# Room temperature synthesized $Co^{2+}$ substituted Mg-Cu-Zn ferrite nanoparticles by molten salt Method

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*Abstract:* A polycrystalline $Mg_{0.25-x}$ $Co_x$ $Cu_{0.25}$ $Zn_{0.5}$ $Fe_2O_4$ System has been synthesized by molten salt method and studied by using X-ray diffraction (XRD) technique, Scanning electron microscopy and chemical composition characterization techniques. The XRD data confirms the formation of single phase cubic structure with lattice constant ranging from 8.39 to 8.41 $A^0$. The porous morphology of nanoparticles was confirmed by scanning electron microscopy images in the range of 50-100nm.

Keywords: Mg-Cu-Zn Ferrite, X-ray diffraction, Scanning Electron Microscopy etc

## I. INTRODUCTION

Electrical and electronic devices are the indispensable needs of the modern age. Therefore the designing and optimizing the performance of these devices with high efficiency is really imperative. In view of this, researchers in different parts of the world have already been working in these directions, encountering problems/discrepancies, seeking solutions to these impediments. Among the various problems, the electromagnetic interference (EMI) is a specific type of environmental pollution, due to the rapid growth in utilization of electrical and electronic devices in industrial, commercial and military applications. In the past decades, the spinel ferrites have been utilized as the most frequent absorbing materials in various forms [1]. These are good microwave absorbing materials because of their high specific resistance, remarkable flexibility in tailoring the magnetic properties and ease of preparation [2].

Recently, multilayer chip filters have been developed as a promising electromagnetic interference (EMI) device [3-5]. They are made with a co-fired multilayer structure of ferrite, dielectric and internal conductors. The rapid development in this research field resulted into the new trend of miniaturization of electronic devices. Better electrical and magnetic properties, especially high initial permeability are required for reducing the number of layers which makes miniaturization of the component feasible.

Many researchers have extensively studied the Ni-Cu-Zn ferritesto fabricate multilayer chip inductors and EMI filters, because of their relatively low sintering temperature, good performances in the high frequency range, high permeability in the RF frequency region, high electrical resistivity and environmental stability [6-10]. However, in case of Ni-Cu-Zn ferrites creation of residual stress due to liquid phase diffusion which occurs during sintering results in a decrease in the permeability and magnetic properties [25, 26]. In addition the nickel and its compounds present in Ni-Cu-Zn ferrites produce carcinogenic effects and environmental toxicity, despite of their high permeability and high resistivity at higher frequencies [11].

The structural, morphological and compositional property of molten salt synthesized for the compositions $Mg_{0.25-x}Co_xCu_{0.25}Zn_{0.5}Fe_2O_4$ with has been investigated in the present study.



## II. EXPERIMENTAL

Ferrite powders with composition $Mg_{0.25-x}Co_xCu_{0.25}Zn_{0.5}Fe_2O_4$ was synthesized using a molten salt method. The molten salt method is the simplest, most versatile, and cost-effective method for obtaining crystalline, phase pure, single phase powders at lower temperatures. The method requires a shorter reaction time with little residual impurities as compared with conventional solid-state reactions [12]. The starting precursors used were analytical reagent grade magnesium sulphate, cobalt sulphate, copper sulphate, zinc sulphate and ferric nitrate. The divalent metal precusors, ferric nitrate, NaOH and NaCl were mixed in the molar ratio (1:2:8:10) and then grounded together in an agate mortar for about 30 min. The reaction was exothermic and started spontaneously. As the reaction proceeded, the mixture became mushy and a gradual change in colour was observed. The as prepared powders were collected and washed several times with

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distilled water to remove unwanted byproducts produced during the reaction. The as prepared powders were calcinated at 700°C for 2 h. The calcinated powders were further used to form the pellets. Initially the calcinated powder was mixed with PVA (organic binder) and grounded in agate mortar. Pellets were formed using a die having 1.5 cm diameter and a hydraulic press machine by applying a pressure of 1.5 ton/cm$^2$. The toroids of samples were fabricated using a die having outer diameter 2 cm, inner diameter 1 cm with average height of 0.3 cm by employing a hydraulic press machine and applying a pressure of 1.5 ton/cm$^2$. All the samples in the present study were sintered at 950°C for 4 hrs in air atmosphere.

