CHARACTERIZATION OF ELECTRICAL RESISTIVITY OF BARIUM – NIOBIUM FERRITE

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ABSTRACT

The spinel ferrites ceramics present important characteristics technologic due the electric conduction and magnetic properties. The spinel ferrites are oxides with chemical formula MFe_2O_4, where M is a metallic divalent ion [1-3,12-14,16-19]. The system $BaNb_xFe_{2-x}O_4$, ferrite was prepared using ceramics techniques in reaction of solid state. The materials have chemical formula given by $BaNb_xFe_{2-x}O_4$, $0.00 \leq x \geq 0.10$; where x in steps of 0.02 for higher iron concentration and to $0.1 \leq x \geq 1.0$ where x in steps of 0.2 for low iron concentration. This present work reports the influence of the niobium ion Nb^{3+} substitution the iron ion Fe^{3+} in the properties electric, such as; resistivity electrical, dielectric constant and activation energy. The samples was pre-sintered in an electrical furnace for 6h in an air atmosphere at 673K, 24h at 873K and the final sintering of the samples were carried out for 48h at 1273K. The DC electrical conductivity was measured using two probe methods in range from ambient temperature 301K, 323K, 373K, 423K, 473K and 523K with voltage of (0V - 40V). The AC resistivity was measured in the function of frequency (20Hz - 1MHz). The electrical conductivity measurements showed is a semiconductor behavior for all the samples, since x= 0.00 until x=1.0.

KEYWORDS: *Resistivity electrical, Ceramic ferrite, NbBa ferrite, Activation energy.*

I. INTRODUCTION

Polycrystalline ferrites are widely used for electronic devices. They constitute a class of good dielectric material with high resistivity [1]. The ferrites have the general formula $MOFe_2O_3$, where M is a divalent ion. Combined with their high permeability, saturation magnetization and low electrical conductivity, this makes them particularly appropriate as cores for induction coils operating at high frequencies [2]. The electrical resistivity is an important and traditional technique of investigation experimental in physics of solid state. The electric resistivity of a material contains information about the mechanisms electronic scattering, for example; phonon scattering, magnum scattering, magnetic impurity scattering, lattice scattering, phase transition, etc. [3-5, 19] In generally there is more of one mechanism present and the variation the parameter external because temperature, magnetic field, chemical substitution is possible through of the measurements of resistivity study the mechanism separate. The ferrite with niobium dilution is search, since is materials that when dilution shows several possibility of agglomeration of magnetic ions, due the diversity interaction magnetic between the sub lattice and the magnetic property is result of iterations between the field magnetic external and the dipole moments magnetic of atom organization [6-10].

II. EXPERIMENTAL DETAILS

The ferrites have the general formula $MDFe_2O_4$, where M is ion of barium divalent and D is an ion of niobium trivalent. The composite utilized was $BaCO_3$, Fe_2O_3 and Nb_2O_3 were weighed in stoichiometric proportion. The ferrite system $BaNb_xFe_{2-x}O_4$ with x variation is (0.00, 0.02, 0.04, 0.06, 0.08, 0.10, 0.20, 0.40, 0.60, 0.80 and 1.00) was prepared using ceramics techniques in reaction of solid state. The samples was pre-sintered in an electrical furnace for 6h in an air atmosphere at 673K, 24h at 873K and the final sintering of the samples were carried out for 48h at 1273K. The surfaces of samples were carefully polished to uniformly smooth surfaces. The electrical resistance of the samples was obtained at different temperature from the current–voltage (I-V) characteristics from the values of the electrical conductivity, thickness and cross-sectional area of the samples. The DC electrical conductivity was measured with temperature using two probe methods in range from ambient temperature 301K, 323K, 373K, 423K, 473K and 523K using a keithley with voltage of (0V - 40V). The real part of dielectric constant (ε'), AC resistivity were measured using a Precision LCR Meter model HP 4284 in the function of frequency (20Hz - 1MHz) where (ε') was calculated from the capacitance(C).

