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Enrichment of Magnetic Alignment Stimulated by γ-radiation in Core-shell type Nanoparticle Mn-Zn Ferrite

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Abstract. Core shell type nanoparticle $Mn_xZn_{1-x}Fe_2O_4$ systems with x=0.55, 0.65 & 0.75 were prepared using auto-combustion method. The systems were characterized using tools like XRD and IR for structure confirmation. Magnetic parameter measurements like Saturation magnetization and coercivity were obtained from hysteresis loop which exhibited a symmetry shift due to core shell nature of the nanoparticles. Nanoparticles of particle size between 21.2nm to 25.7nm were found to show 20 percent shrinkage after being radiated by the γ-radiation. This is due to variation in the cation distribution which also affects the cell volume of the cubic cell. Lattice constant reduction observed is reflected in the magnetic properties of the samples. A considerable hike in the saturation magnetization of the samples was observed due to enrichment of magnetic alignment in the magnetic core of the particles. Samples under investigation were irradiated with gamma radiation from Co^{60} source for different time intervals.

Keywords: Nanoparticles, X-ray spectroscopy, auto-combustion, saturation magnetization, magnetic alignment.
PACS: 81.05.Bc; 81.20.Fw; 87.64.Kd; 85.70.Ge.

INTRODUCTION

Permanent transformations are known to be produced in materials when exposed to high intensity γ- radiation. These transformations depend on the total amount of radiation dose absorbed by the material [1]. These types of materials could have potential applications in new emerging technologies and in medical science. Core-shell type Mn-Zn ferrite nanoparticles are favorable candidates for applications like targeted drug delivery, hyperthermia, biomedical sensors etc. Proposed work is focused on the study of lasting transformations produced in the crystal structure and magnetic structure of gamma irradiated Mn -Zn core shell type nanoparticles.

EXPERIMENTAL

Core- shell type $Mn_xZn_{1-x}Fe_2O_4$ nanoparticles with (x= 0.55,0.65,0.75) were obtained using auto-combustion method using metal nitrates and acetates in stoichiometric proportion as raw material, along with Nitrilotriacetate as complexing agent and Glycine as fuel. The residues obtained after auto-combustion of the mixture were used for characterization and to carry out proposed study.

X-Ray Diffraction patterns of the samples were obtained on Righaku X-Ray diffractometer (Cu kα radiation, λ=1.5418 A^0). Infrared spectra of the samples were obtained using Shimadzu FTIR 8900 assembly. Magnetic properties of the samples were measured using standard Pulse Field Hysteresis Loop Tracer. The $Mn_xZn_{1-x}Fe_2O_4$ ferrite nanoparticles were then exposed to γ-radiation for different time intervals, (doses ranging from 2000 R and 10000 R) for which ^{60}Co was used as γ-radiation source.

RESULTS AND DISCUSSION

XRD

X–ray diffraction patterns of as prepared and gamma radiated samples are presented in figure 1.

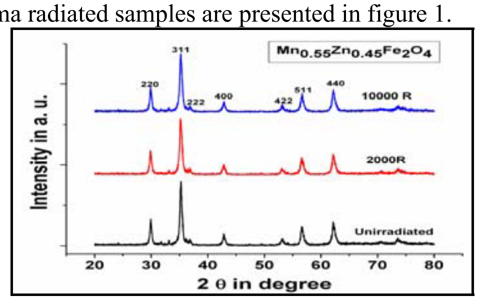

FIGURE 1: XRD pattern of as prepared and γ-radiated $Mn_{0.55}Zn_{0.45}Fe_2O_4$

All samples are found to exhibit monophasic cubic spinel behavior which was confirmed by

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comparing the XRD patterns and the corresponding data with ICDD card 10-0319

Lattice Parameter & Particle Size

Lattice constant and particle size (figure 2) evaluated using XRD data was found to show a decrease with increasing dose of γ-radiation.

