# Synthesis of nanosized chromium substituted copper spinel ferrite.

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**Abstract**

Chromium substituted cupper spinel ferrite nanoparticles with nominal composition $CuCr_xFe_{2-x}O_4$ (for x =0.0 & 0.5) have been synthesized by the sol-gel auto combustion technique. The XRD and TEM were employed to evaluate the structure properties of $CuCr_xFe_{2-x}O_4$ nanomaterials. The XRD analysis confirms the single phase formation. The various parameters such as lattice constants ('a'), cell volume and crystallite size have also been calculated from the XRD data. From Debye Scherrer formula, the crystallite size is found in the range of 30–57 nm, which was supported by TEM studies. The magnetic studies viz magnetization saturation, coercivity etc has been studied at room temperature.

**Keywords**: Nanoparticle, sol-gel combustion technique, XRD, TEM, coercivity etc.

## 1. Introduction

Nanocrystalline ferrites are currently the subject of interest of its wide application in industrial as well as research areas. They are attractive because of their importance in ferrofluids, magnetic drug delivery, hyperthermia for cancer treatment etc [1]. An interesting example is that of $CuFe_2O_4$ which has got some peculiar properties like structural, magnetic etc with the various substitutions allows tunable change in its properties. $CuFe_2O_4$ has an inverse spinel structure with $Co^{+2}$ ions in octahedral sites and Fe3+ ions equally distributed between octahedral and tetrahedral sites [2]. The presence of nonmagnetic ions in spinel was found to alter their electrical properties and studies revealed useful information on the nature of exchange interaction, cation exchange, etc. The structural and magnetic properties of ferrites mainly depend upon chemical composition, methods of preparation,sintering temperature and sintering time, microstructure, particle size and surface to volume ratio. The present work deals to investigates the structural and magnetic properties of via sol-gel autocombustion method.

## 2. Experimental

The synthesis of $CuCr_xFe_{2-x}O_4$ was performed by a sol-gel auto combustion method [3]. The raw materials used to form the precursors are copper nitrate, chromium nitrate, ferric nitrate & urea. The appropriate amounts of reactant were weighed out in a stoichiometric proportion. All the reactant dissolves in a deionized water. This solution of homogenous mixture was put onto the magnetic hot plate at the temperature of 80$^0$C. After sometime, the solution transformed in to gel. The gel form of the solution ignited and fired in a specially designed microwave oven on 600 watt for 7 min. The gel was burnt out completely forming ash. The resulting ash was grinded with a pestle mortar to obtain the ultra fine ferrite powder. The synthesized sample was calcined at 800 $^o$C for about 8 hours in the electric furnace to obtain monophase cubic ferrite.

## 3. Results and Discussion

XRD patterns showed that the $CuCr_xFe_{2-x}O_4$ samples consisted of single phase spinel, which was confirmed to be the same cubic structure as shown in figure 1. The lattice parameters depend on the Cr/Fe cation ratio, because the ionic radii of $Cr^{+3}$ (0.640 Å) has smaller ionic radii as compared to $Fe^{+3}$ (0.690 Å). The average particle size of the samples calculated by Debye Scherrer formula was to be found in the nanometer range. The X-ray density as a function of Co concentration is tabulated in table No. 1.

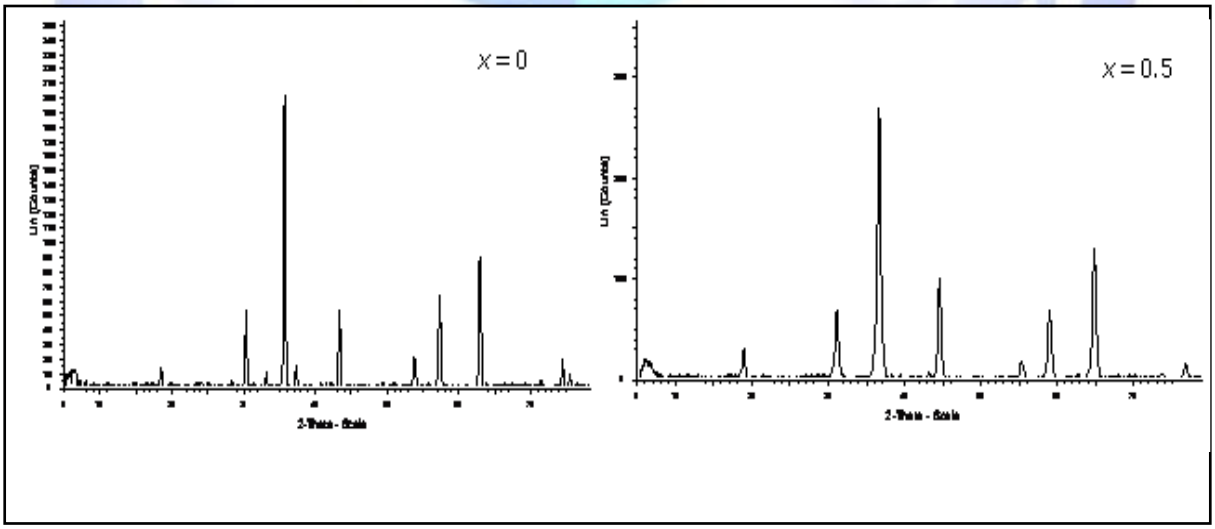


Fig. 1: X-ray powder diffraction patterns of the $CuCr_xFe_{2-x}O_4$ system

**Table No. 1: Lattice parameter, cell volume, density, Porosity and Particle size of Cu-spinel ferrite annealed at 800°C**

| Sr.No | Conc. (x) | a (Å) | V ( Å$^3$) | $\rho_x$ (gm/cm$^3$) | $\rho_m$ (gm/cm$^3$) | P(%) | Particle Size by Scherrer formula (nm) |
|---|---|---|---|---|---|---|---|
| 01 | x = 0.0 | 8.1286 | 537.09 | 5.916 | 3.254 | 44.99 | 30 |
| 02 | x = 0.5 | 8.3379 | 579.65 | 5.437 | 3.102 | 42.94 | 57 |

