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"STRUCTURALANDηBSTUDY OF In^{3+}SUBSTITUTED YTTRIUM IRONGARNET"

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ABSTRACT

Objective: To prepare and study the In^{3+}substituted yttrium iron garnet with reference to structural parameters and IR spectra

Materials and Methods: In^{3+} was added in to yttrium iron garnet (YIG) with a nominal composition of $Y_3In_xFe_{5-x}O_{12}$ with x= 0.0, 0.2 and 0.6. The Samples were prepared by a solid-state sintering method. The samples were characterized by X-ray diffraction technique. The X-ray diffraction studies of compositions revealed the formation of single phase cubic structure with lattice constant ranging from 12.37Å to 12.44 Å. The FTIR spectra of typical samples are taken in the range of 500-4000cm^{-1}.

Results:IR spectra show typical absorption bands indicating the garnet nature of samples.

Conclusion: Magneton number 'η_B'decreases with increasing In^{3+} content x.

Keywords: *Yttrium irongarnet, indium, structural properties and magneton number.*

INTRODUCTION

Mixed metal oxides with iron (III) oxides as their main component are known as ferrites. Historically ferrites represent an important category of materials, which are in great demands due to their numerous applications in many fields. The electrical and magnetic properties of ferrites are strongly dependent on their chemical composition and their method of preparation [1, 2]. It is important to optimize the electrical and magnetic properties of ferrites, for desired applications. Due to their interesting properties scientists, researchers and engineers are still interested in designing the various types of ferries material substituted with different cations with different valencies and prepared by different techniques.

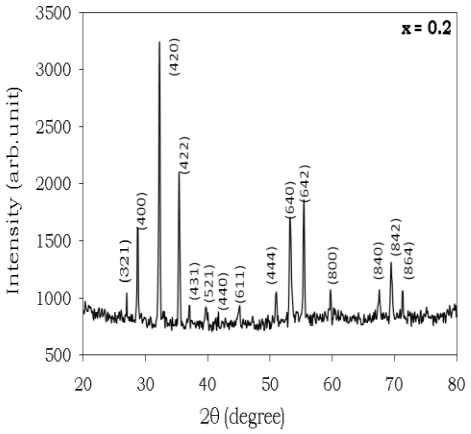
In the various types of ferrites rare earth garnet especially yttrium iron garnet (YIG) is of great importance for scientist and technologist because of their applications in microwave communication devices such as circulators, oscillators, gyrators and phase shifters because of its small ferromagnetic resonance line-width, high electrical resistivity and low dielectric loss in microwave regions in many fields [3].Yttrium iron garnet (YIG) is microwave ferrite, which in polycrystalline form has specific characteristics. The magnetic and crystallographic properties of the magnetic iron garnet have been studied by many workers [4-7]. Substituted iron garnets have found extensive use in wide band non reciprocal microwave devices [8].

Experimental

The samples of In^{3+} substituted $Y_3In_xFe_{5-x}O_{12}$ garnets with x = 0.0,0.2 and 0.6 were prepared by well-known double sintering ceramic method in which a molar ratio of analytical Y_2O_3, Fe_2O_3 and In_2O_3 (all 99.99% pure AR grade chemicals, Mumbai) were mixed thoroughly in stoichiometric proportions and then ground to very fine powder by using agate mortar for about 3 hr. These mixtures in powder form were pre-sintered in a Indfur Programmable muffle furnace at 1200 ^{0}C for 24 hr 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 30 hr and slowly cooled to room temperature at the rate of 2^0 C/min., and then reground for 1 hr. The fine powdered sample was pelletized under the pressure 5 ton/inch^2.

