

## Eu<sup>3+</sup> Doped CoFe<sub>2</sub>O<sub>4</sub> Nanoparticles with XRD and FTIR Analysis

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### ABSTRACT

Pure and Eu<sup>3+</sup> doped cobalt ferrite nanoparticles with the formula CoEu<sub>x</sub>Fe<sub>2-x</sub>O<sub>4</sub> (x = 0.00, 0.10) were synthesized by citrate gel auto combustion method. X-ray diffraction analysis validated both the phase formation and purity of the synthesized nanoparticles. The Fourier-transform infrared (FTIR) spectra of the sample were meticulously recorded within the spectral range of 200-1000 cm<sup>-1</sup>. This analysis provided insights into the formation of the spinel structure.

**Keywords-** Europium (Eu<sup>3+</sup>), Cobaltferrites, XRD, FTIR.

## I. INTRODUCTION

In recent years, the utilization of technological advancements has significantly enhanced various sectors, including sensors, catalysts, medicine, magnetic imaging, magnetic recording, microwave devices, and magnetic data storage [1][2] [3][ 4]. This progress has spurred a considerable interest in research on spinel ferrite nanomaterials.

Among the diverse array of spinel ferrites, cobalt ferrite holds a particularly significant position. This prominence stems from its remarkable characteristics, including high coercivity, exceptional chemical stability, robust mechanical hardness, elevated temperature of magnetic ordering, amplified saturation of magnetization, substantial magneto crystalline anisotropy, and straightforward synthesis methods.

CoFe<sub>2</sub>O<sub>4</sub> nanoparticles, commonly known as cobalt ferrite nanoparticles, exhibit versatile applications beyond the fields previously mentioned. They are also used in tomography, magnetic resonance imaging (MRI), and cancer treatment, showcasing their potential in advancing medical diagnostics and therapy [5][6][7].

Various synthesis methods are available for producing CoFe<sub>2</sub>O<sub>4</sub> nanoparticles, such as sol-gel auto combustion, sonochemical, hydrothermal, microemulsion, and coprecipitation techniques. Among these methods, sol-gel autocombustion stands out as particularly popular due to its ability to offer precise compositional control, operate at low temperatures, and execute the process with ease. Incorporating rare earth (RE) elements into cobalt ferrites has led to a noticeable increase in the phenomenon of nano magnetism and significant modifications in their properties.

This study focused on the synthesis of a range of Co-Eu nanospinel ferrites (CEFO) using the citrate gel auto-combustion method and prepared materials were investigated by using X-ray Diffraction (XRD) and Fourier Transform Infrared Spectroscopy (FTIR).

## II. METHOD AND MATERIALS

The synthesis of cobalt europium nano ferrites, denoted as CoEu<sub>x</sub>Fe<sub>2-x</sub>O<sub>4</sub> (with x = 0.0 and 0.1), was achieved via the citrate gel auto-combustion method utilizing a precise combination of raw materials including

europium nitrate, cobalt nitrate, ferric nitrate, citric acid, and ammonia solution. Employing stoichiometric proportions of these materials dissolved in distilled water resulted in a homogeneous solution. Using citric acid as a fuel because it's really good at mixing things together, we kept the ratio of metal nitrate to citric acid at 1:3 to make a solution called nitrate-citrate. We added ammonia little by little to keep the pH level at 7. Continuous stirring and heating at 100°C for 7–8 hours yielded a viscous gel, which upon evaporation of water formed a dry gel, initiating internal combustion and producing the desired product. The obtained ferrite powder underwent calcination at 500°C for four hours.

### III. CHARACTERIZATIONS

The Eu<sup>3+</sup> doped Cobalt ferrite samples (CEFO) characterized using the X-ray diffraction (XRD) technique to identify their structure and assess phase purity. This analysis was conducted utilizing the Rigaku Corporation's Ultima IV X-ray Diffraction System model in Japan. XRD patterns were generated employing Cu-K $\alpha$  radiation (with a wavelength of  $\lambda=1.540598\text{\AA}$ ) at an operating voltage of 45kV and a current of 40mA within the  $2\theta$  range from 20 to 80 degrees. The FT-IR absorption spectra of specific samples were acquired using potassium bromide (KBr) disks on an FT-IR 6300 instrument

### IV. RESULTS AND DISCUSSIONS

#### 4.1.X-ray diffraction studies:

The X-ray diffraction pattern of CoFe<sub>2</sub>O<sub>4</sub>, synthesized via citrate gel auto combustion method is depicted in Figure 1. The diffraction peaks observed correspond to Bragg's reflections from the (220), (311), (222), (400), (422), and (440) planes,

aligning with the standard crystal structure of CoFe<sub>2</sub>O<sub>4</sub> as per the JCPDS card no. 22-1086. This crystal structure exhibits a spinel cubic type belonging to the Fd-3m space group. The lattice constant of CoEu<sub>x</sub>Fe<sub>2-x</sub>O<sub>4</sub> nanoparticles, where x = 0.0 and 0.1, is computed using the following equation (1).

$$a = d\sqrt{h^2 + k^2 + l^2} \text{ -----(1)}$$

where, d is inter planar distance

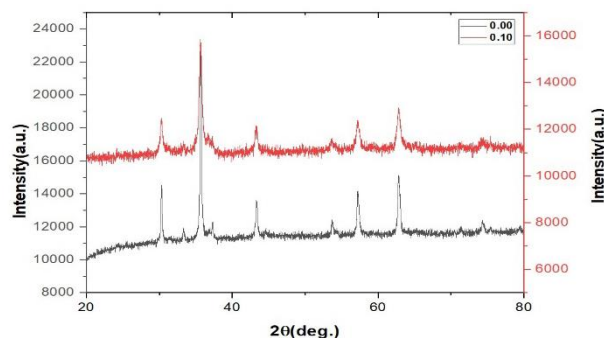


Figure 1: Shows the XRD patterns of Eu<sup>3+</sup> doped cobalt Ferrites (CEFO).

