



DIRECT CURRENT (DC) RESISTIVITY MEASUREMENT OF EUROPIUM SUBSTITUTED YTTRIUM IRON GARNET

Shesherao S. Jawale

Department of Electronics, Yeshwantrao Chavan Mahavidyalaya, Tuljapur,
Dist-Osmanabad- 413 601, Maharashtra, INDIA.

Corresponding author: drssjawalepatil@gmail.com

ABSTRACT:

Samples of $Y_{3-x}Eu_xFe_5O_{12}$ ($x= 0.0$ to 0.5) were prepared by using high purity Y_2O_3 , Eu_2O_3 , Fe_2O_3 and using ceramic technique. The d. c. electrical resistivity measurements were carried out in the temperature range $300-800K$ using two-probe technique on the disc shaped pellets of 10 mm diameter and 3 mm thickness. The resistivity of all the samples decreases with increase in temperature.

KEYWORDS: Direct current (dc) resistivity, Yttrium iron garnet, two-probe technique

INTRODUCTION:

Electrical conductivity of ferrites has been the subject of many investigations since the synthesis of spinels by Snoek [01]. The low electrical conductivity in comparison with other magnetic materials has been the main feature of ferrites, For application at microwave frequency, conductivity value lower than 10^{-6} mho. cm^{-1} are required since the dielectric loss tangent depends upon conductivity. Ferrites play useful role in many technological applications because of their high electrical resistivity and sufficient low losses over a wide range of frequencies. It has observed that the electrical conductivity is markedly changed by controlling the firing temperature by atmosphere, by substituting with appropriate type and amount of substituent. Various investigators [2-4]. have studied electrical properties of ferrites substituted with iso and alio valent dopants.

The ferrite behaves as semiconductors with low mobility of charge carriers and an exponential dependence of electrical conductivity on temperature. The conventional band theory fails to predict the semiconducting properties of these materials. Bloch type wave functions are not appropriate for the description of electrons, which are almost wholly localized on specific cations, in such cases; the conduction has to be explained on the basis of hopping mechanism.

The electrostatic interaction between conduction electron (or hole) and nearby ions may result in a displacement of the latter and hence in polarization of the surrounding region so that the carrier becomes situated at the center of polarization potential wave.

The carrier is trapped at a lattice site, if this potential well is deep enough; its translations to a neighboring site is determined by thermal activation. This has been described by thermal activation. This has been described as the hopping mechanism, for such a process jumping of electrons and holes the mobilities are found to be proportional to

$$\text{Exp. } (\Delta E/kT)$$

Where,

ΔE - is an activation energy, k – is Boltzman constant and T – is absolute temperature

The conduction mechanism in ferrite is quite different from that in semiconductor. in ferrites the temperature dependence of mobility affects the conductivity and the carrier concentration is almost

affected by temperature variation. A mechanism of conduction has been proposed so long as ions of some parent atom but of different valence state are to be found in crystallographically similar positions in the lattice. Thus, the extra electron on the ferrous ions requires little energy in the form of heat, to move to a similar situated adjacent ferric ion. The valence state of two ions is interchanged under the electrons can be considered to constitute the conduction current from the jumping or hopping from iron ion to the next and hence, the conductivity becomes temperature dependence, and the resistivity (ρ) should decrease with increase in temperature according to the relation of the form

$$\rho = \rho_0 \exp (\Delta E/kT)$$

Where,

ρ_0 is the temperature dependence constants, k is Boltzman constants.

This relation is often observed and activation energy ΔE can be interpreted as the energy required for electron jump.

The above equation has been described as "Hopping mechanism" and the probability of hopping will contain a term proportional to $\exp (\Delta E/kT)$, where ΔE is activation energy. According to Heikes and Johnston [5-7]. expression for mobility of a charge carrier subjected to the hopping mechanism.

$$\mu = \frac{e^2 a^2 w_0}{kT \exp(\frac{\Delta E}{kT})}$$

Where, a is the distance between nears neighboring cations.

w_0 is the frequency of vibration of the crystal lattice.

The resistivity of ferrite shows an exponential dependence on temperature and in many cases the slope of the $\log \rho$ Vs $10^3/T$ plots changes at certain temperature of the sample.