The X-ray diffraction (XRD) pattern of the samples were obtained on BRUKER D8 advanced X-ray diffractometer using Cu-K$_\alpha$ ($\lambda$=1.54056 Å) radiation. By making use of Bragg's law theinterplanar distance d (Å) was calculated. Further the lattice parameter 'a' was calculated using the relation for cubic structure. Surface microstructure and chemical composition of the sintered samples was observed using scanning electron microscope (Model SEM-JEOL) operating at 5 kV and gold coated on sample for composition study.

## III. RESULT AND DISCUSSION

In order to know the phase formation of the material study of crystal structure is essential factor. The crystal structure determination of different compositions was done from the XRD studies. The typical XRD pattern for composition X=0.05 of sintered $Mg_{0.25-x}Co_xCu_{0.25}Zn_{0.5}Fe_2O_4$ ferrites is shown in Fig. 1. The XRD pattern revealed the presence of highest intensity peak corresponding to (3 1 1) plane and peaks corresponding to other planes like (2 2 0), (2 2 2), (4 0 0), (4 2 2), (5 1 1) (4 4 0) and (5 3 1) which confirmed the formation of cubic spinel structure. No second phase was detected in the XRD patterns of all the samples. The broad and well resolved peaks in the XRD patterns, clearly demonstrated fine particles of polycrystalline Co doped Mg-Cu-Zn ferrite. The standard JCPDS File No. 08-0234 was used to index the different peaks observed in the XRD pattern by comparing the observed inter planar distances (d) with standard value.

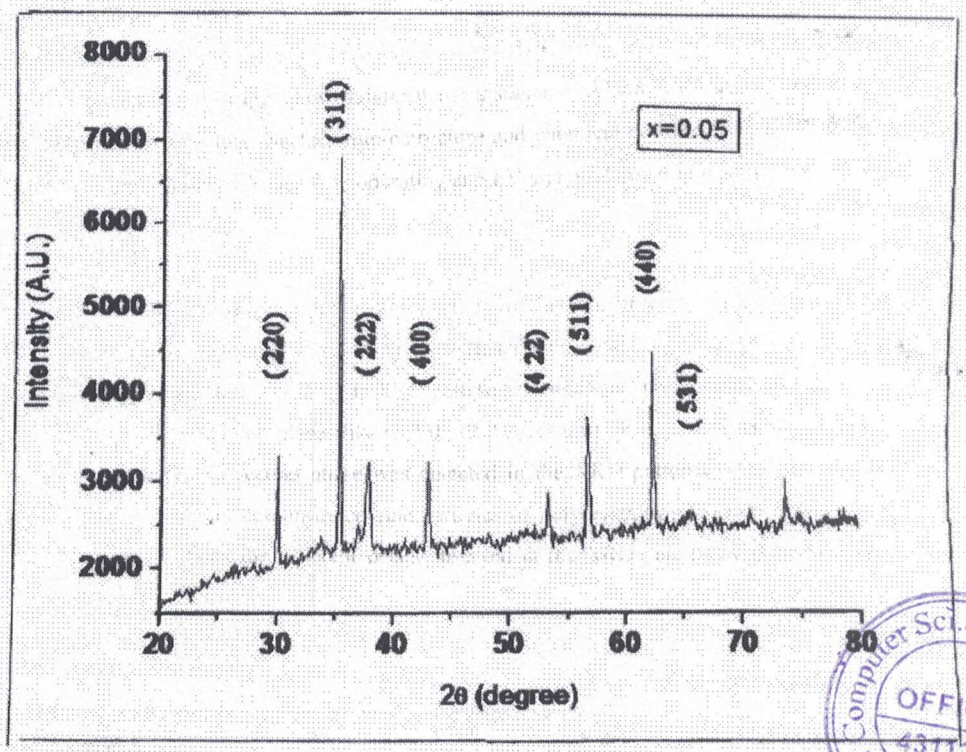




**Figure 1:- X-ray diffraction spectra of 0.05 composition of $Mg_{0.25-x}Co_xCu_{0.25}Zn_{0.5}Fe_2O_4$ ferrites nanoparticles.**