The decrease in lattice constant observed in europium-doped cobalt ferrites may be attributed to Europium ions typically have a larger ionic radius compared to iron ions[8 9]. When europium replaces iron in the lattice, the larger ionic radius of europium can cause lattice expansion[10]. Europium ions generally have a higher positive charge than iron ions. This difference in charge can lead to lattice distortion and contraction to maintain charge balance within the crystal lattice. Calculated XRD parameters were shown in Tab.1.

Table 1: XRD parameters of Europium doped CoFe<sub>2</sub>O<sub>4</sub> nanoparticles.

Composition(x)	0.00	0.10
$2\theta$	35.5772	35.65121
Lattice constant(a) A <sup>0</sup>	8.371423	8.34571
Volume(V)	586.6753768	581.2860074
X-ray Density( $\rho_x$ )	$5.520 \times 10^{-24}$	$5.582 \times 10^{-24}$

#### a. FTIR:

FTIR spectroscopy is an invaluable tool for analyzing the vibrational modes of molecules and solids. When utilized in the examination of rare earth Eu<sup>3+</sup> doped cobalt ferrites, FTIR offers crucial insights into the structural and compositional alterations resulting from the doping process. It facilitates the identification of functional groups, aids in phase analysis to discern different phases of cobalt ferrites, elucidates dopant incorporation into the lattice, detects structural distortions[11] induced by doping, explores the magnetic interactions influenced by rare earth elements, and enables the quantification of dopants by comparing

absorption band intensities. In the FTIR spectra, two prominent bands were evident, each indicative of specific vibrational modes within the crystal lattice are shown in Fig.(2) and Fig(3). The first observed absorption, falling within the 350-400 cm<sup>-1</sup> range for pure and 400-450 cm<sup>-1</sup> for x=0.10, signifies octahedral-metal stretching, while the second absorption, detected between 550-600 cm<sup>-1</sup> for pure and 600-650 cm<sup>-1</sup> for x=0.10, corresponds to tetrahedral-metal stretching [12]. These bands are typical in solids and are attributed to the vibrational motions of ions within the crystal lattice. The presence of characteristic absorption bands in the FTIR spectrum confirms the formation of the spinel structure[13].

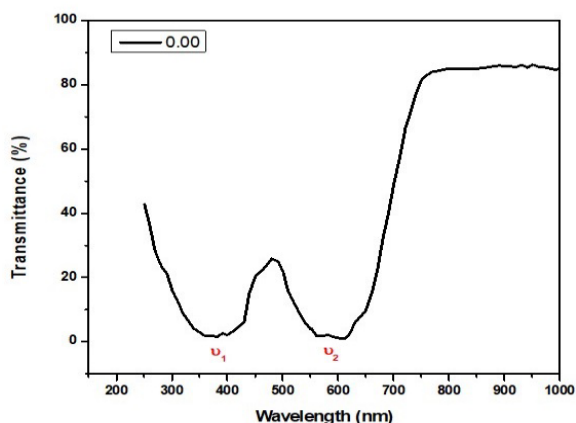


Figure 2: Shows the FTIR spectrum of  $\text{CoEu}_x\text{Fe}_{2-x}\text{O}_4$  at  $x = 0.00$

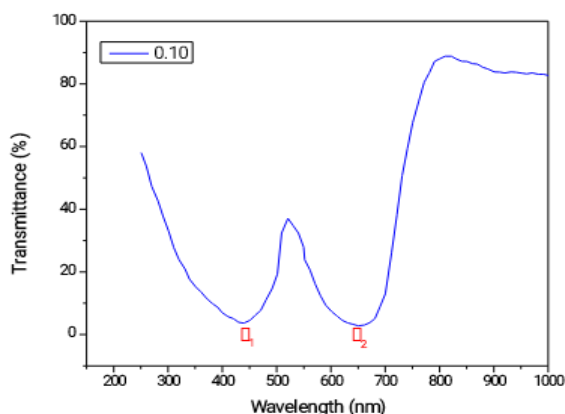


Figure 3: Shows the FTIR spectrum of  $\text{CoEu}_x\text{Fe}_{2-x}\text{O}_4$  at  $x = 0.10$ .

## V. CONCLUSIONS

$\text{CoEu}_x\text{Fe}_{2-x}\text{O}_4$  where  $x = 0.00$  and  $0.10$  were successfully prepared by citrate gel auto combustion method. The X-ray diffraction analysis of  $\text{La}_x\text{CoFe}_{2-x}\text{O}_4$  indicated a single-phase crystalline structure, free from any impurity peaks within the pattern. The FTIR analysis provided confirmation of the formation of the spinel structure. These nanoparticles can find diverse applications across various fields, contributing to advancements in technology, healthcare, and environmental sustainability.

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