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Structural and Morphological Properties of La^{3+} Doped Ni-Zn Nanoferrite

V. D. Kulkarni[*], S. M. Rathod[**]
[*]*Department of Physics, Hutatma Rajguru Mahavidyalaya, Rajgurunagar, Dist-Pune, Pin-410505, MS, INDIA*
**Research Student, Science College, SRTM University, Nanded*
[**]*Nanomaterials & Lasers Research Lab, Department of Physics, Abasaheb Garware College, Pune- 411 004, MS, INDIA*

ABSTRACT
The Study of Structural and Morphological properties of rare earth La^{3+} material doped in Nickel-Zinc nanocrystalline ferrites were synthesized by sol-gel auto combustion method with analytical grade metal nitrate. The prepared samples were sintered at 600°C. The effect of La^{3+} doped Nickel-Zinc ferrite on Structural and Morphological properties was investigated. The XRD graph confirms the formation of $Ni_{0.5}$ $Zn_{0.5}$ $La_xFe_{2-x}O_4$ (where x= 0.025, 0.050, 0.075, 0.1, 0.125) nanoparticles. The particle size and lattice constant was calculated from XRD. It was found to be the size of nanoparticles decreases and lattice constant increases with the increase in La^{3+}concentration. The bulk density, x ray density and porosity was calculated from XRD. The SEM and TEM give the morphological study of the nanoparticles.
Keywords: Ni-Zn nanoferrite, SEM, TEM, Sol-gel method, XRD.

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I. INTRODUCTION

The Sol–gel auto-combustion method has been used to prepare the Lanthanum doped Nickel nanoferrites. It was noted that size of nanoparticles decreases as the La content increases .The structural, morphological and magnetic properties of the Lanthanum substituted nickel nanoferrite were also studied [1]. The nano ferrites were synthesized by the different methods such as Citrate gel method [2] Conventional Ceramic Method [3] Chemical Method [4] oxalate based precursor method [5]. The Sol-gel auto combustion Method has the best stoichiometric control and gives the nanoparticles. The structural and morphological properties of Ni doped Cobalt nanoferrite particles was studied. [6]. The Ni-Co-Zn spinel ferrite nanoparticles were prepared by sol-gel auto combustion method. The prepared nanoparticles were characterized by XRD, FTIR and SEM. The SEM and XRD was shown that the spherical spinel structures. The density and porosity was also studied from XRD [7]. The $Mg_{0.5}Zn_{0.5}La_xFe_{2-x}O_4$ (x=0.0, 0.025, 0.05, 0.075, 0.1) nanoferrite was synthesized using sol-gel method. The structural, morphological and magnetic properties were studied [8]. The yttrium doped cobalt ferrite was prepared by using sol gel auto combustion technique. The structural characterization results the formation of the nanoparticles. The HR-SEM was confirms morphology of prepared nanoferrite [9].

Therefore, the ferrite nanoparticles have the wide applications in various fields. This paper studied the rare earth La^{3+} material substituted in Nickel-Zinc nanocrystalline ferrites were synthesized by sol-gel auto combustion method and characterized by various characterizations.

II. MATERIALS AND METHODS

The $Ni_{0.5}$ $Zn_{0.5}$ $La_xFe_{2-x}O_4$ (Where x= 0.025, 0.050, 0.075, 0.1, 0.125) nanoparticles were prepared by sol-gel auto combustion synthesis Method. All high purity AR grade nitrates was used such as Ferric nitrate ($Fe(NO_3)_3.9H_2O$), Nickel nitrate ($Ni(NO_3)_2{\cdot}6H_2O$), Zinc nitrate ($Zn(NO3)_2{\cdot}6H_2O$), Lanthanum nitrate ($La(NO)_3{\cdot}6H_2O$), Citric acid ($C_6H_8O_7$), Ammonium hydroxide solution (NH_4OH) . Citric acid was used as a Fuel. The stoichiometric ratio proportion of all nitrates and citric acid are required to obtain the final product. All nitrates was added in distilled water and stirred till to get the homogeneous solution. The ammonium hydroxide solution was added slowly to maintain pH 7 during the stirring process. This solution was stirred continuously for 3 to 4 hours to form sol at temperature 100 °C. When sol becomes a viscous brown gel, then auto-combustion takes place. Finally get the fine powder of $Ni_{0.5}$ $Zn_{0.5}$ $La_xFe_{2-x}O_4$ ferrite nanoparticles. This powder was sintered at 600 °C for 4 hours.

