# STRUCTURAL AND OPTICAL STUDY OF MANGANESE ZINC NANO FERRITE

Physics

**KEYWORDS:** Mn-Zn nano ferrite, Co-precipitation, XRD, UV-Vis spectroscopy, photoluminescence spectroscopy

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## ABSTRACT

Mn-Zn ferrites have shown a range of extraordinary applications because of their low core losses and high magnetic permeability. In present work, $Mn_{0.4}Zn_{0.6}Fe_2O_4$ nano ferrite has been prepared using the co-precipitation method. The crystallite size and optical properties of nano Mn–Zn ferrite have been investigated using X-ray diffraction (XRD), UV-Visible spectroscopy and photoluminescence spectroscopy. Different structural parameters viz. crystallite size, strain, lattice constant, dislocation density, packing factor have been calculated with the help of XRD. UV-Visible study has shown maximum absorbance at 266 nm. The emission spectrum obtained from photoluminescence is around 250 nm to 450 nm

## INTRODUCTION

Soft ferrites are mainly versatile because of their various technological applications [1, 2]. Nowadays, through unconventional methods, special focus has been given to obtain nano ferrites specially using chemical methods [3]. The uniform distribution of ions at the molecular level and high purity of the resulting products is provided by chemical methods. These chemical methods are also capable to accurately control the particle size. In order to get high-quality nano ferrites with desired microstructure and reproducible stoichiometric composition co-precipitation method has been used in the present work. The particle size plays a key role in determining the magnetic properties of nano ferrites. To create uniform and non-aggregated nano ferrites, the co-precipitation method provides a good synthesis route [4]. Mn-Zn ferrite shows high magnetic permeability and low core losses [1, 4]. The optical properties on Mn-Zn nano ferrites have been scarcely reported in literature. So in present work the Mn-Zn nano ferrites have been synthesized using co-precipitation method.

## EXPERIMENTAL

Mn-Zn ferrite of composition Mn0.4Zn0.6Fe2O4 has been prepared by co-precipitation technique. The precursors used were manganese (II) chloride (98% Merck, India), zinc (II) chloride (98% Merck, India), iron (III) chloride (98% Merck, India). Sodium hydroxide pallets (98% Merck, India) were used as precipitating agent. According to composition, the required molar solution of these precursors was prepared in distilled water. 4 molar solution of Sodium hydroxide was prepared with the help of distilled water and heated to boiling. In accurate stoichiometric proportions, the Manganese (II) chloride, zinc (II) chloride and iron (III) chloride were taken from their molar solution. These solutions were poured as soon as possible into the boiling solution of NaOH under energetic and constant stirring produced by the magnetic stirrer. The mixing of solutions is very important; otherwise separation of phases can take place. During co-precipitation, pH is set to 11.5-12. Reaction was continued for 50-60 min at temperature 70-80°C under energetic and constant stirring. At the end of reaction, reaction vessel was cooled to room temperature and particles precipitate. Sample was washed five times after precipitation. After washing, the sample was put inside the hot air oven and dried at 358 K overnight. Mortar pestle is used to crush the sample into the powder form. X-ray diffraction (XRD) of sample was done by PANalytical X'Pert Pro model. UV-visible absorbance spectrum of sample has been taken in the wavelength range from 200 nm to 400 nm by using Perkin Elmer UV-Vis-NIR spectrophotometer at room temperature. Fluorescence spectra of sample have been taken by using Perkin Elmer LS-55 fluorescence spectrometer.

## RESULTS & DISCUSSIONS

XRD spectra of the Mn-Zn ferrite sample of composition $Mn_{0.4}Zn_{0.6}Fe_2O_4$ have been shown in figure 1. The peaks have been observed at $2\theta$ = 35.38° corresponds to (111), (220), (311), (400), (331), (422), (511), (440), (620) & (533) respectively. The as-prepared Mn-Zn ferrite sample of composition $Mn_{0.4}Zn_{0.6}Fe_2O_4$ by co-precipitation method has a pure spinel structure (JCPDS 74-2401), which shows that one can achieve a pure Mn–Zn ferrite phase by co-precipitation method. The most prominent peak determined as (311) has been used to calculate the crystallite size, packing factor, lattice constant & strain.

