CHAPTER - V

SUMMARY AND CONCLUSIONS

The universe is not hostile nor yet is it friendly. It is simply indifferent

- John Haynes Holmes

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SUMMARY AND CONCLUSION

The nanocrystalline materials exhibit a variety of properties superior to those of conventional coarse grained polycrystalline material. These include increased strength/hardness, enhanced diffusivity improved ductility/ toughness reduced density, reduced elastic modulus, higher electrical resistivity, specific heat, thermal expansion and super soft properties. Their applications yet to be harnessed can bring about a revolution in different fields of food processing, warfare, conservation of environment etc.

The amount of Ni–Zn and MnZn ferrite materials used in applications of ferrites are much larger than the other materials at high frequencies. The substitution of diamagnetic ions by ferromagnetic ions in ferrites is known to upgrade their magnetic properties and modify their microstructural as well as electrical properties.

Amongst Ni-Zn ferrite $Ni_{0.7}$ $Zn_{0.3}$ Fe_2O_4 shows minimum conductivity [1]. Hence the effect of substitution of Ni by Mg ions on the electrical and magnetic properties was undertaken in the nanocrystalline ferrite series $Ni_{0.7-x}$ Mg_x $Zn_{0.3}$ Fe_2O_4 where x varies from $x = 0.1 - 0.5$.

1. The samples $Ni_{0.7-x}Mg_xZn_{0.3}Fe_2O_4$ where x = 0.1, 0.2, 0.3, 0.4, 0.5 were prepared by Pramanik method.

2. X-ray and IR studies were carried out to ascertain the single phase nature of compositions prepared and also to determine lattice parameter and bond length.

3. Scanning electron micrographs were studied to understand the microstructure.

4. Magnetic studies were carried out to observe the variations in the magnetic moment, saturation magnetization and hystersis with composition at room temperature.

5. D.C. electrical resistivity studies were carried out to understand the conduction phenomenon.

6. A.C. electrical resistivity and dielectric property of these ferrite compositions are studied in the frequency range of 100 Hz to 1 MHz.

The present dissertation consists of 5 chapters. The first chapter deals with a brief review of properties of nanocrystalline ferrites and their applications. Historical background and literature survey is included at the end of the chapter.

The Chapter II deals with the methods of preparation of nanocrystalline ferrites. Different physical, chemical and biological

methods have been discussed. The chapter has been divided into three parts. Part A is devoted to X-ray diffraction studies and part B to I-R studies. The analysis of X-ray diffraction patterns reveals the single phase structure of samples No irregular peaks are observed. Lattice parameter is found to be approximately the same. As the ionic radii of Ni (0.74 A^0) and Mg (0.75 A^0) are comparable such a result is expected. The lattice parameters values of the present samples agree with other divalent substituted Ni – Zn ferrite [2]. The values of R_A and R_B are found to be invariant with Mg^{2+} addition. Part B deals with IR spectra of ferrite in which Wadron's analysis of spectra is briefly given. IR spectra of all the compositions are obtained in the frequency range of 200 cm^{-1} to 800 cm^{-1-} in KBr medium. These reveal two main absorption bands in accordance with Waldron observations [3] The absorption band in the region of 600 cm^{-1} is attributed to tetrahedral complex and other in the vicinity of 400 cm^{-1} to the octahedral complex. The higher frequency band is due to stretching vibrations and lower frequency band is due to bond bending vibrations. The positions of the bands change slightly from one mixed ferrite to another. The change is attributed to the method of preparation, grain size and porosity [4]. However the change observed is not regular and can be due to the differences in microstructure. Some splitting is seen in the first three sample at ν_2.

Part C deals with the SEM studies. It is observed that grain growth is complete and the grains are found to be in the nanometric scale.

Chapter III deals with the electrical properties of ferrite and it is divided into two parts. Part A contains, d. c. electrical resistivity whereas part B deals with a. c. resistivity and dielectric properties. A discussion related with the conduction mechanism in ferrites is presented on the basis of electron hopping in part A. The resistivity of the samples in present system increases with increase in x upto x = 0.3 and then decreases.

Variations of resistivity with temperature shows two regions for x = 0.1 – 0.3. The slope of the first region changes at Curie temperature. Such transition is not seen for x = 0.4 and x = 0.5 which shows semiconducting behaviour. The activation energies in the para-region are greater than those in ferri-region. Activation energies are less than 0.2 eV suggesting that conduction in present samples is due to the electron hopping. In the present case it is observed that Tc increases. This has been attributed to the increase in A-B coupling [5] The compositional variation of resistivity at 300^0C has also studied. It is seen that there is an initial rise in resistivity upto x = 0.3 which has been attributed to replacement of Ni^{2+} ions by Mg^{2+} ions. The resistivity is maximum for x = 0.3, further increase in the Mg^{2+} ions results in lower

resistivity. Such results of minimum conductivity have been observed in the Ni- Zn ferrites [6].

In part B of this chapter, the measurement of a. c. resistivity and dielectric constant are explained. The real part of complex dielectric const (ε^1) is determined for various frequencies in the range of 100 Hz to 1 MHz. ε^1 decrease rapidly with increasing frequency and tend to reach a constant value, exhibiting dispersion for all the samples at lower frequencies. The ε' remains independent after certain frequency. The very high and large dispersions is due to the effect of heterogeneity of the samples like pores, surfaces, defects etc. Electronic polarization also contribution to the low frequency dispersion of ε'. At high frequencies ε' is insensitive to heterogeneity effect and also to polarisation thus resulting in ε' independent of frequency beyond certain frequency [7].

The mechanism of dielectric polarisation is similar to that of conduction [8]. The electron exchange interaction $Fe^{2+} \leftrightarrow Fe^{3+}$ results in local displacement of electrons in the direction of an electric field determining the polarization of ferrites. Normally ε^1 decreases with increasing frequency and reaches a constant value depending on the fact that beyond a certain frequency of a. c. applied field electron exchange does not follow the alternating field. This is the reason why dielectric constant remains constant beyond a certain frequency in the present system [9].

The contribution to a. c. resistivity comes from grain boundary resistivity and grain resistivity [10]. The resistivity at lower frequency (f=0) is considered as grain boundary resistivity and resistivity of high frequency ($f = \infty$) is considered as grain resistivity [11]. Therefore the resistivity of 1 MHz of present samples which is very very small in comparison with d. c. resistivity can be considered as grain resistivity, and main contribution to a.c. resistivity comes from grain boundary resistivity.

Chapter IV comprises of magnetic properties. The magnetic properties of ferrites like hystersis behaviour and magnetization are briefly discussed. The saturation magnetization and magnetic moment increase with x and become maximum at x = 0.3 and then follow a decreasing trend. The decreasing trend in saturation magnetization with increasing Mg^{2+} content can be explained on the basis of magnetization M_A and M_B of tetrahedral (A) and octahedral (B) sublattices respectively. Mg^{2+} ions besides preferring B site is responsible for the partial replacement of Fe^{3+} ions (each having a magnetic moment of 5 μ_B). Replacement by non magnetic Mg^{2+} ions results in lowering of the value of both M_A and M_B. The decrease in the M_A there by decreases the net magnetization. The magnetic moment η_B also decreases from x = 0.3 to 0.5 with increase in Mg content and reduction in magnetic Ni content.

In the present series it was found that the composition $Ni_{0.4}$ $Mg_{0.3}$ $Zn_{0.3}$ Fe_2O_4 shows distinctive features of maximum magnetization and resistivity. Such a composition is suitable for applications such as transformers.

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