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Effect of Gamma Radiation on Magnetic Properties of Magnesium Zinc Ferrite

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Abstract:
The Magnesium - Zinc Ferrite with a composition of $Mg_{(1-x)}Zn_xFe_2O_4(X = 0.2, 0.4, 0.6, and\ 0.8)$. *Ferrite powders have been successfully prepared by solid state reaction. The structural, morphological and composition studies were done by using by X-ray diffraction, high resolution scanning electron microscopy (SEM) and energy dispersive spectroscopy (EDS). The prepared samples are irradiated to high energy gamma radiation of 60Co source of energy 6.972 k Gy per hour (dose: 300 k Gy and 500 k Gy). The XRD spectra are obtained for the irradiated samples and compared with that of the pristine samples to study the changes in the structure. The increase in crystallite size with of radiation dose is observed. The Hysteresis curves were measured using vibrating sample magneto meter (VSM) for both irradiated and un irradiated samples, the results showed a considerable change in saturation magnetization with radiation dose. This may be due to ion induced disorder, cat ion distribution.*

Keywords: *gamma radiation, Mg Zn ferrite, magnetic materials, magnetic properties*

1. Introduction

Ferrites are the interesting materials for the researchers in the recent years due to the vast applications. The ferrites are basically ferromagnetic dielectric materials, which shows both magnetic and electrical properties, such as high permeability and saturation magnetization, high electrical resistivity and low power losses. These materials have gained much importance in the field of commercial important in different fields such as, transformer cores, storage devices, noise filters, recording heads, microelectronic devices, efficient hyperthermia for cancer therapy and on [i]. Magnesium Zinc ferrites are grouped under spinel ferrites, which have the general formula $A_{(1-x)}B_xFe_2O_4$ (A= tetrahedral site and B= Octahedral site which are may be filled with Mn, Co, Ni, Zn, Mg, Fe, etc.). It was observed that the addition of zinc ions also affects the lattice parameter and it would be expected to change the Curie temperature of the material [iii]. The replacement of divalent ions in pure ferrite leads to the modification of the structural, electrical and magnetic properties [iv].

The interaction of high energetic radiation especiallyγ radiation with matter produces temporary or permanent changes. creates structural defects, in turn produces changes in electrical and magnetic properties[v]. Gamma radiations can produce defects of various types such as point defect, cluster, and ionization of atoms. The effect of gamma radiation on microstructure, diffusion coefficient of oxygen ions dielectric properties, thermoelectric power and thermal conductivity of Co Zn ferrite was reported [v,vii,viii]. The radiation induced change in these materials depends on absorbed energy by the material. Hence it has gained importance in the recent years due to large inventions in the field of electronic and technological industries, nuclear facilities, accelerators, space crafts, space vehicles and satellites. Gamma radiations can produce defects of various types such as point defect, cluster, and ionization of atoms. The effect of gamma radiation on several ferrites are reported, [vii-x]. The absorption of large amount of gamma radiation may alter the structural properties.

In the present study we report the synthesis, characterization and effect of gamma irradiation on Mg-Zn ferrite.

2. Experimental

In the present work, we use the conventional ceramic technique to synthesize the Mg-Zn ferrites powder. The Mg-Zn ferrites having general formula $Mg_{(1-x)}Zn_xFe_2O_4$ (where$x = 0.2, 0.4, 0.6, 0.8$). The AR grade Magnesium oxide, Zinc oxide, and Ferric oxide were weighed carefully using a single pan microbalance (LC: 0.1mg) to have proper stoichiometric ratio required in the final product.

The composition was grounded into a very fine powder using an agate mortar, and then pre-sintered at 800^oC for 8 hours. The compositions were grounded again and pressed in the form of pellets, then sintered at 1200^oC for 12 hours and slowly cooled to room temperature

The spinel phase and crystal structure of prepared sample was confirmed by X-ray diffraction using $CuK\alpha$ radiation of wavelength $1.5405\ A^o$ from the X-ray diffractometer over the 2θ range of $10^o - 60^o$with a scanning rate of 2 degrees per minute.

The samples were irradiated with the energetic gamma radiation with energy 6.972 kGy/h. The irradiation source is 60Co gamma cell, located at Centre for Application of Radioisotopes and Radiation Technology (CARRT), Mangalore University, India.

The average crystallite size of the prepared ferrite samples was determined from the full width at half maximum (FWHM) of most intense peak (311) using Debye-Scherrer equation.$D = k\lambda/\beta\cos\theta$

Where, k is Scherrer factor (0.9), λ is the wavelength of X-ray, and is $1.5046\ A^o$, β is the angular line width at half maximum intensity and θ is the Bragg angle of actual peak.

Micro structural analysis of the prepared samples was carried out by scanning Electron microscopy (SEM) and elemental compositional analysis of all samples was done by Energy Dispersive Spectroscopy (EDS).

