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Luminescence Studies of Tb Doped $YGdB_2O_6$ Phosphor

P. Sai Raju[1], D. Srinivasa Rao[2], A.S. Sai Prasad[3], B. Subba Rao[4] and **K.V.R. Murthy[5]**

[1]*Department of Physics, Venus Junior College, Ongole, A.P, India*
[2]*Department of Physics, BVSR Engineering College, Chimakurty, India*
[3]*Department of Physics, Vasavi College of Engineering, Ibrahim Baug, Hyderabad, India*
[4]*Department of Physics, VSR & NVR College, Tenali, India*
[5]*Display Materials Laboratory, Applied Physics Department,*
Faculty of Technology & Engineering, M.S University of Baroda, Vadodara, India

Abstract— *$YGdB_2O_6$ phosphors were synthesized using standard solid state reaction [SSR] method with varying Tb molar concentration as 0.1, 1.0, 1.5 and 2.0%. The mixture of reagents was ground together to obtain a homogeneous powder in acetone base. To prepare Yttrium Gadolinium Borate (YGB) doped with various concentrations of Tb, consists of heating stoichiometric amounts of reactants at 1000°C for 2 h in a muffle furnace. The received powder being ground thoroughly using an agate mortar, to ensure the best homogeneity and reactivity, powder was transferred to alumina crucible, and then reheated in a muffle furnace at 1200°C for 4 hours. The phosphor materials were cooled to room temperature naturally. All samples were found out to be white who are studied for photoluminescence [PL]. Photoluminescence spectra were recorded at room temperature using Shimadzu-5301 Spectrofluorophotometer. The prepared phosphors were characterized by using techniques such as powder X-ray diffraction (XRD), Photoluminescence (PL), Scanning electron microscopy (SEM, EDS), Particle size analysis and Commission International de l'Eclairage (CIE). The effect of doping of Tb in YGB on the PL emission/excitation was also studied. Tb shows all its primary allowed emissions hence it is concluded that this phosphor can be used in display devices.*

Keywords— *Photoluminescence, X-ray diffraction [XRD], Scanning Electron Microscopy [SEM], EDS, Solid State Reaction.*

1. INTRODUCTION

Figures 1 - 3 are the emission & excitation of $YGdB_2O_6$: Tb phosphor under different excitation wavelengths. From figure the excitation is a broad band from 230-280 nm, absorption peaks at 237, 265 & 275 nm. As the Tb concentration increases the absorption peak intensities gradually increases up to 1.5% Tb in $YGdB_2O_6$ phosphor goes out of range. When Tb in 2 mol% the absorption peak intensity reduced by 20% when compared to $YGdB_2O_6$: Tb (1.5 mol%). All the four phosphor samples are excited with 237, 254, 265 & 275 nm. The excitation spectra are monitored at 545nm. The 254nm excitation is considered due to application potential of this phosphor are in devices CFL, Fluorescent Lamps etc. When excited with 237, 254, 265 & 275 nm the emission peaks are dissolved at 487, 545, 552 and a less intense band at 587 - 594 nm.

1.1 Why Solid State Reaction Method

- It is better to prevent waste than to treat or clean up waste after it has been created.
- SSR method output gases are mostly CO_2, H_2O and NH_4 etc., can be stabilized in atmosphere.
- Atom Economy is defined as synthetic methods should be designed to maximize the incorporation of all materials used in the process into the final product.
- Less Hazardous Chemical Syntheses wherever practicable, synthetic methods should be designed to use and generate substances that possess little or no toxicity to human health and the environment. Chemical reactions should be designed to affect their desired function while minimizing their toxicity which is nothing but designing safer chemicals
- If possible, synthetic methods should be conducted at ambient temperature and pressure.
- In SSR most of the above conditions are satisfied except the temperature. Therefore SSR can be called green chemistry route

2. EXPERIMENTAL

The following is the final basic reaction used to prepare the YGB:Tb_x phosphors

$$Y_2O_3+Gd_2O_3+2B_2O_3+Tb_2O_3 \xrightarrow[\text{Air}]{1200\ ^oC,\ 2\ Hrs} YGdB_2O_6\text{: Tb}$$

2.1 General Flow Chart of Phosphor Synthesis

Raw Materials (Matrix, Activator) → Blending, Mortar and pestle (Laboratory scale) → Synthesis (firing 1200°C for 2 hours) → Coarse Crushing → Final Product→Characterization→ Applications

2.2 Characterization Techniques

Photoluminescence spectra were recorded at room temperature using Shimadzu - 5301 Spectrofluorophotometer and the phosphor is excited with 254, 268 and 278nm excitations. Due to high emission intensity of the present phosphor the sample holder is redesigned as follows: Shimadzu-5301 Spectrofluorophotometer supplied sample holder diameter: 25mm. We made 15, 10, 8, 5mm dia sample holders so as to record the PL within the range of the machine (1015units). In the present study 8mm diameter sample holder was used. The phosphors were characterized using XRD and SEM.