The crystallite size of the sample has been calculated by Scherrer's formula;

$$D = 0.89\ \lambda / \beta \cos\theta$$

where D is the crystallite size, $\lambda$ is the wavelength of X-ray, $\beta$ is the full width half maxima and $\theta$ is the Bragg's angle. The calculated crystallite size (D) with the help of Scherrer's formula is 8.42 nm.

The packing factor (P) [5] has been calculated using the relation:

$$P = D/d$$

where d is the interplanar spacing. The calculated value of packing factor (P) is 82.083.

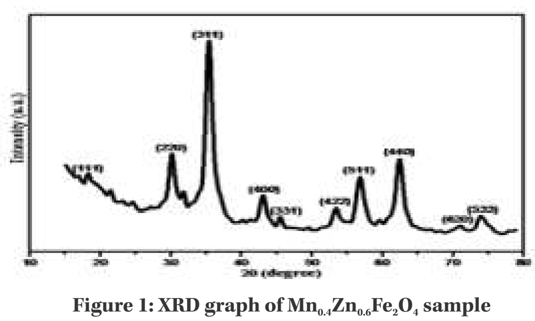

**Figure 1: XRD graph of $Mn_{0.4}Zn_{0.6}Fe_2O_4$ sample**

The lattice constant (a) [6] has been calculated using the relation:

$$a = d\,(h^2 + k^2 + l^2)^{1/2}$$

where h, k, l are the miller indices of the calculated diffraction peak. The calculated value of lattice constant (a) is 8.404 A°.

The value of strain ( $\varepsilon$ ) has been calculated by using the Stokes Wilson relation [7];

$$\varepsilon = \beta / 4\tan\theta$$

The calculated value of strain is 0.0135.

The value of dislocation density ( $\delta$ ) has been calculated using the relation:

$$\delta = 15\,\varepsilon\ /aD$$

The calculated value of dislocation density is 3.29×10-3 $A^{\circ -2}$.

UV-visible absorbance spectrum of nano Mn0.4Zn0.6Fe2O4 ferrite has been shown in figure 2(a). The maximum absorbance is observed at 266 nm. The UV-visible absorbance spectrum is shown in figure 2(a).

The absorption coefficient ( $\alpha$ ) has been calculated using the measured absorbance (A) [8]:

$$\alpha = 2.303 \log(A) / t$$

where A is the absorbance and t is the thickness of the sample. The thickness of the sample used for calculation of absorption coefficient ( $\alpha$ ) was 1 cm

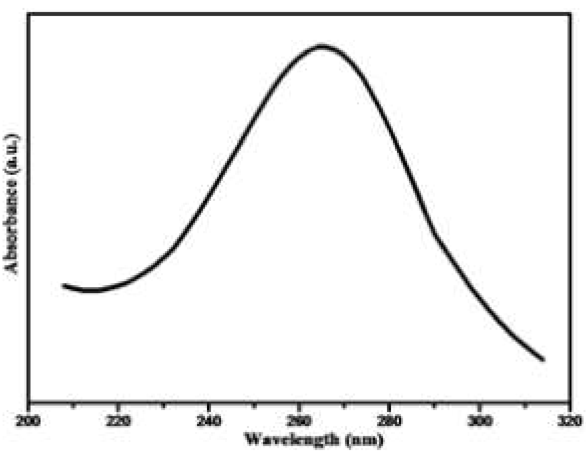


**Figure 2(a): UV-Visible absorbance spectrum of $Mn_{0.4}Zn_{0.6}Fe_2O_4$ sample**

Near the absorption edge, with the help of optical absorption coefficient (α), the optical band gap ($E_g$) has been calculated using the relation [8]:

$$(\alpha h\nu)^2 = B(E_g - h\nu)$$

where h is Planck's constant, is the frequency of incident photon, B is a constant and $E_g$ is optical band gap. Figure 2(b) shows a plot between $(\alpha h\nu)^2$ and h. Now, by extrapolating the linear part of absorption edge to the photon energy axis gives the value of optical band gap. The calculated value of the optical band gap is 3.09 eV.

