



X-ray and IR study of In³⁺ doped Ni-Cu-Zn Ferrite

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ABSTRACT

A series of polycrystalline spinel ferrites with composition $Ni_{0.3}Cu_{0.4}Zn_{0.3}In_xFe_{2-x}O_4$, $x = 0.0, 0.05, 0.10, 0.15, 0.2$ and 0.25 were prepared by the standard ceramic method to study X-ray and IR characteristics. X-ray diffraction pattern of the sample revealed single phase cubic spinel structure. Lattice constant increases by increasing In³⁺ concentration except at $x=0.05$. Also, crystal size increases by increasing In³⁺ Concentration. Two main absorption bands are observed in frequency range 200-800 cm^{-1} . The higher frequency band (ν_1) lies in the range 583 - 592 cm^{-1} while lower frequency band (ν_2) varies in the range 408 - 415 cm^{-1}

KEYWORDS: Spinel ferrites, Lattice constant, Crystal size, IR spectra, Band positions

1. INTRODUCTION

Now a days engineers and researchers have attractions in studying different characteristics of spinel ferrites because of its many important applications in modern telecommunication and electronic devices. The ferrites are magnetic semiconductors which cannot be replaced by any other magnetic material because ferrites are stable, relatively inexpensive, easily manufactured and have wide spread applications in various fields. Properties of ferrites have highly sensitive to the preparation methodology, sintering conditions etc. In applications like switched mode power supplies (SMPS), where the spinel ferrite materials are used as power transformer cores, the most required properties are high saturation magnetization and low core losses at high induction levels and at high frequencies [1].

Properties of ferrites are dependent upon several factors such as composition, method of preparation, substitution and doping of different cations, sintering temperature and time, sintered density, grain size and their distribution. Apart from the fact that they have very complex structures, their physical properties themselves are dependent on several valence electrons of the divalent or trivalent metal ions of tetrahedral (A) and octahedral [B] sites. Several attempts have been made to enhance the qualities of ferrites by employing various methods. The most general method is the incorporation of same suitable nonmagnetic/diamagnetic impurities at the (A) or [B] sites. This method enables them to acquire improved electrical, magnetic, and optical properties. Ni-Cu-Zn ferrites have been widely used in multilayer chip inductor because of their sintering properties at high frequencies, low sintering temperature and high

electrical resistivity [2-3]. These properties make this ferrite system very attractive.

Spinel ferrites are prepared through various methods like solid state reaction method [4]; high energy ball milling method [5]; sol-gel method [6]; chemical co-precipitation method [7]; microwave sintering method [8]; auto combustion method [9], conventional ceramic technique [10], conventional two-step synthesis method [11] etc. Ni-Cu-Zn ferrite has been synthesized through solid state reaction method by many investigators [12-15].

In this paper we report, the basic composition NiCuZnFe₂O₄ has been doped with trivalent indium ions to study their effect on the structural properties such as Xrd, IR etc.

2. EXPERIMENTAL DETAILS

Polycrystalline spinel NiCuZnFe₂O₄ ferrites doping with In³⁺ having chemical formula Ni_{0.3}Cu_{0.4}Zn_{0.3}In_xFe_{2-x}O₄, where *x* values range from 0.00 to 0.25, in step by 0.05, have been prepared by the conventional ceramic preparation technique. Analytical reagent oxides such as NiO, CuO, ZnO, In₂O₃ and Fe₂O₃ having purity 99.9% pure were used. The proper amount of ingredients was weighed and mixed in their proper proportions and ground in agate mortar for 2hrs. Formed materials were sintered at 700°C for 12 hours in muffle furnace and then slowly cooled to room temperature. Again, presintered material were ground for minimum 2hrs. The pellets were made by applying a pressure of 5 ton/inch² for 10 minutes. Finally, these pellets and remaining materials were sintered at 980°C for 24 hours and slowly cooled to room temperature.

