IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
Volume 3, Issue 1, March 2020
Impact Factor: 4.819

X-Ray Diffraction and Di-Electrical Property Study of Lanthanum (La^{3+}) Substituted Yettrium Iron Garnet

Ganesh B. Akat
Department of Chemistry,
Kohinoor Arts, Commerce & Science College, Khultabad Dist. Aurangabad (MS), India
ganeshbakat@gmail.com

Abstract: *Polycrystalline yttrium lanthanum iron garnets $Y_3La_xFe_{5-x}O_{12}$ (x = 0.0, 0.2 and 0.4) with varying La substitution ($0 \leq x \leq 0.4$) have been prepared in the pellet form and studied by X-ray diffraction and di-electrical property measurements. The lattice constants are determined, and the applicability of Vegard's law has been tested. The garnet series has the general formula $Y_3La_xFe_{5-x}O_{12}$ (x = 0.0, 0.2 and 0.4) and that were synthesized by using doublesintering solid state reaction method. The samples were characterized by X-ray diffraction technique (XRD). The X-ray diffraction studies of compositions revealed the formation of single-phase cubic structure with lattice constant ranging from 12.48 to 12.35 Å up to x = 0.4. The dielectric properties were investigated using LCR-Q meter in the frequency range 100 Hz to 1 MHz. The dielectric constant (ε'), dielectric loss (ε'') and dielectric loss tangent (tan δ) were measured as a function of frequency by using LCR-Q meter. The frequency dependence of dielectric measurements was carried out for given samples.*

Keywords: Garnet, YLaG, X-ray diffraction, Dielectric Properties

I. INTRODUCTION

Iron oxide and other metal oxides combine to form ferrites, which are ferrimagnetic oxides. Ferrites are divided into three types based on their crystal structures: garnet, spinel, and hexagonal ferrite. Because of their superior properties, structural, magnetic, electrical, and catalytic—which are all distinct from those of their bulk counterparts and their potential for use in a variety of cutting-edge fields, including magnetic drug delivery, catalysts, sensors, biological, biomedical, and medical science, spinel ferrites are the subject of extensive research. Due to their multiple uses in a variety of industries, ferrites are a significant class of materials that are in high demand. Ferrites' chemical composition and technique of preparation have a significant impact on their electrical and magnetic properties. For intended uses, ferrites' electrical and magnetic properties must be optimized. Scientists, researchers, and engineers are still interested in inventing different sorts of ferries materials that are substituted with various cations with variable valences and manufactured using various processes because of their intriguing features.[1,2,3.]

Because of its use in circulators, gyrators, and phase shifters, as well as its small ferromagnetic resonance linewidth, high electrical resistivity, and low dielectric loss in microwave regions, yttrium iron garnet (YLaG), one of the different types of ferrites, is of particular importance to scientists and technologists.[3] Microwave ferrite, or yttrium iron garnet (YLaG), has unique properties when it is polycrystalline. Numerous researchers have looked at the magnetic and crystallographic characteristics of magnetic iron garnet.[4-9] Wide band nonreciprocal microwave devices have made substantial use of substituted iron garnets[11-12]

II. EXPERIMENTAL

Initial studies on the effect of small substitutions of lanthanum for iron in polycrystalline yttrium iron garnet showed a substantial increase in the initial permeability over that of YLaG. Since previous substitution of other ions has produced either little change or a decrease in the permeability, we have studied the effect of lanthanum substitution on the garnet

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
Volume 3, Issue 1, March 2020
Impact Factor: 4.819

structure in more detail. The samples of La^{3+} substituted $Y_3La_xFe_{5-x}O_{12}$ garnets with x = 0.0,0.2 and 0.4 were prepared by well-known double sintering ceramic method in which a molar ratio of analytical Y_2O_3, Fe_2O_3 and La_2O_3 were mixed thoroughly in stoichiometric proportions and then ground to very fine powder by using agate mortar for about 4 hr. These mixtures in powder form were pre-sintered in programmable muffle furnace at 1300 ^{0}C for 23 h and cooled to room temperature slowly at the rate of 2 ^{0}C/min. The samples were reground and re-fired at 1350 ^{0}C for 28 h and slowly cooled to room temperature at the rate of 2^0 C/min., and then reground for 1 h. Thefine powdered sample was pelletized under the pressure of 5 ton/inch^2.

