J Integral Sci, 2018, Volume 1, Issue 1, 25-28. ISSN: 2581-5679

www.jisciences.com

Research Article

Journal of Integral Sciences

Synthesis and Photoluminescence studies of Eu doped $Y_3Al_5O_{12}$ phosphor

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Received: 13th March 2018 Revised: 22st March 2018 Accepted: 25th March 2018

Abstract

The present study reports the synthesis and variation of photoluminescence behavior of $Y_3Al_5O_{12}$ (YAG) with respect to Eu concentration. The phosphor was synthesized using standard solid state reaction technique (SSR). The prepared phosphor materials were characterized using powder X-ray diffractometry [XRD], scanning electron microscopy [SEM], and Photoluminescence [PL] (Emission and Excitation). We have studied the effect of dopants on the photoluminescence YAG phosphor monitoring at 400nm. From the PL emission spectrum as increasing the Eu concentration the luminescence peaks at 592nm, 610nm and 631nm are gradually increased which is the fundamental emission of Eu. It is found that, the YAG: Eu^{+3} phosphors can act as phosphor in compact fluorescent lamps and the results may conclude, these nano phosphors may be a good candidates for display devices.

Keywords: Solid State Reaction, Photoluminescence, Rare Earth ions and X-ray diffraction.

1.0 Introduction

Recently, many researchers are studying on improvement of luminescent properties of phosphor to develop different luminescence devises (Shinoya and Yen, 1999). The rare earth ions doped with inorganic compounds forms an significant class of phosphors which have more stability, color emision and finally luminescence. Yttrium aluminum garnet (YAG) phases have been widely used as a host material for lasers and phosphors for their excellent luminescent properties and stable physical and chemical properties. Recently, YAG doped with a small amount of element such as Eu, Ce and Tb has been evolved due to a widely utilized in many fields, such as optical display panels, cathode ray tubes, optoelectronic, sensitive devices, nanoscale electronic and plasma display panels due to their special chemical and physical properties (Hinastu *et al.,* 1999). So, the present study carried out on the synthesis and variation of photoluminescence behavior of $Y_3Al_5O_{12}$ (YAG) with respect to Eu concentration.

2.0 Materials and Methods

2.1 Chemicals and apparatus

All the chemical reagents were analytical grade. For synthesis of YAG phosphor pure and doped with varying concentrations of Eu (0.5, 1.0, 1.5, 2.0, 2.5 and 3.0 mol %) rare-earth ions prepared using solid state reaction. Stoichiometric proportions of raw materials namely Yttrium Oxide (Y_2O_3), Aluminum Oxide(Al_2O_3), by adding Europium oxide(Eu_2O_3) were used as starting materials, and grinded in motor and mixed and compressed into a crucible and heated at 1200°C for 4 hours in a muffle furnace at the rate of 300°C per hour. Synthesized materials were characterized by X-ray diffractometer (XRD) (Synchrotron Beam Indus -II) with Cu Kα radiation (λ = 0.15406 nm), Scanning Electron Microscope (SEM) (JEOL, JSM-6380), Spectrofluorophotometer (SHIMADZU, RF-5301 PC) using 150 Watt Xenon lamp as excitation source.

2.2 Synthesis and Physical Characterization

The stoichiometric proportions are weighed and ground into a fine power using agate mortar and

pestle for 1 hour, the ground samples were placed in an alumina crucible and heated at 1200°C for 4 hours in muffle furnace with a heating rate of 5°C /min. The samples are allowed to cool to room temperature in the same furnace for about 20 hours. The prepared samples were again ground in to powder for taking the characteristic measurements. All the synthesized phosphor samples were characterized by X-ray diffraction (Synchrotron Beam Indus -II) to identify the crystallinity and phase purity of the phosphor. Spectrofluorophotometer (Schimadzu, RF-5301 PC) with 150 watt Xenon lam as excitation source at room temperarure was used to measure photoluminescence (PL) emission and excitation spectra. The particle morphology of the prepared solid nano powders was characterized by SEM.

3.0 Results and Discussion

3.1 Phase characterization

The XRD patterns of YAG: xEu (x=2.5) phosphors are can be observed and all the diffraction peaks matched well with the Joint Committee on Powder Diffraction Standards (JCPDS) No.33-0040 (pure YAG) (Fig. 1). All the reflection peaks can be voluntarily indexed to those of the pure cubic phase with primitive structure of YAG (PDF 33-0040) with space group Ia3d, no other impurity phases were detected at these doping levels (Kondala Rao *et al.*, 2015). The results showed the expected chemical components in the phosphors. It is obvious that Eu3+ ions successfully substituted Y^{3+} ions and the small amount of Eu^{3+} ions in YAG host lattice did not change its crystalline structure.

