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# Magnetisation and Curie Temperature Studies on Some Li-Cd Ferrites

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**Abstract.** Hysteresis loops for Li-Cd ferrites with the general formula $Li_{0.5-x/2}Fe_{2.5-x/2}Cd_xO_4$ (with $x = 0, 0.1, 0.2, \ldots, 0.7$) exhibits good rectangular properties. For the low concentration of $Cd^{2+}$, the squareness of the hysteresis loop is preserved. For the higher concentration of $Cd^{2+}$, hysteresis loop rectangularity is impaired. The magnetic moment for Li-ferrite is 2.19 $\mu_B$ and increases with increase in Cd content up to $x = 0.2$ and then decreases. The measured value of magnetisation of Li-ferrite at 300 K is 2806 gauss. The maximum value of magnetisation about 3640 gauss has been obtained for $Cd^{2+}$ concentration of 20% and then decreases with increase in Cd content. The observed variation in magnetisation is due to changes in the number of tetrahedral and octahedral coordinated $Fe^{3+}$ ions which are coupled ferrimagnetically via a super exchange interaction. The initial increase of magnetisation up to $x = 0.2$ is explained on the basis of Neel's two sublattice model. For the samples $x > 0.2$ Y-K angle increases as Cd increases and magnetisation decreases. The Curie temperature ($T_c$) of the samples in the series were obtained by Loroia technique and it is found that with increase in $Cd^{2+}$ content the Curie temperature decreases. The overall strength of the A-B interaction determines the Curie temperature of the compound. A decrease in the super exchange interaction decreases the Curie temperature.

KEY WORDS: Ferrites, Lithium ferrites, saturation magnetisation, Curie temperature.

## 1 Introduction

Ferrites are the magnetic materials composed of oxides containing ferric ion as the main constituent. They are dark grey or black in appearance and very hard and brittle ceramic materials. The magnetic properties arise from interactions between metallic ions occupying particular position relative to the oxygen ions in the crystal structure of the oxides [1]. Chemical composition, crystal structure, cation distribution and microstructure are the parameters that affects the hysteresis properties of the ferrites. These properties are also influenced by sintering conditions, the porosity, grain size and stoichiometry [2–5]. Lithium (Li) ferrites materials with Co, Mn, Ti and Al substitutions are of technologically important for use in radar. The high Curie temperature ($T_c$) and rectangular B-H loop characteristics have made these materials for latching devices such as phase shifters.

## 2 Preparation and Characterization

Li-Cd ferrites with the general formula were prepared by $Li_{0.5-x/2}Fe_{2.5-x/2}Cd_xO_4$ (with $x = 0, 0.1, 0.2, \ldots, 0.7$) by the standard ceramic method. XRD studies confirms single phase formation and lattice parameter calculated are in good agreement with the reported value. Infrared (IR) absorption studies of the samples in the KBr medium shows bands due to distribution of octahedral (B-sites) and tetrahedral (A-sites) ions. Detail investigation on XRD and IR absorption studies are reported elsewhere [6].

## 3 Hysteresis and Magnetisation Studies

The hysteresis technique has proved to be a novel technique to characterize the basic magnetic properties of the ferrites. The hysteresis parameters were measured with the help of a high field loop tracer [7]. Hysteresis loops for Li-Cd ferrites at room temperature are presented in Figure 1. From Figure 1 it is seen that hysteresis loop of Li-ferrite exhibits good rectangular properties. For the low concentration of $Cd^{2+}$, the squareness of the hysteresis loop is preserved and for high concentration of rectangularity is impaired. From hysteresis data at room temperature the value of saturation magnetisation (Ms) was calculated and magnetic moment ($n_B$) along with the Y-K angles were calculated using the relation