Structural measurements

Typical X-Ray diffraction pattern for x = 0.2 sample in shown in the following Fig.1. The mixed garnet ferrites system under investigation has been structurally investigated by X-ray diffraction technique.

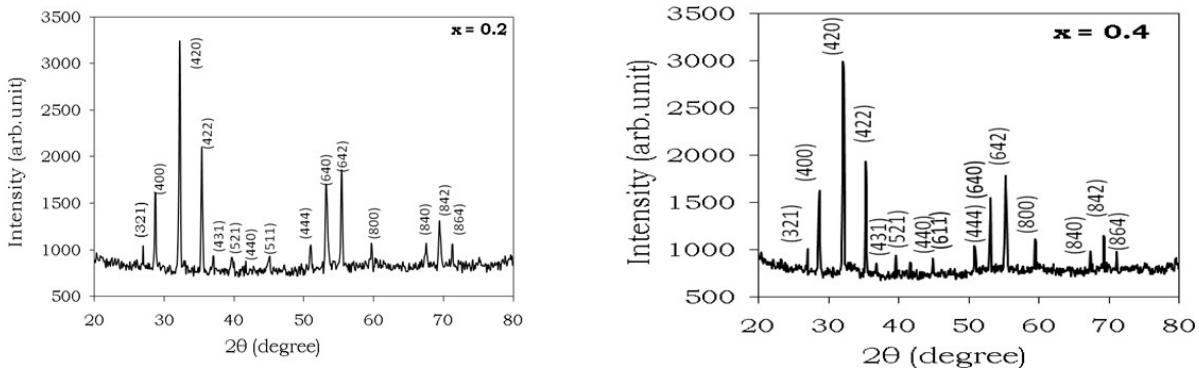

Fig. 1: X-Ray diffraction pattern of $Y_3La_xFe_{5-x}O_{12}$ for x = 0.2 and x=0.4 sample.

The XRD pattern shows the reflections namely (321), (400), (420), (422), (431), (521), (611), (444), (640), (642), (800) and (842). No extra peaks other than cubic structure have been observed in the XRD pattern. The Bragg peaks are sharp and intense. The lattice parameters are calculated using XRD data and are given in table 1. It is observed from table-1 that lattice constant (Fig.2) increases with increase in lanthanum content 'x' as shown in Fig.1. The ionic radii of yttrium (0.90Å) Fe^{3+} is (0.68Å) and lanthanum (0.82Å) hence we observe variation in the lattice parameter with lanthanum substitution. The bulk density of all samples was measured using Archimedes principle and values are tabulated in table 1. Bulk density increases with increase in lanthanum content 'x'. Using the values of molecular weight andvolume of the sample X-ray density was calculated. The values of X-ray density are also listed in table1.

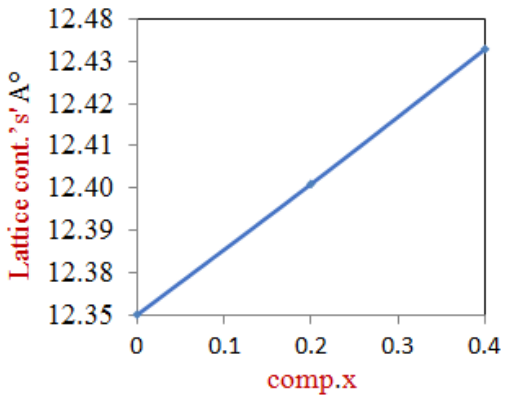

Fig. 2: Lattice constant of $Y_3La_xFe_{5-x}O_{12}$ (x = 0.0, 0.2 and x=0.4)

