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Elastic and Structural Properties of Mn^{2+} Ions Substituted Zn-Co Mixed Ferrites

Ganesh B. Akat
Department of Chemistry,
Kohinoor Arts, Commerce & Science College, Khultabad Dist. Aurangabad (MS), India
ganeshbakat@gmail.com

Abstract: *Magnetic oxides, which are commonly known as ferrites are ferromagnetic in structure. Ferrites have been recognized as one of the most important electromagnetics in modern industry and their processing and application technologies have been improved incessantly in the last 20 years. composition $Zn_{0.5}Co_{0.5-x}Cd_xFe_2O_4$ (x = 0.0, 0.3, 0.5) Cd^{2+} ions substituted Zn-Co ferrites having have been prepared using the common ceramic technology of double sintering and oxides of AR grade. The preparation of the monophase cubic spinel structure of the ferrite phase is confirmed by X-ray diffraction (XRD) and infrared spectrum analyses. Due to the enormous ionic radius of Cd^{2+} ions, it was discovered that the lattice constant increased as the cadmium level increased. The bond length, jump length of the tetrahedral (A) site as well as the octahedral [B] site, tetrahedral edge length, shared and unshared octahedral edge length, and other structural parameters were estimated. These parameters included the lattice parameter, X-ray density, cation distribution, ionic site radii, oxygen positional parameter, and theoretical lattice parameter. By contrasting the observed and predicted lattice characteristics, it was possible to confirm the estimated cation distribution of ferrite and is IR, elastic parameters, including both the modulus analysis were estimated.*

Keywords: Modulus, IR Spectral Analysis, X-ray diffraction, Structural and Elastic properties

I. INTRODUCTION

The mixed Zinc-Cobalt ferrites are technologically important materials as it possesses high saturation magnetization, high resistivity, high stability,[1] and low loss energy over a wide range of frequency.[2,3,4] In fact, cadmium substituted Zn-Co mixed ferrite are the subject of intensive investigations in the field of fundamental and applied research due to their wide applications in electronic industry.[5] The physical properties of spinel ferrites depend on the type, amount of dopant and distribution of cations over the tetrahedral (A) and octahedral [B] sites.[6,7] In electronic materials the elastic module is of much importance because they show the nature of binding force in polycrystalline materials and also helps to understand the thermal properties of these materials

II. EXPERIMENTAL PART

The ferrite with composition $Zn_{0.5}Co_{0.5-x}Cd_xFe_2O_4$ (x = 0.0, 0.3, 0.5) were synthesized by standard double sintering ceramic method.[8,13,14] Grinding using agate mortar (4 h) was carried out for each sample. The samples were pre-sintered at 1250 K for 12 h. The samples were furnace cooled to room temperature. The prepared samples were characterized by X-ray powder diffractometer in the 2θ range 20 ^{0}C - 80^{0}Cat room temperature to confirm single phase spinel structure. The infrared spectra of a prepared sample were recorded at room temperature within the range 200 cm^{-1} to 800 cm^{-1} on the infrared spectrometer (Model of PerkinElmer). The sintered powder is again reground and sintered at 1556 K for 12 h. Then the powder of samples compressed into pellets of 10 mm diameter using a hydraulic press with pressure 6 ton/inch^2 and sintered at 1270K for 10 h.

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III. RESULTS AND DISCUSSION

Theincrease of observed lattice parameter 'a' and X-ray density 'ρ' with increase of the cadmium content was due to the difference in ionic radii and atomic weight of the component ions in the ferrite system.[15] The peaks appeared in the XRD pattern (fig.1) of the ferrites are identified. However, the nonappearance of extra peaks reveals the formation of single-phase cubic spinel structure of ferrite. The distribution of cations in the tetrahedral (A) and octahedral [B] sites can be expressed as[16] $(Cd_xCoyFe1\text{-}x\text{-}y)\ ^{A}[Zn_{0.5}Co_{0.5\text{-}x\text{-}y}Fe_{1+x+y}]^{B}O_4^{-2}$ The good agreement between experimentally estimatedand theoretical lattice parameters confirms the assumed cation distribution of the ferrites.[17-21] The theoretical lattice parameter of ferrite samples estimated using the relation[9] were listed in table 1.

