# CHAPTER - V

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## SUMMARY AND CONCLUSIONS

Ni-Zn Ferrites are technologically important as they have many applications from low frequency to microwave frequencies. They are easy to prepare both by ceramic as well as chemical method & do not require any special preparation conditions, therefore we decided to work on Ni-Zn Ferrite system. We selected the composition $Ni_{0.6-x}Co_xZn_{0.4}Fe_2O_4$ addition of small content of $Co^{2+}$ improves the initial permeability but for higher concentration of $Co^{2+}$ the $\mu_i$ remains constant. For several telecommunication applications the variation of $\mu_i$ with temperature should be linear & minimal. $Co^{2+}$ was selected as it improves temperature coefficient of $\mu_i$ & also to study the effect of $Co^{2+}$ on bulk magnetic properties.

The present investigation involved the following steps.

1. preparation of $Ni_{0.6-x}Co_xZn_{0.4}Fe_2O_4$ ferrites by the oxalate method.

   where x = 0.01, 0.02, 0.03, 0.04 & 0.05
2. X-ray studies to confirm the ferrite formation & to determine the lattice constant.
3. Microstructure analysis to understand role of grain size on the physical properties.
4. Bulk magnetic properties
   - a) A.C. Susceptibility to understand the domain structure.
   - b) Initial permeability studies to understand the variation of $\mu_i$ with temperature and compostion.
5. Hysteresis study at room temperature to observe the variation of magnetic moment, coercieve force, remanence

ratio.

The reports of these studies have been presented in this dissertation.

CHAPETER - FIRST : deals with the introduction of ferrites in which importance of ferrites, Historical development,crystal structure of spinel ferrites along with classification are discussed. Many wokers has been studied the initial permeability on Ni-Zn ferrites, the review of work done on initial permeability ($\mu_i$) has been reported briefly. The theory on initial permeability have been discussed briefly. Applications based on permeability for Ni-Zn ferrite are mentioned, orientation of work & References are given at the end of the chapter.

CHAPTER - TWO : is divided in to two parts viz. preparation and XRD studies.

PART - A : Deals with various methods of preparation are given along with the stages of sintering & pressing, a short introduction of hot pressing technique is given. A detailed explanation (procedure) used for sample preparation viz. by oxalate method is presented. The compostion $Ni_{0.6-x}Co_xZn_{0.4}Fe_2O_4$ where x = 0.01 to 0.05 were prepared, these samples are decomposed at 500°c for 30 minute, in air atmosphere in a furnace furnace was cooled slowly. After decompostion milling will be done, using hydraulic press torroids were prepared & finally sintered at 1050°c for 4 hrs in air atmosphere. Flow chart of wet method is presented.

PART - B : The XRD studies deals with the idea of X-ray diffraction and Braggs law. The method of X-ray diffraction is discussed briefly. The XRD pattern of all the ferrite samples are obtained to confirm the single phase formation of ferrites. The lattice constant 'a' is calculated for 400 plane for all samples The interplanar distance 'd' are calculated, the observed 'd' values & calculated 'd' values are in good agreement for all the indexed planes; which confirms the formation of spinel ferrite. The variation of lattice parameter 'a' with $Co^{2+}$ content is presented. The XRD pattern of all the samples are presented. At the end of this chapter references are given.

CHAPTER THREE : is divided in to three parts such as

PART - A : In Magnetization studies introduction, magnetization in ferrites, magnetic anisotropy, magnetostriction, magnetization process, Hysteresis loop & Domain state discussed briefly. The experimental technique & formulae for magnetization calculation is given, magnetic moment is calculated using the formula

$$n_B = \frac{\text{Mol.weight} \times 6's}{5585}$$

It is observed that magnetic moment ($n_B$) decreases monotonically with increasing $Co^{2+}$ content for higher concentration of $Co^{2+}$, for ($x = 0.05$) content the $n_B$ decreases by large amount from hysteresis loop coercive force, remanence ratio & $4\pi Ms$ is calculated. Similar trend to that of $n_B$ has been exhibited by the variation of $4\pi Ms$ as a function of $Co^{2+}$ ion concentration. The values of remanence ratio (R) & Coercive Force (Hc) as a function of $Co^{2+}$ are presented. The remanence ratio is known to be proportional to under $\sqrt{K_1}$ with the addition of $Co^{2+}$ which has +ve value of $K_1$ to Ni-Zn ferrite that has -ve value of $K_1$, results in overall decrease of $K_1$ in magnitude which leads to the decrease of R. It is seen that Hc decreases with addition of $Co^{2+}$ which can be related to the higher rate of decreases of $K_1$ that of Ms with the addition of $Co^{2+}$.

<u>PART</u> - <u>B</u> : deals with a.c. susceptibility studies. The compostions of $Ni_{0.6-x}Co_xZn_{0.4}Fe_2O_4$, $X_{ac}$-T exhibit temperature invariant a.c.susceptibility up to the curie temperature. This suggests that the ferrite compostions investigated contain M.D. Grains. Near $T_c$, the susceptibility drops sharply. This can be confirmed from the shape of $\mu_i$-T curve which resembles to that of $X_{ac}$-T shpaes, at the end references are given.

<u>PART</u> - <u>C</u> : deals with initial permeability studies. The initial permeability ($\mu_i$) values have been measured as a function of compostion & temperature. It is observed that $\mu_i$ remains constant with the variation of temperature, except composition 0.01 & 0.04 where there is small variation in $\mu_i$ with temperature near $T_c$ curves drops sharply which suggest single phase formation of the ferrite material, we have not observed any peak in $\mu_i$->T variation because rate of change of Ms & that of anisotropy field may be same. We have also studied the variation of inital permeability ($\mu_i$) with $Co^{2+}$ at room temperature, $\mu_i$ is maximum for $Co^{2+}$ = 0.01 & then it becomes decreases slowly with variation of $Co^{2+}$, $\mu_i$ remains constant also curie temperatue is obtained from

these curves.

CHAPTER FOUR : Microstructure studies microstructure & ferrites, aspects of microstructure, that is sintering, grain growth, controll of grain size, controll of porosity experimental technique have be discussed briefly. The SEM photogrphs of the composition $Ni_{0.6-x}Co_xZn_{0.4}Fe_2O_4$ for x = 0 to 0.05. We have studied the micrograph of x = 0 to 0.02 compositions, which clearly indicates the fine grain nature of the ferrites formed - a characterstic of chemical method of ferrite preparation. It is seen that on an average the grain size is less than 0.5μM. Carefull observation of every micrograph reveals that the porosity within the material is very low & there is no change of either microstructure or the grain size & topology with the addition of $Co^{2+}$ in the material.