III. RESULTS AND DISCUSSIONS

3.1 Structural Properties:

The X- ray diffraction patterns (XRD) of the prepared sample of $Ni_{0.5}$ $Zn_{0.5}$ $La_xFe_{2-x}O_4$ (where x= 0.025, 0.050, 0.075, 0.1, 0.125) nanocrystals were studied using X ray diffractometer with Cu Kα radiation of wavelength 1.5405 AU. The x-ray diffraction pattern of the synthesized lanthanum doped Nickel-Zinc nanoferrite shown in Fig 1. The particle size was calculated using Scherer's formula,

$$d = (0.9*\lambda)/ (\beta*\text{Cos}(\theta))$$

Where, λ =wavelength of X-ray used, θ = peak position and β = FWHM of the peak θ and it is corrected for instrumental broadening.

The lattice constant (a) was calculated by the formula,

$$a = d1 * \sqrt{h^2 + k^2 + l^2}$$

Where, $d1$ = inter planner spacing, and (h, k, l) are the Miller Indices.

The X-ray density (ρx), bulk density (ρb) and porosity (P) were obtained using the formulae

$$\rho x = \frac{Z * M}{N * a^3}$$

$$\rho b = \frac{m}{\pi r^2 t}$$

$$P\ (\%) = 1 - \left(\frac{\rho b}{\rho x}\right) * 100$$

Where, Z = number of atoms per unit cell,

M = Molecular weight of the composition,

N = Avogadro's number

m =mass of the pellet of sample

r = radius of the pellet of sample

t = thickness of the pellet of sample

The average particle size, lattice constant, bulk density, x ray density and porosity is given in Table 1.The average particle size of nanoparticles is decreases, as concentration of the lanthanum increases shown in Fig.2 and particle size decreases from 19.6758 nm to 16.9868 nm. The lattice constant of nanoparticles is increases, as concentration of the lanthanum increases. This can be explained on the basis of ionic radii of the ions. The bulk density decreases as concentration of the Lanthanum increases. The x ray density increases as concentration of Lanthanum increases and which is shown in Fig.3.The porosity is also increases as concentration of Lanthanum increases

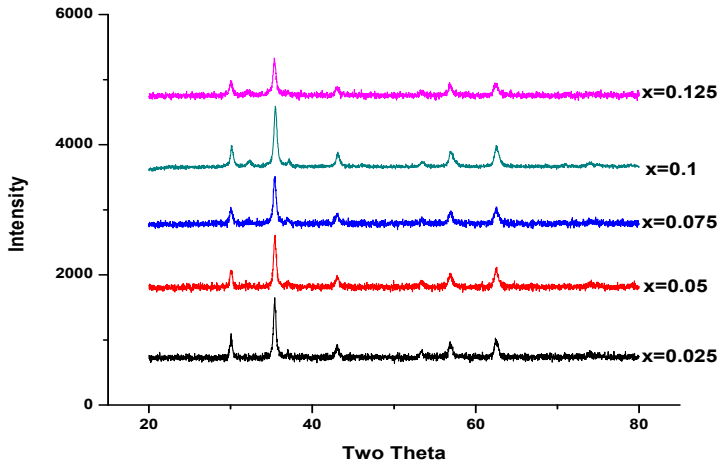

Fig.1: XRD patterns of $Ni_{0.5}$ $Zn_{0.5}$ $La_xFe_{2-x}O_4$ nanoferrites

Table 1 Values of Structural properties of $Ni_{0.5}Zn_{0.5}$ $La_xFe_{2-x}O_4$ from XRD

Concentration (x)	Average Particle Size (nm)	Lattice Constant(a) in (AU)	Bulk density in (gm/cm^3)	X-ray density in (gm/cm^3)	Porosity in %
0.025	19.6758	8.3957	2.2506	5.3657	58.0551
0.050	18.5936	8.3969	2.1421	5.4276	60.5319
0.075	18.0695	8.3987	2.2158	5.4705	59.4944
0.100	17.9846	8.3990	2.1207	5.5268	61.6277
0.125	16.9868	8.4592	2.0371	5.5309	63.1687