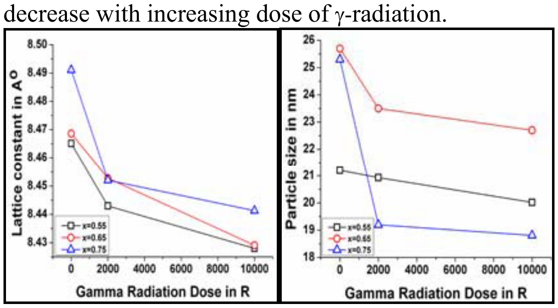


FIGURE 2: a) Variation of Lattice constant, b) Variation of Particle size of $Mn_xZn_{1-x}Fe_2O_4$ with γ- radiation dose.

This decrease in lattice constant and particle size can be attributed to migration of cations from an environment with relatively weak binding potentials to more stable positions. This possibility seems to prevail in case of Fe^{+2} and Fe^{+3} ions [3,4]

Infra Red Spectroscopy (IR)

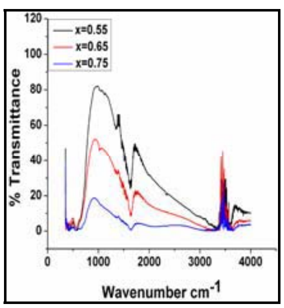


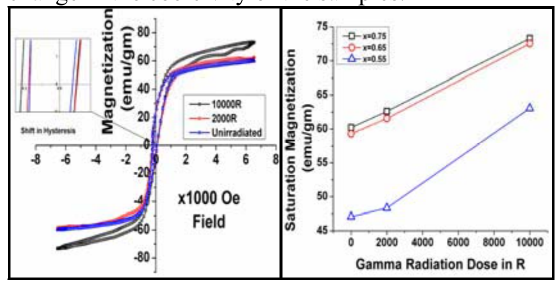
FIGURE 3: IR pattern of un-irradiated $Mn_xZn_{1-x}Fe_2O_4$.

Figure 3 shows the IR spectra of as prepared samples. IR absorption peaks exhibit Me_T─Me_O stretching vibration at 350-330 cm^{-1} which merges with the Me_O─O stretching vibration at 450-485 cm^{-1} resulting in a wide band. The band at 600-500cm^{-1} is due to Me_T─O─Me_O stretching vibration [2]

Where Me_T is a metal ion at tetrahedral site and Me_O is a metal ion at octahedral site.

Magnetic Properties

The hysteresis loops obtained for sample $Mn_{0.75}Zn_{0.25}Fe_2O_4$ are presented in figure 4(a). The insert in the figure (4a) shows a typical asymmetry of the hysteresis loops about the origin which supports the core-shell nature of nanoparticles [5]. The effect of radiation has resulted in enhancement of saturation magnetization of all the samples without destroying the core-shell nature of the nanoparticles as shown in figure 4(b). The enrichment of magnetic alignment is attributed to transfer of Fe^{+3} ions from octahedral site to tetrahedral site which is compensated by transfer of Mn^{+2} and Zn^{+2} to octahedral site from tetrahedral site [3]. This exchange also brings about a reasonable change in the coercivity of the samples.



(a) (b)

FIGURE 4: a) Hysterisis loops $Mn_{0.75}Zn_{0.25}Fe_2O_4$ b) Variation of saturation magnetization of $Mn_xZn_{1-x}Fe_2O_4$ with gamma radiation dose.

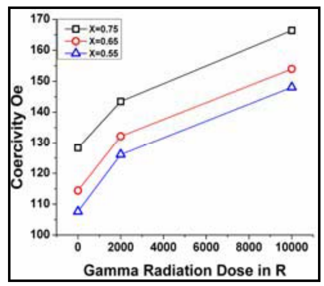


Figure (5) shows change of coercivity of the nanoparticles. Increase in coercive field with increasing γ-radiation dose may be due to increase in core diameter of the core-shell nanoparticles [5,6].

FIGURE 5: Coercivity variation of $Mn_xZn_{1-x}Fe_2O_4$ with γ-radiation dose

CONCLUSION

The core-shell type nanoparticles produced by auto-combustion method were found to show diminution in lattice constant and particle size when radiated with γ-radiation. Enrichment in magnetic alignment along with increase in the size of core of the core-shell particles are other interesting outcomes of radiating the samples with γ-radiation.

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