CHAPTER - V

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SUMMARY AND CONCLUSIONS

Studies of ferrites has assumed considerable importance during last few decades because of their important applications in electrical, electronics, computer and microwave communications. The important properties of ferrites that make them suitable for these applications are their high electrical resistivity and low eddy current losses. Besides, the properties of ferrites can be suitably modified by the proper use of substituents, heat treatment and microstructure. The role of microstructure in ferrite research has been very well understood and established.

Presently, the attention has been focused on power ferrite materials which require high magnetization and resistivity. For such materials, nickel ferrite is the most promising base materials. The Mg ions increase the resistivity thereby lowering the dielectric losses and decrease saturation magnetization. And improves mechanical strength of microwave ferrites. Secondly the Mg ferrite is a partially inverse ferrite whose cation distribution depends on sintering temperature. The substitution of Zn^{2+} ions has the effect of lowering the magnetizxation, Curie temperature and enhancing the electrical conductivity. The Co^{2+} ion having positive anisotropy constatn also influence the magnetic properties of mixed ferrites. The present work was undertaken to see the effect of these substitutions on the electrical and magnetic properties of Ni-Mg mixed ferrites.

The present investigation involved the following steps.

1. Synthesis of $Ni_{0.5-x}$ $Mg_{x-0.01}$ $Zn_{0..5}Co_{0.01}Fe_2O_4$ ferrites with x = 0.1, 0.2, 0.3, 0.4, 0.5 by ceramic method.

2. X-ray and IR studies to confirm the formation of solid state reaction and to determine the lattice parameters, bond length, site radii and vibrational frequencies respectively.

3. DC electrical conductivity to study the conduction mechanism.

4. Hysteresis and magnetization studies to understand magnetization behaviour.

5. Variation of initial permeability with temperature.

The thesis has been divided into five chapters. The first chapter is devoted to the introduction of ferrites. The spinel structure, classification, theories of ferrimagnetism and properties such as electrical resistivity, dielectric properties and magnetization are discussed. Some important applications of ferrites are given alongwith orientation of problem at the end.

The second chapter outlines the preparation and structural characterization of the present ferrites. This chapters has been divided into three sections. These includes the preparation of ferrites by ceramic method, characterization by XRD and infrared absorption spectroscopy.

Part-A.

The said ferrite system was synthesized by the conventional ceramic method using the high purity oxides. The details of the actual sample preparation by using the ceramic method are given in this section. The mechanism of solid state reaction and sintering process are discussed. The samples were presintered at 1000^0 C for 12 hours and finally sintered at 1200^0 C for 24 hours and then furnace cooled at a rate of 60^0 C/hour. Pellets of 1 cm diameter and toroids with inner diameter 1 cm and outer diameter 2 cm were prepared by applying a pressure of 7 tones per square inch for 5 minutes using hydraulic press.

Part-B

X-ray diffraction patterns were obtained using Philips X-ray diffractometer (Model PW 1710) with CuK_α (λ= 1.5418 Å) radiation. All the patterns confirm single phase formation of the ferrites with no impurity phases. The lattice parameter and interplaner distances were calculated using the usual procedure. The observed and calculated values of interplaner distances are found to agree well with each other. The lattice parameter increases from 8.394 Å to 8.428 Å with content of magnesium. The linear variation of lattice parameter indicates that the present system obeys Vegard's law.

The X-ray diffraction data was also used to calculate the bond lengths (R_A, R_B) and site radii, (r_A, r_B). They are found to increase linearly with the content of the magnesium. The x-ray density, actual density and porosity were calculated. Porosity of the samples is found to be lie within 20%.

Part-C

The infrared absorption spectra were recorded at room temperature in the range of 200-800 cm^{-1} in KBr medium on a Perkin Elmer IR spectrometer. (Model 783). IR spectra show two main absorption bands ν_1 and ν_2. The high frequency band ν_1

is attributed to intrinsic vibrations of tetrahedral complexes and lies in the range 563 cm^{-1} to 599 cm^{-1}, while low frequency band is attributed to the intrinsic vibrations of octahedral ion complexes and lies in the range 387 to 429 cm^{1-}. The difference in band position is expected because of the difference in Fe^{3+} - O^{2-} distances for octahedral and tetrahedral complexes. The force constants Kt and Ko are found to increase with increase in bond lengths R_A and R_B.

The third chapter deals with the electrical properties of the ferrite samples. DC electrical resistivity studies were carried out by two probe method from room temperature to 600^0C. The variation of room temperature resistivity with x shows that the sample with x = 0.2 has the maximum resistivity of 2.10^6 and it decreases later on. The variation of DC resistivity is attributed to inhomogeneous nature of ferrites, grain boundaries voids, presence of Fe^{2+} ions and sintering conditions.

The plots of logarithm of resistivity vs reciprocal of temperature are linear upto Curie temperature and show a ferri to paramagnetic transition at Curie temperature. Such a transition is also observed by many workers in other ferrites.

Conduction phenomena at low temperature is due to impurities while at high temperature, it is due to either electron hopping .

From these plots, it is seen that temperature at which spin-spin interaction vanishes due to thermal vibration is known as Curie temperature which separates upper ferromagnetic region from lower paramagnetic region. Transition temperature decreases with increase in x. This is explained on the basis of strength of A-B interaction between the magnetic ions which in turn depends upon their density and magnetic nature. The activation energy in the paramagnetic region is found to be higher than that of ferrimagnetic region. The lowering of activation energy in ferrimagnetic region is attributed to magnetic ordering. The conduction mechanism is Verwey type in which electron exchange takes place between Fe^{2+} and Fe^{3+} ions by hopping mechanism. The formation of Fe^{2} is due to sintering conditions and other factors.

The fourth chapter includes studies of magnetic properties and is divided into two parts : hysteresis and permeability.

Part-A

The magnetic properties of ferrites like hysteresis behaviour and magnetization are briefly discussed. The hysteresis studies were carried out using a high field hysteresis loop tracer at room temperature. The saturation magnetization and magnetic moment decreases with increasing x. This variation is explained on the basis of cation distribution and of the magnetizations M_A and M_B, of tetrahedral (A) and octahedral (B) sublattices respectively.

Part-B

The permeability measurements were performed on toroidal samples using LCR meter bridge. (Model Aplab 4912) from room temperature to 600^0 C at 1 kHz test frequency. The variation of initial permeability (μi) with temperature is reported. The μi lies in the range 45 to 95.

The variation of initial permeability with temperature shows that the initial permeability increases slowly to the peak value at certain temperature and drops to zero at Curie temperature. This increase in μi with temperature is due to fact that the anisotropy decreases with temperature faster than saturation magnetization. The highest value of μi corresponds to zero value of anisotropy energy. The μi then decreases to zero at Curie temperature. The peaking behaviour is found to increase with higher concentration of Mg^{2+} ions.

The Curie temperature of samples noted from μi vs temperature curves are found to decrease with increase in x content of Mg. This is expected since the magnetic dilution of samples weakens the A-B interaction on addition of Mg and Zn. The Curie temperature are found to lie below 520 ^{0} K in the present case.