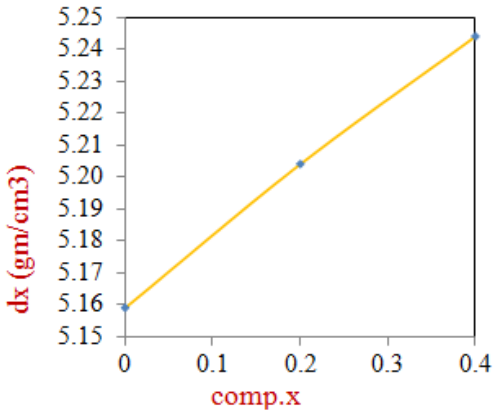

Fig. 3: X-ray density of $Y_3La_xFe_{5-x}O_{12}$ (x = 0.0, 0.2 and x=0.4)

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
Volume 3, Issue 1, March 2020
Impact Factor: 4.819

x	a (Å)	dx (gm/cm^3)	dB (gm/cm^3)	P (%)	t (µm)
0.0	12.350	5.151	4.12	20.23	3.37
0.2	12.401	5.201	4.18	19.94	3.23
0.4	12.441	5.241	4.24	19.01	3.14

Table 1: Lattice constant (a), X-ray density (dx), bulk density (dB), porosity (P) and particle size (t) of $Y_3La_xFe_{5-x}O_{12}$.

X-ray density increases with composition 'x' as shown in Fig.3. The observed variation in X- ray density is attributed to an increase in volume of the samples. The crystallographic parameters (lattice constant, X-ray density) are in good agreement with reported values.[12] The most intense peak (420)of XRD pattern was used to evaluate particle size of the samples. The particle size was calculated by using Scherer's formula, the values of particle size for all the composition is listed in Table 1.

III. RESULTS AND DISCUSSIONS

Dielectric measurements

The dielectric constant measurements were carried out on disc shaped pellets as a function of frequency by using two probe methods. The real ε and imaginary 111 parts of the dielectric constant andloss tangent tan δ of Y3LaxFe5-xO12 were computed according to Smith and Wijn.[13,14] The variation of the dielectric constant and dielectric loss 111 with respect to frequency at room temperature is shown in Fig 4 (a). It can be observed from figures 4 (a) that dielectric constant and fig.4 (b) dielectric lossboth decreases with increase in frequency. It can also be observed that dielectric loss decreases with increasing frequency much more rapidly than. This behavior of dielectric constant is attributed by assuming that mechanism of polarization in ferrite is similar to that of conduction mechanism. Iwauchi.[15] reported strong co-relation between the conduction mechanism and dielectric behavior of the ferrites.[16-19] Fig. 4(c) shows the variation of dielectric loss tangent with frequency at 300 K for all the values of 'x'. It is observed from Fig. 4(c) that the parameter tan δ decreases exponentiallywith the increase of frequency.

x	Frequency								
	100 (Hz)			10 (kHz)			1(MHz)		
	ε '	ε "	tan δ	ε '	ε "	tan δ	ε '	ε "	tan δ
0.0	861	261	0.29	712	121	0.27	483	111	0.24
0.2	891	372	0.41	851	339	0.39	501	171	0.35
0.4	921	421	0.45	889	391	0.42	510	189	0.38

Table: 2 Room Temp. dielectric constant (ε′), dielectric loss (ε″) and dielectric loss tangent (tanδ) at 100 Hz, 10 KHz and 1 MHz of $Y_3La_xFe_{5-x}O_{12}$.

