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Study of Gamma Irradiation Effect on the Structure and Cation Distribution of Co-Zn Spinal Ferrite

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Abstract: *Among the several spinel ferrites, cobalt ferrite is a promising material for the production of permanent magnet for recording media, magnetic fuse and catalyst. Because of this, polycrystalline ferrites have been extensively studied.In the present work, we report our results on the structural properties of Co-Zn spinal ferrite prepared by ceramic technique before and after radiation gamma rays..*

Keywords: ferrite, gamma radiation, intensity ratio, x –ray diffraction

I. INTRODUCTION

The polycrystalline ferrites which have high electrical resistivity and low eddy current losses are used as high-frequency transformers, memory cores, recording heads, and a variety of devices. The physical and electrical properties depend on the preparation technique and the type of substitution. The electron exchange interaction Fe^{2+}- Fe^{3+}resultsin a local displacement of
electron during the sintering of ferrite [1].
In certain materials, a permanent change may be produced by radiation damage to the crystal [2]. In these materials, the change is a function of the total dose absorbed in the material. Gamma radiation effect techniques are used to cause radiation damage in the material. During last two decades the swift heavy ion irradiation in magnetic oxide and ferrite has been of a great interest to understand the damage structure, modification and their properties [3-5]. The effect of gamma radiation on the physical properties of spinel ferrite has been the subject of interest for scientist [5, 6].
Effect of laser radiation on the properties of Co –Zn ferrite is reported [7]. Similarly effect of gamma radiation on structural properties of Co-Zn spinal ferrite has been reported. To our knowledge no systematic work on the effect of gamma radiation on the structural, electrical and magnetic properties of Co-Zn spinal ferrite has been reported.

Experimental Procedure

Polycrystalline samples of spinel ferrite having the generic formula $Co_{1-x}Zn_xFe_2O_4$ with x = (0.0, 0.2, 0.4, 0.6, 0.8, 1.0) were prepared using the standard ceramic technique. The pure oxides (CoO, ZnO, and Fe_2O_3) of 99.9% purity supplied by MERCK were used. The powders were mixed in stoichiometric proportion and ground in an agate mortar pestle to obtain a very fine powder. The powder was then sintered at 900^0C for 12 hrs. The sintered powder is again ground and palletized. These pellets are finely sintered to 1100^0C for 24 hrs and then cooled to room temperature for 24 hrs. Finally, the samples were polished to obtain disc with two uniform parallel surfaces. The powder X-ray diffractionwere obtained by using Phillips X-ray diffractometer model 3710 in the 2θ range of 20^0 to 80^0 at room temperature.

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II. RESULTS AND DISCUSSION

X-Ray Characterization

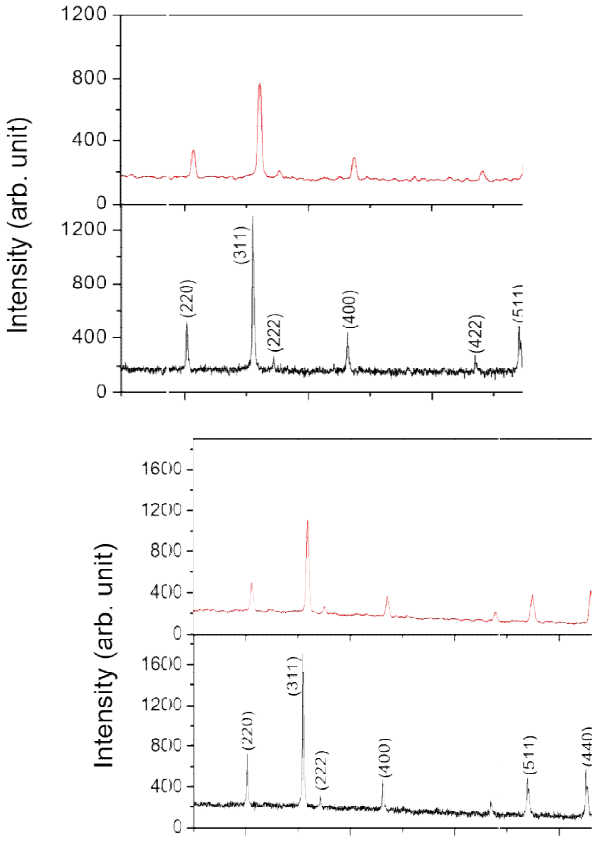

Fig 1

X-ray diffraction pattern of gamma radiated and unirradiated $Co_{1-x}Zn_xFe_2O_4$ are illustrated in Fig.1The inter planer spacing with their corresponding reflection and relative intensity where identified. Table 1 shows the inter planer spacing for various reflections according to the x-ray diffraction pattern.

It is observed from x-ray diffraction patterns that the intensity of reflected lines significantly changes after irradiation. The Bragg's peaks of the x-ray diffraction pattern are also slightly shifted after radiation effect. Similar results where observed in case of Ni, Zn and Co spinal ferrite [8].

