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Synthesis of Nanosized Y^{3+} Doped Ni-Mg-Cd Ferrite Powders and their Structural, Magnetic properties by Sol-gel Auto Combustion Method

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Abstract

Nanoparticles of $Ni_{0.4}Mg_{0.4}Cd_{0.2}Y_yFe_{2-y}O_4$ (where y= 0.025, 0.050, 0.075, 0.100 and 0.125) were synthesized by a simple and less cost effective method involving sol-gel auto combustion at low temperature. Metal nitrates, such as Yttrium nitrate, Nickel nitrate, Cadmium nitrate, Magnesium nitrate and Ferric nitrate, were used as the source materials. Citric acid was used as the burning agent. The pH of the precursor was maintained at 7. The prepared samples were sintered for 400 ^oC. Structural and magnetic properties of nano-crystalline ferrite powders have been investigated using XRD and VSM. The role of Yttrium substituted Nickel-Magnesium-Cadmium shows the formation of crystal phase, which was identified by X-ray diffraction method. The lattice constants decrease with the increasing in Y^{3+} and decrease in Fe contain. We report the synthesis of nanoparticles, soft and spinel with crystalline size is in the range of 23.092 to 17.02nm. The Vibrating Sample Magnetometer was used to obtain the Hysteresis parameters. The magnetic property of the prepared samples shows remarkable changes with changes the Y^{3+} percentage.

Keywords: Sol-gel, Ni-Mg-Cd Nanoferrite, Structural characterization, VSM, etc.

Introduction

Nanoferrites are very important magnetic materials because of their high resistivity and low energy losses (eddy current) and hence have vast technological application in the field of electronics and telecommunications due to wide range of frequencies[1]. Ferrites are the ferromagnetic materials which posses the combined properties of magnetic conductor and electrical insulator[2].

From crystal structure point of view, ferrites are generally divided into two groups: cubic or spinel ferrites and hexagonal or hexaferrites. Ferrite nanoparticles are important because of their scientific aspect and applications in permanent magnets and high density information storage devices[3,4]. It is used in the wide range of applications in gas sensing[5], catalytic applications[6,7], Li ion batteries[8] high density magneto-optic recording devices, color imaging, bioprocessing, magnetic refrigeration and ferrofluids[9].

The increase in the electrical conductivity at low temperature is attributed to the impurities, which reside at the grain boundaries[10]. The increase in the electrical conductivity at low temperature is attributed to the impurities, which reside at the grain boundaries[11]. In addition, magnetic properties can be controlled and tailored to practical applications through the appropriate choice from a number of divalent cations in their structure[12]. The tendency increases in the occupancy of Mg ion by substituted Nd^{3+} in Zn-Mg ferrites[13].

Despite the many other attempts, there is no specific report on Y^{3+} doped in Ni-Mg-Cd to the best of our knowledge. Therefore, authors have been interested to investigate the properties of yttrium doped Ni-Mg-Cd ferrites by simplest chemical route.

In the present study, a small amount of yttrium was added to Ni-Mg-Cd to form $Ni_{0.4}Mg_{0.4}Cd_{0.2}Y_yFe_{2-y}O_4$ (where y= 0.025, 0.050, 0.075, 0.100 and 0.125) powders with the anticipation of decreasing the crystalline size of sample and changing the structural as well as magnetic properties favorably. In this particular study, nanocrystalline $Ni_{0.4}Mg_{0.4}Cd_{0.2}Y_yFe_{2-y}O_4$ powders were synthesized by a sol-gel combustion method to achieved pure high density powder and smaller grain size using metal nitrate in aqueous media and by adding ammonium hydroxide to destabilize the solution. The structural and magnetic properties changes in the yttrium doped Ni-Mg-Cd nanopowders were examined by XRD and VSM at various calcinations temperature.

Materials and Methods

Yttrium (Y^{3+}) substituted in Ni-Mg-Cd ferrite powders were synthesized by sol-gel auto combustion technique at low temperatures for different compositions $Ni_{0.4}Mg_{0.4}Cd_{0.2}Y_yFe_{2-}$

$_yO_4$ (where y= 0.025, 0.050, 0.075, 0.100 and 0.125). Raw materials are used in the experiments are AR grade metal nitrates such as $Ni(NO_3)_2$, $Cd(NO_3)_2$, $Mg(NO_3)_2$, $Y(NO_3)_2$, and $Fe_2(NO_3)_2$ all from Merck company of purity of 99% using stoichiometric ratio and dissolved in doubled distilled water. The $C_6H_8O_7$ is used as a fuel in the ratio of 1:3. The mixture of the raw material was stirred at low temperature on hot plate magneto-stirrer by maintaining pH between 7 to 8. After maintained the pH, it was continuously stirred and heated at 80 ^{0}C to obtain uniform gel. After 3.5 hours, gel is converted into ash (powder). That's powder were sintered at 400^{0}C. The structural property is studied by X-ray diffraction (XRD) and average grain size is calculated. It is found in crystal nature and average particle grain size is 23.092-17.02 nm. Also lattice constant, (hkl) planes and grain size was calculated by Bragg's law and Scherer's formulae. From VSM the magnetic properties of the samples show remarkable changes with change of Y^{3+} percentage.