The temperature dependence of d. c. resistivity of all the sample was studied using two-probe method, in the temperature range 300-600K. The samples in the forms of discs were polished well to have smooth parallel surfaces, and then these surfaces were contact. The sample was held in a simple holder and the whole assembly was placed in an electric furnace, the temperature of the furnace was controlled. A slow rate of change of temperature is maintained throughout the experiment. The temperature was measured using a calibrated chromel-alumel thermocouple in contact with the surfaces of the samples. The resistance of each pellet has been measured for rising and falling temperature. During each measurement, sufficient time was allowed for the sample to attain the equilibrium temperature. The resistivity ρ of the sample was calculated with the help of cross-sectional area and thickness of pellets using the following formula.

$$\rho_{dc} = [\pi r^2 / t] \times R \text{ ohm-cm}$$

Where, r is the radius of pallet, t is thickness of pellet and R is resistance of pellet.

EXPERIMENTAL:

Samples of $Y_{3-x}Eu_xFe_5O_{12}$ (x= 0.0 to 0.5) were prepared by using high purity Y_2O_3 , Eu_2O_3 , Fe_2O_3 and using ceramic technique. The oxides were mixed thoroughly in stoichiometric proportions to yield the desired composition and wet ground. The mixture was dried and presintered at 1050°C for 24 hours in air and cooled to room temperature. The powder was reground and pelletized using hydraulic press. The cylindrical pellets were finally sintered at 1350°C for 24 hours and slowly cooled to room temperature at the rate of 2°C per minute to obtain garnet phase.

The d. c. electrical resistivity measurements were carried out in the temperature range 300-800K using two-probe technique on the disc shaped pellets of 10 mm diameter and 3 mm thickness. For

good ohmic contact a silver paste was applied on both the surface of the pellets. The measurements were recorded in a regular interval of 20K. The temperature of the samples was sensed by Cr-Al thermocouple with an accuracy of $\pm 1^\circ\text{C}$.

RESULTS AND DISCUSSION:

The d. c. electrical resistivity measurements of all the samples were carried out using two-probe technique in the temperature range 300-800k for all the samples of $\text{Y}_{3-x}\text{Eu}_x\text{Fe}_5\text{O}_{12}$. The variation of electrical resistivity 'p' as a function of temperature for all the samples are shown in Fig. 4.10, Fig. 4.11 and Fig. 4.12.

The nature of these plots suggests that the curve is divided in two parts corresponding to ferromagnetic and paramagnetic region. The plot obeys the exponential relation,

$$P = p_0 \exp\left(\frac{E_g}{kT}\right)$$

Were,

E_g is activation energy,

p_0 is the temperature dependent factor and

k is Boltzman constant.

All the plots exhibit a kink near a temperature, which may correspond to the Curie temperature of the samples.

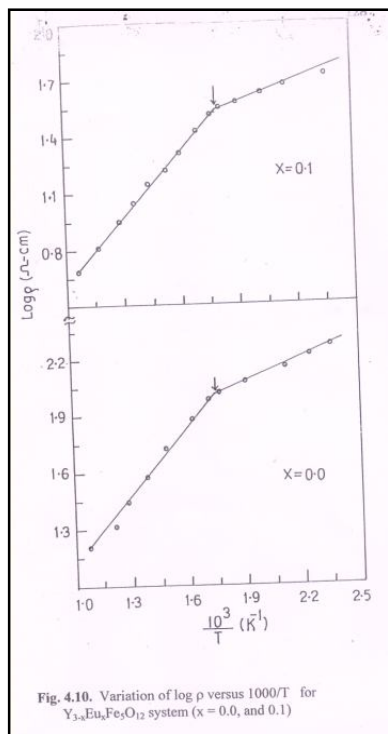


Fig. 4.10. Variation of log ρ versus 1000/T for $\text{Y}_{3-x}\text{Eu}_x\text{Fe}_5\text{O}_{12}$ system ($x = 0.0$, and 0.1)