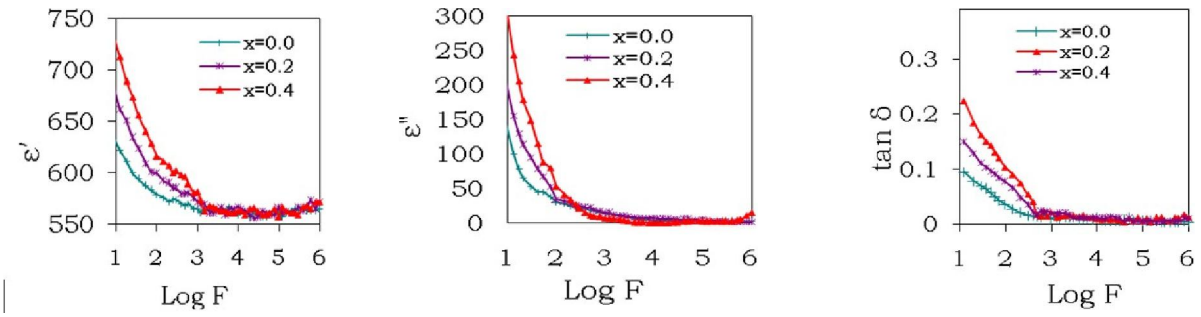

Fig.4: Variation of (a) dielectric constant (□'), (b) dielectric loss (□'') and (c) dielectric loss tangent(tan □) with logarithm of frequency (log f) of $Y_3La_xFe_{5-x}O_{12}$ (x = 0.0, 0.2 and 0.4)

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
Volume 3, Issue 1, March 2020
Impact Factor: 4.819

IV. CONCLUSION

The garnet system Y3LaxFe5-xO12 (x = 0.0, 0.2 and 0.4) has been successfully prepared by standard ceramic technique. The X-ray diffraction results showed the formation of single-phase cubic spinel structure. The Lattice constant (a), X-ray density (dx), bulk density (dB), porosity (P) and particle size (t) are in the reported range. The lattice parameter increases slightly with La3+ substitution. The dielectric constant (□□) and dielectric loss (□□□) both decreases with increase in frequency. It can also be observed that dielectric loss (□□□) decreases with increasing frequency much more rapidly than (□□). The dielectric loss tangent (tan δ) also decreases exponentially with the increase in frequency.

REFERENCES

[1]. R.G. KulKarni and V.U. Patil, J. of Mat. Sci. 17 (1982) 843
[2]. J. Baszsynski- Acta Phys. Poilym 35 (1969) 631
[3]. Ibetombi Soibam, Sumitra phanjoubam, H. B. Sharma, H N K Sharma and Chandra Prakash. Ind. J. Phys. 83 (3) (2009) 285.
[4]. B. K. Kuanr, P. K. Singh, P. Kisan, N. Kumar, S.L.N. Rao, G.P. Srivastava. J. Appl. Phys. 8 (1986) 63
[5]. Guo Cuijing, Zhang Wei, Ji Rongjin, Zeng Yanwei. J.Magn. Magn. Mater. 323 (2011) 611.
[6]. S. Geller and M. A. Gilleo J. Phys. chem. Solids 3 (1957) 30.
[7]. M. A. Gilleo and Geller S.Phys. Rev. 110, (1958) 73.
[8]. M. A.Gilleo, J. Phys. Chem. Solids 13 (1960) 33.
[9]. E. E. Anderson, J. Phys. Soc. Japan Suppl. 17 (1962) 365.
[10]. B. Lax and K. Button, "Microwave ferrites and ferri-magnetics", McGraw-Hill Book Co. Inc New York (1962).
[11]. J. Richard Cunningham and Elmer, E. Anderson J.Appl.Phys.32, (1961) S388
[12]. J. Smit and H. P. J. Wijn, Ferrites, New York, Wiley, 1959.
[13]. Hongjie Zhao Ji Zhou Yang Bai Zhilun Gui Longtu Li, J. Magn. Magn. Mater. 280 (2004) 208.
[14]. K. Iwauchi, Jap. Appl. Phys. 10 (1971) 1520.
[15]. V. R.K. Murthy and J. SobhandriPhys. Status Solidi (A) 38 (1977) 647
[16]. E.J.W. Verwey and J. H, DeboerRed. Trans Chim. Phys. Boss 55 (1936) 531
[17]. Van L.G. Uitert J. Chem. Phys 23 (1956) 1294
[18]. Van L. G. Uitert J. Chem. Phys 23 (1955) 1883
[19]. K.H. Rao Ph.D. Thesis, Andra University, Waltair (1981)