The variation of Magnetization with magnetizing field at room temperature was measured in the range of 0 to10 K Oe using vibrating Magnetometer (VSM)

3. Results and Discussion

3.1. XRD Measurement

The room temperature X-ray diffraction patterns of Mg-Zn ferrite, before and after gamma irradiation are shown in Figure. 1. X-ray diffraction pattern shows all the allowed reflection lines corresponding to cubic spinel phase and also showed slight shift in the peak position, decrease in relative intensity and increasing of crystallite size. The similar results were observed in earlier reports [viii, x, xi]. The increase in particle size is due to formation of ferrous ions (Fe^{2+}) which have large radius than that of ferric ions (Fe^{3+})[ix, x]. Due to gamma irradiation the distorted lattice is formed, the dependence of lattice parameter on (Zn^{2+}) becomes non linear [ix].

It is well known that the Zn^{2+} ions inhabit the tetrahedral sites (A-sites) and most of Mg^{2+} ions inhabit octahedral sites (B-sites). Starting from the basic ferrite $MgFe_2O_4$, Zn^{2+} ions are substituted to replace Mg^{2+}ions. The replacement takes place by the movement of Fe^{3+} ions from A-sites to B-sites. The radius of tetrahedral site remains same before and after irradiation. Whereas radius of octahedral site is higher than before irradiation due to formation of ferrous ions [ix]. The calculated average ferrite crystallite size is tabulated in the table 1below,

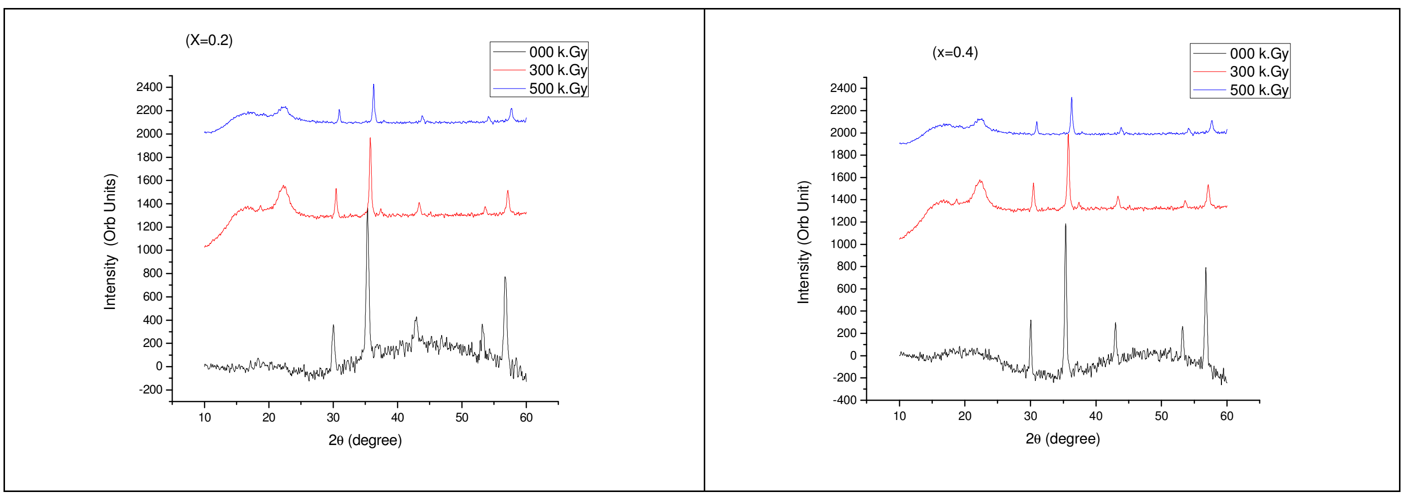


Figure 1: XRD pattern for un- irradiated and irradiated samples of Mg-Zn ferrite

Composition	Crystallite size in nm		
	Before irradiation	After irradiation	
		300 KGy	500 KGy
X=0.2	163	174	177
X=0.4	152	163	179
X=0.6	133	148	163
X=0.8	122	128	133

Table 1: Variation of crystallite size before and after irradiation

3.2. SEM Studies

The microstructure and morphology of irradiated and uni-radiated ferrite samples are studied using Scanning electron microscopy technique. (model FEIXL 40 SIRION FEG digital scanning). microscope.

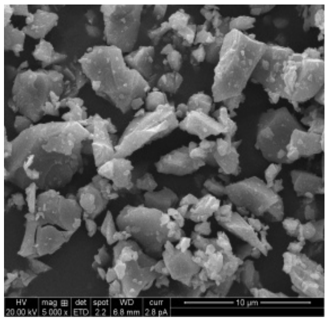
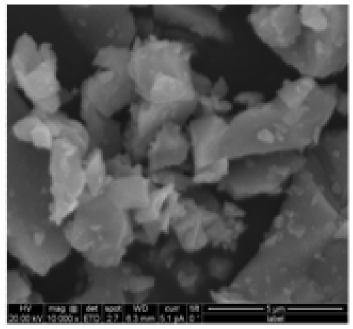
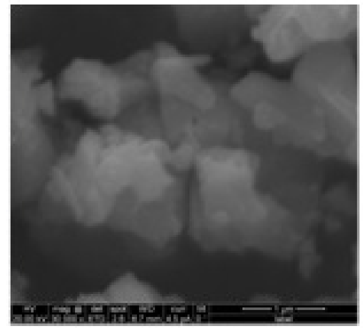
X	Un irradiated sample	300 kGy	500 kGy
0.4			

Figure 2: SEM morphology of synthesized ferrite. (Before and after irradiation)

The images show that the particles have an almost homogeneous distribution, and some of them are in agglomerated form. It is evidenced by SEM images that the particles are in nano meter range. The particles were observed as uniform grains (in different SEM images) confirming the crystalline structure of Mg-Zn ferrites which were detected by XRD studies.

