Synthesis,Magnetic and optical properties of $Ni_{0.5}Co_{0.5}$ Al Nanoferrite by autocombution Technique

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***Abstract*— A simple and low cost effective method involving sol-gel auto combustion at low temperature is used to synthesize Ni $_{0.5}Co_{0.5}$ Al_x Fe_{2-x} O_4. nanoparticles. The magnetic and optical properties of the synthesized samples were studied. The role of Al^{3+} substituted shows the formation of crystal phase, which was identified by X-ray diffraction method. The lattice constants decrease with the increasing in Al^{3+} containt. We report the synthesis of nanoparticles with crystalline size is in the range of 50 - 18 nm. The FTIR characterization shows the bond formation and synthesized material is ferrite. The Vibrating Sample Magnetometer was used to obtain the Hysteresis parameters. The magnetic properties of the samples shows remarkable changes with change of Al^{3+} percentage. UV-spectroscopy, to calculate the band gap energy is in the range so that prepared sample is in the nature of semiconductor.**

Keywords; sol-gel, Ni-Co nanoferrite, FTIR, XRD, VSM and UV

I. INTRODUCTION:

Ferrite nanoparticles are of great interest because of their scientific aspect and applications in permanent magnets, targeted drug delivery and high density information storage devices. From crystal structure point of view, ferrites are generally divided into two groups: cubic or spinel ferrites and hexagonal or hexaferrites [1,2]

Cobalt ferrite is a well known hard magnetic material with a high coercivity and a moderate magnetization. These properties along with its great physical and chemical stabilities, make $CoFe_2O_4$ nanoparticles suitable for many practical applications such as audio/ video tapes, high density digital recording disks, etc.[3-4]. On other hand Nickel ferrite is a typical soft magnetic material [5], which has many applications in electronic devices, such as inductors and transformator cores[6]. Aluminum and Chromium substituted Co-Ni spinel nano ferrites were prepared by sol-gel auto combustion method were investigated crystallite size estimated from peak(311) was in range 13-21nm[7]. Ni substituted cobalt ferrite nanoparticles were prepared by sol-gel method. The crystallite size and lattice parameter studied in the range of 120-70nm and 8.350 – 8.300 respectively. [8]. Nickel substituted cobalt ferrites are highly resistive and magnetostrictive. Studies of Van Uitert and Jilg showed that a very large increase at room temperature respectively of nickel ferrite is achieved by substituting 1or 2 percent of cobalt ions.[9-10].

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Particles with nanosize exhibit unique chemical and physical properties. In particular nano composite material composed of nanometric metal and metal oxide particles embedded in vitreous matrices reveal a variety of interesting magnetic, electric and catalytic properties. Ferrites are ferrimagnetic semiconductors that opened a new area in the physics of material science and the needful high resistivity ferrites led to synthesis of various ferrites. The electrical and magnetic properties of ferrites depend on the method of preparation [11], Site preference [9] and valance distribution [10]. Magnetic properties of magnetic nano materials particularly in ferrites materials also depend on their chemical composition and methods of synthesis [12]. The substitution effect and the change of the preparation condition are allowed to improve the properties of ferrites. Generally ferrites were commercially used in radio frequency circuits, transformer cores , antennas and for high speed digital tape.

In this investigation, the effect of Al^{3+} substitution in Ni $_{0.5}Co_{0.5}$ fe_2O_4 are studied. The sol-gel method is used to synthesize the nanoparticles of $Ni_{0.5}Co_{0.5}$ Al_x fe_{2-x} O_4. The structural, optical and magnetic properties of the synthesized samples have been discussed in the contents.

2. EXPERIMENTAL METHOD AND MATERIALS:

Ni-Co-Al ferrite powders were synthesized by sol-gel auto combustion technique at low temperatures for different compositions $Ni_{0.5}$ $Co_{0.5}$ Al_x $Fe_{2-x}O_4$ (where x=0.1, 0.2, 0.4, 0.8,). Raw materials are used in the experiments are AR grade nitrates i.e. $Ni(NO_3)_2$, $Co(NO_3)_2$, $Al(NO_3)_2$, $Fe_2(NO_3)_2$and $C_6H_8O_7$ is used as a fuel in the ratio 1:3. all from Merck co. of purity of 99 % using stoichiometric ratio and dissolved in distilled water. The mixture of the raw material was stirrered at 80 ^{0}C on hot plate magneto-stirrer. Maintaining pH 7, it was continuously stirrered to obtain uniform gel. After 4-5 hours it converts from gel to ash form, which was sintered at 560 ^{0}C. The FTIR characterization shows the bond formation and synthesized material is ferrite. The structural and average grain size is studied by X-ray diffraction (XRD), it is in crystal nature and average particle size is 50 - 18 nm. Particle size decreases with increasing the percentage of Al^{3+}. 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 Al^{3+} percentage. Optical properties studied from UV-spectroscopy to calculate the band gap energy increases with increasing Al^{3+} it is in the semiconductor range so that prepared sample confirms the nature of semiconductor material.