$$5(1.5 + x/2)\cos(\text{YK}) - 5(1 - x) = n_B\,. \tag{1}$$

Table 1 shows the saturation magnetisation (4$\pi$Ms), magnetic moment ($n_B$), Y-K angles and Curie temperature data for $Li_{0.5-x/2}Fe_{2.5-x/2}Cd_xO_4$ ferrites. The magnetic moment for Li-ferrite is 2.19 $\mu_B$ which is in good agreement with the reported value [8, 9]. The measured value of magnetisation of Li-ferrite at 300 K in present case is 2806 Gauss. The maximum value of magnetisation viz. 3640 Gauss has been obtained for the $Cd^{2+}$ concentration of 20%. In case of hot-pressed Li-ferrite the value of saturation magnetisation reported by West and Blankenship is 3745 Gauss [10]. The value of magnetic moment ($n_B$) increases as the content of Cd increases up to $x = 0.2$ and then decreases. Variation

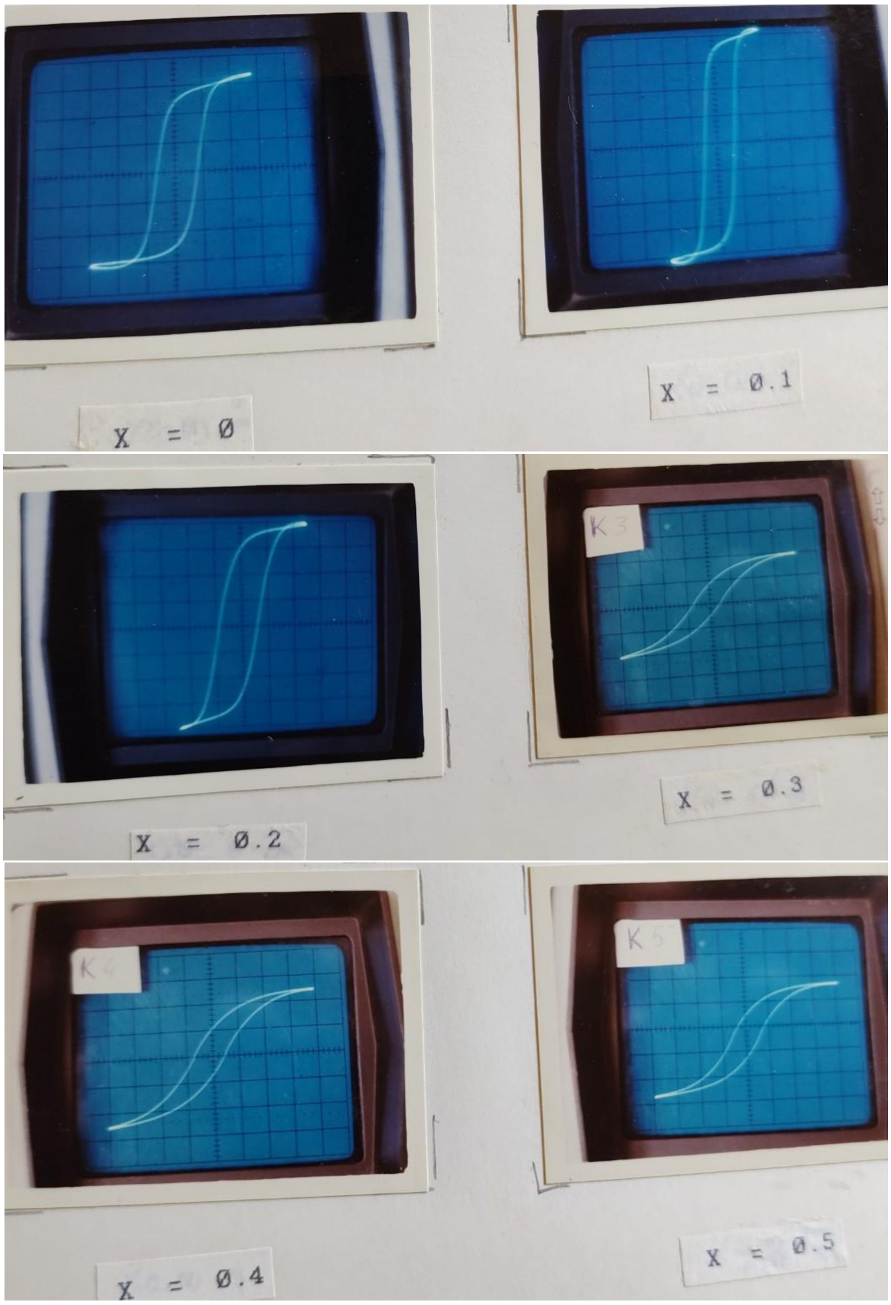


Figure 1. Hysteresis loops for Li-Cd ferrites at room temperature.