Results and Discussion

XRD characterization: Figure-1 shows the Powder XRD: (LabX XRD-6100, Shimadzu), X-ray diffraction (XRD) patterns of typical samples of $Ni_{0.4}Mg_{0.4}Cd_{0.2}Y_yFe_{2-y}O_4$ (where y= 0.025, 0.050, 0.075, 0.100 and 0.125). The XRD patterns shows well developed diffraction line assigned to cubic spinel phase. The all measured XRD peaks match well with the standard patterns of cubic spinel ferrite. Interplane distance and planes are calculated by Bragg"s diffraction law and index method using equation 1 and 2. The prepared samples nanoparticles exhibit several diffraction peaks which can be indexed as cubic structure. The average crystalline size of the prepared nanoparticles was found in the range of 23.092-17.02 nm for 400^{0}C of the composition by using Scherer's formula. The intensity and width of the Bragg's peak Conforming good crystallinity and nanoparticle size it is also good agreement with research article.

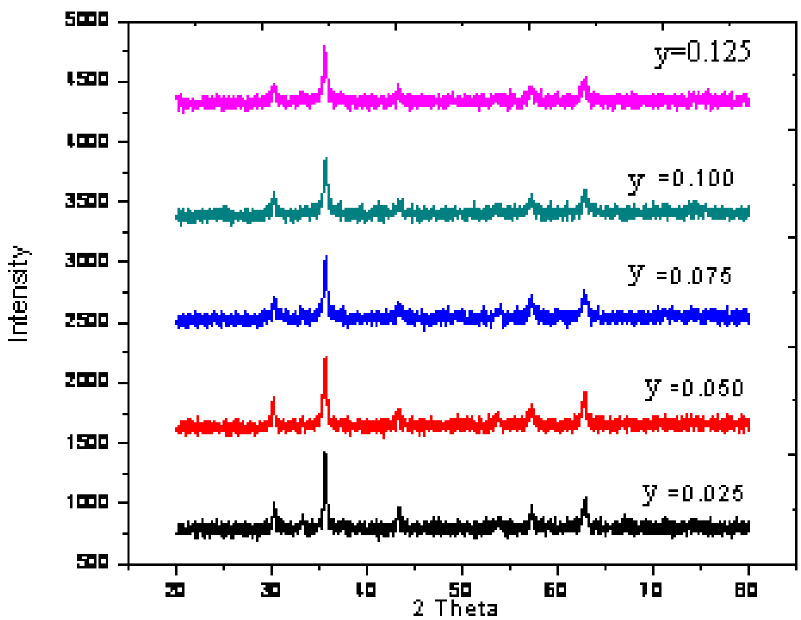

Figure-1
XRD pattern of $Ni_{0.4}Mg_{0.4}Cd_{0.2}Y_yFe_{2-y}O_4$ nanoferrites

Table-1
XRD pattern of $Ni_{0.4}Mg_{0.4}Cd_{0.2}Y_yFe_{2-y}O_4$ nanoferrites

Obs. No.	Composition	Average grain size (t) nm	Lattice constant (a) A^o
1	$Ni_{0.4}Mg_{0.4}Cd_{0.2}Y_{0.025}Fe_{1.975}$	23.092	2.1309
2	$Ni_{0.4}Mg_{0.4}Cd_{0.2}Y_{0.050}Fe_{1.950}$	24.352	2.1338
3	$Ni_{0.4}Mg_{0.4}Cd_{0.2}Y_{0.075}Fe_{1.925}$	20.534	2.1305
4	$Ni_{0.4}Mg_{0.4}Cd_{0.2}Y_{0.100}Fe_{1.900}$	21.984	2.1300
5	$Ni_{0.4}Mg_{0.4}Cd_{0.2}Y_{0.125}Fe_{1.895}$	17.02	1.9228

The interplane distance were calculated by using Bragg's equation from the relation

$$n\lambda = 2d\sin\theta \quad (1)$$

The lattice parameter 'a' was calculated using following relation

$$a = d\sqrt{h^2 + k^2 + l^2} \quad (2)$$

Where (hkl) is the miller indices, λ is the wavelength of X-ray radiation and θ is the Bragg angle. The results of interplane distance and lattice parameter are shown in Table-1.

