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STRUCTURAL AND ELECTRICAL BEHAVIOR OF Co-Ti SUBSTITUTED NICKEL NANO FERRITE PREPARED BY SOL-GEL AUTO COMBUSTION ROUTE.

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Abstract

Nanocrystalline powder of Co-Ti doped nickel ferrite has been prepared by sol-gel auto combustion method. XRD study shows formation of mono phase homogeneous compound with cubic structure. The average crystallite size of the prepared ferrite calculated using Scherrer equation was in the order of 26-34 nm. The lattice parameter is found to increase with increasing doping concentration of the Co-Ti content. The electrical resistivity as a function of temperature was investigated by using four probe technique. The observed results can be explained on the basis of verwey hopping mechanism between Fe^{2+} and Fe^{3+} ions. Dielectric constant (ἐ) was measured in the frequency range up to 10 KHz and they show dispersion with increase in frequency. The variation of mentioned parameter with frequency is explained qualitatively with the aid of conduction process theory.

Keywords: Nanocrystalline, sol-gel auto combustion, XRD, scherrer, dielectric constant, etc.

Introduction

According to the crystal structure nickel ferrite have inverse spinel structure with very high resistivity and negligible eddy current losses are technologically essential materials that are used in the fabrication of electronic and micro- wave devices [1, 2]. The substitution of Co-Ti in nickel ferrite modifies the properties of nickel ferrite which are useful in many device applications. The rich crystal chemistry in spinel ferrite systems offers excellent opportunities for understanding and fine-tuning the various properties of nanoparticles by chemical manipulations [3]. The nanocrystalline mixed spinel ferrites materials are used in various technological issues like nano ferrite doped microstrip patch antenna for improving the overall antenna performance, microwave dielectric property study and antenna miniaturization [4]. The substitution of Co-Ti was found to have a significant influence on the electromagnetic properties. Therefore it would be meaningful to investigate the structural and electrical properties of Ni ferrites. Generally, in most types of nano-particles prepared by sol-gel methods, control of size and size distribution is not possible [5]. In order to overcome these difficulties, nanometer size reactors for the formation of homogeneous nanoparticles of nickel ferrite are used. In this research paper, the structural and electrical properties are taken into consideration with the doping of Co and Ti in nickel spinel ferrite.

Experimental

The chemicals used in the present investigation were of analytical grade (AR) with high purity of 99.99%. The same were used without any further purification. The generic series of Co-Ti substituted nickel ferrite was prepared by the sol-gel auto combustion method. Metal nitrates, such as nickel nitrate, cobalt nitrate, titanium nitrate and ferric nitrate, were used as the source materials and urea was used as the chelating agent to reduce agglomeration [6, 7].

Characterization

The structural characterization of samples has been studied by X- ray diffraction (Bruker Advance X-ray diffractometer). Electrical resistivity and microwave dielectric constants in the form of pressed pellets were measured by Impendence Precision Analyzer (Wayn Kerr 6500 B).

Result and Discussion

Figure 1 shows the powder X-ray diffraction pattern (XRD) of Co-Ti substituted nickel ferrite nano-particles calcinated at 800°C. A watchful assessment of XRD pattern reveals the formation of slightly broader peaks suggestive of the low crystallite size of the synthesized samples. The entire peak belongs to cubic spinel structure and the investigation of XRD pattern confirms the formation of mono phase samples. The average crystallite size was calculated using the Scherrer's formula from the broadening of XRD peak corresponding to most intense (311) peak of the XRD pattern [8].

The values of lattice parameter with Co-Ti content was obtained using XRD data and are listed in **Table 1**. It is observed that the lattice parameter increases with increasing content of Co-Ti. This behavior of lattice parameter is explained on the basis of difference in ionic radii of Fe^{3+} (0.69 Å) and Co^{2+} (0.88 Å) and Ti^{4+}(0.74 Å) . Similar types of results were observed in the investigation of few researchers [9, 10]. In the case of our samples, the lattice parameters were found to be slightly higher than those reported by others. The enhanced lattice parameters might be occurred due to sol- gel method [11].

From the plot of log ρ versus 1000/T as shown in figure 2, it is observed that resistivity decreases with increase in temperature indicating the semiconducting nature of the samples A change in slope is contributed to change in conduction mechanism or phase transition from ferrimagnetic to paramagnetic. The conduction mechanism can be explained on the basis of Verwey model [12]. According to Verwey, the conduction mechanism in ferrite occurs mainly due to hopping of Fe^{2+} and Fe^{3+} ions in the octahedral [B] site. The charge carriers are located with ions or vacant site and conduction takes place through hopping process [13].

Figure 3 displays the variation of dielectric constant, ε ′, as a function of frequency at room temperature from 100 Hz–1MHz. Normally, dielectric constant (ε′) decreases with increasing frequency. Similar behavior of dielectric constant with frequency was observed by many researchers [14, 15].

The decrease of the dielectric constant (ε′) with Co and Ti ions substitution can be explained on the basis of the mechanism of polarization process in ferrites, which is similar to that in the conduction process [16]. By the electronic exchange, one obtains local displacement of electrons in the direction of electric field. These displacements determine the polarization in ferrites. It is known that effect of polarization is to reduce the field inside the media. The decrease of polarization with increase of frequency may be due to the fact that, beyond a certain frequency of the electric field, the electronic exchange between ferrous and ferric ions cannot follow the alternating field. Hence dielectric constant may decrease substantially as frequency is increased.