3.2 The characterization of luminescent properties

Fig 2 is the PL emission and excitation when the pure phosphor is monitored at 400nm, the excitation found at 254nm which is curve-1 and curve-2 is when the phosphor is excited with 254nm the emissions are found at 365,400,469 with intensity 107, 84 and 67 units. The emission at 365 is at strongest which is attributed to crystal field of the material. The emissions 400nm and 469nm are due to release of electron from O^- ions on excitation. This is due to low crystalline density of the phosphor material (Sankar and Subba Rao, 2000).

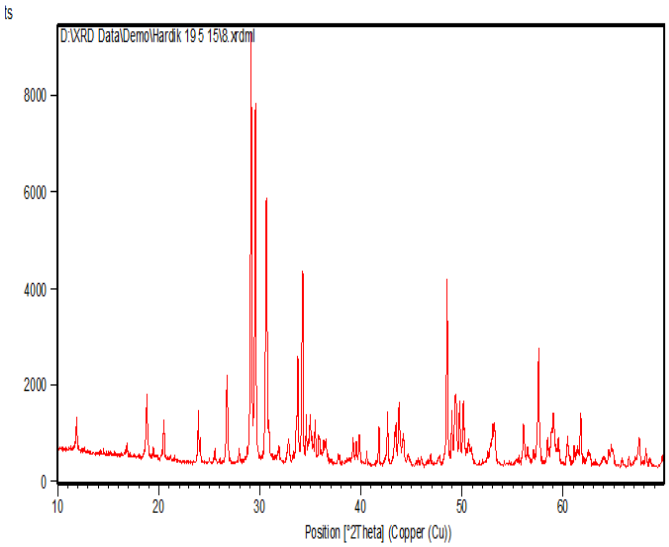

Fig 1. XRD pattern of Eu^{3+} doped YAG phosphor

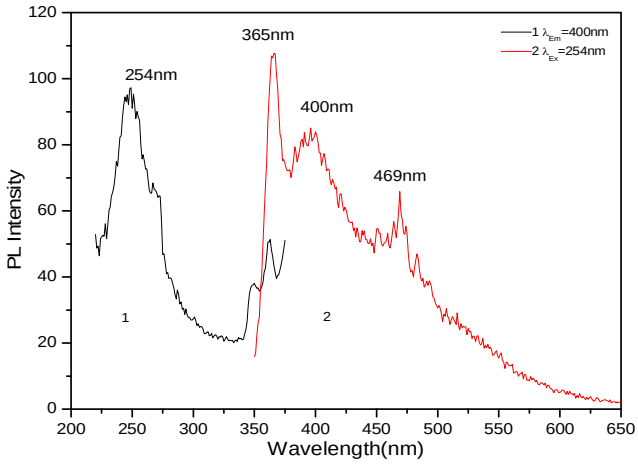

Fig 2. Excitation and Emission spectrum pure YAG phosphor

Fig 3 is the PL emission and excitation spectra of Y3Al5O12 phosphor with various Eu [0.5, 1, 1.5, 2, 2.5 and 3%] concentrations. All the phosphors are excited with 254nm and the emission is recorded from 350 to 650nm. The samples demonstrate strong excitation peaks at 254 nm, which conforms to the value of the charge transfer band in the YAG:Eu3+ system. Therefore, stronger charge transfer transitions providing the energy to the excited 5D levels can lead to luminescence enhancement in well dispersed nanocrystals (Feldmann *et al.*, 2003). This additional transition (CTS) besides the charge transfer band

