

Synthesis, Structural and FTIR analysis of Zinc substituted Cobalt Ferrite

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ABSTRACT

This work reports the structural studies of the Zn -doped cobalt spinel ferrite ($\text{Co}_{0.8}\text{Zn}_{0.2}\text{FeO}_4$). Low-cost solid-state reaction method (SSR) was used to synthesize ($\text{Co}_{0.8}\text{Zn}_{0.2}\text{FeO}_4$). Different techniques were used to characterize synthesized material. The X-ray diffraction (XRD) analysis and Fourier Transform Infrared (FTIR) were carried out to study the structural properties. Formation of cubic spinel structure was ascertained by XRD analysis. XRD results shows that the resultant particles are crystalline, pure single-phase spinel structure. The crystallite size was found to be increased with the Zn concentration in cobalt spinel ferrite. The lattice constant (a), X-ray density (dx), were calculated and it is found to be align with reported values. Fourier Transform Infrared Spectra (FT-IR) was used to determine the stretching frequencies at tetrahedral and octahedral site and they found in their realm. The Cobalt-Cobalt and Cobalt-Oxygen stretching, and the shift in the stretching frequency attributed that formation of ($\text{Co}_{0.8}\text{Zn}_{0.2}\text{Fe}_2\text{O}_4$).

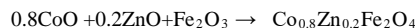
1 Introduction

Due to their high resistivity, negative temperature coefficient of resistance, and high dielectricity the ferrites have opened new area in the field of material science. The development of magnetic ceramics is attracting considerable scientific and technological interest due to their potential applications [1]. Ferrite are the suitable materials for high frequency applications, microwave absorbers, induction devices due to their high electrical resistivity and high initial permittivity. These materials possess high Curie temperature, high saturation magnetization and comparatively low energy loss. These materials are industrially important due to their inherent magnetism at room temperature. Among these ferrite materials the soft spinel ferrites are prominent class of ferrites those are extensively used in microwave applications, biomedical field, drug delivery systems, magnetic field applications and catalysis. The composition of Co-Zn spinel ferrites is a mixed spinel, in these the oxygen ions are closely packed with tetrahedral (A) and octahedral (B) sites. The cubic crystal remains unchanged during the compositional alterations. i.e. if the foreign metal with comparable size is substituted at the A or B site the cubic system remains unchanged. Therefore, the chemical and physical properties of the material can be tailored with the substitution of foreign element in the system. These spinel structure adopts the Fd-3m space group. As stated, the properties of the mixed spinel

structure can be altered to meet the requirement of particular application. The variables like calcination temperature, synthesis method, and the composition can be changed. In literature there are large number of synthesis methods of spinel ferrites are available and each method has its advantages and disadvantages. Scientist have worked on various synthesis methods to increase the structural, magnetic, optical and electrical properties of spinel ferrites. Due their novel physical properties researchers explored structural characteristics of zinc substituted cobalt ferrite. ($\text{Co}_{0.8}\text{Zn}_{0.2}\text{Fe}_2\text{O}_4$) attracts much attention due to its unique and excellent properties like high saturation magnetization Ms, high coercivity Hc

2 Experimental

$\text{Co}_{0.8}\text{Zn}_{0.2}\text{Fe}_2\text{O}_4$ is prepared ceramic method route using CoO , Fe_2O_3 , ZnO , used was from Radial chemicals with 99.8% purity. It follows the following reaction:



The starting materials CoO , ZnO and Fe_2O_3 are taken in 0.8 : 0.2 : 1.0 molar ratio and mixed using mortar and piston for 3-4 hrs. After homogeneous mixing the mixture is calcined at 950 °C for 8 hours in programmable furnace. They are allowed to cool down to room

temperature. Then product is again grinded for 3-4 hours in mortar with piston. The product is then heated to 1000 °C in programmable furnace for 10 hrs and then cooled to room temperature slowly to get $\text{Co}_{0.8}\text{Zn}_{0.2}\text{Fe}_2\text{O}_4$ ferrite.

3. Characterization

Structural characterization of ferrite powders was carried out by using a Bruker AXS D8 Advance diffractometer (Cu-K α radiation). Indexing for the confirmation of phase formation was done by comparing the experimentally obtained X-ray diffractograms with standard Joint Committee on Powder Diffraction Standards (JCPDS) data for cubic spinel ferrite. The X-ray density of the samples was calculated using the following relation $d_x = \frac{8M}{Na^3}$ where, M is a molecular weight of sample. N is a Avogadro's number (6.023×10^{23}), a is the lattice constants. The FTIR characterization has been done to understand the bond formation and synthesis material is ferrite [4-5]. It helps us to understand the structure of functional groups and their linkages. The IR study reveals analysis of absorption of Zn substituted Co-ferrites. The IR spectra of samples in present case were obtained from common facility Centre.

