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Sol-Gel Auto Combustion Synthesis of Gd^{3+} Doped $Ni_{0.5}Co_{0.5}Fe_2O_4$ Nanoparticles and Examinations of Magnetic Properties

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Abstract: *The nanoparticles of Gd doped $Ni_{0.5}Co_{0.5}Fe_2O_4$ for composition of $Ni_{0.5}Co_{0.5}Gd_yFe_{2-y}O_4$ (y=0.025) synthesized by sol-gel auto combustion technique using citric acid as a fuel. The structural and morphological characterizations were carried out by X-ray diffraction technique. The particle size obtained by FWHM of (311) plane using Scherrer's formula obtained to be 31 nm. Magnetic properties were investigated using Vibrating sample magnetometer (VSM) technique. The saturation magnetization values show the ferromagnetic nature. The structural and magnetic parameters are in the reported range.*

Keywords: *Ferrite, magnetic properties, nanoparticles.*

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I. Introduction

Nanocrystalline materials are of countless importance in the current years from the research and technological applications point of view as these materials exhibit unique crystallographic structure and stimulating chemical physical properties which are different than that of bulk materials [1]. In the family of spinel ferrites mixed Ni-Co ferrite with inverse spinel structure has been widely studied as they display attractive magnetic properties as well as electrical making them useful in wide range of applications [2-3]. The properties associated with Ni-Co ferrite are strongly prejudiced by method of preparation.

Sol-gel auto combustion method is a unique technique which produces nanoparticles below 40 nm. The most widely used wet chemical method for the synthesis of spinel nanoferrites is the sol-gel auto combustion method. This method has several advantages over the other synthesis methods due to its low processing temperature, high chemical homogeneity, the possibility of controlling the size and morphology of particles etc [4].

Ni-Co mixed ferrite is an interesting spinel ferrite exhibiting cubic structure depending upon various parameters like the heat treatment, cation distribution, etc. Rare earth Gadolinium (Gd^{3+}) is a magnetic ion, when substituted in Ni-Co ferrite can lead to modifications in the structural, microstructural and magnetic properties. The precise doping of Gd^{3+} cations in Ni-Co-ferrite can fabricate the ferrites that can be suitably used in microwave and magnetic recording devices [5-6].

In the present work, we report our results on structural and magnetic properties of rare earth Gadolinium (Gd^{3+}) doped to Ni-Co nanoferrite with composition $Ni_{0.5}Co_{0.5}Gd_yFe_{2-y}O_4$ (where, y=0.025) synthesized by sol-gel auto combustion technique.

II. Experimental

Nanoparticles of Gd^{3+} Doped $Ni_{0.5}Co_{0.5}Fe_2O_4$ for composition of $Ni_{0.5}Co_{0.5}Gd_yFe_{2-y}O_4$ (y=0.025) with average size 31 nm were prepared by sol gel auto combustion method using citric acid as a fuel. The analytical grade (AR) nickel nitrate ($Ni(NO_3)_2.6H_2O$), cobalt nitrate ($Co(NO_3)_2.6H_2O$), gadolinium nitrate ($Gd(NO_3)_3.9H_2O$), ferric nitrate ($Fe(NO_3)_3.9H_2O$) and citric acid ($C_6H_8O_7$) were used as raw materials (99.9% pure). The metal nitrates to fuel (citric acid) ratio was taken as 1:3. Ammonia solution was added to maintain the pH 7. The temperature required for the synthesis of nanoparticles was low that is around 110 ˚C. The as-synthesized powder is sintered at 700 ˚C for 4 hr and then used for further investigations. The X-ray diffraction technique was employed to confirm the phase purity and nano-crystalline nature of the prepared sample. The XRD patterns were recorded in the 2θ range of 200- 800C at room temperature using Cu-Kα radiation. The magnetic properties were investigated at room temperature using Vibrating sample magnetometer (VSM) technique. colons, etc.

III. Results and Discussions

Room temperature X-ray diffraction pattern of $Ni_{0.5}Co_{0.5}Gd_yFe_{2-y}O_4$ (y=0.025) nanoparticles is shown in Figure 1. X-ray diffraction pattern shows the presence of the desired phase of cubic spinel structure with no extra peaks of impurity phases. The observed Bragg's reflections are slightly broader confirming the nanocrystalline nature of the samples.)

