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# MAGNETIC PROPERTIES OF SOME FERRITES

## THESIS

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## SUMMARY

The first chapter of the thesis, gives a summary about the crystal structure, ionic distribution & super-exchange interaction in magnetic materials. Saturation magnetization and permeability and their temperature dependence are discussed.

The second chapter deals with a review on the magnetic properties of some ferrites. A detailed review about the initial permeability of ferrites is given.

The third chapter is devoted to the experimental part of the work. It contains the ceramic method which is used to prepare different compositions of  $\text{Cu}_{1-x}\text{Cd}_x\text{Fe}_2\text{O}_4$ , where ( $x = 0.0, 0.1, 0.2, 0.3, 0.5$  and  $0.7$ ). The samples were pressed into the toroidal form (pressure  $3 \text{ tons/cm}^2$ ) and finally sintered at  $1100^\circ\text{C}$  for 3 hours. The circuit used for tracing B-H loop and measurement of initial magnetic permeability  $\mu_i$  was given. The voltage amplifier and integrating circuits are also classified. This chapter also gives a detailed description for the circuit and methods of measurements of the initial magnetic permeability.

The fourth chapter includes the results of measurements, and discussion of the obtained results in the light of previous data and theoretical works on the subject. This was done in three main directions : first, the magnetic properties of this system at room temperature, and second, the effect of temperature on the saturation magnetization  $M_s$  &  $\mu_i$  from which we calculated the effect of temperature on the first order anisotropy constant and found its compositional dependence. Comparison for all measured parameters with values in the literature was made and found to be satisfactory.

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## INTRODUCTION

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## INTRODUCTION

A recent article which appeared in the U.S.A. [1] discussed the possibility of finding superconductivity in materials based on Cu-oxide spinels. It was found that superconductivity in these materials can be found at relatively high temperatures 90°K. This opens a new era in technological and scientific applications of these materials. Beside this, high permeability materials find important applications in increasing the recording efficiency of magnetic heads Stopples [2]. It is well known that the efficiency of recording is correlated to the value of the initial permeability of the material of the head. High permeability is needed for increasing the recording efficiency.

The present work deals with study of magnetic properties of a system of mixed Cu-Cd ferrite spinels. The study may be divided into two parts :- The first part deals with the study of the saturation magnetization and other magnetic properties such as coercive force and remanent magnetization. Temperature and composition behaviour of these parameters is studied.

The second part of the work deals with the study of the initial permeability and its temperature dependence for  $\text{Cu}_{1-x}\text{Cd}_x\text{Fe}_2\text{O}_4$  system. Using results of the first and the second parts we calculated the first order anisotropy constant  $k_1$  for this system and its temperature dependence.