Table 1. Saturation magnetisation ($4\pi$Ms), magnetic moment ($n_B$), Y-K angles and Curie temperature data for $Li_{0.5-x/2}Fe_{2.5-x/2}Cd_xO_4$ ferrites

| Cd content $x$ | $4\pi$Ms (Gauss) 300 K | $n_B$ 300 K | Y-K angle degree (room temperature) | Curie temperature (°C) |
|---|---|---|---|---|
| 0.0 | 2806 | 2.19 | 0 | 650 |
| 0.1 | 3319 | 2.57 | 0 | 552 |
| 0.2 | 3640 | 2.85 | 0 | 480 |
| 0.3 | 2984 | 2.61 | 14.1 | 407 |
| 0.4 | 3059 | 2.58 | 29.29 | 352 |
| 0.5 | 2741 | 2.39 | 41.34 | 337 |
| 0.6 | 997 | 1.2 | 70.43 | 285 |
| 0.7 | 711 | 0.7 | 70.80 | 210 |

of magnetic moment and saturation magnetisation with Cd content is shown in Figure 2 and Figure 3, respectively. The magnetisation behavior of this series is similar to that of Mg-Zn, Li-Zn, Li-Zn-Zr [11–13]. In these series at lower concentration of Zn magnetisation increases and then decreases with increasing concentration of Zn due to canting of spins. The presence of canted spins have been confirmed by studying Mossbauer spectra in case of Li-Zn ferrite [14].

## 4 Results and Discussion

The observed variation of magnetisation further be explained due to change in the number of tetrahedral and octahedral coordinated $Fe^{3+}$ ions which are coupled ferrimagnetically via a super exchange interaction. The $Li^{+}$ and $Cd^{2+}$ ions are nonmagnetic, but they affect the magnetisation through a preference for specific lattice sites. The cation distribution of the present system is given by

$$(\mathrm{Cd_x^{2+}Fe_{1-x}^{3+}})_\mathrm{A}[\mathrm{Li_{0.5-x/2}Fe_{1.5+x/2}}]_\mathrm{B}\mathrm{O_4^{2-}} \quad (2)$$

The nonmagnetic $Cd^{2+}$ ion enter the tetrahedral site and thus increase Ms by increase in the magnetic moment difference between the B and A site. The initial increase of magnetisation up to $x = 0.2$ can, therefore, be explained on the basis of Neel's two sublattice model [15]. The decrease of magnetisation needs to be explained on the basis of three sublattice model [16]. The decrease of Ms above $x = 0.2$ is due to the magnetic dilution of the A-sublattice with Cadmium and therefore weakening of the exchange interaction between the $Fe^{3+}$ (A) ions and $Fe^{3+}$ (B) sublattices. The $Fe^{3+}$(B) – $Fe^{3+}$(B) antiferromagnetic interaction leads to departure from a parallel alignment of the Fe(B) spins and therefore to spin canting at the B-site. From Table 1 it can be seen that, for the samples with $x = 0, 0.1$, and 0.2 the values of Y-K angles are zero. For the remaining samples (i.e., for $x > 0.2$) Y-K angle increases as $Cd^{2+}$ increases favoring more and more canting on B-site.