The general chemical reaction of the synthesis sample is as follows

$$\mathbf{Ni(No_3)6H_2O+CO(NO_3)2.6H_2O+Al(NO_3)_{2.}9H_2O+Fe(NO_3)_3.\;9H_2O + 3C_6H_8O_7 \xrightarrow[\text{100}^{0}\text{C For 5hrs}]{} NiCoAlFe_2O_4}$$

3. RESULTS AND DISCUSION:

A. FTIR Spectroscopy:

The FTIR (Fourier Transform Infrared Spectrometer) characterization from figure 1shows the bond formation and two main metal – oxygen bands at the range of 500-600 cm^{-1} so that it is conform that the synthesized material is ferrite.

B. Optical (UV Spectroscopy)Properties:

Optical properties were studied from UV-spectroscopy to calculate the band gap energy, it increases with increasing Al $^{3+}$ i.e. 2.13eV to 2.48eV. It is in the semiconductor range so that prepared sample is in the nature of semiconductor material.

C. XRD charecterization:

Figure 4 & 5 shows the X-ray diffraction (XRD) patterns of typical samples of $Ni_{0.5}$ $Co_{0.5}$ Al_x $Fe_{2-x}O_4$ (where x= 0.1, 0.2, 0.4, 0.8,). The XRD patterns shows well developed diffraction line assigned to pure inverse spinel phase. The all measured XRD peaks match well with the standard patterns of inverse spinel ferrite. Interplane distance and planes are calculated by Bragg's diffraction law and index method using equation 1 and 2. The $NiCoAlFe_2O_4$ nanoparticles exhibit several diffraction peaks which can be indexed as cubic structure. The average crystalline size of the prepared NiCoAlFe2O4 nanoparticles was found 50nm & 18 nm for the composition of x= 0.1 & 0.8, by using Sherrer's formula.The intensity & width of the Bragg's peak Conforming good crystallinity & nano particle size it is also good agreement with research article [8].

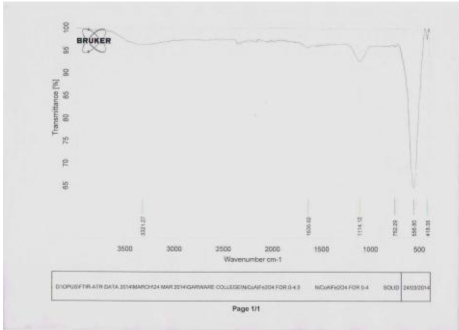

Fig.1:FTIR of $NiCoAl_{(x)}Fe_{(2-x)}O_{4;}$ x=0.4

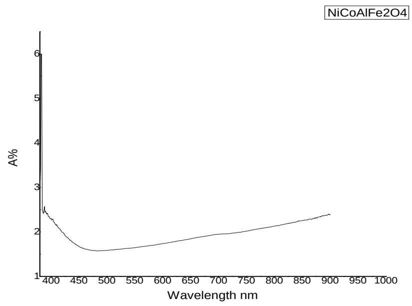

Figure.3:UV spectra of $NiCoAl_{(x)}Fe_{(2-x)}O_{4;}$ x=0.4

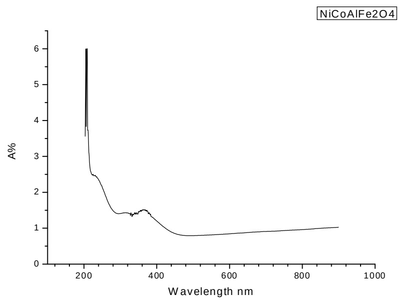

Figure.2: UV spectra of $NiCoAl_{(x)}Fe_{(2-x)}O_{4;}$ x=0.2

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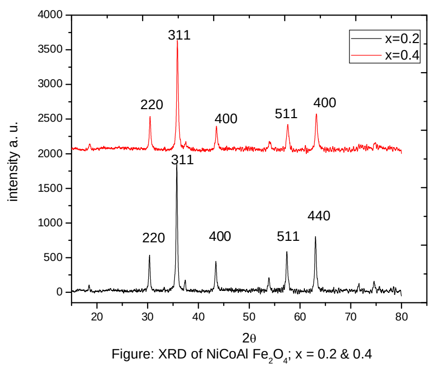