**THEORETICAL CONSIDERATION**

**CHAPTER I**

## CHAPTER I

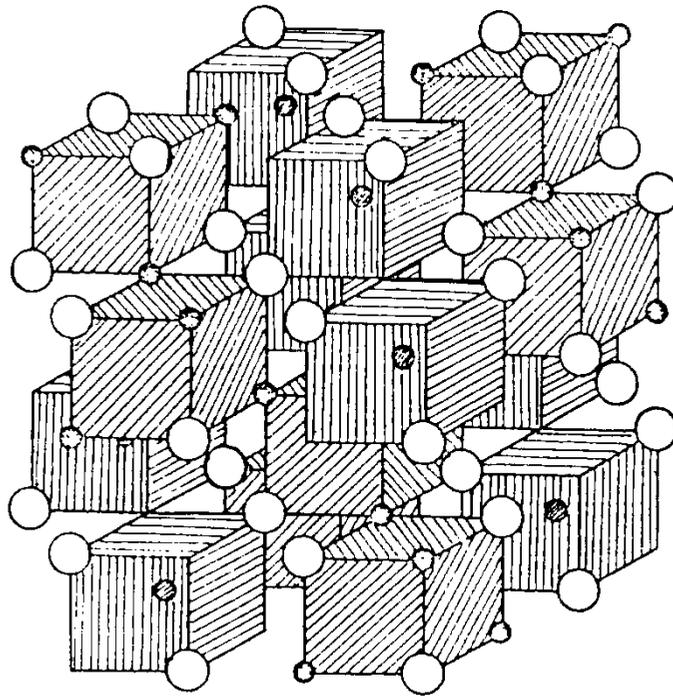
### THEORETICAL CONSIDERATION

#### 1.1- Structure of Ferrites :

The term ferrite denotes a group of iron oxides which have the general formula " $MO.Fe_2O_3$ ", where M is a divalent metal ion such as  $Mn^{2+}$ ,  $Fe^{2+}$ ,  $Co^{2+}$ ,  $Ni^{2+}$ ,  $Cu^{2+}$ ,  $Zn^{2+}$  or  $Cd^{2+}$ . Magnetite  $Fe_3O_4$  (or  $FeO.Fe_2O_3$ ), is a typical ferrite which is well known magnetic oxide since ancient times. By replacing the divalent iron in  $Fe_3O_4$  by another divalent ion, ferrites can be produced which have different intensities of intrinsic magnetization. Furthermore, just as we can get various magnetic alloys by mixing a number of metal elements, by mixing two or more kinds of  $M^{2+}$  ions we can obtain mixed ferrites, which show various interesting and useful magnetic properties.

Cubic ferrites have the so-called spinel crystal structure which is shown in fig. (1.1). The white circles in this figure represent the oxygen ions, the black and hatched circles represent the metal ions. The radius of the oxygen ions is about  $1.32 \text{ \AA}$ , which is much larger than that of metal ions ( $0.6 \sim 0.8 \text{ \AA}$ ) [3]. The oxygen ions in this lattice touch each other and form a close-packed face-centered cubic lattice. In this oxygen lattice, the metal ions take interstitial positions which can be classified into two groups :-

- i- A group of lattice sites (A-sites) called tetrahedral sites or 8a sites, each of which is surrounded by four



- oxygen
- 16d
- ⊗ 8a

*Fig. (1.1). Spinel Structure.*

oxygens as shown by the hatched circles in the figure.

- ii- A group of sites (B-sites) called octahedral or 16d sites, each of which is surrounded by six oxygens as shown by black circles.

The distribution of the metal ions is very important for the magnetic properties of these materials. This distribution may occur as :

- i- In the "normal spinel" structure of a ferrite the  $Me^{2+}$  ions occupy A-sites and  $Fe^{3+}$  ions occupy B-sites. The formula of this structure can be written as :  $Me^{2+}(Fe_2^{3+})O_4$ , the brackets around the  $Fe^{3+}$  ions indicating that they occupy octahedral sites (B-sites). The number of oxygen ions which surround A and B sites are in the ratio of 2:3.
- ii- In the "inverse spinel" structure of a ferrite, the divalent  $Me^{2+}$  ions occupy octahedral sites, the  $Fe^{3+}$  ions are distributed in equal numbers over the A and B-sites. The arrangement may thus be represented by  $Fe^{3+}(Fe^{3+}Me^{2+})O_4$ .
- iii- In the intermediate case the arrangement take the type  $Fe_x^{3+}M_{1-x}^{2+}(Fe_{2-x}^{3+}Me^{2+})O_4$ .

The factors which influence the distribution of metal ions over A and B-sites have been considered to be the radii of the metal ions, the matching of the electronic configuration of the metal ions to the surrounding oxygen ions, and the electrostatic energy of the lattice.

### 1.2- Crystal Structure and Ionic Distribution :

The majority of ferrites have the spinel structure (after mineral  $MgAl_2O_4$ ). The general formula for spinel can be written as  $XY_2O_4$ . The unit cell contains eight molecules, i.e. eight divalent metal ions (X), 32 oxygen ions (O) and 16 trivalent ions (Y). The radius of the oxygen ion is about 1.32 Å, which is much larger than that of the metal ions (0.6-0.8 Å). Hence the oxygen ions in this lattice touch each other and form a close packed face centered cubic lattice. Fig. (1.2) shows schematically the spinel structure [4]. Fig. (1.2a) represents face-centered cubic structure of some of the X-ions (the other ions are not shown). The unit cell is divided into four subcells of type I (Fig. (1.2b)) and four of type II (Fig. (1.2c)). Each subcell of one type being surrounded by six subcells of the other type. Type I subcell,

