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ELECTRICAL PROPERTIES OF TITANIUM DOPED NICKEL FERRITE

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ABSTRACT:

Polycrystalline spinel ferrite with composition $Ni_{1+x}Ti_xFe_{2-2x}O_4$ in the step of 0.1 from x= 0.0 to 0.7; have been prepared by conventional double sintering ceramic method. The prepared samples were characterized by powder X-ray diffraction (XRD) technique to confirm the formation of single phase cubic spinel structure. The present works were made to find the effect of non-magnetic Ti^{4+} substitution on the DC electrical properties and reports on DC electrical resistivity, activation energy, Curie temperature etc. The resistivity (ρ) has been found to increase by increasing concentration of Ti^{4+} ions. The logρ versus temperature measurement was carried out in order to deduce activation energy in both ferrimagnetic and paramagnetic regions. Activation energy corresponding to slope for both the region of each prepared sample has been estimated.

KEYWORDS: XRD, DC resistivity, activation energy, Curie temperature

1. INTRODUCTION

Electrical properties of ferrites have been the subject of many researchers since the artificial production of spinals by Snoek [1].The amount of charge transported through a unit block material on the application of a unit electric field per unit volume is known as the electrical conductivity of the solids. Magnetic oxides, which are commonly known as ferrites, attracted the attention of physicist and technologists because they are magnetic semiconductors as well as electric insulator. Hence ferrites, which are ferrimagnetic semiconductor, opened a new area in the physics of material and the need for high resistivity ferrite led to the synthesis of the various ferrites. The increasing demand for low loss ferrites resulted in detailed investigations on the various aspects of the conductivity and on the influence of the various substitutions on the electrical conductivity, thermo- electric power, hall mobility etc. It is an experimental fact that, electrical conductivity of ferrite depends much upon the amount of iron present in the lattice in the ferrous state. A high concentration of ferrous ions leads to high electrical conductivity. In ferrites the electron concentration is of the order of ~10^{22} per cm^3. The low mobility of electrons ($10^{-4}cm^2$/vs.) and holes (10^{-8} cm^2/vs.) limits their conductivity. Suitable preparation technique and chemical composition control the conductivity in the ferrites [2]. Many workers has studied the electrical properties of ferrites [3, 4, 5] It has been observed that electrical conductivity markedly changed by controlling the sintering temperature, sintering atmosphere, by substituting with appropriate type and amount of substituent. Ferrite is useful material due to
high electrical resistivity, high magnetization, low dielectric losses, low eddy current, high permeability and low cost; which makes Ni-ferrite suitable itself for technological application like telecommunication, transformer, SMPS, microwave devices chips [6].

In this work, we reports the formation of single cubic spinel ferrite and DC electrical transport properties of Ti^{4+} substituted $Ni_{1+x}Ti_xFe_{2-2x}O_4$ ferrite for typical combinations of x in the step of 0.1.

2. EXPERIMENTAL

2.1 SAMPLE PREPARATION

High pure oxides of relevant metals were mixed in stoichiometric proportions to prepare a series of polycrystalline samples of $Ni_{1+x}Ti_xFe_{2-2x}O_4$,

where $0.0 \leq x \leq 0.7$, in the step of 0.1were prepared by double sintering ceramic technique [7].

Each sample was wet ground for 4 hours using agate mortar. The samples were pre-sintered in a muffle furnace at 900°C for 12 h. The pre-sintered samples was reground and compressed into a pellet form using hydraulic press with a pressure of 6 ton per inch^2. These pellets were sintered at 1200°C in air for 18 h and were slowly cooled to room temperature.

2.2 X-RAY DIFFRACTION (XRD)

XRD patterns were recorded using Phillips X-ray diffractometer at room temperature in the 2θ range of 20^0 to 80^0 to confirm the single phase cubic spinel structure. The XRD data is used to find lattice parameter value.

2.3 DC ELECTRICAL MEASUREMENT

The DC electrical resistivity measurement of pelletized ferrite samples were done on home built greater accuracy resistivity apparatus by two-probe technique using spring loaded copper electrodes. The pellet was held between two electrodes of specially designed sample holder. The measurements were taken in the temperature range of 300–800 K. The measurements were recorded in the step of 10 K. The temperature of the sample was sensed by chromel-alumel thermocouple.

3. RESULTS AND DISCUSSION

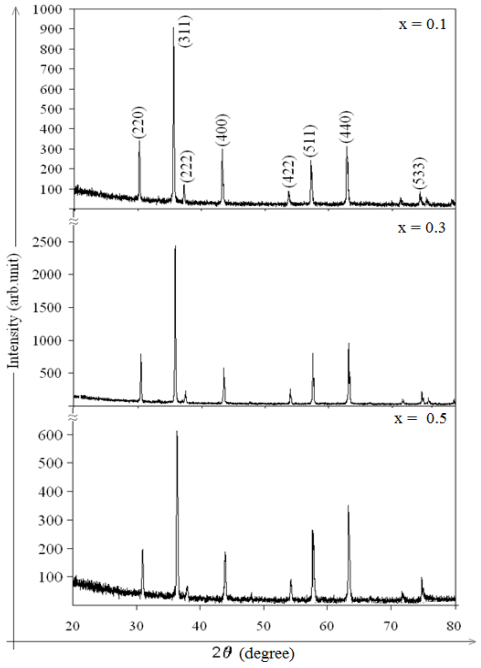

Fig.1. *X-ray diffraction pattern for typical sample x = 0.1, 0.3, 0.5 of $Ni_{1+x}Ti_xFe_{2-2x}O_4$ system*

