

Dielectric and Magnetic properties of γ -irradiated $Mg_{(1-x)}Zn_{(x)}$ Ferrite



Physics

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ABSTRACT

Magnesium zinc ferrite powder with general formula $Mg_{(1-x)}Zn_{(x)}Fe_2O_4$ ($X=0.2,0.4,0.6,&0.8$) was synthesized by usual ceramic method. Phase purity of the samples were confirmed by X-ray diffraction. The prepared samples were irradiated to high energy gamma radiation of ^{60}Co with dose rate 6.972 k Gy per hour (dose: 300 k Gy and 500 k Gy). The radiation induces modification on electrical behaviors, frequency dependent of ac conductivity, dielectric constant, loss tangent were studied. The irradiated samples showed an increase in electrical conductivity. The dielectric constant increases with radiation dose. The Hysteresis curves were measured using vibrating sample magneto meter (VSM) for both irradiated and un irradiated samples, the results showed an increase in saturation magnetization with radiation dose. This may be due to ion induced disorder, cat ion distribution.

Introduction:

Ferrites are magnetic oxides which have been comprehensively studied during last decades, due to their technologically wide importance in the field of communication and electronic devices. They are still a matter of interest because of promising materials for magnetic recording media, micro wave devices, and miniature of electro-optic modulators, transformer cores, ferrite insulators, memory core industry [1, 2, 3]. Magnesium ferrite is the most significant among the ferrites. It has a cubic structure of normal spinel-type and finds a number of applications in heterogeneous catalysis, adsorption, sensors, and in magnetic technologies [4]. The magnetic properties of a spinel ferrite are strongly dependent on the distribution of different cations among tetrahedral (A) and octahedral (B) sites in the crystal lattice [3].

Radiation interaction with material is now in focus due to wide advance in the field of electronic and nuclear industries, in space-crafts and satellites. Irradiation is a powerful tool to enhance crystallographic defects and changes in properties of ferrites. Various kinds of radiations such as fast neutron, energetic ions and γ -rays were used to study the effect of radiation on the properties of ferrites with different compositions [5-12]. The recent studies reported that the magnetic property of ferrite was improved on high energy irradiation [9]. In this present study the effect of gamma radiation on dielectric and magnetic properties of $Mg_{(1-x)} - Zn_{(x)}$ ferrite with different composition was studied.

2. Materials and Methods:

The Mg Zn ferrite samples were prepared from high purity oxides using double sintering ceramic method. The composition was ground to a very fine powder using agate mortar, and then presintred at $800^\circ C$ for 8 hours. The composition was grounded again and pressed in the form of pallet and then sintered at for 12 hours and slowly cooled to room temperature. The $1200^\circ C$ formation of spinal phase and crystal structure was confirmed by X-ray diffraction using Cu K α radiation of wavelength 1.5405 Å over the range 10 to 60 degree with a scanning rate 2θ of degree per minute.

The samples were irradiated with energetic gamma radiation with a dose rate of 6.972 k.Gy per hour. The irradiation device is ^{60}Co gamma cell at Centre for Application of Radioisotope and Radiation Technology (CARRT), Mangalore University, Mangalore, India.

For measuring the electrical conductivity, the samples were inserted between two silver electrodes where the silver paste was used as a contact material. The conductivity of the sample (σ) was calculated using the relation

$$\sigma = d / R A \quad \dots (1)$$

Where, A and d are the cross-section area and the thickness of the sample, respectively.

Parallel plate Capacitance (C_p) and dielectric parameters were measured for the pallets samples using LCR bridge meter model PSM1735(N4L make). The dielectric constant ϵ' and dielectric loss ϵ'' were calculated using the formulas.

$$\epsilon' = (C_p d) / (\epsilon_0 A) \quad \dots (2)$$

$$\epsilon'' = \tan \delta \epsilon' \quad \dots (3)$$

Where, ωC_p is the capacitance of the parallel plate, d is the thickness of the pallets, A is the cross-sectional area of the flat surfaces of the sample and ϵ_0 is the permeability of free space ($\epsilon_0 = 8.854 \times 10^{-12}$ F/m) The ac conductivity and dielectric measurement of all ferrite samples were measured with standard two probe technique. The ac conductivity was calculated using the formula.

$$\sigma_{ac} = \epsilon' \epsilon_0 \omega \tan \delta \quad \dots (4)$$

Where, ω is the angular frequency. The parameters, σ_{ac} , ϵ' and $\tan \delta$ and were measured as a function of frequency within the range 1 KHz - 1 ω MHz at room temperature.