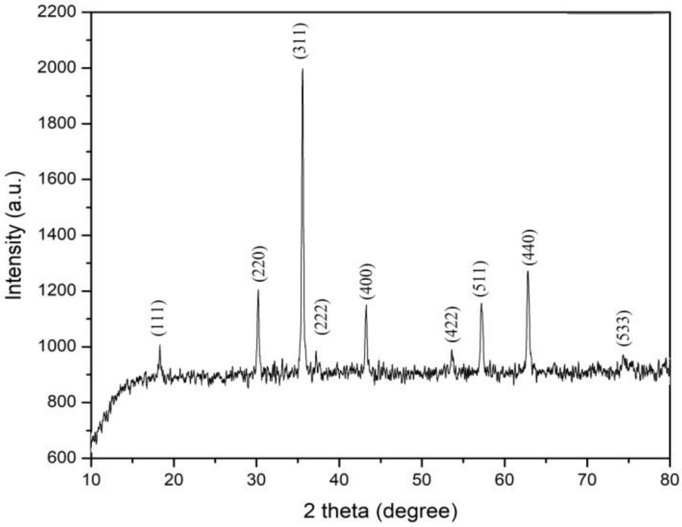

Figure 1. XRD pattern of $Ni_{0.5}Co_{0.5}Gd_yFe_{2-y}O_4$ (y=0.025) nanoparticles

The crystallite size (t) was determined from the FWHM of the most intense reflection (311) using Scherrer's formula [6, 7]. The crystallite size of the present cobalt ferrite sample is found to be of the order of 31 nm. The structural parameters like lattice constant (a) and X-ray density (d_X) were calculated using standard relation and their values are found to be 8.395 Å and 5.268 gm/cm^3 respectively. The bulk density (d_B) was measured using Archimedes principle and it is found to be less as compared to X-ray density d_B = 3.890 gm/cm^3 [8].

Magnetic hysteresis loop recorded at room temperature using VSM technique of present ferrite nanoparticles is shown in Figure 2. The hysteresis curve exhibit normal ferromagnetic magnetic behavior. The saturation magnetization (Ms), coercivity (Hc) and remanent magnetization (Mr) values for the prepared nanoparticles is given in Table 1. It is observed from table 1 that the saturation magnetization and coercive field shows higher value which may be due to nanocrystalline of the Ni-Co ferrite sample. These values of magnetic parameters agree well with the reported values [9]. Further, on comparison with bulk Gd doped Ni-Co ferrite samples, these values of magnetic parameters are found to be slightly higher [10].

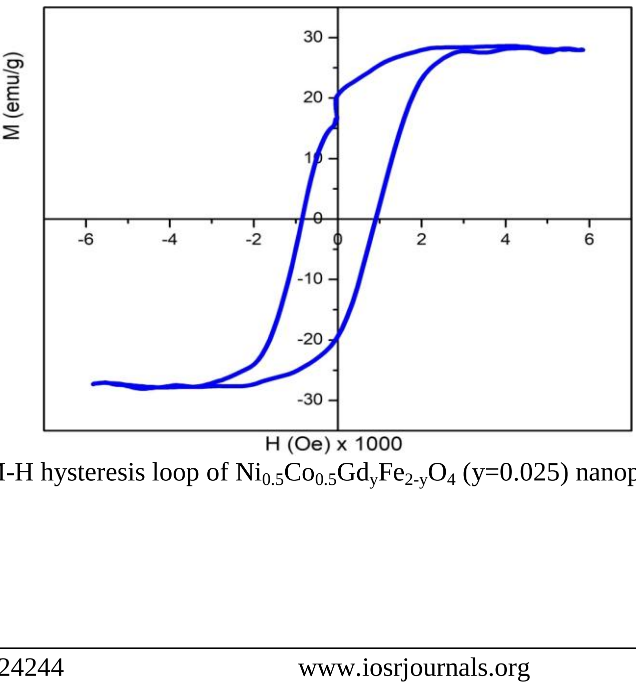

Fig 2. M-H hysteresis loop of $Ni_{0.5}Co_{0.5}Gd_yFe_{2-y}O_4$ (y=0.025) nanoparticles

Table 2. Magnetic parameters of nano-size $Ni_{0.5}Co_{0.5}Gd_yFe_{2-y}O_4$ (y=0.025) nanoparticles

Ms (emu/gm)	Mr (emu/gm)	Hc (Oe)	Mr / Ms
29.74	21.37	12.88	0.7184

IV. Conclusion

The nanocrystalline Gd^{3+} doped $Ni_{0.5}Co_{0.5}Fe_2O_4$ for composition of $Ni_{0.5}Co_{0.5}Gd_yFe_{2-y}O_4$ (y=0.025) with an average crystallite size of 31 nm was successfully synthesized by sol-gel auto combustion method using citric acid as a fuel. The single phase cubic spinel structure was confirmed through X-ray analysis. The lattice constant was in reported range. The VSM graph shows the typical ferromagnetic nature of the prepared sample. The saturation magnetization, coercivity and remanent magnetization all shows increased values as compared to bulk Gd doped $Ni_{0.5}Co_{0.5}Fe_2O_4$ ferrite sample.

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