III. RESULTS AND DISCUSSION

Candeia et al. BaFe2O4 shows a tunnel structure with iron having a tetrahedral coordination. Corners of the FeO4-tetrahedral change their directions block wise in one layer parallel to the a/b-plane. As a result, large and long tunnels are created by 12 FeO_4-tetrahedral in the tetrahedral network of orthorhombic-$BaFe_2O_4$. Each of the large tunnels contains two Ba2+ (Ba(1)) atoms (double tunnels). In addition, smaller compressed quadrangular tunnels exist containing exclusively Ba2+ (Ba(2)) (single tunnels) and those tunnels which are too small for an intercalation of Ba2+ (vacant tunnels). The sequence double tunnel–single tunnel–vacant tunnel–single tunnel repeats along the a-axis. Ba(1) shows a monocapped trigonal prismatic oxygen surrounding in the large tunnels. Along the tunnel direction there are no connections between these BaO polyhedral. The surrounding of Ba(2) is different, as soon as it shows edge-sharing BaO - polyhedral resulting in (BaO) - chains along the tunnels [11-12]. With the increase of the ion niobium other phases are formed and it can be observed in the electrical resistivity.

Composition dependence of electrical resistivity

Experimental data for mixed Ba-Nb-Ferrite are given in table 1 and that the electrical resistivity variation is $1.19x10^9$ Ωm to $1.45x10^6$ Ωm. Among all BaNb Ferrite the sample exhibits highest value of the electrical resistivity.

Table 1. Composition dependence of electrical resistivity

Composition	Electrical resistivity (Ωm)
$BaFe_2O_4$	1.1910^9
$BaNb_{0.02}Fe_{1.98}O_4$	3.1410^9
$BaNb_{0.04}Fe_{1.96}O_4$	7.3810^9
$BaNb_{0.06}Fe_{1.94}O_4$	9.2010^8
$BaNb_{0.08}Fe_{1.92}O_4$	1.7110^9
$BaNb_{0.10}Fe_{1.90}O_4$	4.4910^{10}
$BaNb_{0.20}Fe_{1.80}O_4$	5.5710^{10}
$BaNb_{0.40}Fe_{1.60}O_4$	6.8310^5
$BaNb_{0.60}Fe_{1.40}O_4$	4.5910^{10}
$BaNb_{0.80}Fe_{1.20}O_4$	9.2910^3
$BaNb_1Fe_1O_4$	1.4510^6

Observe that the values electrical resistivity in function of the samples present a behavior non-linear, in general, can be explained by the Verwey mechanism, where the electron hopping between cations with two different valence states distributed randomly on equivalent lattice sites. According to this model, ferrites are known to form a close-packed oxygen (anions) lattice with the metal ions (cations) situated at the tetrahedral sites (A sites) and the octahedral sites (B site) these cations can be well treated as isolate from each other, to a first approximation. The increase in the conductivity is due to the increase of the mobility of the charge carriers, which are produced from hopping of electron in the sub lattices. The decrease in the resistivity is due to the increase of the mobility of the charge carries, which are produced from hopping of electron in the sub lattices [13,19].

Variation of electrical conductivity with temperature

The temperature dependence of the electrical conductivity of BaNb ferrites in different compositions was investigated from ambient temperature 301K, 323K, 373K, 423K, 473K and 523K.

Ravinder et. al. present the conduction at lower temperature (below Curie temperature) is due to hopping of electrons between Fe2+ to Fe3+ ions, where at higher temperature (above Curie temperature) due to polaron hopping[2,4-5]. Figure 1(a until k) shows the variation of Logσ with 1000/T is shown from 301K, 323K, 373K, 423K, 473K and 523K.