surface morphology of ferrite nanoparticles are essential for applications such as magnetic, sensor and electronics. Among the parameters of microstructure, like grain size and porosity, former is more important parameter which affects the magnetic erties of ferrites strongly. The grain growth, being a result of inter particle mass transport, appears to be dominated by the bimodal sion mechanism [12], lattice and grain boundary diffusion. Scanning electron microscopy (SEM) was used to determine the ructure of the sintered Co substituted Mg-Cu-Zn ferrites. The SEM images of different compositions of sintered $Mg_{0.25-x}Co_xCu_{0.25}Zn_{0.5}Fe_2O_4$ ferrites are shown in Fig. 2. Highly dense microstructure was observed for all Co added sample 0.05 composition.

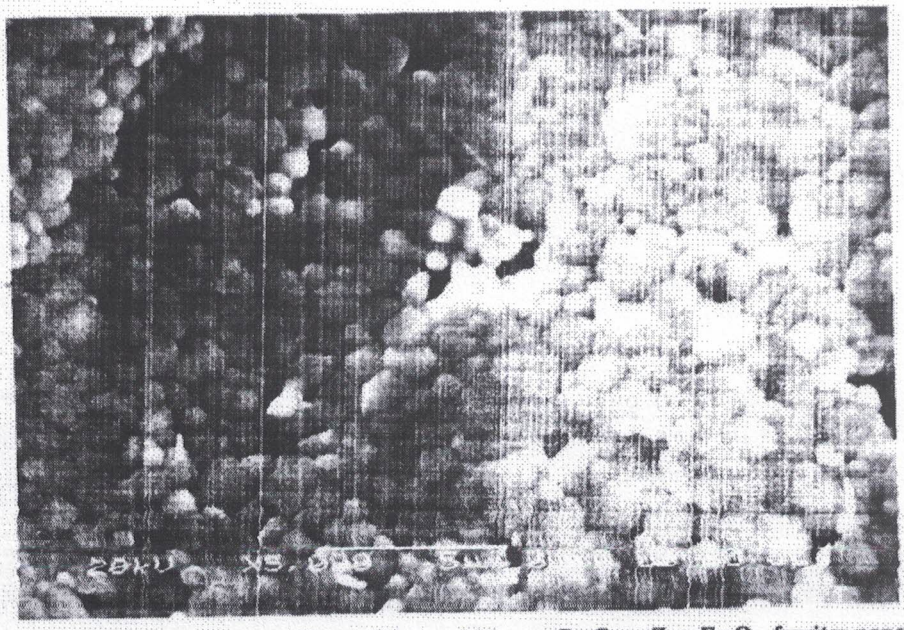

**Figure 2: The SEM image of compositions of sintered $Mg_{0.25-x}Co_xCu_{0.25}Zn_{0.5}Fe_2O_4$ ferrites nanoparticles.**

rder to confirm the chemical composition, EDS analysis was carried out for all the samples and a typical EDS spectra $Mg_{0.25-x}Co_xCu_{0.25}Zn_{0.5}Fe_2O_4$ ferrites with x=0.05 is given in Fig. 2.

## IV. CONCLUSION

The structural, morphological, and compositional properties of molten salt synthesized spectra $MG_{0.25-x}CO_xCU_{0.25}ZN_{0.5}FE_2O_4$ ferrites noparticles of composition X= 0.05was investigated. The structural study confirmed formation of fine spinel type material and proved the *versatility of the molten salt method. Micro structural study* validated the dense microstructure with high relative density. The structural and morphological studies confirmed that above material is in the range of 50-100 nm showing nanoparticles.

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