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# DIRECT CURRENT (DC) RESISTIVITY MEASUREMENT OF YTTRIUM-EUROPIUM GARNET ($Y_{2.8}Eu_{0.2}Fe_{5-x}Al_xO_{12}$)

**Shesherao S. Jawale**
Department of Electronics, Yeshwantrao Chavan Mahavidyalaya, Tuljapur,
Dist-Osmanabad- 413 601, Maharashtra, INDIA.
**Corresponding author:** drssjawalepatil@gmail.com

**ABSTRACT:**

Series of $Y_{2.8}Eu_{0.2}Fe_{5-x}Al_xO_{12}$ were prepared using by high purity oxides of $Y_2O_3$, $Eu_2O_3$, $Fe_2O_3$ and $Al_2O_3$. The d. c. electrical resistivity measurements were carried out on the disc shaped pellets using two-probe technique. A silver paste was applied on both surfaces of the pellet to ensure good electrical contacts. The measurements were recorded in the temperature range 300-800K. The resistivity of all the samples decreases with increase in temperature.

**KEYWORDS:** Chromel-alumel thermocouple, direct current (dc) resistivity, Yttrium iron garnet, two-probe technique

## INTRODUCTION:

Magnetic oxides are the most promising ferromagnetic materials from the application perspective. They are generally known as ferrites and their structure was put forward by Neel in 1948. Ferrites are classified into spinels, garnet ferrites and hexaferrites. Variety of cations can be substituted in these magnetic oxides owing to their structure. This substitution results in the changes of microstructure and the magnetic properties of magnetic oxides. Yttrium Iron Garnet is standing at the first position in the rare earth garnet family and it is a technologically important magnetic oxide. It was synthesized byresearchers named Bertaut and Forrat for the first time in 1956 [1]. Geller and Gilleo studied its structure and ferrimagnetism [2]. The study of YIG is important because it has low and adjustable saturation magnetization[3], extremely narrow line width[4], high electrical resistivity[5] and high radiation stability[6], a low dielectric loss[13] which makes it suitable for microwave devices like oscillators, isolators, circulators, latching phase shifter, filters and so on[7-12]. It has lowest spin-wave damping and high Curie temperature so that experiments can be performed at room temperature. They are also starting to appear in low-frequency instruments such as spectrum analyzers, signal sources, sweepers, counters and synthesizers. YIG serves as best microwave material in 1 to 10 GHz frequency band [13].

Electrical conductivity of ferrites has been the subject of many investigations since the synthesis of spinals by Snoek [14]. 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 [15-17]. 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,

$\Delta E$- 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 ($\rho$) should decrease with increase in temperature according to the relation of the form

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

Where,

$\rho_0$ is the temperature dependence constants, k is Boltzman constants.

This relation is often observed and activation energy $\Delta E$ 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 $\Delta E$ is activation energy. According to Heikes and Johnstion [18-20]. Expression for mobility of a charge carrier subjected to the hopping mechanism.

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

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:

The sample of the series $Y_{2.8}Eu_{0.2}Fe_{5-x}Al_xO_{12}$ were prepared using high purity oxides of $Y_2O_3$, $Eu_2O_3$, $Fe_2O_3$ and $Al_2O_3$. Appropriate quantities of the constituents were mixed thoroughly in agate pestle mortar for 4 hours. The resulting powders were ground for 2 hours. The powder were ground and preheated at $1100^0$C at 24 hours. Then it was further mixed and ground cylindrical pellets and fired at $1400^0$C for 24 hours. Finally, the pellets were cooled to room temperature at the rate of $2^0$C per minute.

The d. c. electrical resistivity measurements were carried out on the disc shaped pellets using two-probe technique. A silver paste was applied on both surfaces of the pellet to ensure good electrical contacts. The measurements were recorded in the temperature range 300-800K. Temperature of the sample was measurements were recorded in the sample was measured using chromel-alumel thermocouple. Sufficient time was given at each temperature so that the system attained stability. The accuracy of temperature measurement was $\pm 1^0$C.

## RESULTS AND DISCUSSION:

The electrical resistivity ($\rho$) of each compound in the pellet from were measured as a function of temperature in the range 300K-800K. The measurements were carried out using two-probe technique. Silver paste was applied on both the surfaces of the pellet to ensure proper electrical contact.