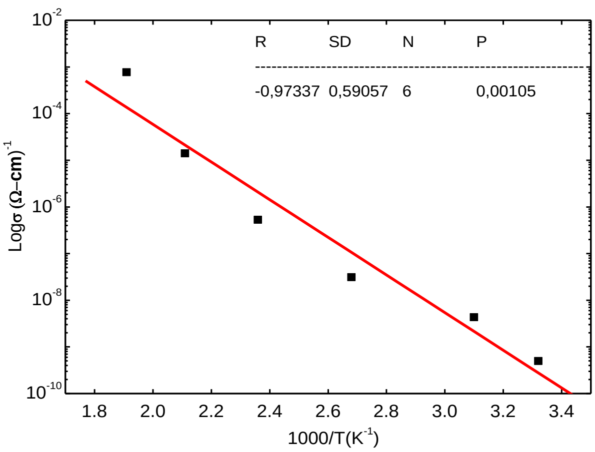

Figure 1a. The variation of Logσ with 1000/T is shown from the $BaFe_2O_4$

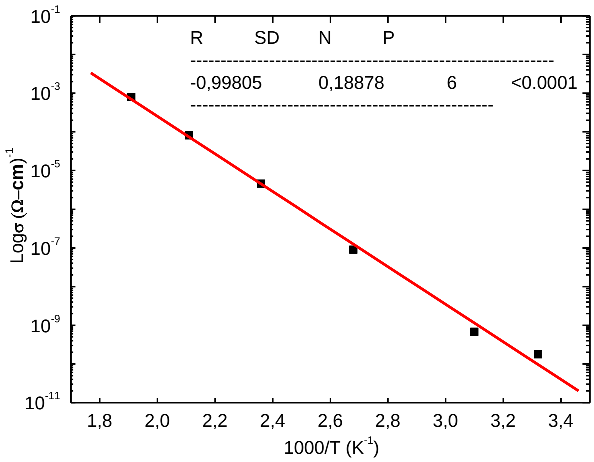

Figure 1c. The variation of Logσ with 1000/T is shown from the $BaNb_{0.4}Fe_{1.96}O_4$.

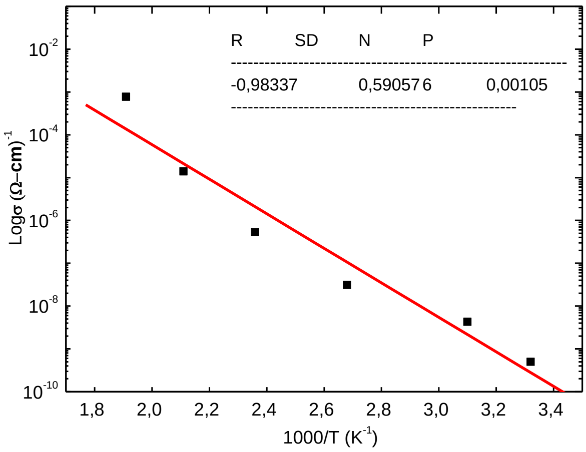

Figure 1b. The variation of Logσ with 1000/T is shown from the $BaNb_{0.02}Fe_{1.98}O_4$.

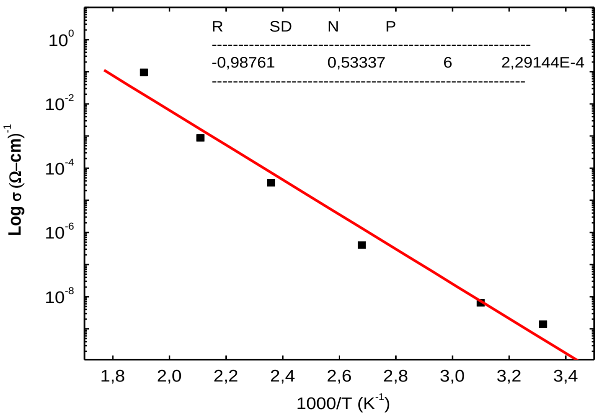

Figure 1d. The variation of Logσ with 1000/T is shown from the $BaNb_{0.06}Fe_{1.94}O_4$.