The X-ray diffraction analyses were recorded at our Common research facility centre, Shri Chhatrapati Shivaji College, Omerga using RegakuMiniflux II, Desktop X-ray diffractometer. To study the absorption bands, IR spectra in the range 200 to 800 cm⁻¹ were recorded at room temperature on infrared spectrometer (model 783 Perkin –Elmer).

3. RESULT AND DISCUSSION:

In the study of structural properties, all prepared samples were analyzed by using x-ray diffractogram which represent that formed material gives cubic spinel structure. For cubic structure, the most intense peaks in all samples indexed as (220), (311), (222),

(400), (422), (333), (440), (620) and (533) are found to match well with standard value of single-phase cubic spinel. No additional peaks corresponding to any structure in starting and doped samples was detected except *x*=0.25. X-ray diffraction pattern of all analysed samples are shown in Fig. 1.

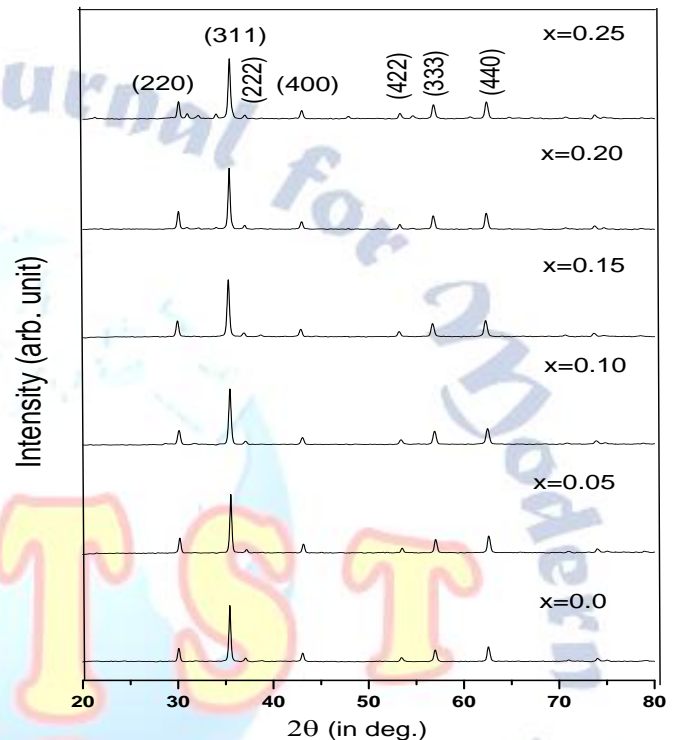


Figure 1 X-ray diffraction pattern of Ni_{0.3}Cu_{0.4}Zn_{0.3}In_xFe_{2-x}O₄, *x*= 0.0, 0.05, 0.10, 0.15, 0.2 and 0.25 ferrite system.

The lattice constant of the samples was determined by using relation [16],

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

The average crystalline size was determined from the diffraction peak broadening with use of Scherrer's equation [17]

$$t = \frac{0.9\lambda}{\beta \cos\theta} \text{ --- (2)}$$

where λ the wavelength of the CuK α ($\lambda = 1.54056 \text{ \AA}$) radiation, β is full width at half of the intensity maximum [FWHM] of (311) plane in radian.

The lattice constant and crystal size of the sintered ferrite materials evaluated from Xrd analysis were represented in table 1. From table 1, It is observed that for base ferrite value of lattice constant *a* is 8.3984 \AA but in doping In³⁺ ions at *x*=0.05 lattice constant decreases after that as In³⁺ substitution increases lattice constant increases. This can be related to fact that the In³⁺

ion has ionic radius of (0.91 Å) which is larger than the entire composition. When the larger indium ions enter the lattice unit cell expands while preserving the overall cubic symmetry [18].