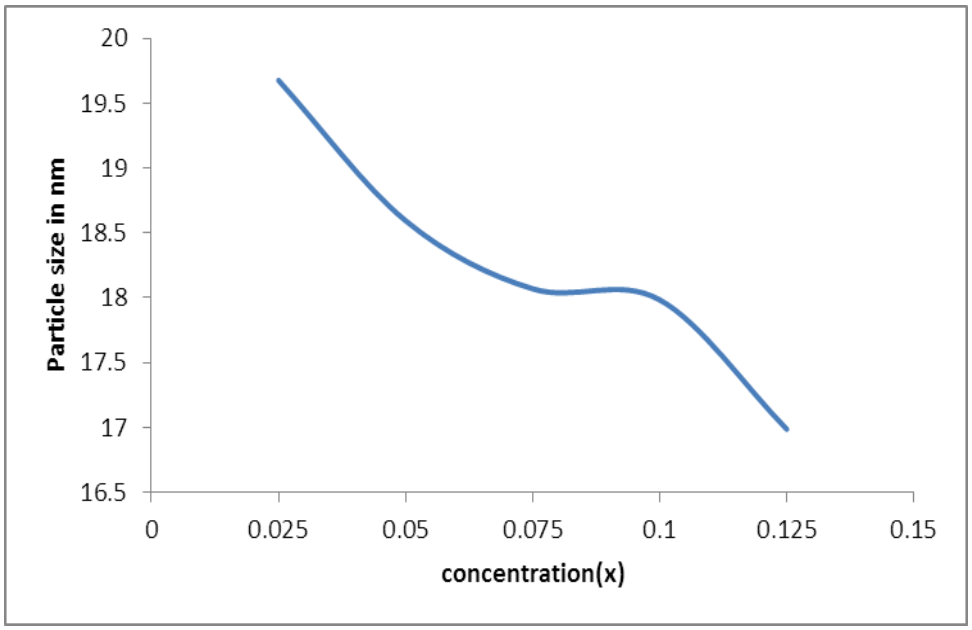

Fig.2: Plot of particle size versus concentration of Lanthanum

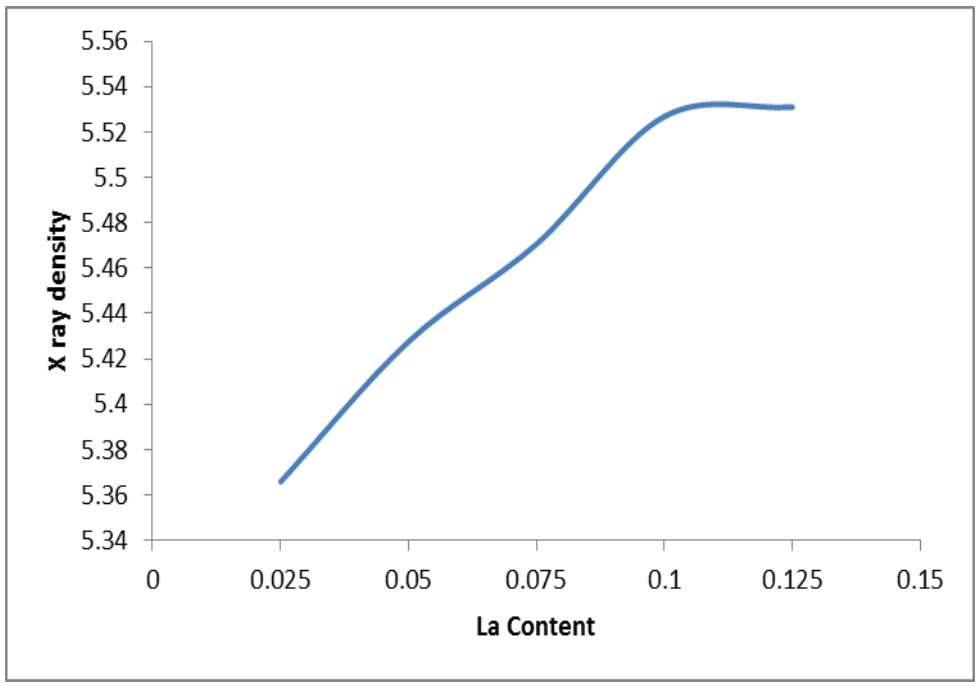

Fig.3: Plot of X ray density versus concentration of Lanthanum

3.2 **Morphological Properties:**

3.2.1 Scanning Electron Spectroscopy (SEM)**:-**

The SEM image of $Ni_{0.5}Zn_{0.5}$ $La_xFe_{2-x}O_4$ at x=0.05 nanoferrite is shown in Fig.4. The SEM image of $Ni_{0.5}Zn_{0.5}$ $La_xFe_{2-x}O_4$ nanoferrite at x=0.05 shows that continuous distribution of nanoparticles.