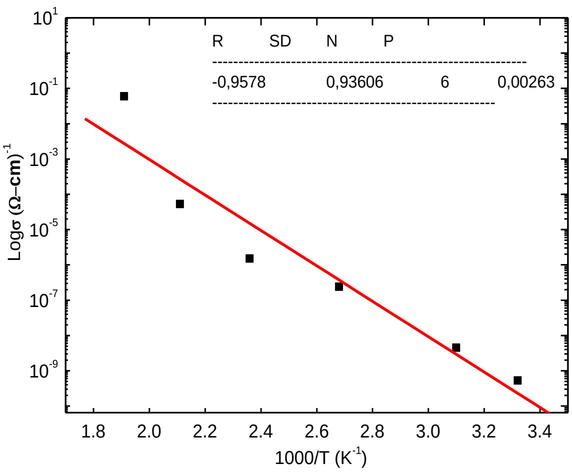

Figure 1e. The variation of Logσ with 1000/T is shown from the $BaNb_{0.08}Fe_{1.92}O_4$.

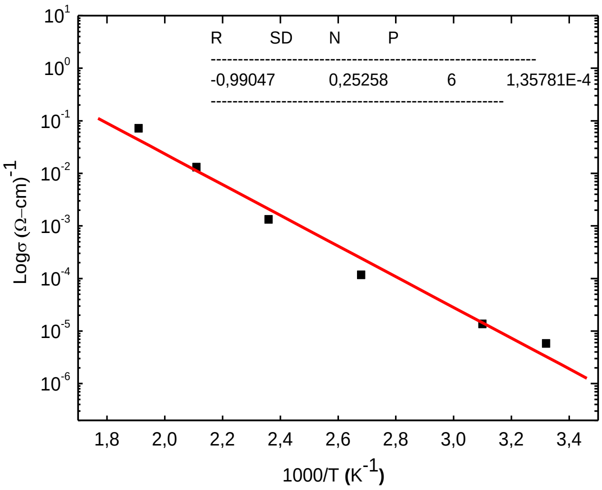

Figure 1h. The variation of Logσ with 1000/T is shown from the $BaNb_{0.40}Fe_{1.60}O_4$.

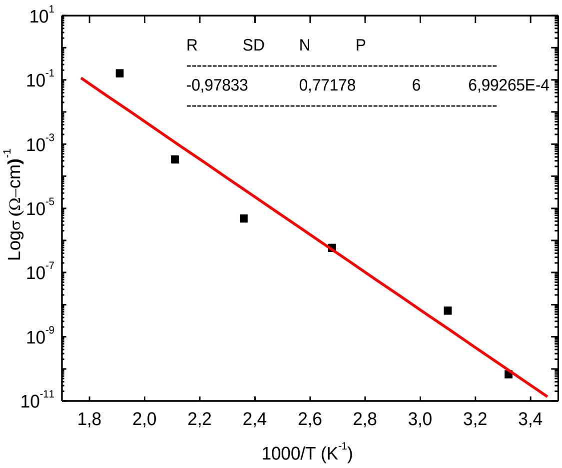

Figure 1f. The variation of Logσ with 1000/T is shown from the $BaNb_{0.10}Fe_{1.90}O_4$.

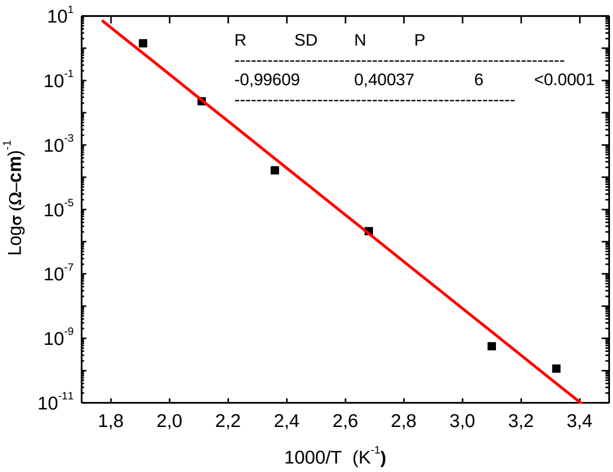

Figure 1i. The variation of Logσ with 1000/T is shown from the $BaNb_{0.60}Fe_{1.40}O_4$.