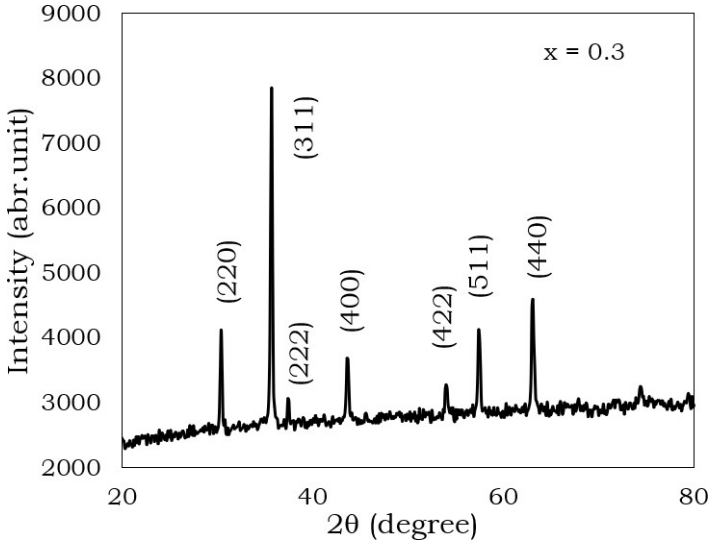

Fig. 1: Typical XRD Pattern of $Zn_{0.5}Co_{0.5\text{-}x}Cd_xFe_2O_4$ (x=0.3)

The increase ofionic radius 'rA' of tetrahedral site with Cd ion content was due to the larger ionic radius of Cd ions. But the values of oxygen positional parameter are almost the same in the ferrite systems. The mean ionic radius of the tetrahedral site 'rA' found to be increase with Cd ion content whereas mean ionic radius of the octahedral site 'rB' decreases with cadmium content. The band positions of IR spectrum are listed in table 1. The force constant for tetrahedral 'k_t' and octahedral 'k_o' sites, longitudinal 'V_l' and transverse 'V_s' elastic wavevelocities, elastic moduli for ferrite samples were estimated using the relations.[16] The shift of band position υ_1 towards lower wavelength side was due to the substituted Cd^{2+} ion, preferably it occupies the tetrahedral (A) site.[10] The octahedral [B] site was occupied by Zn^{2+}ions, where Fe^{3+}, Co^{2+} ions occupy both tetrahedral and octahedral sites.

Table 1: Structural and elastic parameters of ferrites system $Zn_{0.5}Co_{0.5\text{-}x}Cd_xFe_2O_4$ (x= 0.0, 0.3, 0.5)

Parameters	x = 0.0	x = 0.3	x = 0.5
a (Å)	9.331	9.421	9.218
ρ x 10^3 (kg/m^3)	5.215	5.344	5.569
d x 10^3 (kg/m^3)	4.021	3.875	3.932
rA(Å)	0.681	0.764	0.792
rB(Å)	0.678	0.647	0.678
L_A (Å)	3.784	3.751	3.676
L_B (Å)	2.751	2.947	3.002
RA(Å)	1.215	1.565	1.926
RB(Å)	1.872	2.021	2.020
ath(Å)	9.125	8.521	8.577

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u	0.481	0.401	0.393
υ_1 x 102 (m^{-1})	591.2	601.0	581.0
υ_2 x 102 (m^{-1})	3.571	0344	357
k_t (N/m)	1.545	1.854	2.357
k_o x 10^2 (N/m)	0.922	0.957	0.877
V_l (m/s)	5131	5501	5592
V_s (m/s)	3121	3210	3228
G x10^9 kg $m^{-1}s^{-2}$	50.14	52.54	58.51
B x10^9 kg $m^{-1}s^{-2}$	1.545	169	0185
E x10^9 kg $m^{-1}s^{-2}$	132.5	145.5	155.21
σ	0.354	0.451	0.384

The increase in rigidity modulus 'G', bulk modulus 'B' and young's modulus'E' with increase of the cadmium content, may be due to the strengthening of inter atomic bonding between various atoms continuously. The decreases of octahedral force constant with increase of the Cd ion content, was due to the substitution of Cd ion content, which decreases the amount of Co^{2+} and increases the amount of Fe ionsin the octahedral [B] sites.[9,11]. The values of poison's ratio are found to be 0.35 for all the ferrites.The present estimated values of poison's ratios are lying in the range of -1 to 0.5, which reveals the theory of isotropic elasticity.[18,19]

IV. CONCLUSION

Comparing the observed and predicted lattice parameters allowed researchers to confirm the estimated cation distribution of ferrites. The amount of cadmium has an impact on the structural parameters determined through X-ray diffraction. The cubic spinel structure of the ferrite phase was formed, as seen by the X-ray diffraction pattern. It is discovered that cadmium concentration causes an increase in the lattice constant and X-ray density. The present results' estimated elastic parameters and those from preceding papers agree rather well. The interatomic bonding between distinct atoms, which is being continually strengthened in the future, is used to explain how the elastic parameters are observed to rise with an increase in cadmium content.

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