Table 1 Variation of lattice constant, crystal size and band positions with composition x

x	Lattice Constant a (in Å)	Crystal size t (in nm)	IR absorption band position	
			ν_1 (cm^{-1})	ν_2 (cm^{-1})
0.0	8.3984	416.96	583.30	408.92
0.05	8.3777	417.07	580.53	411.81
0.10	8.4069	347.47	585.41	408.92
0.15	8.4239	416.76	590.29	414.70
0.20	8.4255	521.08	596.01	415.67
0.25	8.4365	463.20	592.16	406.02

From table 1, it is observed that crystal size changes from value 416.96nm to 463.20 nm. By addition of In^{3+} ions crystal size varied randomly from $x= 0.10$ it was 347.47nm lowest value and at $x= 0.20$ crystal size 521.08nm highest value. Generally crystal size depends upon the sintering temperature and homogeneity of material during grinding process.

IR spectra of all the compositions at room temperature with $x = 0.0, 0.05, 0.10, 0.15, 0.20$ and 0.25 are shown in the Fig. 2.

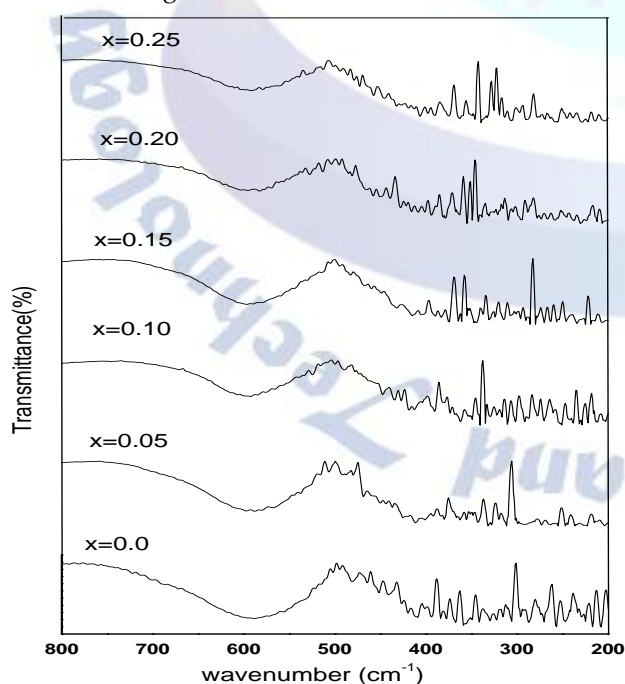


Figure 2 IR absorption spectra of $\text{Ni}_{0.3}\text{Cu}_{0.4}\text{Zn}_{0.3}\text{In}_x\text{Fe}_{2-x}\text{O}_4$, $x = 0.0, 0.05, 0.10, 0.15, 0.2$ and 0.25 ferrite system

From the figure 2, it is noted that the peak intensity changes with addition of In^{3+} concentration, and broadening of the band observed around 415 cm^{-1} . The broadening of the bands is higher at higher concentrations.

The IR spectra of all the compositions have been used to locate the band positions, which are given in the table 1. In the present study, the absorption bands for the ferrites have been found in the expected range. The higher frequency band (ν_1) lies in the range $583 - 592 \text{ cm}^{-1}$ while lower frequency band (ν_2) varies in the range $408 - 415 \text{ cm}^{-1}$. This difference in the band position is expected because of difference in the $\text{Fe}^{3+} - \text{O}^{2-}$ distance for octahedral and tetrahedral complexes. Waldron [19] and Hafner [20] studied the vibrational spectra of ferrites and attributed the bands ν_1 and ν_2 to the tetrahedral and octahedral groups respectively.

4. CONCLUSION

In the present series, X-ray diffraction pattern confirms the single-phase cubic spinel structure with sharp peaks indicates formation of polycrystalline spinel ferrite. Lattice constant increases by increasing In^{3+} concentration. Also, crystal size increases by increasing In^{3+} concentration. Two absorption bands are observed in the study of IR spectra, high frequency band is in the range $583-592 \text{ cm}^{-1}$ and low frequency band is in the range $408-415 \text{ cm}^{-1}$.

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Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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