Miller Indices (hkl) and inter planer spacing (d) before and after irradiation of$Co_{1-x}Zn_xFe_2O_4$

Table 1

Plan	Inter Planer spacing (Å)					
	Before			After		
hkl	**0**	**0.2**	**0.4**	**0**	**0.2**	**0.4**
(111)	3.076	3.017	2.963	3.076	3.017	2.963
(220)	2.538	2.562	2.527	2.538	2.562	2.527
(311)	2.601	2.425	2.419	2.601	2.425	2.419
(222)	2.095	2.115	2.095	2.095	2.115	2.095
(400)	2.074	2.014	1.872	2.074	2.014	1.872

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(422)	1.718	1.703	1.711	1.718	1.703	1.711
(511)	1.625	1.418	1.324	1.625	1.418	1.324
(440)	1.491	1.235	1.488	1.491	1.235	1.488

Cation Distribution:

The cation distribution of the given sample should be known in order to understand its structural and magnetic properties. Various methods viz. X- ay diffraction [9], neutron diffraction [10], Mossbauer [11] and magnetization [12] are available to determine the cation distribution in a spinel ferrite. The present work uses the X-ray diffraction method to determine cation distribution in $Co_{1-x}Zn_xFe_2O_4$ spinel system. In this method, X-ray intensity ratios were calculated for various planes using Berger's equation [13]. Here temperature factor and absorption factors are not considered in our calculations because they do not have much effect at room temperature [14].The values of p and $L_p$are taken from the literature [15] whereas the structural factor F for various planes has been calculated using a computer program.The calculations of intensity ratio were made for various possible distributions of cations at the tetrahedral (A) site and at the octahedral [B] site.

Table:2 Cation distribution and intensity ratios before and after irradiation

x		A-site	*B-site*	I(220)/I(400)		I(422)/I(220)	
				Obs.	Cal.	Obs.	Cal.
0.0	Before	($Fe_{1.0}$)	[Co1.0Fe1.0]	2.145	2.056	1.759	1.719
	After	(Fe0.92Co0.08)	[Co0.92Fe1.08]	2.573	2.467	2.11	2.063
0.2	Before	(Fe0.800Zn0.200)	[Co0.800Fe1.200]	3.394	2.415	1.639	1.074
		(Fe0.799Zn0.200Co0.001)	[Co0.799Fe1.201]		2.701		1.451
		(Fe0.795Zn0.200Co0.005)	[Co0.795Fe1.205]		2.98		1.576
	After	(Fe0.800Zn0.200)	[Co0.800Fe1.200]	3.266	2.657	1.723	1.182
		(Fe0.795Zn0.200Co0.005)	[Co0.795Fe1.205]		2.971		1.596
		(Fe0.719Zn0.200Co0.081)	[Co0.719Fe1.281]		3.277		1.734

Diffusion:

The diffusion information may be helpful in the analysis of structural defects in the oxygen sub-lattice. The ionic crystal always attains thermodynamic equilibrium by the process of diffusion. If atom 'A' jumps to the surface it leaves a vacancy behind in its original lattice site. Atom 'B' then may jump into the vacancy and this process continues so on. And in this way vacancies may be distributed throughout the crystal lattice. The motion of the vacancy as it diffuses

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through the crystal is a random walk process in which each new jump is uncorrelated in the direction with the previous one [7]. The diffusion study of oxygen atoms in ferrite systems was performed in the literature [8]. The present investigation was carried out is an attempt to throw light on effects of ionizing radiation on the physical properties of ferrite system. The diffusion coefficient of oxygen vacancies for $Ni_{1-x}Zn_xFe_2O_4$ before and after irradiation is shown in Fig.2 as a function of temperature.

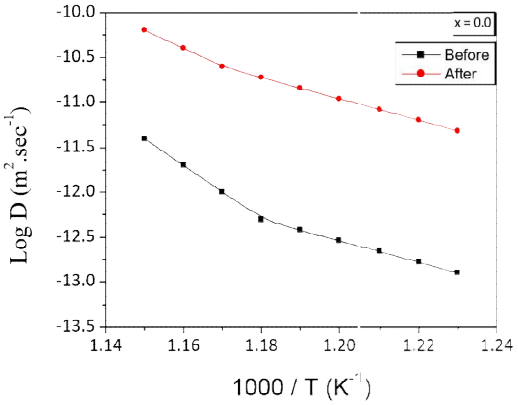

Fig. 2 : Variation of log D with 1000/T of $Ni_{1-x}Zn_xFe_2O_4$ for x = 0.0 and 0.2

It is clear that diffusion coefficient increases with increasing temperature. The diffusion of oxygen ions occurs when defects or structural vacancies are present in the lattice. In the given samples Zn^{2+} ions occupy tetrahedral sites and cancel substituted Ni^{2+} ions at octahedral sites which leads to migration of ferric ions from the (A) sites to [B] sites. Fig.1 (a, b) shows the variation of diffusion coefficient of oxygen vacancies, before and after radiation. The substitution of Zn^{2+} ions instead of Fe^{3+} ions at the tetrahedral site creates lattice vacancies, since the valency of Zn^{2+}ions is less than that of Fe^{3+} ions. The increase of temperature increases the mobility of vacancies which make more oxygen vacancies to be diffused.

Result and Discussion

The distribution of cations over tetrahedral (A) site and octahedral [B] site at which the calculated intensity ratio and observed intensity ratio are agreed closed to each other. It is clear from both the tables that there is a change in the samples before and after radiation. A comparative intensity ratio data for samples before and after irradiation is studied. The change in cation distribution data may be due to the formation of Fe2+ ions at octahedral sites.

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