3. RESULTS AND DISCUSSIONS

3.1 Photoluminescence Study

Fig.1 is the emission & excitation of $YGdB_2O_6$: Tb phosphor under different excitation wavelengths. From figure the excitation is a broad band from 230-280 nm, absorption peaks at 237, 265 & 275 nm. As the Tb concentration increases the absorption peak intensities gradually increases upto 1.5% Tb in $YGdB_2O_6$ phosphor goes out of range. When Tb in 2 mol% the absorption peak intensity reduced by 20% when compared to $YGdB_2O_6$: Tb (1.5 mol %). All the four phosphor samples are excited with 237, 254, 265 & 275 nm. The excitation spectra are monitored at 545nm. The 254nm excitation is considered due to application potential of this phosphor are in devices CFL, Fluorescent Lamps etc. When excited with 237, 254, 265 & 275 nm the emission peaks are dissolved at 487, 545, 552 and a less intense band at 587 - 594 nm.

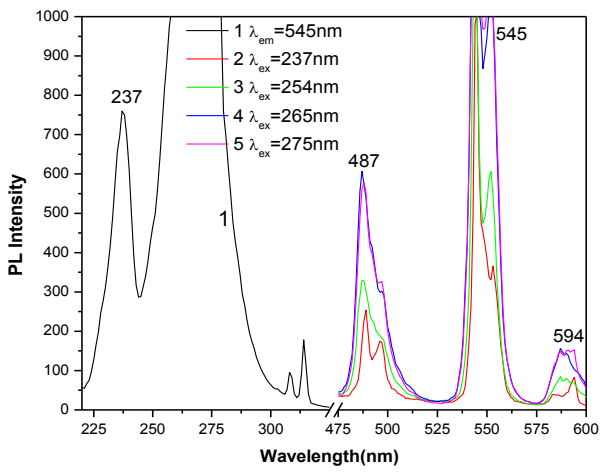

Fig. 1: PLE and PL spectra of $YGdB_2O_6$:Tb(1.5%) phosphor under different excitations

Table.1 contains various emission peak intensities of Tb doped YGB under different excitations presented for better comparison and understanding.

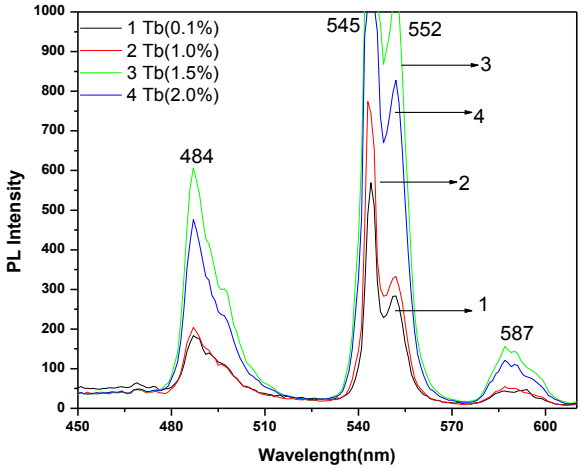

Fig. 2: PL spectra of Tb (0.1 – 2.0%) doped $YGdB_2O_6$ phosphor under 265nm excitation

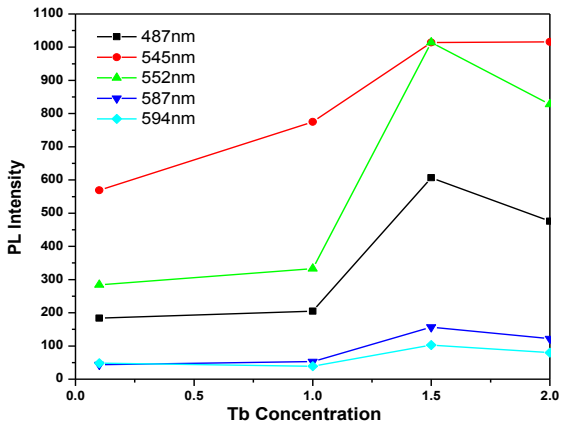

Fig. 3: Tb concentration Vs PL intensity of emission peak wavelengths of $YGdB_2O_6$ phosphor

Fig.2 PL emission spectra of Tb doped $YGdB_2O_6$ under 265nm excitation. It is interesting to note the emission at 484, 545 and 552 are very good intensities and with less intense band at 587- 594 nm is found for 1.5 mol % Tb doped under 265 nm. The behavior of PL observed for various peaks in Tb doped $YGdB_2O_6$ phosphor when excited with 265nm is presented in fig 3 and the same is tabulated in Table-1 for better understanding. Table 2 is the emissions from the phosphors and the transistors of Tb^{3+}.