RESULT AND DISCUSSION

Mixed garnet ferrites system under investigation has been structurally investigated by X-ray diffraction technique. The typical XRD pattern shows the reflections namely (321), (400), (420), (422), (431), (521), (611), (444), (640), (642), (800), (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 increases with increase in indium content 'x'. The ionic radii of yttrium (0.89Å) Fe^{3+} is (0.67Å) and indium (0.81Å) hence we observe variation in the lattice parameter with indium 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 indium content 'x'. Using the values of molecular weight and volume of the sample X-ray density was calculated. The values of X-ray density are also listed in Table-1. X-ray density increase with composition 'x'. The observed variation in X-ray density is attributed to increase in volume of the samples. The crystallographic parameters (lattice constant, X-ray density) are in good agreement with reported values [9] .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.



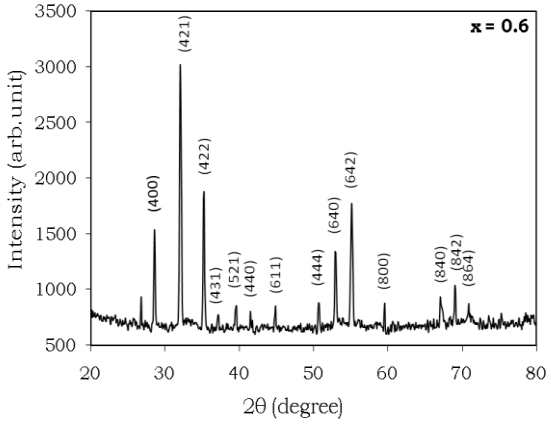


Fig. 1: Typical XRD patterns of $Y_3In_xFe_{5-x}O_{12}$. (x = 0.2 and 0.6)

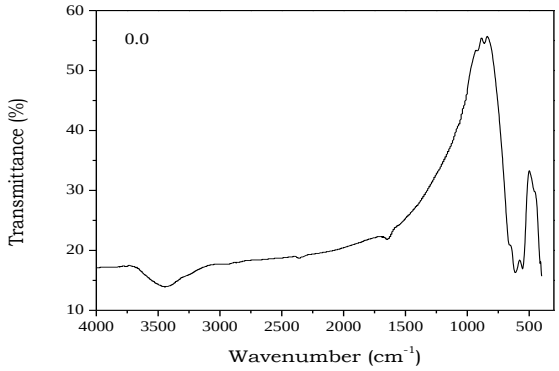
Table: 1Lattice constant (a), X-ray density (dx), Bulk density (d_B) porosity (P) and particle size (t) of $Y_3In_xFe_{5-x}O_{12}$.

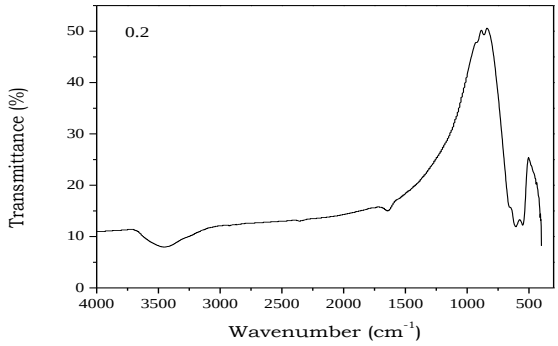
x	a (Å)	dx (gm/cm³)	d_B (gm/cm³)	P (%)	t (µm)
0.0	12.370	5.179	4.13	20.25	3.42
0.2	12.401	5.224	4.19	19.97	3.25
0.6	12.443	5.333	4.36	18.24	3.53

IR spectra from fig.2 show typical absorption bands indicating the garnet nature of the samples. The band positions obtained from IR spectra are given in Table-2thevibrational frequency depends upon the cation mass, cation oxygen bonding force, distance etc. From IR spectra, it is revealed that, a broad band appears at around 611 cm^{-1}, 547 cm^{-1} and 670 $cm^{-1,}$ assignable to the stretching mode of the tetrahedral in the YIG and this indicates that the crystallization of samples is more complete [10-12]. The values of absorption bands are given in Table 2. Our results on IR studies are in good agreement with the literature reports. [13]