**Table 5.1: Activation energy ($E_g$) for $Y_{2.8}Eu_{0.2}Fe_{5-x}Al_xO_{12}$ system ($x = 0.0$ to $1.0$)**

| Composition 'x' | Activation energy $E_g$ $(ev)$ | | |
|---|---|---|---|
| | $E_f$ | $E_P$ | $\Delta E = E_f - E_P$ |
| 0.0 | 0.0695 | 0.0355 | 0.0341 |
| 0.2 | 0.2207 | 0.0993 | 0.1214 |
| 0.4 | 0.0993 | 0.0397 | 0.0596 |
| 0.6 | 0.3437 | 0.0099 | 0.3338 |
| 0.8 | 0.844 | 0.795 | 0.0050 |
| 1.0 | 0.0894 | 0.0298 | 0.0596 |

Graphs of logarithm of resistivity versus reciprocal of temperature were plotted for all the samples. Fig. 5.8 and fig. 5.9 shows the plots of log $\rho$ versus 1000/T for all the samples of the series

$Y_{2.8}Eu_{0.2}Fe_{5-x}Al_xO_{12}$.

All the plots show linear relationship. A change of slope is observed at the Curie temperature, which closely resemble to their ferromagnetic curie temperature.

The resistivity plots obeys the relation

$$\rho = \rho_0 \exp\left(\frac{E_g}{KT}\right)$$

Where,
$E_g$ is activation energy,
$\rho_0$ is the temperature dependent factor and K is Boltzman constant.

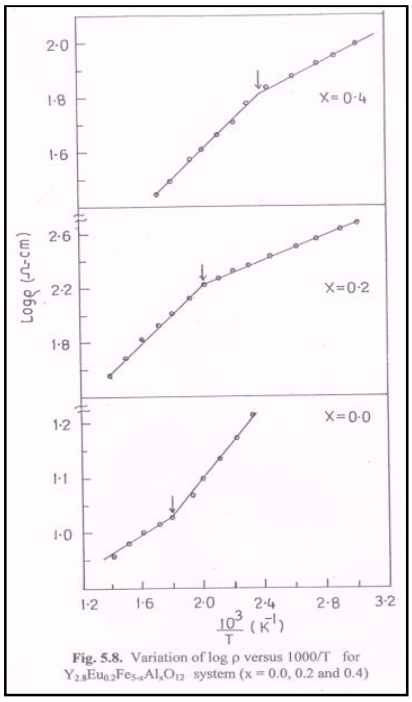


Fig. 5.8. Variation of log ρ versus 1000/T for $Y_{2.8}Eu_{0.2}Fe_{5-x}Al_xO_{12}$ system (x = 0.0, 0.2 and 0.4)

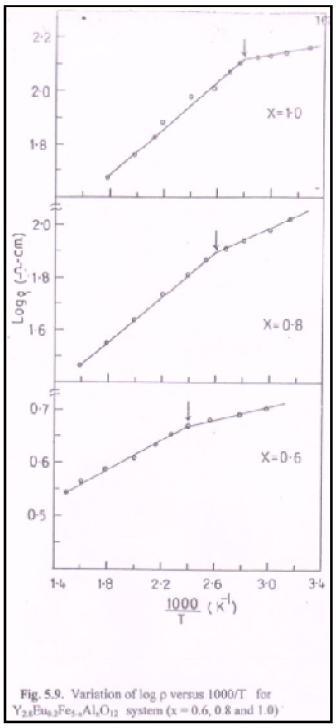


Fig. 5.9. Variation of log ρ versus 1000/T for $Y_{2.8}Eu_{0.2}Fe_{5-x}Al_xO_{12}$ system (x = 0.6, 0.8 and 1.0)

Using the plots of log $\rho$ versus 1000/T and above equation the values of activation energy for all the samples were calculated and the values are given in table 5.1. The plots yield to different values of activation energy below and above Curie temperature.

## CONCLUSION:

All the plots show linear relationship. A change of slope is observed at the Curie temperature, which closely resemble to their ferromagnetic curie temperature. The resistivity of all the samples decreases with increase in temperature. The activation energy obtained from log p versus 1000/T plots is in the reported range.