Fluorescence spectra of $Mn_{0.4}Zn_{0.6}Fe_2O_4$ sample has been taken by using fluorescence spectrometer. As shown in figure 3, the observed emission spectrum is around 250 nm to 450 nm. There are two fluorescence peaks of Mn-Zn soft ferrite sample. First fluorescence peak of low intensity is observed between 250 nm to 275 nm and second peak of high intensity is observed between 300 nm to 450 nm. There occurred energy difference between the peaks of emission in photoluminescence and peaks of absorbance, which is termed as stokes shift [9].

There is approximately 75 nm stokes shift in our spectra. The emergence of stokes shift may be due to lattice distortions, electron–phonon interactions, point defects and interface defects [10].

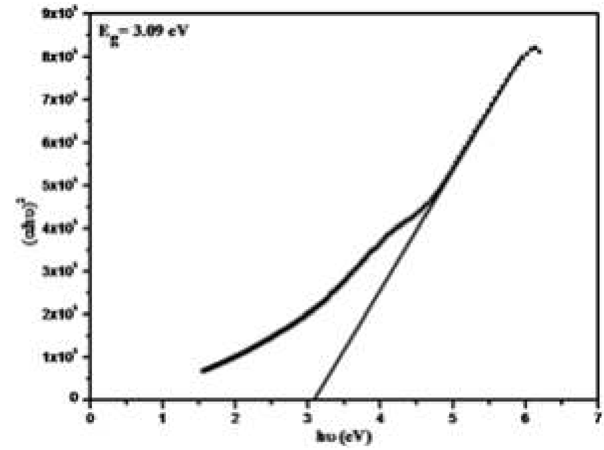


**Figure 2(b): Variation of $(\alpha h\nu)^2$ with Photon energy ($h\nu$).**

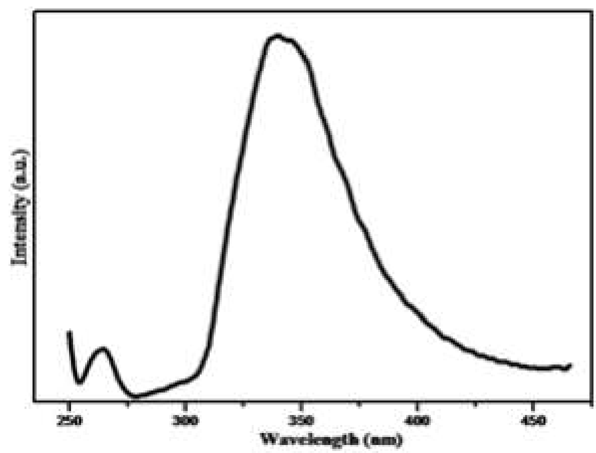


**Figure 3: Fluorescence spectra of Mn0.4Zn0.6Fe2O4 sample**

**CONCLUSIONS**

Mn-Zn nano ferrite has been successfully synthesized using the co-precipitation method. A single phase cubical spinel structure has been observed. The calculated crystallite size of Mn0.4Zn0.6Fe2O4 sample is 8.42 nm. UV-Visible spectrum of maximum absorbance obtained at 266 nm. The optical band gap (Eg) using Tauc plot has been found to be 3.09 eV. Fluorescence emission of Mn0.4Zn0.6Fe2O4 nano ferrite is around 250 nm to 450 nm. Stokes shift has been observed and is approximately 75 nm.

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