CHAPTER SIX

SUMMARY AND CONCLUSIONS
The ferrimagnetic spinel ferrites have proved their potential in the field of applications in electronic and Computer industries. Owing to the high resistivity of these compounds eddy current losses are considerably reduced at high frequencies which has helped the replacement of transformer cores at high frequencies. One can therefore understand that the ferrites, especially soft ferrites need to be developed with high resistivity. On the other hand the magnetic properties should be enhanced. This can be achieved by the partial substitution of divalent ion in the formula $\text{MFe}_2\text{O}_4$ by a nonmagnetic ion such as Cd, Li, Zn. There is an enormous work done on the Zn substituted Nickel ferrites however very little work is found in literature on Cd substituted ferrites in general; and we are presenting the work on Cd substituted Nickel ferrite for the first time. It is interesting to note that Zn ferrite is a semiconductor and when substituted for divalent Ni ion in Nickel ferrite the resistivity is found to decrease while Cd
substitution helps to improve the resistivity favourably owing to very high resistivity of Cd ferrites. Further Zn substituted and Cd substituted ferrites exhibit similar properties but Cd substituted ones give better i.e. high resistivity, which should be the aim in developing soft ferrites. Therefore we have developed polycrystalline $\text{Cd}_x\text{Ni}_{1-x}\text{Fe}_2\text{O}_4$ ferrites and subjected them to the study by different tools; the details of which are covered up in brief in the following lines.

The thesis is divided into Six Chapters. The first chapter is of introductory nature. This chapter explains the historical background of ferrites, crystal structure and spinel structure in detail. Neel's two sublattice theory and Yafet Kittle theory related to the ferrimagnetic materials are also discussed in this first chapter. The orientation of the present work is given at the end of this chapter.

The second chapter deals with the preparation and characterisation studies of the prepared
ferrites by XRD, IR, Curie temperature measurement and SEM. Chapter two is therefore subdivided into five sections A, B, C, D and E. In the Section A, different methods of preparation of ferrites have been discussed. At the end of this part actual method which is used for preparation of ferrite which is under investigation has been discussed in detail. The general formula for the ferrite system under investigation is \( \text{Cd}_{x}\text{Ni}_{1-x}\text{Fe}_2\text{O}_4 \) \((x = 0.0, 0.2, 0.4, 0.6, 0.8 \text{ and } 1.0)\). Section B deals with the XRD study. The diffractograms were recorded on Philips Computarised diffractometer PW 1710 using \( \text{CuK}_\alpha \) radiations \( (\lambda = 1.54056\text{Å}) \). The well defined X-Ray diffraction peaks with no ambiguous reflections confirms the formation of single phase spinel structure. Alongwith the diffractograms the results are discussed in brief.

Infrared absorption for the series of the samples are discussed in Section C. IR study show two prominent band \( \nu_1 \) and \( \nu_2 \) in the interval 570 cm\(^{-1}\) to 600 cm\(^{-1}\) and 400 cm\(^{-1}\) to 440 cm\(^{-1}\) respectively and are found to be in the expected range for spinel ferrites. The \( \nu_1 \) band could be attributed to the intrinsic vibrations of the
tetrahedral groups and $\gamma_2$ to the octahedral groups. The change in band position may be due to the changes in the $\text{Fe}^{3+} - \text{O}^{2-}$ with the increase of Cadmium content.

Section D deals with the Curie temperature measurements. Curie temperatures were measured by using Laroia technique and their variation with Cadmium content is discussed. Curie temperatures are found to be decreasing as Cadmium content increases. It is explained as the presence of some of Ni$^{+2}$ and Fe$^{+3}$ on octahedral B-Sites on addition of Cd$^{2+}$ on tetrahedral site, decreases A-B interaction.

SEM study is presented in Subsection E. It is seen that grain size increases with Cd content, without any exaggerated grain growth.

Chapter three is devoted to d.c. and a.c. electrical resistivity studies of the system. This chapter is subdivided in two sections A and B.
Section A begins with the discussion of conduction mechanism and hopping process. These studies have been carried out in temperature range 300K to 1000K. The resistivity found to be temperature dependent and is found to obey the relation,

\[
\rho = \rho_0 \exp \left( \frac{\Delta E}{K T} \right)
\]

The linear decrease of resistivity with temperature shows a break at a critical temperature. Such a break is observed for the samples \(x = 0\) to \(x = 0.6\), the compositions \(x = 0.8\) and \(1.0\) do not show such type of break and therefore suggesting these samples are paramagnetic at and above room temperature. The room temperature resistivity is also discussed in this section. Room temperature resistivity is found to increase with increase of Cd content. This variation in resistivity is explained on the basis of model based on phonon assisted electron hopping.

The a.c. electrical conductivity has been studied for the samples \(x = 0.0\) to \(x = 1.0\) and
discussed in Section B of the same chapter three. This section starts with theories on A.C. electrical conductivity. The measurement of capacitance (c), resistance (R) and loss tangent (\(\tan \delta\)), were made on the computerised instrument of Hewlet Packard, U.S.A. in the frequency range from 10 KHz to 15 MHz at ERTL Bombay. It is seen that dielectric constant (\(\varepsilon'\)) decreases with increase of frequency which is rather a normal behaviour. The dispersion is minimum for the sample \(x = 0.0\) and addition of \(\text{Cd}^{2+}\) tends to increase the dispersion of the dielectric constant (\(\varepsilon'\)). This is explained on the basis of polarisation process in ferrites. The variation of loss tangent (\(\tan \delta\)) with frequency shows a peak for the compositions \(x = 1.0\) to \(x = 0.2\) while composition \(x = 0.0\) does not show such type of peak. Detailed explanation for this behaviour is presented in this section. Dispersion in A.C. resistivity is also discussed on the basis of koops model at the end of this section.

Chapter four deals with the studies on magnetic properties of the developed ferrites. At
the beginning, theories of magnetisation process and hysteresis have been discussed. Magnetisation study at 300K i.e. room temperature carried out on high field hysteresis loop tracer. Compositional dependence of $n_B$ indicates that as Cd$^{2+}$ content increases, $n_B$ increases upto $x \ll 0.2$ and then decreases. This behaviour is explained on the basis of canted spin arrangement, in these ferrites. The saturation magnetisation is obtained at infinite field by extrapolating the variation of $M_s$ with $1/H$ from which the saturation magnetisation is estimated at absolute zero. Using these values, magnetisation in the system is explained and Cation distribution is proposed.

Chapter Five consists Mossbauer study at room temperature. This chapter begins with the introduction and importance of Mossbauer effect as a tool for the study of ferrites. Mossbauer spectra are obtained at room temperature and all isomer shifts are measured with respect to a metallic iron foil (25 $\mu$m). Average hyperfine field, $(H_n)$, average quadrupole splitting $(Q_s)$ as
well as average Isomer Shifts (Is) are calculated and their variation with Cd content is explained in detail. On the Mossbauer study we have proposed the cation distribution for the said system at the end of this chapter. This work is carried out at NCL Pune.

Chapter six consists of summary of the work carried out during the course with conclusions, in brief.

The reference to the Chapters are given at the end of each Chapter and due acknowledgement is given with thanks to the persons and laboratories from where the help was sought.