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## REFERENCES:

[1] Bertaut, F., Forrat, F.: The structure of ferromagnetic ferrite of rare earth. Compt. Rend. 242,382 (1956)
[2] Geller, S., Gilleo, M.A.: The crystal structure and ferrimagnetism of yttrium iron garnet. J. Appl.Phys. 41, 1355 (1970)
[3] Harris VG, Geiler A, Chen Y, Yoon SD, Wu M, Yang A, Chen Z, He P, Parimi PV, Zuo X, Patton CE, Abe M, Acher O, Vittoria C. Recent advances in processing and applications of microwave ferrites. J Magn Magn Mater 2009;321 362 (14):2035 - 47

[4] Z. Azadi Motlagh, M. Mozaffari , J. Amighian, A. F. Lehlooh, M. Awawdeh, S. Mahmood, Mössbauer studies of Y3Fe5−xAlxO12 nanopowders prepared by mechanochemical method,Hyperfine Interact DOI 10.1007/s10751-010-0234-z
[5] Haibo Yang, Ge Zhang, Ying Lin, Ting Ye, Pan Kang, Electrical, magnetic and magnetoelectric properties of BaTiO3/BiY2Fe5O12 particulate composites, Ceramics International, http://dx.doi.org/10.1016/j.ceramint.2015.01.139
[6] Kirischuk V et al. Long-term stability of yttrium - iron garnet films under irradiation by neutrons, protons, deuterons and electrons. Nucl Instrum Methods Phys Res Sect A 2007;580(1):419 - 22.
[7] Chen, Y.F., Wu, K.T., Yao, Y.D., Peng, C.H., You, K.L., Tse, W.S.:The influence of Fe concentration on Y3Fe5−xAlxO12 garnets. Microelectron. Eng. 81, 329 - 335 (2005)
[8] Ravi BG, Guo XZ, Yan QY, Gambino RJ, Sampath S, Parise JB. Phase evolution and magnetic properties of Al substitutedyttrium iron garnet nanopowders and plasma- sprayed coatings. Surf Coat Technol 2007;201(16 - 17):7 597 - 605.
[9] E. J. J.Mallmann, A.S.B.Sombra, J. C. Goes, P. B. A.Fechine, Yttrium Iron Garnet: Properties and Applications Review, Solid State Phenomena Vol. 202 (2013) pp 65-96, doi:10.4028/www.scientific.net/SSP.202.65
[10] Ce-Wen Nan, M. I. Bichurin, Shuxiang Dong, D. Viehland, and G. Srinivasan, Multiferroic magnetoelectric composites: Historical perspective, status, and future directions, J. Appl. Phys. 103, 031101 (2008); doi: 10.1063/1.2836410
[11] J.P. Ganne, R. Lebourgeois, M. Paté, D. Dubreuil, L. Pinier, H. Pascard, The electromagnetic properties of Cu-substituted garnets with low sintering temperature, Journal of the European Ceramic Society, 27 (2007) 2771-2777
[12] J. Douglas Adam et al IEEE TRANSACTIONS ON MICROWAVE THEORY AND TECHNIQUES, VOL. 50, NO. 3, MARCH 2002
[13] Martha Pardavi-Horvath, Microwave applications of soft ferrites, Journal of Magnetism and Magnetic Materials 215-216 (2000) 171-183.
[14] Cullity B. D., "Elements of X-ray Diffraction"(Addition Wesley Public Inc. Reading, mass) (1956).
[15] D. S. Birajdar, Devatwal U. N. and Jadhav K. M J. Mater. Sci. 37 (2002) 1443.
[16] Jani N. N. Trivedi B. S., Joshi H. H. Bichile G. K. and Kulkarni R. G., Bull. Mater. Sci 21 (1998) 639
[17] A. K. Ghatge, S. A. Patil S. K. Parangpe, Sil. State Commun. 98 (1996) 885
[18] A. M. Shaikh, S. C. Watawe, S. S. Bellad, S. A. Jadhav, B. K. Chougule Mat. Chem. and Phys. 65 (2000) 46
[19] Shannon R. D. and Orewitt C. T., Acta. Cryst. B 25 (1969 ) B 20 (1970)
[20] Sung Ha Lee, Kwang Pyo Chae, Seok Won Hong and Yound Bae Lee Solid state Comm. 83 (1992) 97.