Fig.1 illustrates the powder XRD pattern for typical samples x= 0.1, 0.3, 0.5 prepared spinel ferrite $Ni_{1+x}Ti_xFe_{2-2x}O_4$ ($0.0 \leq x \leq 0.7$) system. The XRD pattern shows the presence of most intense peak corresponding to Bragg reflections (220), (311), (222), (400), (422) and (511) without extra reflections. The analysis of XRD pattern reveals the formation of single phase cubic spinel ferrite structure. The XRD pattern also shows slight shift in peak position towards higher 2θangle due to substitution of Ti^{4+} ions in nickel ferrite. The inter planer spacing 'd' values for the recorded peaks were calculated according to Bragg's peaks.

The value of lattice parameter 'a' of the spinel ferrite system was calculated using the relation,

$$a = d\sqrt{N}$$

where, d- inter planner spacing, $N = (h^2+k^2+l^2)$; (*h k l*) being the Miller indices of diffraction peaks.

Table 1: Values of variation of activation energy in ferromagnetic and paramagnetic region of $Ni_{1+x}Ti_xFe_{2-2x}O_4$ ($x= 0.0 \leq x \leq 0.7$) system

Ti content x	Lattice constant 'a' (Å)	Activation energy (eV)		ΔE (eV)
		E_F	E_P	
0.0	8.332	0.305	0.699	0.394
0.1	8.325	0.203	0.385	0.183
0.2	8.320	0.259	0.325	0.066
0.3	8.316	0.296	0.359	0.063
0.4	8.313	0.283	0.709	0.426
0.5	8.311	0.234	0.411	0.177
0.6	8.308	0.151	0.340	0.189
0.7	8.306	0.188	0.581	0.393

The lattice constant obtained from XRD data for all the samples are presented in **Table 1**.The value of the lattice parameter for nickel ferrite (a = 8.331Å) agree close to the reported data [8]. It can be seen that the lattice parameter decreases slowly with the Ti concentration x. In the present series of $Ni_{1+x}Ti_xFe_{2-2x}O_4$; (where $x = 0.0 \leq x \leq 0.7$). Two Fe^{3+} ions are replaced by combination of divalent Ni^{2+} ions and tetravalent Ti^{4+} ions. The change in the lattice constant is related with the ionic radii of the constituent ions. The ionic radii of Ni^{2+} (0.72Å) and Ti^{4+} (0.64Å) are less than the ionic radii of $2Fe^{3+}$ ions hence we observe decrease in lattice parameter [9].

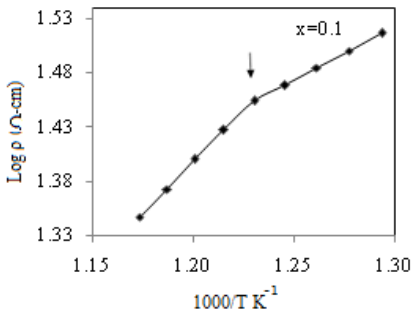

Fig.2.*Variation of log ρ Vs 1000/T for typical samples x = 0.1*

The variation of logarithm of resistivity (logρ) versus reciprocal of temperature (1000/T) is depicted in **Fig.2**. The plot exhibits two regions with change in slope. These regions are namely ferrimagnetic and paramagnetic region. The temperature at which slope changes may corresponds to Curie temperature (Tc) of the samples. The resistivity plots obeys the exponential relation given by,

$$\rho_{DC} = \rho_o \exp\left(\frac{\Delta E}{kT}\right)$$

where, ΔE -is the activation energy in electron volt (eV), need to release an electron from one ion to the neighbouring ions giving rise to the electrical conductivity. k -is the Boltzmann constant and T is absolute temperature.

Using the above relation and the values of the slope from resistivity plots, the activation energy corresponds to ferrimagnetic region and paramagnetic region is calculated. The value of activation energy for paramagnetic and ferrimagnetic region is given in the **Table 1.** The table indicates the higher values of activation energy for paramagnetic region compared to that of ferrimagnetic region. The activation energy in the present case is below 0.2 eV this suggest that the conduction mechanism in the present case is due to the hopping of electrons ($Fe^{3+} \rightleftharpoons Fe^{2+}$, Ni^{2+}) [10]. During sintering process some of Fe^{2+} ions have been transformed to Fe^{3+} ions and generated electrons which take part in conduction mechanism. The presence of Fe^{2+} and Fe^{3+} on equivalent lattice site (octahedral B-site) may cause the low surface resistivity.

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