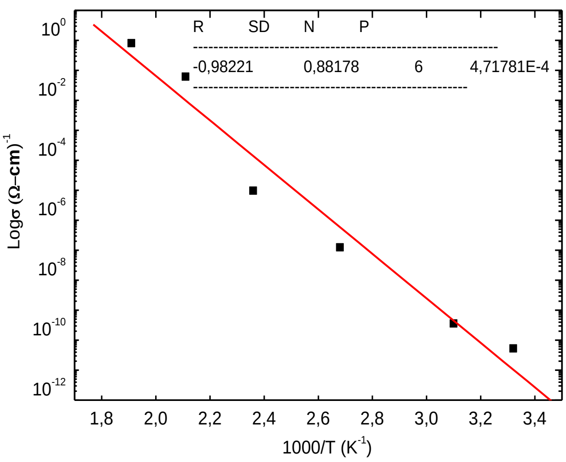

Figure 1g. The variation of Logσ with 1000/T is shown from the $BaNb_{0.20}Fe_{1.80}O_4$.

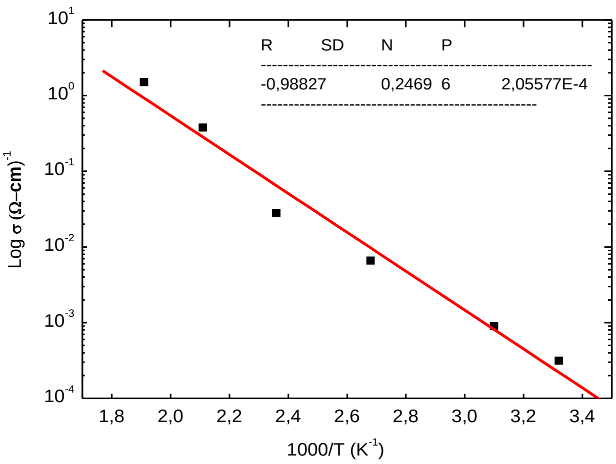

Figure 1j. The variation of Logσ with 1000/T is shown from the $BaNb_{0.80}Fe_{1.20}O_4$.

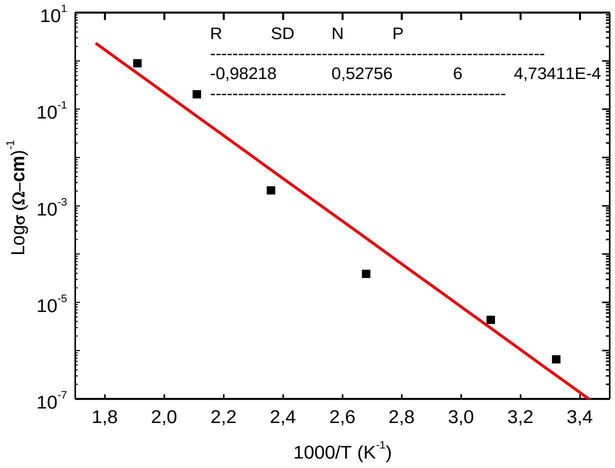

Figure 1k. The variation of Logσ with 1000/T is shown from the $BaNb_{1.00}Fe_{1.00}O_4$.

When more than one straight line is obtained this indicate the different conduction mechanisms. The slope of these lines given the activation energy in the low and high temperature regions, respectively obey the relation $\sigma=\sigma 0 \exp^{(-E/KT)}$ where E is the activation energy, K the Boltzmann constant and T is the absolute temperature.