Table: 2Vibrational band frequencies (ν_1, ν_2, ν_3, ν_4) of $Y_3In_xFe_{5-x}O_{12}$, for x = 0.0, 0.2, 0.6

x	ν_1 (cm^{-1})	ν_2 (cm^{-1})	ν_3 (cm^{-1})	ν_4 (cm^{-1})
0.0	547.1	611.9	670.1	---
0.2	547.1	605.5	861.0	914.0
0.6	469.5	609.7	865.9	914.9





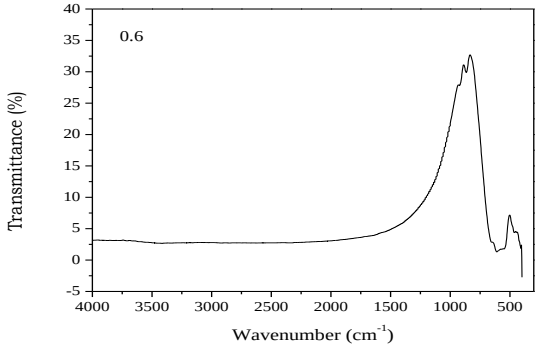


Fig.2: IR spectra of $Y_3In_xFe_{5-x}O_{12}$ of typical sample x = 0.0, 0.2, and 0.6.

Fig 4 shows variation of magneton number 'η_B'with In^{3+} content x. From field dependence of magnetization and observed magnetic moments (Table 3), it is clear that, samples with x = 0.0, 0.2and 0.6 shows ferrimagneticbehavior which decreases with In^{3+} content x. It can be seen from Fig 3 that, the spontaneous magnetization decreases very slowly with x. In the present series $Y_3In_xFe_{5-x}O_{12}$, In^{3+} is substituted for Fe^{3+} ions. Based on Neel's theory of ferrimagnetism in ferrites, [15] the substitution of non-magnetic ions like In^{3+} in place of Fe^{3+} ions at octahedral [a] can lead to a decrease in saturation magnetization as shown in Table 3 and Fig.3 However, the observed magneton number decreases with non-magnetic In^{3+} ions. Assuming that In^{3+} ions occupy octahedral [a] sites, Y^{3+} ions occupy dodecahedral {c} sites and Fe^{3+} ions [a] and (d) sites, the cation distribution can be written as

$$[Fe_{1-X}\ In_x]^{a}\ \{Y^{3+}\}^{c}\ (Fe)^{d.} \qquad \ldots.2$$

Using above proposed cation distribution, the magneton number for each sample was calculated. The calculated values of magneton number are listed in Table 3, it is observed from Table 3, that calculated magneton number and observed do not match with each other. The observed discrepancy in the magneton number can be explained on the basis of Yafet Kittle angle [16].

Table 3: Ms emu/gm and ηB of $Y_3In_xFe_{5-x}O_{12}$.

comp. x	Mol. wt	Ms emu/gm	Ms*Mol. wt	ηB
0	737.98	31.1672	23000.77	4.118312
0.2	749.774	26.3095	19726.18	3.531993
0.6	773.362	21.3261	16492.8	2.953052

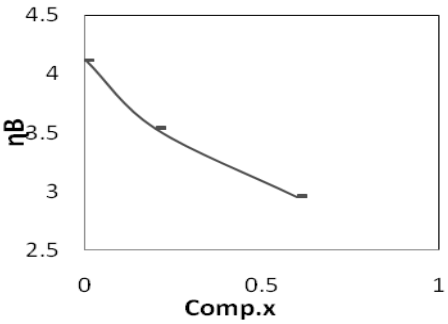


Fig. 3: Variation of magneton number (η_B) versus comp.x

CONCLUSION

The garnet system In-YIG was prepared by a solid-state sintering method. The parameter lattice constant increases slightly with In^{3+} substitution. IR spectra show typical absorption bands indicating the garnet nature of the samples.Magneton numbers decreases with composition x.

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