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MAGNETIC PROPERTIES OF YTTRIUM-EUROPIUM GARNET $Y_{2.8}Eu_{0.2}Fe_{5-X}Al_xO_{12}$ SYSTEM

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ABSTRACT:

The samples of $Y_{2.8}Eu_{0.2}Fe_{5-x}Al_xO_{12}$ system were prepared by 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 1100^0C at 24 hours. Then it was further mixed and ground cylindrical pellets and fired at 1400^0C for 24 hours. Finally, the pellets were cooled to room temperature at the rate of 2^0C per minute. It is observed that the saturation magnetization and magneton number both decreases with increase in Al substitution.

KEYWORDS: Yttrium-europium garnet, Saturation magnetization, magneton number

INTRODUCTION:

Magnetic semiconductor ferrites were studied extensively due to their wide field of technological application. The crystal structure of these materials controls their physical properties. The electrical and magnetic properties of ferrites depend upon the method of preparation, nature of dopants, dopant concentration, etc. The properties of prime importance are resistivity, magnetization, Curie temperature and permeability. All these properties can be modified so as to suit the desired application by selecting a suitable method of preparation, nature and type of dopant etc.

Mixed metal oxides with iron oxide as their main components are known as ferrites. They have been studied over a long period of five to six decades for their basic properties as well as wide range of applications. Ferrites have been recognized as one of the most important electro-ceramic in modern industry and its processing and application technology has been improved. In the last twenty years ferrites, ferromagnetic ceramics emerged as one of the important materials due to their high electrical resistivity with low eddy current losses. They show a wide diversity of composition, properties and applications. They have established their use in many branches in communication and engineering because of their applicability at high frequency without excessive losses.

Ferrites are magnetic ceramic usually composed of iron and metals possessing combined properties of magnetic conductor and electrical insulator. Magnetic oxides, which are commonly known as ferrites are ferromagnetic in structure [1-5].

The ferromagnetic oxide yttrium iron garnet (YIG) is an important material for a number of technical applications. Depending on the type of application, it is used in the form of bulk, single crystal,

epitaxially grown thin film or polycrystalline sintered samples. These three forms are necessarily properties, e.g. resistivity, optical absorption, lattice constant and photo magnetic properties [6]. Thus, the study of electrical and magnetic properties of pure yttrium iron garnet and substituted yttrium iron garnet is important from the theoretical and application point of view. The magnetic crystallographic properties of pure yttrium iron garnet and substituted yttrium iron garnet have been studied extensively [7-9].

To our knowledge very few reports of the structural, electrical and magnetic properties of substituted yttrium iron garnet are available in the literature [10-12]. In the present work, systematic investigations of magnetic properties of yttrium-europium garnet $Y_{2.8}Eu_{0.2}Fe_{5-X}Al_xO_{12}$ system were carried out.

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 1100^0C at 24 hours. Then it was further mixed and ground cylindrical pellets and fired at 1400^0C for 24 hours. Finally, the pellets were cooled to room temperature at the rate of 2^0C per minute.

The saturation magnetizations of the ferrite sample were measured with the help of high filed hysteresis loop tracer at room temperature. The experimental set up of electromagnet; pick up coil system, balancing and integral circuits and a preamplifier. The instrument is provided with an air gap of 1 cm width, wherein variable alternating field can be produced. The multi-coil slide in to the pole gap and the current in the emerging coil were increased to produce the required magnetic field. The balancing network were adjusted such that there will be horizontal line on oscilloscope screen, when there was no specimen in multi-coil. The current was then reduced to zero and the coil was pulled out and reintroduced in the pole gas with the sample placed in its center. The current in the emerging coil was raised to a sufficient value till the sample saturates. The hysteresis loop is visible on the screen when respective signals were supplied to the vertical and horizontal deflecting plates of the oscilloscope.

The vertical displacement, which corresponds to saturation magnetization of hysteresis on screen was calibrated by placing a small nickel sample between the two pole pieces. Calibration factor (C.F.) for Ni is

$$\textbf{C. F.} \ \frac{\text{Standard magnetization for Ni x mass of Nickel}}{\text{Vertical displacement in mV}}$$

The vertical displacement (h) in terms of mV were taken at room temperature for each sample and saturation magnetization was calculated using the relation

$$\sigma_s = h(mV) \times C.\ F.\ (emu/mV)$$

The magnetic moment per formula unit Bhor magneton (n_B) is given by

$$n_B = \frac{\sigma_S \ x \ molecular \ weight \ of \ sample}{5585}$$

Using hysteresis loop technique the saturation magnetization (σ_s) and magneton number (n_B) were obtained.

RESULT AND DISCUSSION:

The saturation magnetization per formula unit in Bohr magneton, i.e. magneton number n_B (μ_B) was calculated for all the samples using hysteresis loop technique. The data of magnetization were recorded at room temperature. The values of saturation magnetization σ_s and magneton number n_B are summarized in table 5.1.

