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STRUCTURAL AND MAGNETIC PROPERTIES OF $MN_{0.8}CO_{0.2}FE_2O_4$ FERRITE NANOPARTICLES

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Abstract

Cobalt doped Manganese ($Mn_{0.8}Co_{0.2}Fe_2O_4$) spinel ferrite nanoparticles have been synthesized by green sol-gel auto combustion technique with lemon juice. The prepared sample was sintered at 550˚C for 8 hrs. The structure and morphology of prepared sample were investigated by X-ray diffraction (XRD) and Field Emission Gun Scanning electron microscopy (FEG-SEM) technique. The X-ray diffraction pattern confirm the single phase formation and the crystallite size of synthesized $Mn_{0.8}Co_{0.2}Fe_2O_4$ ferrite nanoparticles were found to be within the range of 8 -12nm.The magnetic properties were studies by using vibrating sample magnetometer (VSM). The saturation magnetization, coercivity, remanence, Bohr magneton and anisotropy constant (K) were calculated from the M-H hysteresis loop.

Keywords: *Nanoparticles, Saturation magnetization, anisotropy constant and Bohr magneton.*

INTRODUCTION

Nano structured spinel ferrite have been largely counted during the last decades, many scientists have devoted their effort for studying ferrite nano materials especially for many technological and industrial applications like sensors, data storage devices, medical applications, catalysis for water splitting and microwave absorption etc..This is because ferrites exhibits excellent chemical stability, moderate saturation magnetization and mechanical hardness [1-4]. Thus much attention has been paid to synthesize and characterization of nanoparticles of spinel ferrites. It is necessary to be fabricate new materials of more predictable properties than what are currently available. In addition, the doping of metallic ion like Co in manganese ferrite may increase the nano magnetism phenomenon. Spinel ferrite in the nano form with large surface to volume ratio and super paramagnetic nature is accountable for improved Nano magnetism in spinel ferrite [5-8]. Co doped manganese ferrite, unpaid to strong ferromagnetism and high Curie temperature, is

used in electronic appliances and Mi-Co magnet since it stays magnetized even when the applied magnetic field is removed and it has superior heat resistance, temperature characteristics, and corrosion resistance also, Co doped manganese ferrite is an interesting material because of its good chemical stability and moderate saturation magnetization. [9-12]. Structure and morphology also depends on preparation method of nanomaterials. Spinel ferrites nanoparticles were synthesis by several methods, such as co-precipitation, spray pyrolysis, solid state reaction and sol-gel auto combustion methods. Among these methods sol-gel auto combustion method with lemon juice is an excellent to prepare nanoparticles with maximum purity. By using different amount of lemon juice we control the size of nanoparticles. Also this method has several advantages over the other synthesis methods due to its low processing temperature, high chemical homogeneity, thermal stability of controlling the size and morphology of particles etc. [13-17].

In this research work, we synthesize and characterised by different tools like X-ray diffraction and field emission gun electron microscopy for the investigation of structural, microstructural properties and magnetic properties of the sample were studied by vibrating sample magnetometer.

MATERIALS AND METHOD

Cobalt doped Manganese ($Mn_{0.8}Co_{0.2}Fe_2O_4$) spinel ferrite nanoparticles were synthesized using sol-gel auto combustion technique with lemon juice as a chelating agent. AR grade chemicals such cobalt nitrate ($Co(NO_3)_2.6H_2O$), manganese nitrate($Mn(NO_3)_2 . 6H_2O$) and ferric nitrate ($Fe(NO_3)_2 . 9H_2O$) were used. All nitrate were dissolved in 100ml de-ionized water separately and mixed one another.Certain amount of lemon juice is added in the mixture and stirred continuously for 2hrs. To make solution neutral, ammonium hydroxide was added and obtained solution was heated at 90^0C. After 5hours the solution becomes gel and the gel was turn into loose powder. Finally, $Mn_{0.8}Co_{0.2}Fe_2O_4$crystalline powderwas obtained after calcining the loose precursors at 550^0C for 8 hours.This powder was used for further investigations of structural properties and magnetic properties.