4. Results and discussion

4.1 X-Ray Diffraction Studies

Fig.1 Represents the XRD pattern of synthesized $\text{Co}_{0.8}\text{Zn}_{0.2}\text{Fe}_2\text{O}_4$ ferrite. The diffraction pattern analysis by using the (111), (220), (311), (222), (400), (422), (511), (440), (620), (533), (622) and (444) reflection planes. These planes confirm cubic structure of $\text{Co}_{0.8}\text{Zn}_{0.2}\text{Fe}_2\text{O}_4$. The Bragg's condition for diffraction maxima is given by

$$2d_{hkl} \sin\theta = n\lambda \quad \text{---(1)}$$

$$\text{Where } d = \frac{a}{(h^2+k^2+l^2)^{1/2}} \quad \text{---(2)}$$

The peaks positions and relative intensities match standard CoFe_2O_4 (JCPDC card no. 22-1086). It can be observed that the diffraction peaks are either all even or all odd, which shows that synthesized material has a spinel phase with lattice constant = 8.3794 Å and thus validates the cubic structure. X-ray density of the ferrite d_x is calculated by $d_x = \frac{8M}{Na^3}$. ---(3)

The detailed information of synthesized material such as lattice parameter (a), interplanar distances (d), observed intensity, observed intensity % (I_o %), standard intensity % (I_s %), volume of unit cell (V), X-ray density (d_x) of $\text{Co}_{0.8}\text{Zn}_{0.2}\text{Fe}_2\text{O}_4$. are shown in Table 1.

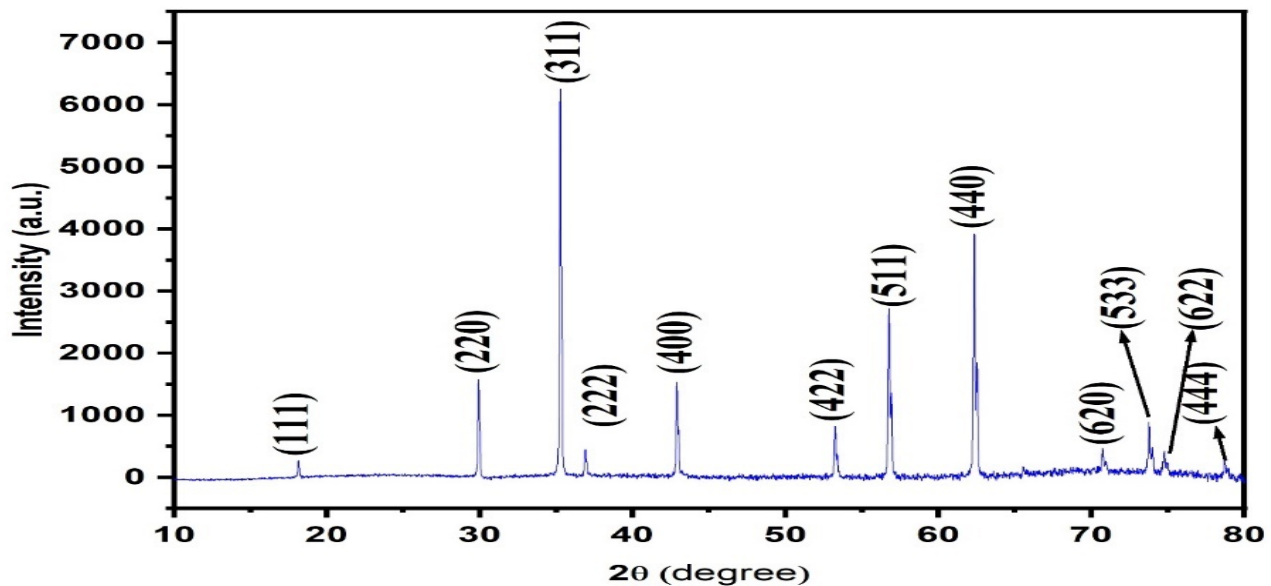


Fig. 1. The XRD pattern of nano $\text{Co}_{0.8}\text{Zn}_{0.2}\text{Fe}_2\text{O}_4$ ferrite

Table1.- lattice parameter(a), interplanar distances(d), volume of unit cell(V), X-ray density (d_x)