Table 5.1: Saturation magnetization (σ_S) for magneton number n_B (μ_B) for $Y_{2.8}Eu_{0.2}Fe_{5-x}Al_xO_{12}$ system ($x = 0.0$ to 1.0)

Com. 'x'	σ_S (emu/g)	Magneton number n_B (μ_B)		Magneton number $n_B(\mu_B)$ normalized	
0.0	31.080	4.17	4.556	1.000	1.000
0.2	27.1995	3.62	4.356	0.868	0.956
0.4	24.346	3.22	4.156	0.772	0.912
0.6	20.720	2.72	3.956	0.652	0.868
0.8	16.576	2.15	3.756	0.516	0.824
10	11.655	1.50	3.556	0.360	0.781

It is observed from table 5.1 that saturation magnetization σ_s and magneton number n_B decreases with the addition of non-magnetic aluminum.

The variation of magneton number n_B with addition of Al content x is depicted in fig. 5.5.

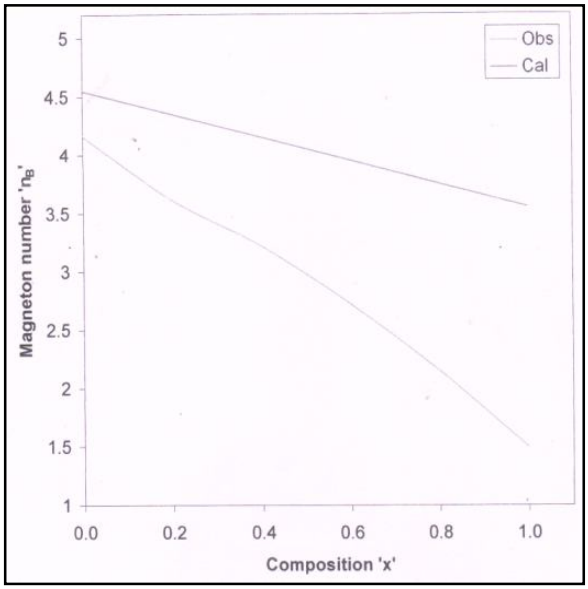

Fig. 5.1Variation of observed and calculated magnetron number 'nB' with concentration 'x' for the system $Y_{2.8}Eu_{0.2}Fe_{5-x}Al_xO_{12}$

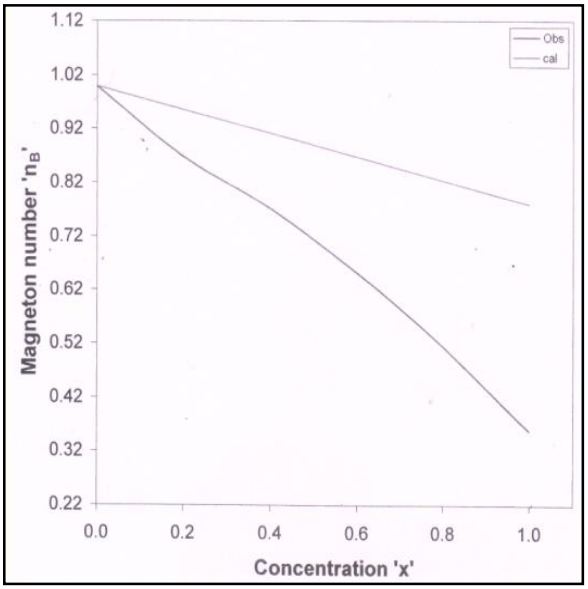

Fig. 5.2 Variation of normalized and calculated magneton number 'nB' with concentration 'x' for the system $Y_{2.8}Eu_{0.2}Fe_{5-x}Al_xO_{12}$

It can be observed from Fig. 5.1that magneton number n_B decrease with increase in Al content X. this is due to fact that Al^{3+} ions replaces magnetic Fe^{3+} ions of 5 μ_B, thereby decreasing the magneton

linkages. Similar behaviour of magneton number n_B with substitution of non-magnetic ions was observed [13].

Applying the Neel's model to $Y_{2.8}Eu_{0.2}Fe_{5-x}Al_xO_{12}$ garnet system, the Neel's magnetic moment for all the samples were calculated. The Neel's magnetic moments for all the samples were calculated. The Neel's magnetic moment for system is given by

$$n_B^N = M_D - (M_A + M_C)$$

Where,
$M_D, M_A, and\ M_C$ are the magnetic moments for d, a and c site respectively.

The calculated magnetic moment values for all the samples are given in table 5.1. It is clear from table 5.1 that observed and calculated value $of\ n_B$ decreases with Al substitution. The observed and calculated value of magneton number (n_B) do not match with each other suggesting that a significant canting exist. The variation of calculated magneton number with Al substitution is also shown in fig. 5.1. for sake of comparison. The graph of normalized observed and calculated magneton number versus composition is shown in Fig. 5.2.

The normalized values of observed and calculated magneton number are presented in table 5.1

CONCLUSION:

1. The saturation magnetization magneton number both decreases with increase in Al substitution.
2. The observed and calculated magnetic moment both decreases with Al substitution but differ from each other

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