(CTB) will provide energy to the $5D_J$ states of Eu^{3+}, and the absorbed energy in ^5D_J states will transfer to ^7F_J states. Hence, the charge transfer to Eu^{3+} will become more probable, leading to the enhancement of luminescence emission in the YAG:Eu^{3+} nanoparticles. The 365,399,469nm peaks observed in undoped YAG and also Eu doped phosphors the position and intensities are nearly same. The doping of the Eu generates a hump in green region that is at 535nm whose intensity is nearly same for all the Eu concentration in YAG phosphor. The other emissions from Eu^{3+} in YAG phosphors are 592,610,631 along with other satellite peaks of Eu. As the Eu concentrations increases in YAG phosphors the PL intensity of the 592,611,631 nm peaks increases its intensity up to Eu (2.5%) in YAG phosphor. After 2.5% of Eu in YAG phosphor the intensity marginally decreases. This is due to the standard quenching effect. Which is attributed to the columbic repulsion of nearby Eu ions leads to non release of electrons from 4f shells. The emissions 592,610,631 are standard Eu^{3+} ions, which is attributed to the following transitions of RE^{3+}. The emission peaks are produced by Eu^{3+}. 592nm ($^5D_0 \rightarrow {}^7F_1$), 610nm ($^5D_0 \rightarrow {}^7F_2$) and 631($^5D_0 \rightarrow {}^7F_3$) (Kondala Rao *et al.*, 2015), it is interesting to note here the emissions below 600 are considered magnetic dipole component and above 600 components are attributed to hyper sensitive electric component of the phosphor material.

3.3 SEM analysis

The typical SEM micrographs of the phosphor powders are depicted in Fig 4. The morphology of resulting sample which reveals the formation of polycrystalline material with grain size shape distribution is irregular and average grain size is in sub-micrometer range, due to agglomeration of smaller grains which forms due to thorough crushing and high temperature processing of the samples (Danielson *et al.*, 1998; Rahul *et al.*, 2007). This proves the solid state synthesis method is approving for synthesis macro structured samples of reported phosphor. The size of particles were range in 2-5μm.

From SEM images (Ropp, 1991) it has been noted that the agglomeration of synthesized powder phosphors has been increased with the change in Eu content, owing to the density variation.

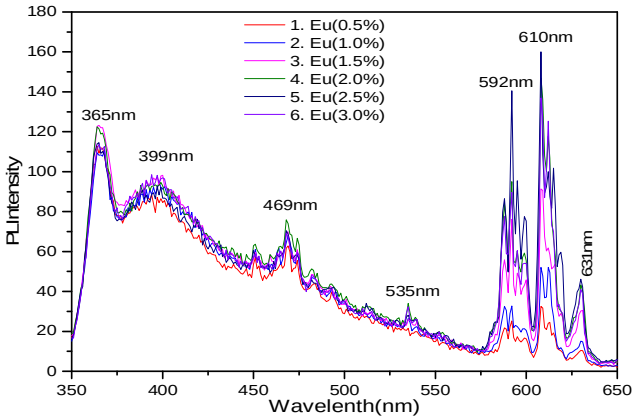

Fig 3. Excitation and Emission spectrum Eu^{3+} doped YAG phosphor

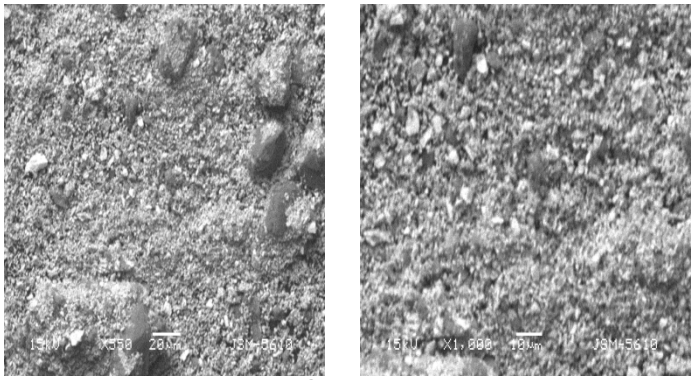

Fig 4. SEM of Eu^{3+} doped YAG phosphor

4.0 Conclusion

The YAG base and Eu^{3+} doped YAG phosphors were successfully synthesized by conventional solid state reaction method and its photoluminescence studies were investigated in detail. The YAG based orange red emitting phosphor, tested by X-ray diffraction pattern and SEM micrographs show the formation of microcrystalline sample. The photoluminescence studies of synthesized Eu^{3+} doped YAG phosphor material shows intense orange red emissions at 592nm and 610nm & 631nm corresponding to characteristic transitions corresponding to MD ($^5D_0 \rightarrow {}^7F_1$) and ED ($^5D_0 \rightarrow {}^7F_2$ & $^5D_0 \rightarrow {}^7F_3$) of Eu^{3+} ion under the excitation wavelength of UV 254nm respectively. These phosphors with fine shape emissions may find

potential applications in the fields of minute color displays in the near future. The luminescence enrichment observed in the nano phosphors is of practical importance for this system to be applied to field emission devices.

Conflict of interest

We have none to declare.

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