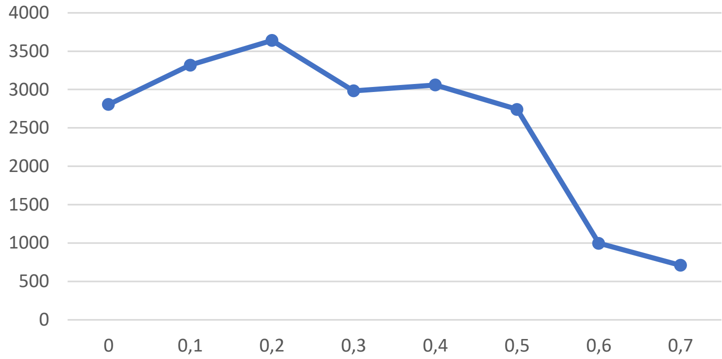


Figure 2. Variation of saturation magnetisation with Cd content.

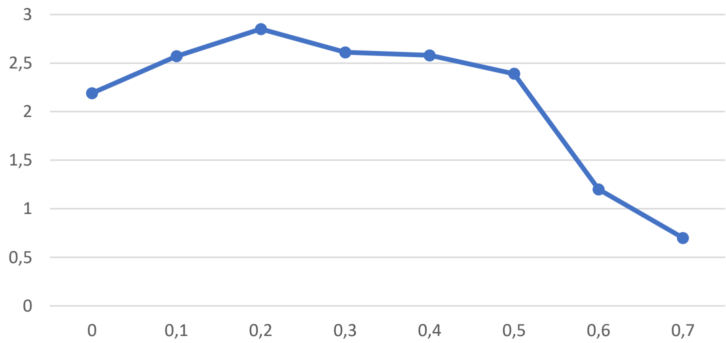


Figure 3. Variation of magnetic moment with Cd content.

A magnetic phase transition from ferromagnetic to paramagnetic state occurs at a certain temperature known as Curie temperature. The Curie temperature is one of the important properties of the microwave ferrites. At Curie temperature the magnetic order is destroyed by thermal randomization. There are different methods of the measurement of Curie temperature. The Loroia technique is the relatively simple technique [17]. The Curie temperature of the samples in the series obtained by Loroia technique are presented in Table 1. Figure 4 shows the variation of Curie temperature with the Cd content. The Curie temperature for Li-ferrite is 650°C. On addition of Cadmium the Curie temperature goes on decreasing. The value of Curie temperature for Li-ferrite have been reported to lie between 590 to 680°C [18]. Our value of Curie temperature, i.e. 650°C, agrees well with these reported values. The decrease of Curie temperature with increase of Cd2+ concentration is as follows.

The cation distribution of the present series is given by equation (2). The overall strength of the A-B interaction determines the Curie temperature of the com-

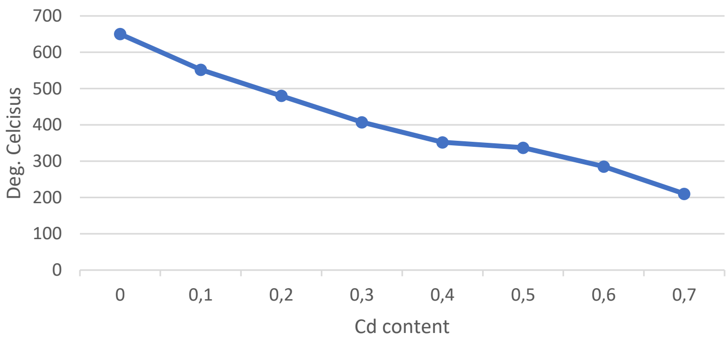


Figure 4. Variation of Curie temperature with Cd content.

pound, through intra sublattice interactions A-A and B-B can also sometimes become important. This strength is a function of the number of such A-B interaction, which in turn depends upon the number of $Fe^{3+}$ ions in the formula unit and also on their distribution on A and B-sites. For larger Cd concentration the diminishing number of $Fe^{3+}$ ions at A-site are less able to maintain the A-B super exchange interaction. A decrease in the super exchange interaction decreases the Curie temperature. The amount of different phases present and non-stoichiometry in the material also affects the Curie temperature.

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