RESULTS AND DISCUSSION

The X-ray diffraction pattern of the $Mn_{0.8}Co_{0.2}Fe_2O_4$spinel ferrite nanoparticles is shown in Fig. 1. The XRD pattern shows the single phase cubic spinel structure the sample and there was no any impurity peaks observed in XRDpattern. The sharp and high intensity peaks indicates that the prepared nanomaterial is in high crystallite.The lattice parameter was found to be 8.360. The intensity of (311) plane is more as compared to other planes like (220),

(222), (400), (422) and (511) and is chosen for the determination of crystallite size. The average crystallite size of the sample was calculated using Scherer's formula,

$$D = \frac{k\lambda}{\beta cos\theta} \quad (1)$$

k is the grain shape factor (0.9) and λ, θ, and β are the X-ray wavelength, Bragg diffraction angle, and full-width at half-maximum of the diffraction peak respectively.

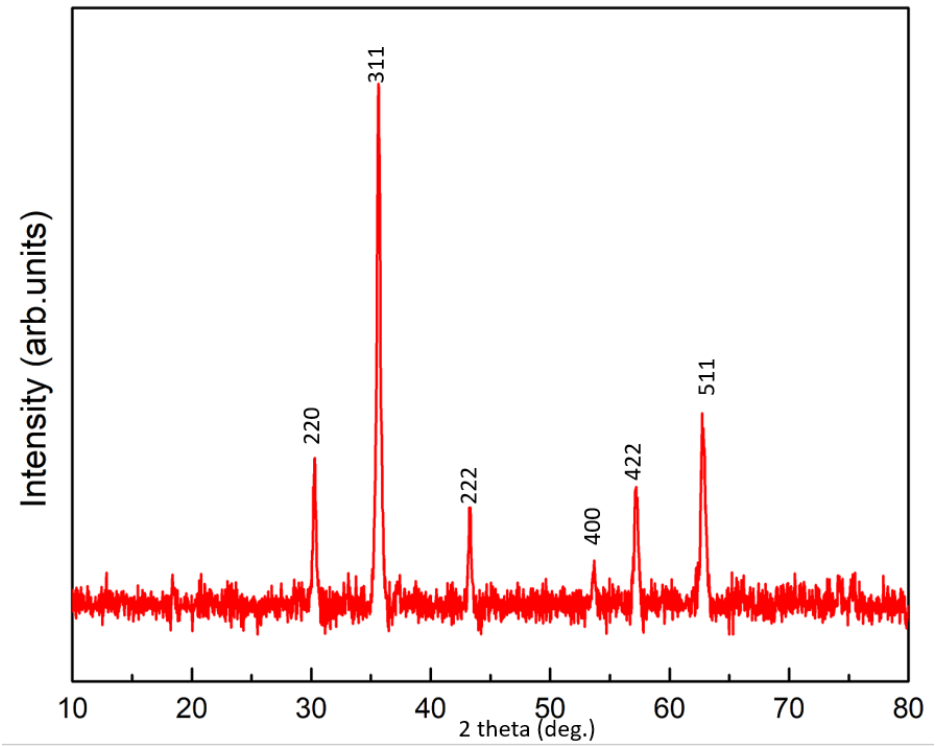

Fig. 1 XRD pattern of $Mn_{0.8}Co_{0.2}Fe_2O_4$

The X-ray density was calculated using the following equation

$$D_x = \frac{8\,M}{N_A a^3} \quad (2)$$

The lattice constant, X-ray density, and average particle size were calculated using XRD data and values are given in table 1.