Figure4:XRD of $NiCoAl_{(x)}Fe_{(2-x)}O_4$; x= 0.2 & 0.4

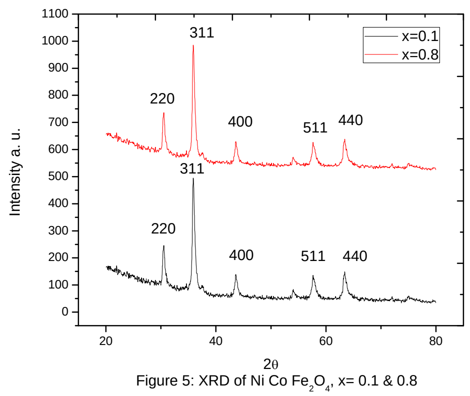

Figure5:XRD of $NiCoAl_{(x)}Fe_{(2-x)}O_4$; x= 0.1& 0.8

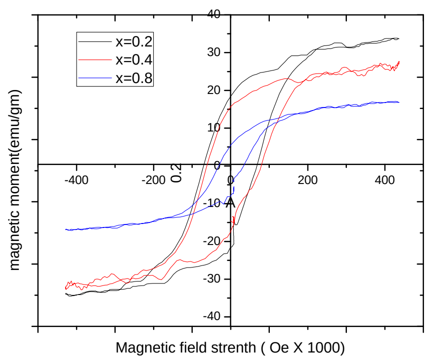

Figure6:VSM of $NiCoAl_{(x)}Fe_{(2-x)}O_4$; x=0.2, 0.4 &0.8

TABLE I. LATTICE PARAMETER AND PARTICLE SIZE OF $NiCoAl_{(x)}Fe_{(2-x)}O_4$

Composition x	*Lattice constant'a'*	*'t' particle size nm*	*Inteplane distance'd'(311)*
0.1	**8.273**	**50.22**	**0.2492**
0.2	**8.290**	**37.114**	**0.2515**
0.4	**8.293**	**34.34**	**0.2494**
0.8	**8.306**	**18.35**	**0.2491**

TABLE II. VSM OF $NiCoAl_{(x)}Fe_{(2-x)}O_4$

Compo sition x	VSM of $NiCoAl_{(x)}Fe_{(2-x)}O_4$		
	Hc (Oe)	*Mr emu/gm*	*Ms emu/gm*
0.2	**64013.8155**	**018.4945**	**033.9368**
0.4	**59633.0797**	**016.7000**	**027.7333**
0.8	**40251.5723**	**07.6070**	**017.1157**

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

$$n\lambda = 2d\sin\theta \qquad [1]$$

The lattice parameter **'a'** was calculated using following relation

$$a = d \times \sqrt{h^2 + k^2 + l^2} \qquad [2]$$

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 Scherrer's formula

$$t = \frac{0.9\lambda}{\beta\cos\theta} \qquad [3]$$

Where, 't' is the particle size, and β is the FWHM (full width half maxima) of the peak θ

D. VSM charecterization (Hystreessis loop)

Figure 6 shows the magnetic properties of the synthesis samples, it shows that the compositions of Al^{3+} containt increase the Hc (Coercievity) , Mr (Magnetic remenance) and Ms (Magnetic saturation) all are decreasing. The results are illustrated in table2.

3. Conclusion:

The nanoferrites were synthesized using sol-gel technique. The increase in the Al^{3+} concentration gives the significant changes in the particle size and magnetic properties of the composition $Ni_{0.5}$ $Co_{0.5}$ Al_x $Fe_{2-x}O_4$ (where x=0.1, 0.2, 0.4, 0.8,). The FT-IR spectroscopy study shows two main metal oxygen bands at in the range of 500-600 cm^{-1}confirming the formation of single phase cubic inverse structure of Al^{3+} substitute in Ni-Co ferrite. The crystalline particle size were found that significantly decrease with increasing the Al^{3+}

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concentration it is in the range of 50- 18nm. The lattice parameter increases with increasing Al^{3+} in Ni-Co ferrite due to less ionic radii of Al^{3+}. The UV study shows band gap energy increases with increase in Al^{3+} concentration. It is in the range of semiconductor materials. So that synthesized samples is in the nature of semiconductor materials. From the hysteresis loop, it is clear that the synthesized sample converts from hard to soft ferrite with increasing Al^{3+} containts.

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