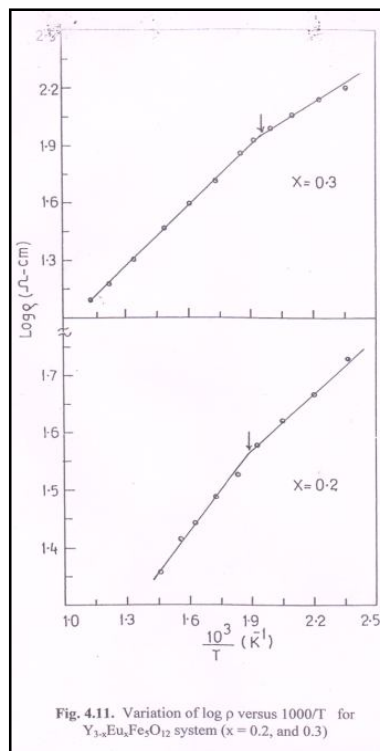


Fig. 4.11. Variation of log ρ versus 1000/T for $\text{Y}_{3-x}\text{Eu}_x\text{Fe}_5\text{O}_{12}$ system ($x = 0.2$, and 0.3)

Using the above equation and the plots of log ρ versus reciprocal of temperature, the activation energy of all the samples has been calculated and the values were presented in Table 4.1.

Table 4.1: Activation energy (E_g) for $Y_{3-x}Eu_xFe_5O_{12}$ system ($x = 0.0$ to 0.5)

Composition 'x'	Activation energy E_g (eV)		
	E_f	E_p	$\Delta E = E_p - E_f$
0.0	0.23	0.09	0.14
0.1	0.21	0.08	0.13
0.2	0.29	0.12	0.11
0.3	0.19	0.11	0.08
0.4	0.21	0.14	0.07
0.5	0.21	0.15	0.06

The variation of activation energy with Eu substitution is shown; it is decreases with increase in Eu substitution.

The analogous behaviour of $\log \rho$ versus $1000/T$ was observed in $R_{3-x}Ca_{2-x}Fe_{5-x}Me_{5-x}O_{12}$ (where, $R=Y, Sm, Eu, Gd$ and $Me=Sb$ and Nb) garnet system.

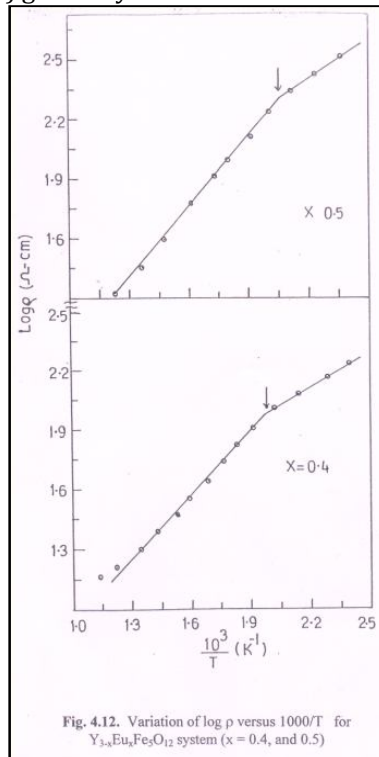


Fig. 4.12. Variation of $\log \rho$ versus $1000/T$ for $Y_{3-x}Eu_xFe_5O_{12}$ system ($x = 0.4$, and 0.5)

CONCLUSION:

The resistivity of all the samples decreases with increase in temperature. The activation energy obtained from $\log \rho$ versus $1000/T$ plots is in the reported range.

ACKNOWLEDGEMENT:

The author is thankful to Prof. Dr. K. M. Jadhav, Department of Physics, Dr. Babasaheb Ambedkar Marathwada University, Aurangabad for his guidance and support.

REFERENCES:

- [01] Cullity B. D., "Elements of X-ray Diffraction"(Addison Wesley Public Inc. Reading, mass) (1956).
[02] D. S. Birajdar, Devatwal U. N. and Jadhav K. M J. Mater. Sci. 37 (2002) 1443
[03] Jani N. N. Trivedi B. S., Joshi H. H. Bichile G. K. and Kulkarni R. G., Bull. Mater. Sci 21 (1998) 639
[04] A. K. Ghatge, S. A. Patil S. K. Parangpe, Sil. State Commun. 98 (1996) 885
[05] A. M. Shaikh, S. C. Watawe, S. S. Bellad, S. A. Jadhav, B. K. Chougule Mat. Chem. and Phys. 65 (2000) 46
[06] Shannon R. D. and Orewitt C. T., Acta. Cryst. B 25 (1969) B 20 (1970)
[07] Sung Ha Lee, Kwang Pyo Chae, Seok Won Hong and Yound Bae Lee Solid state Comm. 83 (1992) 97.