The figures showed also that the value of log σ increase almost linearly with increasing temperature up which is the characteristic of semiconductor ferrites. With increasing thermal creation of theses carriers, so, the behavior of the activation energy was explained by the double exchange mechanism [14,19].

The values of the activation energy are also listed in fig.2.The reported data of activation energy can understand that the values of the low conductivity indicate that the elements with only one oxidation state are present at the B sites.

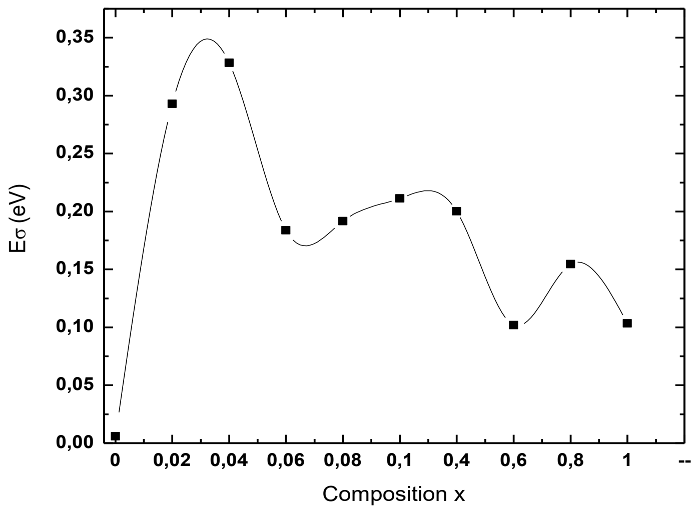

Figure 2. Composition dependence of activation energy

Variation of dielectric constant (ε') with the composition and frequency

The real part of dielectric were measured at as a function of higher frequency (20kHz – 1MHz) where ε' was calculated from the capacitance and is shows in Figure 3.

According to Rabkin et at. The process of dielectric polarization in ferrite takes place though a mechanism which is the same as that of conduction process [15-16]. In the samples when x=0.6 and 0.8 the mechanism increase ions of iron in the B sites leading to an increase in the polarization at the surface of the samples. All the samples revealed dispersion due to Maxwell-Vagner [17-18] interfacial polarization. The increase of frequency, decrease the dielectric constant due scattering process between s-s and s-d interbands, take place due to electron–phonon interaction which decreases the intergranular spacing giving rise the same hopping length in tetrahedral and octahedral sites.

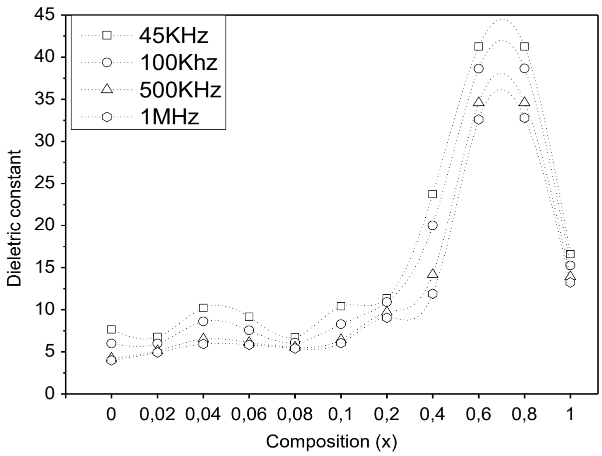

Figure3. Variation of dielectric constant (ε') with the composition and frequency

IV. CONCLUSION

The curves of the electric current in function of the applied voltage had presented for all the characteristic systems of a material semiconductor. Being that this $BaNb_{0.80}Fe_{1.20}O_4$ have lower electrical resistivity compared to the others. The dielectric constant decrease with increasing frequency. This behavior is explained qualitatively by the assumption that the mechanism of the polarization process in ferrite is similar to that of conduction process.

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