Sr. No.	2θ	θ	d value (Å)	observed intensity	I _o %	I _s %	Miller indices			a (Å)	V (Å) ³	d _x (g/cm ³)
							h	k	l			
1	18.31	9.155	4.8414	277.85	4.44	10	1	1	1	8.385551	589.6506	5.315103
2	30.05	15.025	2.9714	1569.14	25.11	30	2	2	0	8.404388	593.6334	5.279443
3	35.63	17.815	2.5178	6248.96	100	100	3	1	1	8.350598	582.3079	5.382125
4	37.19	18.595	2.4157	446.37	7.14	8	2	2	2	8.368230	586.0044	5.348175
5	43.19	21.595	2.0930	1528.31	24.45	20	4	0	0	8.372000	586.7967	5.340954
6	53.61	26.805	1.7082	825.53	13.21	10	4	2	2	8.368437	586.0478	5.347779
7	57.06	28.530	1.6128	2679.02	42.87	30	5	1	1	8.380355	588.5552	5.324996
8	62.64	31.320	1.4819	3880.50	62.09	40	4	4	0	8.382892	589.0900	5.320161
9	71.02	35.510	1.3262	464.60	7.43	4	6	2	0	8.387625	590.0884	5.311160
10	74.13	37.065	1.2780	891.11	14.26	9	5	3	3	8.380406	588.5661	5.324897
11	74.13	37.065	1.2635	427.51	6.84	4	6	2	2	8.381111	588.7145	5.323555
12	78.98	39.490	1.2113	269.29	4.30	2	4	4	4	8.392133	591.0402	5.302607
										8.379477	588.3746	5.326746

Average crystallite size (D) is calculated by using the Debye–Scherrer formula. $D = \frac{k\lambda}{\beta \cos\theta}$, where Crystalline size (D) is measured in nano-meter, Lambda (λ) wavelength of X-ray (1.5406 Å) and θ the Bragg angle for a given peak. The accuracy of this equation is subject to the error limitations of crystallite shape factor K and purely diffraction broadening β. In our case, K is taken as 0.9. The determined average crystallite size (D) of samples is 54.95 nm .

The distance between the magnetic ions is called hopping Lenth, the hopping lenth in A site is L_A (tetrahedral) and B site is L_B (octahedral) was calculated using following formula

$$L_A = \sqrt{3}a/4$$

---(4)

$$L_B = \sqrt{2}a/4$$

---(5)

The values of crystallites size (D) , lattice parameter (a) , volume of unit cell (V), X-

ray density(d_x), hopping lengths L_A and L_B

of $Co_{0.8}Zn_{0.2}Fe_2O_4$, are shown in Table 2.

Table2.- crystallites size (D), lattice parameter (a), volume of unit cell (V), X-ray density(d_x), hopping lengths L_A and L_B

D(nm)	a (Å)	V (Å) ³	d_x (g/cm ³)	L_A (Å)	L_B (Å)
54.95	8.37947	588.374	5.32674	3.62841	2.962592
	7	6	6	9	5

4.2 FTIR studies

Fourier Transform Infrared Spectroscopy is such a technique used

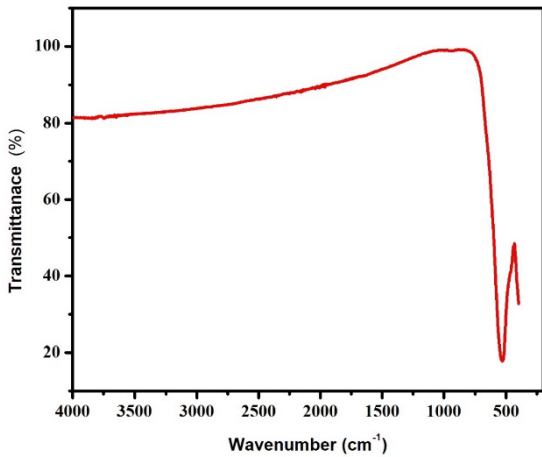


Fig. 2. The FT-IR spectra of nano $Co_{0.8}Zn_{0.2}Fe_2O_4$ ferrite

FTIR spectra of the prepared samples, and the absorption band results are presented in Table 2.

Table 3 Values of wavenumber at tetrahedral site (ν_1), wavenumber at octahedral site (ν_2) of $Co_{0.8}Zn_{0.2}Fe_2O_4$.

compound	ν_1 (cm-1)	ν_2 (cm-1)	ν_{avg} (cm-1)
$Co_{0.8}Zn_{0.2}Fe_2O_4$	432	533	482.5

It shows two absorption bands, ν_1 and ν_2 , at ~ 432 cm-1 and ~ 533 cm-1, respectively, confirming the formation of the spinel structure [9]. The high-frequency band (ν_1) corresponds to bending vibrations at the A site, and the low-frequency band (ν_2) corresponds to stretching vibrations of $Fe^{3+}-O^{2+}-Fe^{3+}$ at the B site. In the region of 400-600 cm-1, the bands in FTIR are attributed to the tremblant of the ions of metal [10-11].

5 Conclusions

The structural and FTIR properties of $Co_{0.8}Zn_{0.2}Fe_2O_4$ spinel ferrites were successfully investigated by the solid state method and FTIR analysis. The prepared samples confirmed the single-phase cubic spinel structure from the XRD patterns. An increase in lattice parameter was observed in the range of 8.379477 Å. Two peaks at ~ 432 cm-1 and 533 cm-1 appeared in the range of 400-600 cm-1, confirming the formation of the ferrite composite from FTIR analysis shown.

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