3.3. Elemental Analysis by EDS

The elemental analysis of all the Mg-Zn ferrite samples with different compositions were analyzed by Energy Dispersive Spectrometer (EDS) and the elemental percentage (%) and atomic percentage (%) of different elements in the samples were shown in the Table 2.

Element	**X=0.2**		**X=0.4**		**X=0.6**		**X=0.8**	
	Wt (%)	At (%)	Wt (%)	At (%)	Wt (%)	At (%)	Wt (%)	At (%)
O	8.20	24.32	8.63	24.67	8.92	24.80	9.03	24.46
Mg	1.13	2.21	3.03	5.70	4.46	8.16	6.02	10.73
Fe	61.57	52.34	65.64	53.75	70.05	55.77	75.22	58.36
Zn	29.09	21.13	22.70	15.88	16.56	11.27	9.73	6.45

Table 2: EDS analysis of elemental percentage and atomic percentage of prepared samples

3.4. Magnetic Properties

The relation between Magnetization and Magnetizing fields (M-H curve) depends on microstructural composition and distribution of metal ions among tetrahedral (A) and octahedral (B) sites. For our sample, hysteresis curve with a normal type i.e. S shape was observed at room temperature. The Hysteresis loop for x=0.6 of before and after irradiation is shown in Figure 3. It is observed that Magnetization (M_s), remanence (M_r) were increased with dose for all samples. Similar results are reported for other ferrites. [xii,xiii,]

The observed variations can be understood on the basis of super exchange interactions among the tetrahedral [A] and octahedral [B] site ions in the spinel lattice. According to Neel's model of ferrimagnetisms [xiv], there exist three kinds of exchange interactions: (AA, BB and AB interaction) of these, AB interaction predominates over AA and BB interactions. These interactions align all the magnetic spins at A and B site in one direction and in opposite to each other. The net magnetic moment of the lattice is the difference between the magnetic moments of B and A sub lattices, $\text{i.e. } M_B - M_A$

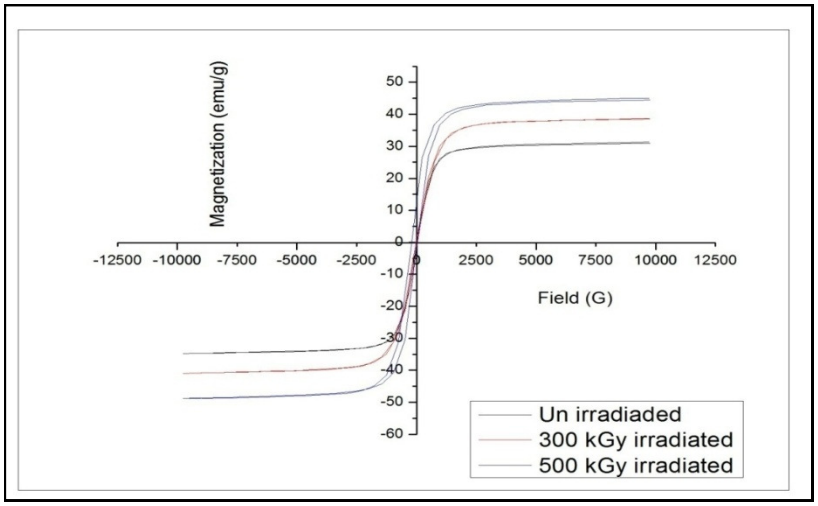


Figure 3: Hysteresis loops for before and after irradiation of x=0.6

It is observed that saturation magnetization is increased with increase in crystallite size and similar results were reports for γ irradiated ferrites [xvi,xvii]. On irradiation Fe^{3+} ion concentration at B site (Octahedral) increases than in A site (tetrahedral) which contributes strengthening the AB interaction [xiii]

The increase in M_s may be due to magnetic disordering produced by irradiation results in overall magnetization of the system. [xiii]. The increase in the ratio of Fe^{2+}/Fe^{3+} after irradiation results in increase in saturation magnetization values of irradiated samples.

4. Conclusion

The XRD pattern confirms that formation of single phase spinel structure ferrite, and due to irradiation shift in peak, decrease in intensity and increase in average crystallite size crystalize size. TheVSM measurements shows increasing in saturation magnetization These results reveal that Structural and Magnetic properties of Mg Zn ferrites are highly affected by γ-ray irradiation.

5. References

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