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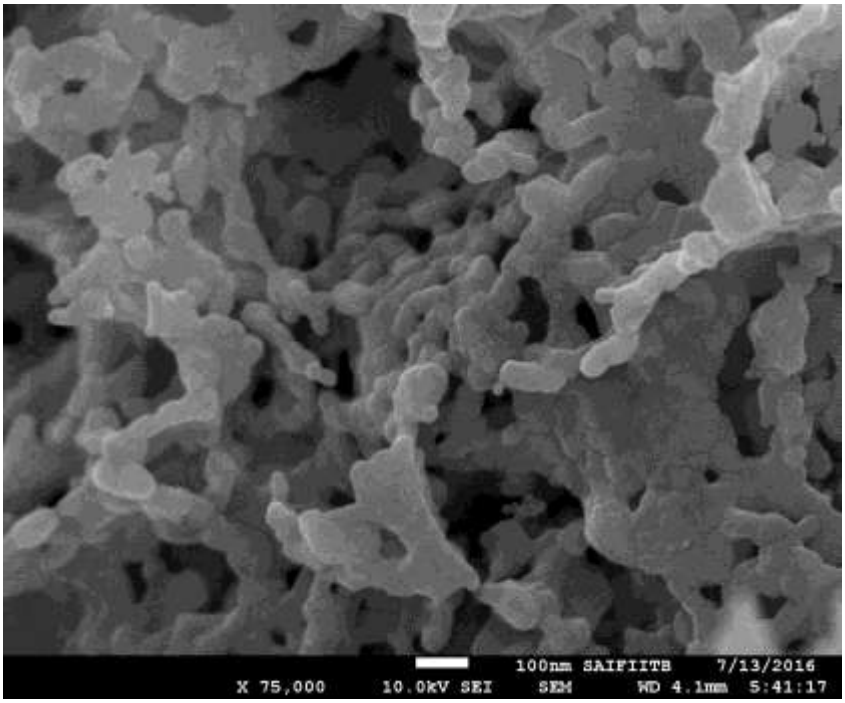

Fig.4. SEM image of $Ni_{0.5}Zn_{0.5}La_xFe_{2-x}O_4$ nanoferrite at x=0.05

3.2.2 Transmission Electron Spectroscopy (TEM) :-

The TEM image of $Ni_{0.5}Zn_{0.5}La_xFe_{2-x}O_4$ nanoferrite at x=0.075 is shown in Fig.5.The size of the nanoparticles observed from TEM micrograph vary from the 19.20 nm to 40.71 nm. It was good agreement with the particle size obtained from XRD. The observed particle size in TEM is increased and this could be due to accumulation of particles.

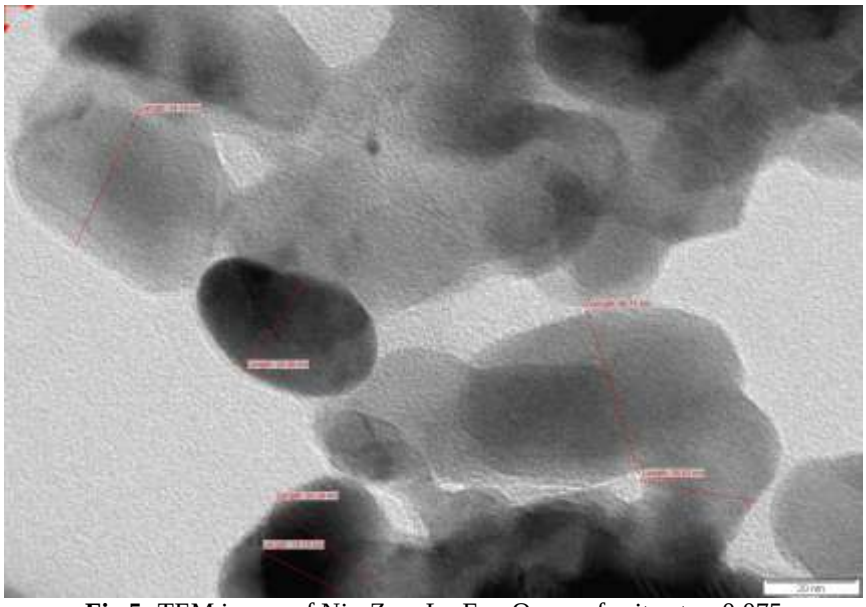

Fig.5: TEM image of $Ni_{0.5}Zn_{0.5}La_xFe_{2-x}O_4$ nanoferrite at x=0.075

IV. CONCLUSIONS

The Synthesized Nanoparticles of $Ni_{0.5}Zn_{0.5}La_xFe_{2-x}O_4$ was synthesized by sol gel auto combustion method. The XRD pattern of synthesized samples was concluded that the particle size decreases as concentration of lanthanum increases. The lattice constant of nanoparticles is increases, as concentration of the lanthanum increases. The x ray density and porosity increases as concentration of Lanthanum increases. The SEM image shows the continuous distribution of the nanoparticles. The

TEM image gives the particle size which is comparable that particle size obtained from XRD.

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