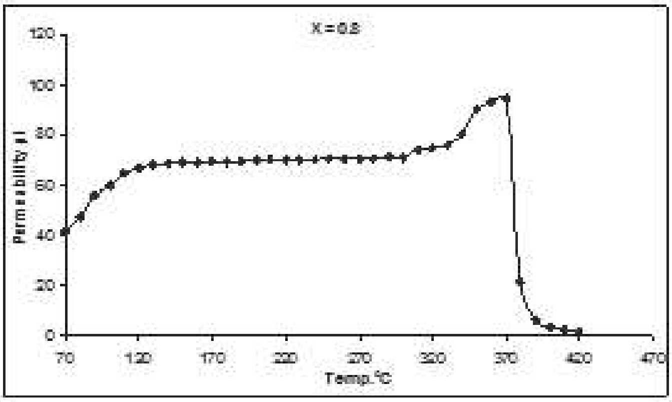


**Fig. 2. Permeability versus temperature plot.**

The values of initial permeability for all the samples were calculated and the values are presented in Table 2. It can be seen Table 2 that Initial Permeability increases with copper substitution. Similar variation in permeability with composition was observed in another well-known spinel ferrite [11].

**Table 2. Saturation Magnetization ($M_S$), Magneton Number (nB), Curie Temperature Tc and Initial Permeability (μi)of $Ni_{1-x}Cu_xFe_2O_4$ system**

| X | $M_S$ (emu/gm) | nB (μB) | $T_C$ ($^0$C) | μi |
|---|---|---|---|---|
| **0.0** | 23.33 | 1.8525 | 550 | 24.38 |
| **0.4** | 20.26 | 1.8104 | 480 | 28.55 |
| **0.8** | 19.51 | 1.5238 | 420 | 42.86 |

### 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 usingLoria technique. The saturation magnetization (Ms) and curie temperature decreases with increasing copper content x. Curie temperature also obtained using permeability data. The permeability values are affected much by copper substitution. Initial permeability increases with copper substitution.

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