Table: 1. lattice parameters (a), X-ray density, porosity and Crystallite size of $Ni(CoTi)_{x/2}Fe_{2-x}O_4$ sample for different 'x' values.

Sr.No	Conc. (x)	a (Å)	X-ray density (gm/cm^3)	Porosity P(%)	Particle Size (D) nm
01	x = 0	8.5319	5.202	38.75	36
02	x =0.2	8.6492	5.299	33.77	24

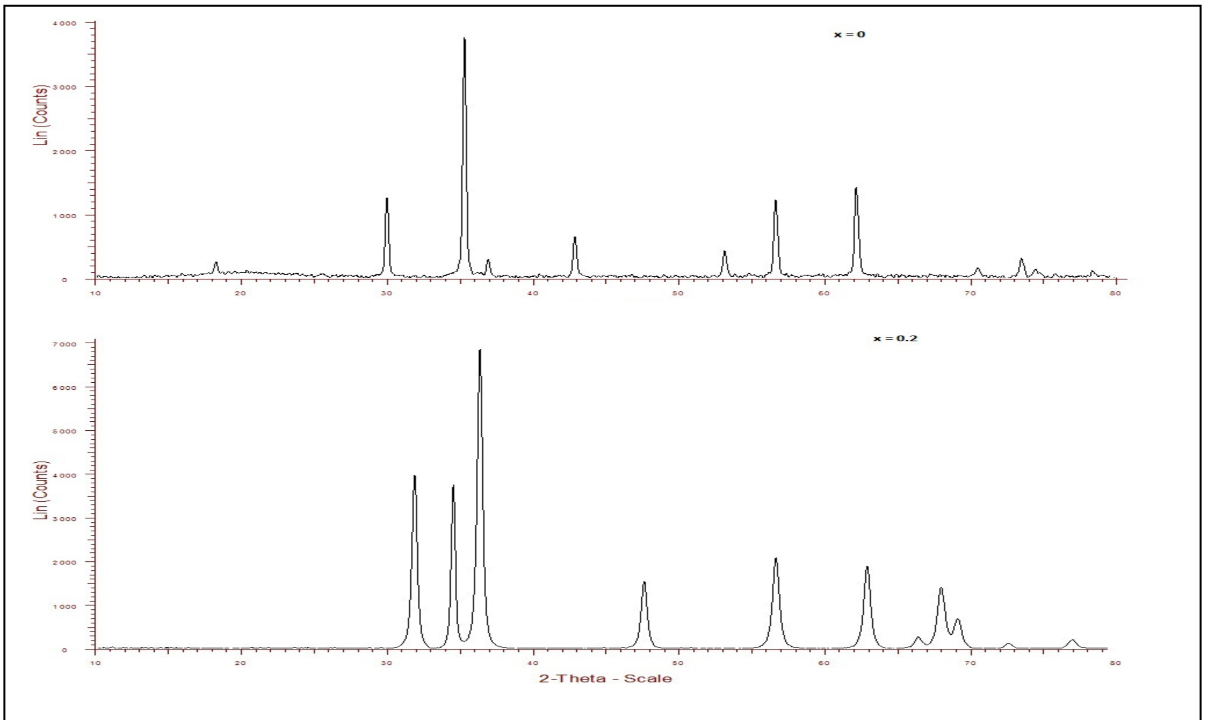

Figure 1: XRD patterns of $Ni(CoTi)_{x/2}Fe_{2-x}O_4$ system

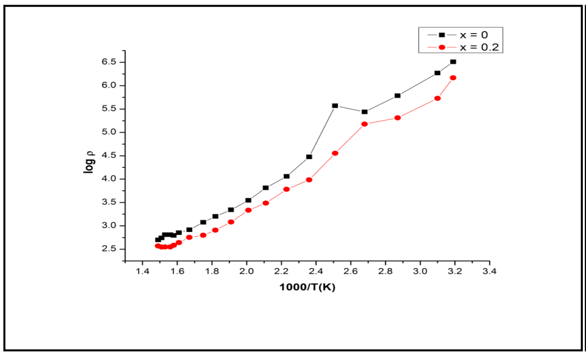

Figure 2: Plot of logρ vs 1000/T(K) of $Ni(CoTi)_{x/2}Fe_{2-x}O_4$ system

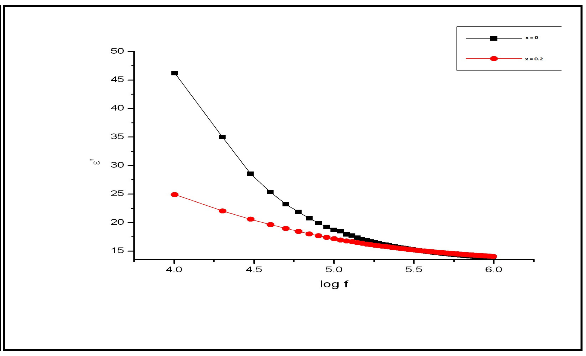

Figure 3 Variation of ἐ with log frequency at constant temperature.

Conclusion

The sol-gel auto combustion method yield nano-meter nickel ferrite particles. The X-ray diffraction studies clearly showed the formation of single phase spinel structure. The D.C. electrical resistivity decreases with increase in temperature, which confirms the semiconducting behavior of synthesized samples. The frequency dependence of the dielectric constant arises from charge carriers present in nickel ferrite.

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