CHAPTER - V

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Magnetic materials comprise of a large vareity of materials such as ferromagnetic metals, alloys, ferrimagnetic oxides etc. Of these, ferrites have notable technological applications because of their combined properties of a magnetic material and an electrical insulator. Extensive work has been done on ferrites with a view to determine their electrical and magnetic properties and to tailor make them for sduitable applications.

The spinel ferrites with varying amount of non-magnetic ions like zinc and cadmium have been the subject matter of many researchers today. The interest arises mainly because of their applications at microwave frequencies and interesting properties. The effect of Zn^{2+} ions on the magnetic properties of Mg-Zn ferrites has been recently investigated by Kulkarni. The infra-red absorption studies on some magnesium zinc ferrites have been carried out by Sobhanadri. The effect of sintering temperature on the electrical and magnetic properties and microstructurehas been reported by Sasmile.. In order to see the effect of trivalent rare earth impurity doping on the electrical conductivity and magnetization we have undertaken some studies on samarium doped magnesium-cadmium ferrites. Very little information is available on the electrical and magnetic studies of rare earth ion doped Mg-Cd ferrite system, even though the systems Mg-Mn and Mg-Zn have already been evaluated. Further, it is also interesting to study this system at a particular composition like $Mg_{0.5}Cd_{0.5}Fe_2O_4$ where its magnetization is higher. In order to reveal the role of composition, heat treatment and microstructure in governing their electrical and magnetic properties the following studies have been undertaken -

1) Preparation of samarium doped magnesium-cadmium ferrites with the general formula $Mg_xCd_{1-x}Sm_yFe_{2-y}O_4$ with x=0.5 and y=0, 0.1, 0.2, 0.3, 0.4 and 0.5 by the method of double sintering.

2) XRD studies to confirm the single phase formation and to calculate the lattice parameters.

3) Infrared absorption studies to obtain knowledge about the internal vibrations, find out positions of absorption bands and to study the variation of force constant with bond lengths.

4) Measurement of electrical conductivity as a function of temperature to propose the conduction mechanism.

5) Magnetization studies to see the effect of samarium content. and

6) To establish the correlation between the electrical and magnetic properties and the chemical structure of the samples.

Chapter I describes general properties of ferrites. The historical developments, crystal structure, types of ferrites, electrical and magnetic properties, magnetization, Yafet-Kittle theory to explain ferrimagnetism are briefly discussed here. The applications of ferrites and the ferrite spectrum and ferrite tree and the orientation of the problem are included at the end of the chapter.

Chapter-II is divided into four sections. Section A is devoted to the methods of preparation, ceramic method being discussed in somewhat more details. The samples for the present series were prepared by ceramic method and sintered at 1000^oC for 40 hours in air medium. The pellets and toroids were prepared from the presintered powder and were finally sintered at 1000^oC.

X-ray diffractograms of the samples were obtained by using the computerised XRD unit (Philips Model APD 1710) using CuKα radiation (λ=1.5418 A^o). The lattice parameters and interplaner distances were calculated by using the standard formula for the cubic system. The diffraction maxima have been indexed in the light of the structure of natural spinel, $MgAl_2O_4$. The allowed reflections in the X-ray diffraction pattern for spinel structure are (111), (220), (311), (222), (400), (422), (333), (511), (440). There is a close agreement between observed and calculated d values. The agreement between observed and calculated 'd' values is a indication of the fact that these ferrites are fully formed with spinel structure.A little change in the lattice parameters has been observed with Sm addition. The small variation of lattice constant in case of undoped and doped samples may be due to variation in cation distribution or modification in the lattice.

Necessary theoretical background for infra-red absorption is discussed in section C. I.R. spectra were recorded in the frequency range of 200 cm^{-1} to 800 cm^{-1} by using IR spectrometer (Perkin-Elmer Model,783) in the KBr medium. In the present samples two prominent absorption bands are observed. The high frequency absorption band is designated as ν_1 while the low frequency absorption band is designated as ν_2. The high frequency band ν_1 is attributed to the intrinsic vibrations of the tetrahedral complexes and the low frequency band ν_2 to the octahedral complexes. The force constants however do not bear any systematic relation with R_A and R_B.

The Curie temperatures of the samples were determined by Loroia technique. These are in good agreement with the Curie temperatures determined by d.c. conductivity and permeability studies. It is found here that as the content of samarium increases the Curie temperatures decrease. This is attributed to the weakening of A-B interactions.

The ferrites follow the semiconducting behaviour of temperature dependent resistivity and log ρ vs $10^3/T$ plots are linear, with magnetic transition at Curie temperature. The activation energy for concduction has been calculated by using the relation

$$\rho = \rho_0 \exp (\Delta E / kT)$$

In general the activation energy for conduction in the ferrimagnetic region is less than the activation energy in the paramagnetic region. It is proposed that the polaron model of conductivity be operative. The activation energies calculated are found to decrease with the samarium concentration except for the samples y = .4, .5 for which it increases. The activation energies also decreases with decrease in porosity.

The chapter IV comprises of the magnetic properties of present ferrites. The saturation magnetization M_s and remanance ratio (M_r/M_s) of the ferrites were measured from hysteresis loops taken at 300 and 80 K with the help of high field hysteresisloop tracer. The results on magnetic properties of Sm doped Mg-Cd ferrites show that -

1) Both saturation magnetization (M_s) and magneton number (n_B) at 300 and 80 K decreases with increasing samarium concentration.

2) Remanance ratio (M_r/M_s) increases with increasing samarium concentration.

3) The increase in M_s at 300 K is quite large compared to that at 80 K.

4) The magnetic parameters increases with decrease in porosity.

The observed magnetization is explained on the basis of cation distribution. Neel's two sublattice model is used for calculating the theoretical magnetic moment. The decrease in magnetic moment is attributed to decrease in Fe_A – Fe_B interaction energy. Curie temperature also show a decreasing trend with Sm content They show one to one correspondance with magnetization. This may due to decrease in Fe^{3+} -o- Fe^{3+} linkages, their strength and their angle. On the addition of Sm A-B interaction is weakened while B-B intera ction goes through a change in its tendency from ferromagnetic to antiferrimagnetic type. This interpretation also supports the decrease in Curie temperature of the sample.

In general the trivalent impurity ions like Sm^{3+} have a tendency to occupy B doyr thereby replacing some of the Fe^{3+} ions to the tetrahedral sites. This reduces the B-site magnetization and ultimately the other parameters like permeability, Curie temperature.