The variation of Magnetization with magnetizing field at room temperature was measured in the range of 0 to 10 K Oe using vibrating Magnetometer (VSM).

Result and Discussion

3.1 Frequency dependence ac Conductivity.

The variation of the ac conductivity as a function of frequency at room temperature, before and after γ - irradiation for the sample with, as an example, is shown in Figure. 1. It was observed that, increases with increasing frequency and its value for irradiated samples are higher than that of unirradiated ones

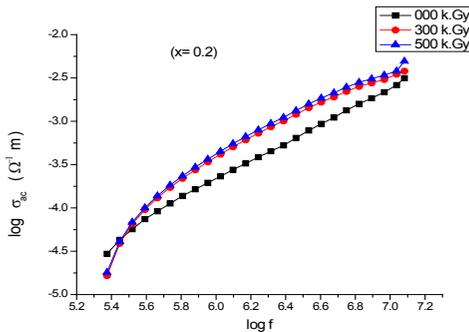


Figure:1 variation of ac conductivity with frequency for before and after gamma irradiation.

The graph shows that for all the compositions the AC conductivity of un- irradiated and irradiated samples increases gradually with the increase of frequency, similar results were observed in other types of ferrite [2,23]. The increase in conductivity is due to increase in hopping of charge carriers $Fe^{2+} - Fe^{3+}$ at the adjacent octahedral sites [19]. According to Maxwell-Wagner two-layer model [21], the hopping frequency of electron between Fe^{2+} and Fe^{3+} ions at the meta interface is less at lower frequencies. As the frequency of applied field is increased, the conduction mechanism becomes more active by promoting the hopping of charge carriers between Fe^{2+} and Fe^{3+} ions, thereby increasing the hopping frequency. It has been reported that ac conductivity as a function of frequency is large in ferromagnetics [20].

3.2 Frequency dependence Dielectric constant.

Figure 2 shows the variation of ϵ' as a function of frequency at room temperature for the sample $x = 0.4$, as an example, in $Mg_{(1-x)}Zn_xFe_2O_4$ ferrite system before and after γ -irradiation. It could be seen that, ϵ' initially decreases rapidly with increase in frequency then it gradually decreases with frequency.

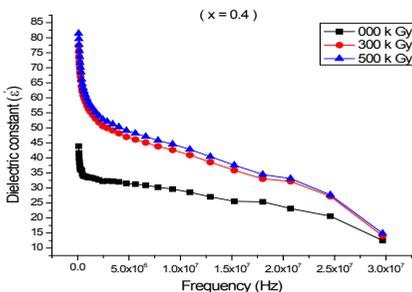


Figure: 2. Variation of Dielectric constant with frequency for before and after gamma irradiation.

The dielectric properties of ferrite materials depends on several aspects, like composition, method of preparation, grain size etc. The study of dielectric constant is an important parameter, in a materials phase transition occurring. The results observed are similar to previously reported on ferrites [22,9]. The variation of ϵ' is explained on the basis of space polarization.

The dielectric constant highly depends on exchange of electron between Fe^{2+} and Fe^{3+} ions. On irradiation the formation of Fe^{2+} at A site (octahedral) and increases the ratio of (Fe^{2+}/Fe^{3+}) ions [23,37] This leads to local displacement of charges which is responsible for polarization. The increase in dielectric constant may be due to two reasons; first one is the increase in hopping rate of charges $Fe^{3+} \rightarrow Fe^{2+}$ and $Mg^{3+} \rightarrow Mg^{2+}$ Jumping electron along the direction applied field leads to raise in dielectric constant.[38]. And another one is liberation of electrons which are trapped at vacancies at different depths by the incident radiation.[39]

3.3 Frequency dependence Dielectric loss.

The frequency dependence of the dielectric loss (imaginary part of the dielectric constant) ϵ'' of the synthesized samples were studied at room temperature. The variation is shown in Figure. 3 with ϵ'' is shown as an example. It is observed that, ϵ'' increases with increase in frequency initially and decreases. The value of ϵ'' increased after γ -irradiation for all the investigated samples.