Table1. The Lattice constant, X-ray density and Average particle size

Sample	Lattice constant (a) (Å)	X- ray density (gcm^{-3})	Average paricle size (nm)
$Mn_{0.8}Co_{0.2}Fe_2O_4$	8.360	5.262	12

Fig.2 shows morphological pattern of the prepared Sm doped cobalt ferrite nanoparticles taken by Field emission gun scanning electron microscope (FEG-SEM). Evidently, from FEG-SEM image it was seen that the morphology of the particles were almost cubical in shape, but agglomerated to some extent due to the interaction between magnetic nanoparticles. The formation of nano size crystallites was confirmed through FEG-SEM image.

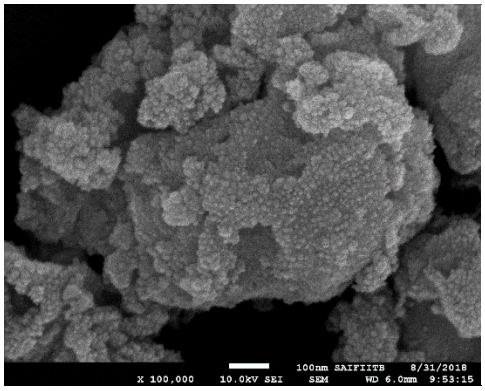

Fig. 2 FEG- SEM image of $Mn_{0.8}Co_{0.2}Fe_2O_4$spinel ferrite nanoparticles

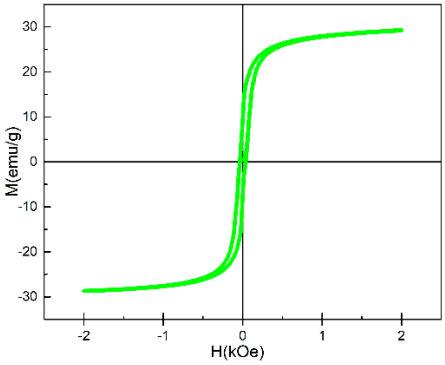

Fig. 3Magnetic hysteresis loop of $Mn_{0.8}Co_{0.2}Fe_2O_4$spinel ferrite nanoparticles

The magnetic properties of the $Mn_{0.8}Co_{0.2}Fe_2O_4$ spinelferrite nanoparticles were analysed at room temperature by using a vibrating sample magnetometer (VSM) with an applied field -2 kOe ≤ H ≤ 2 kOe [17- 18]. Fig. 3 shows the magnetization (M) versus the applied magnetic field (H) for $Mn_{0.8}Co_{0.2}Fe_2O_4$ spinel spinel ferrite nanoparticles.The value of saturation magnetization (Ms), remnant magnetization (Mr) and coercivity (Hc) for $Mn_{0.8}Co_{0.2}Fe_2O_4$ spinel ferrite nanoparticles were calculated from Fig. 3 and listed in table 2. The following equations were used for calculating the anisotropy constant and Bohr's magneton,

$$\text{Anisotropy constant (K)} = \frac{H_C \ X \ M_S}{0.96} \qquad (3)$$

Bohr magneton= $\frac{M\ X\ M_S}{5585\ X\ D_x}$ (4)

Table 2. Magnetic parameters of $Mn_{0.8}Co_{0.2}Fe_2O_4$ spinel spinel ferrite nanoparticles

Sample	M_s (emu/g)	M_r (emu/g)	H_c(kOe)	Mr/Ms	Anisotropy constant (erg/cm^3)	Bohr magneton
$Mn_{0.8}Co_{0.2}Fe_2O_4$	29.235	11.177	0.0375	0.382	1.142	0.2302

CONCLUSION

Cobalt doped Manganese ($Mn_{0.8}Co_{0.2}Fe_2O_4$) spinel ferrite nanoparticles successfully synthesized by sol-gel auto combustion technique with lemon. From X-ray diffraction, single phase nanosize crystallites was conformed and particle size of the sample was obtained by field emission gun scanning electron microscopy with the help of Ima-J software and average particle size of the sample is 12nm. The value of saturation magnetization (Ms) from M- H loop was obtained to be 29.235 emu/g and Anisotropy constant 1.142 erg/cm^3. This material is good candidate for microwave absorption in high frequency band.

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