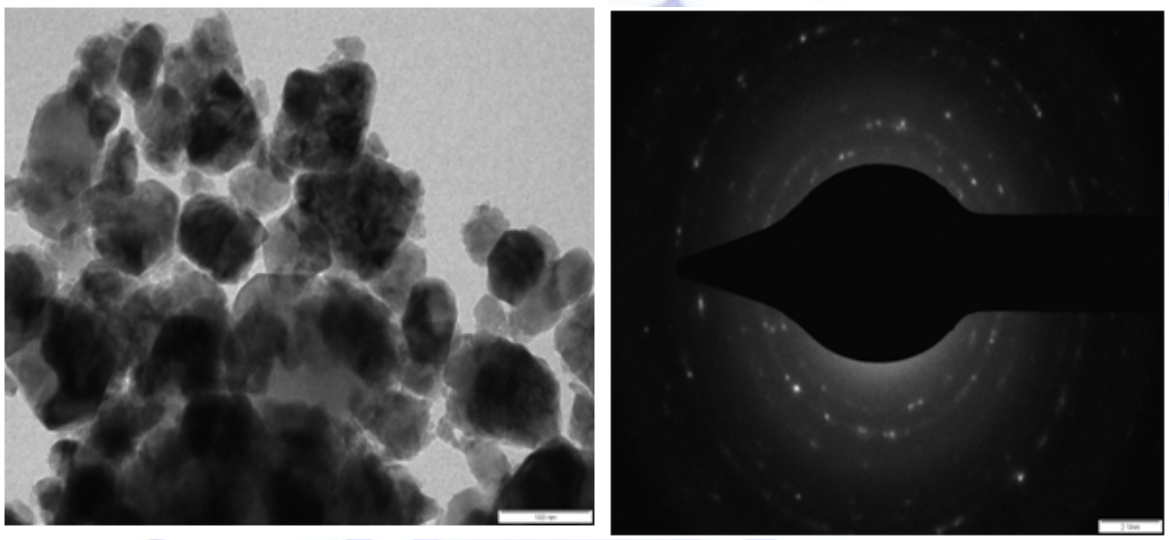

Fig. 2: TEM images pattern of the $CuCr_xFe_{2-x}O_4$ system

Fig. 2 shows the TEM images of the samples calcinated at 800 °C, from the micrographs we observe that the oxides particles are finely dispersed and spherical in shape within narrow size range. The micrographs shows spherical particles with the particle size distribution of below 100 nm. It seems that the size of the particles is below 100 nm which resembles with the measurement of the crystallite size of sample by D Scherrer formula as between 30- 57 nm [4].

**Table No. 2: Saturation Magnetization, Coercivity and Retentivity of Cu-spinel ferrite annealed at 800$^0$C.**

| Sr.No | Conc. (x) | Saturation Magnetization(emu/g) | Coercivity (G) | Rententivity (emu) |
|---|---|---|---|---|
| 01 | x = 0.0 | 0.049 | 38.219 | 0.000549 |
| 02 | x = 0.5 | 1.8680 | 102.05 | 0.17447 |

Hysteresis loops for the synthesized samples annealed at 800$^0$C are shown in the figures 4 and 5 respectively. It is observed that the saturation magnetization ($M_s$) increases with increase in particle size [5, 6]. From the table no. 2, it can be seen that the saturation magnetization increases from 0.049 emu/g to 1.8680 emu/g on increasing Cr concentration from x = 0.0 to x = 0.5. The variation of the coercivity with concentration (x) and average grain size has also been studied. It is observed that as the concentration and grain size increases, the value of coercivity ($H_c$) reaches the maximum value. The variation of $H_c$ with grain size can be explained on the basis of domain structure and anisotropy of the crystal [7-10].

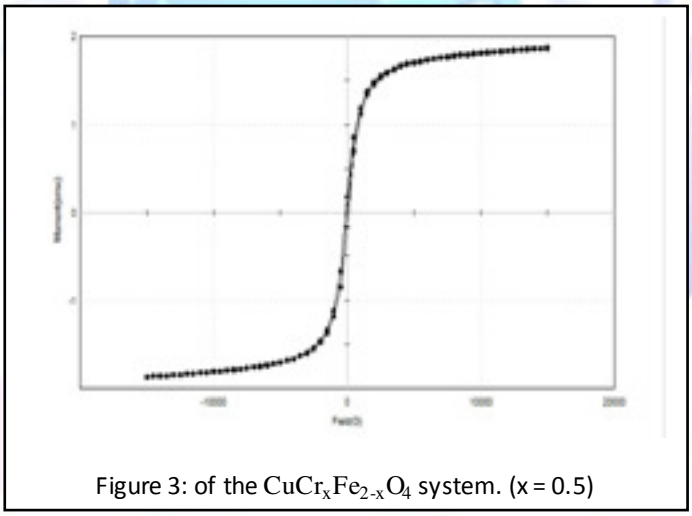

Figure 3: of the $CuCr_xFe_{2-x}O_4$ system. (x = 0.5)

## 4. Conclusion

From the XRD spectra, the structure of $CuCr_xFe_{2-x}O_4$ is a single phase normal spinel. TEM analysis revealed that the particles are nearly spherical. The particle size determined from TEM was found to be in close agreement with the XRD studies. From the magnetic properties it is clear that, the values of saturation magnetization and coercivity increases with the concentration of $Cr^{+3}$.

## 5. References


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