The particle size were calculated using Scherer's formula

$$t = \frac{0.9\lambda}{\beta\cos\theta} \quad (3)$$

Where, "t" is the particle size, and β is the FWHM (full width half maxima) of the peak θ.

VSM characterization (Hysteresis loop): Figure-2 shows the magnetic properties of the synthesis samples. It shows that the compositions of Y^{3+} contain decrease the Hc (Coercievity), Mr (Magnetic remenance) and Ms (Magnetic saturation) all are decreasing. The results are illustrated in Table-2.

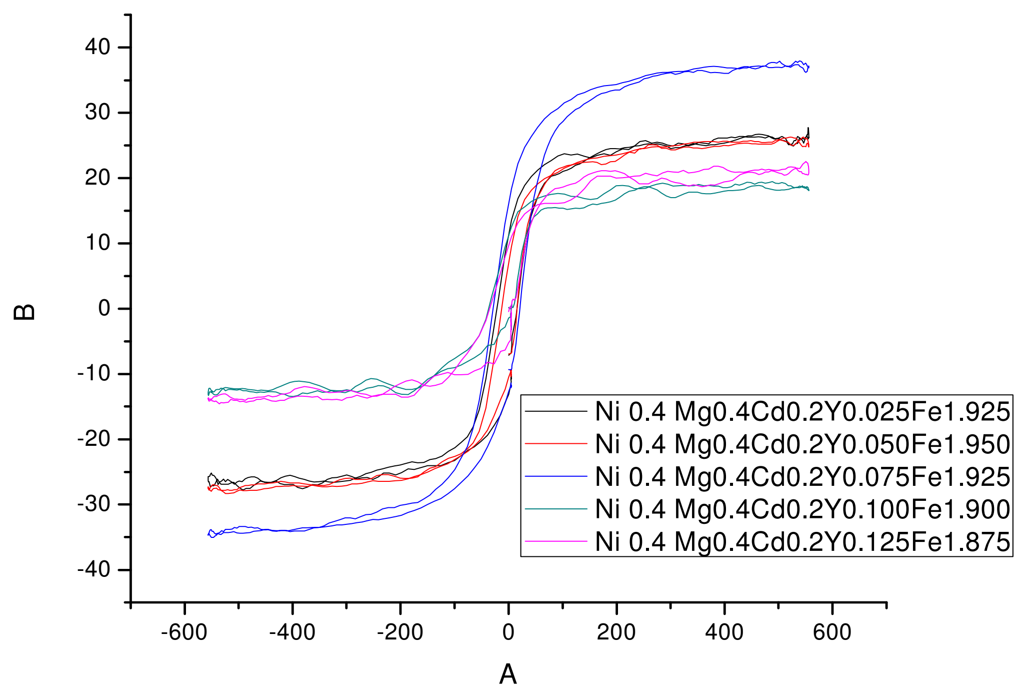

Figure-2
Hysteresis loop shows magnetic properties of $Ni_{0.4}Mg_{0.4}Cd_{0.2}Y_yFe_{2-y}O_4$

Table-2
VSM Observations of $Ni_{0.4}Mg_{0.4}Cd_{0.2}Y_yFe_{2-y}O_4$ nanoferrites

Obs. No.	Composition	Hc (Oe)	Mr (emu/gm)	Ms (emu/gm)
1	$Ni_{0.4}Mg_{0.4}Cd_{0.2}Y_{0.025}Fe_{1.975}$	18518.5185	013.5374	027.7551
2	$Ni_{0.4}Mg_{0.4}Cd_{0.2}Y_{0.050}Fe_{1.950}$	13017.5802	013.1299	025.2665
3	$Ni_{0.4}Mg_{0.4}Cd_{0.2}Y_{0.075}Fe_{1.925}$	13619.1358	008.5546	020.4479
4	$Ni_{0.4}Mg_{0.4}Cd_{0.2}Y_{0.100}Fe_{1.900}$	21172.8395	009.5282	016.4688
5	$Ni_{0.4}Mg_{0.4}Cd_{0.2}Y_{0.125}Fe_{1.895}$	22592.5926	006.9935	018.5621

Conclusion

Y^{3+} doped $Ni_{0.4}Mg_{0.4}Cd_{0.2}Y_yFe_{2-y}O_4$ nanoferrites were synthesized using sol-gel technique. The increase in the Y^{3+} concentration gives the significant changes in the particle size and magnetic properties of the composition $Ni_{0.4}Mg_{0.4}Cd_{0.2}Y_yFe_{2-y}O_4$ (where y= 0.025, 0.050, 0.075, 0.100 and 0.125). The synthesis of nanoparticles with crystalline size decreases as the concentration increases and is in the range of 23.092-17.02 nm for 400 ^{0}C are cubic spinel ferrite. From the hysteresis loop, it is clear that the synthesized sample is soft magnet.

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