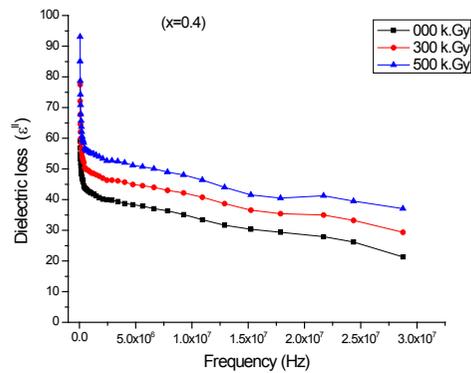


Figure: 3. Variation of Dielectric loss with frequency for $Mg_{(1-x)}Zn_xFe_2O_4$ (X=0.4) before and after gamma irradiation

The variation of dielectric loss with frequency is similar to that of dielectric constant [23, 31]. The decrease in dielectric value makes these ferrites to be used in the high frequency application [31, 33]. Dielectric loss depends mainly on three factors: eddy current, electric dipole loss, and hysteresis loss [23, 32]. The eddy current is proportional to conductivity of ferrite. The conductivity of the ferrite is proportional to frequency. In turn it increases the eddy current loss. This results in decrease of ϵ'' as frequency increases specifically at high frequencies, as the dipole orientation cannot follow the applied field. The increase in ϵ'' after irradiation, results increase in the conductivity of the sample. This result holds good with the following relation [23].

$$\sigma_{ac} = \epsilon'' \epsilon_0 \omega \dots (5)$$

3.4 Magnetic Properties

The fundamental property of any magnetic material is the relation between Magnetization Vs Magnetizing fields (M-H

curve) and it is 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 4. It is observed that Magnetization (Ms) remanence (Mr) were increased with dose for all samples. Similar results are reported for other ferrites.[27,28,29]

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 [25], there exist three kinds of exchange interactions: (AA interaction), (BB interaction) 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,

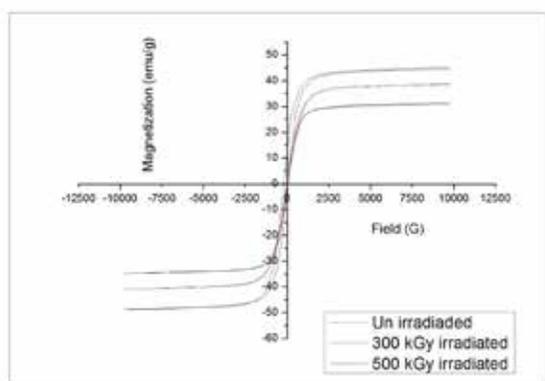


Figure :4, Hysteresis loops for before and after irradiation of $x=0.6$

The average crystallite was increased with irradiation and presented in our previous paper [34]. It is observed that saturation magnetization is increased with increase in crystallite size and similar results were reports for γ irradiated ferrites [35, 36]. On irradiation Fe^{3+} ion concentration at B site (Octahedral) increases than in A site (tetrahedral) which contributes strengthening the AB interaction [28]

The increase in may be due to magnetic disordering produced by irradiation results in overall magnetization of the system.[28]. The increase in the ratio of (Fe^{2+}/Fe^{3+}) after irradiation results in increase in saturation magnetization values of irradiated samples.

Conclusion

The Dielectric studies shows increase in ac conductivity, dielectric loss and dielectric constant due to increase in (Fe^{2+}/Fe^{3+}) ion ratio. The defect in the crystal lattice and re – distribution of cat-ion between A and B sites caused increasing in saturation observed by VSM measurements. These results reveal that dielectric and Magnetic properties of Mg Zn ferrites are highly affected by γ -ray irradiation.

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