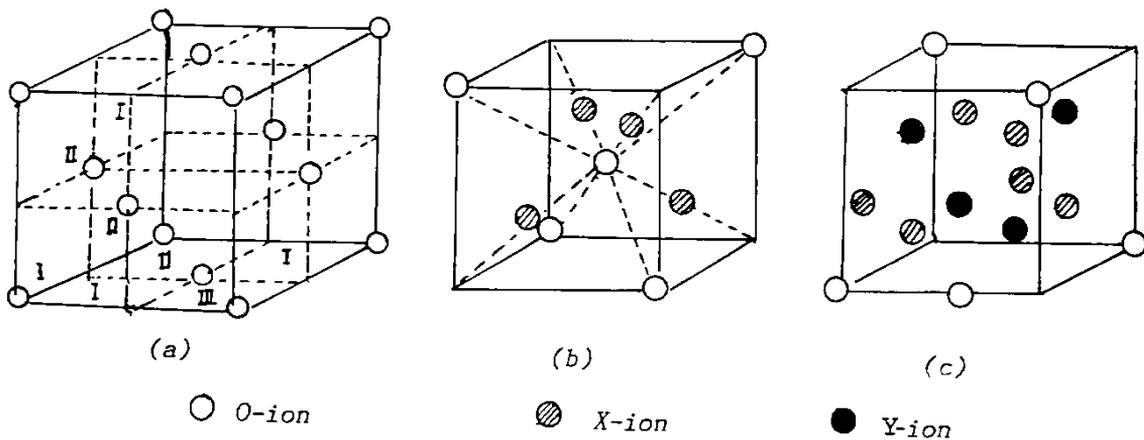


Fig. (1.2). Spinel structure  $XY_2O_4$

contains four X-ions in opposite corners and one X-ion at the center of volume. Four oxygen ions are located half-way along the body diagonals and away from the X-ions in the corners, while type II subcell contains four X-ions in opposite corners and four oxygen ions half-way along the body diagonals and towards the X-ions in the corners. Instead of the X-ion at the center of volume, this subcell contains four Y-ions, located half way along the body diagonals and away from the X-ions.

The available positions for metal ions are therefore of two known kinds and sizes: (A) tetrahedral position surrounded by four nearest oxygen ions, see Fig. (1.2b) and (B) (octahedral position surrounded by six nearest oxygen ions see Fig. (1.2c)). In the mineral spinel  $(\text{MgAl}_2\text{O}_4)$  Mg ions occupy A-sites. The Al ions occupy the B-sites.

In ferrospinels of normal structure,  $\text{Fe}^{3+}$  ions occupy positions of  $\text{Al}^{3+}$  ions on B-sites and divalent ions also occupy positions of  $\text{Mg}^{2+}$  ions on A-sites, and the chemical formula becomes  $\text{Me}^{2+}\text{Fe}_2\text{O}_4$ , where Me is the divalent metal ion.  $\text{CdFe}_2\text{O}_4$  and  $\text{ZnFe}_2\text{O}_4$  are examples of simple ferrites having normal spinel structures. The formula for a normal ferrite such as Zn-ferrite can be written as  $\text{Zn}^{2+}(\text{Fe}^{3+}\text{Fe}^{3+})\text{O}_4^{2-}$ .

Ions in closed brackets occupy B-sites. The zinc ions on A-sites have no magnetic moment and consequently there is no A-A interaction. B-B interaction at B-sites occur between

iron ions which have a magnetic moment of  $5 \mu_B$ . B-B interaction leads to the known antiferromagnetic order, i.e. to opposite and equal sets of magnetic ions giving zero magnetic moment. When the opposing arrays of magnetic moments are unequal the material will have a ferrimagnetic property. Useful magnetic ferrites are obtained by combining two different simple ferrites together. For example, the formula for a mixed Ni-Zn ferrite can be written as :