Table 2

Wavelength (nm)	*Transitions*	*Energy (eV)*
484	$^5D_4 \rightarrow {}^7F_6$	2.562
545	$^5D_4 \rightarrow {}^7F_5$	2.275
552	$^5D_4 \rightarrow {}^7F_5$	2.246
584	$^5D_4 \rightarrow {}^7F_4$	2.123
594	$^5D_4 \rightarrow {}^7F_4$	2.087

3.2 XRD Study

Fig.4 is the XRD patterns of $YGdB_2O_6$ doped with Tb phosphor. The calculated crystallite size is 45.39nm respectively. As it is found that, the same host containing the same concentrations (1.5%) of RE^{3+} doped phosphor forms different crystallite sizes. The variation may be due to the RE^{3+} ions diameter. More the diameter of the ions, lesser is the crystallite size. In the present case 'Tb' doped phosphor having 5% less crystallite size when compared to Eu doped phosphor.

3.3 SEM Study

Fig.5 is the SEM micrographs of $YGdB_2O_6$: Tb (1.5%) phosphor of different magnifications. The particles are irregular in shape and agglomerated and the size is around 2 - 5 microns.

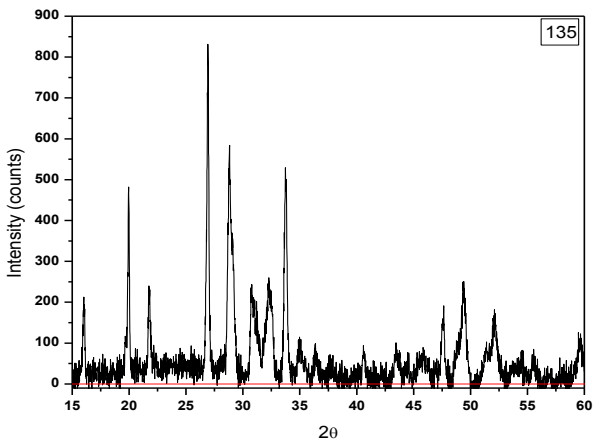

Fig. 4: XRD pattern of $YGdB_2O_6$:Tb(1.5%) phosphor

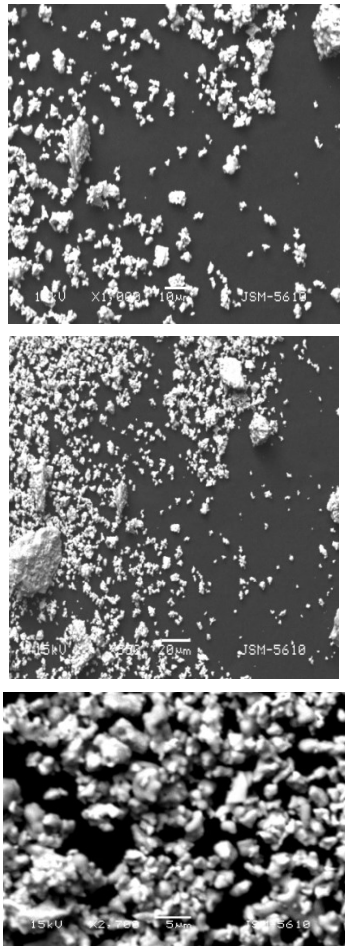

Fig. 5: SEM images of 1.5% Tb doped $YGdB_2O_6$ phosphor

3.4 EDS Study

Fig.6 is the EDS spectrums of the phosphor under characterization. From the EDS spectrum it is found most of the phosphors consist of host and dopants only. However from Fig.6 consists of few impurity elements like Nickel, Cobalt, Gallium, Tantalum, Tungsten, and Copper. The Cu & W may be from the instrument accessories. Other elements are in ppm level which can be found from intensities on the Y – axis of EDS (Energy Dispersion Spectrum) spectra of different phosphors. The impurities Nickel, Cobalt, Gallium, and Tantalum are from the rare earth oxides.

Table 1: Intensity of various emission peaks of $YGdB_2O_6$:Tb^{3+} (0.1, 1.0, 1.5, & 2.0 mol%) phosphor under 265nm excitation

Sr. No.	*Excitation Wavelength*	*Tb Concentration (mol%)*	*Intensity of different Emission peaks under 265nm Excitation*			
			487	*545*	*552*	*587*
1	265nm	0.1	184	569	284	44
2		1.0	205	775	333	53
3		1.5	607	>1014	>1014	157
4		2.0	476	>1016	828	122

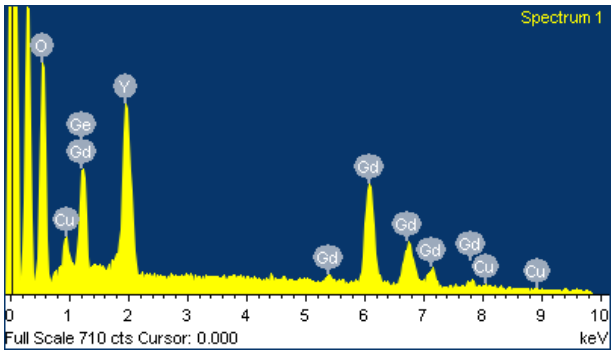

Fig. 6: EDS spectrum of 1.5% Tb doped $YGdB_2O_6$ phosphor

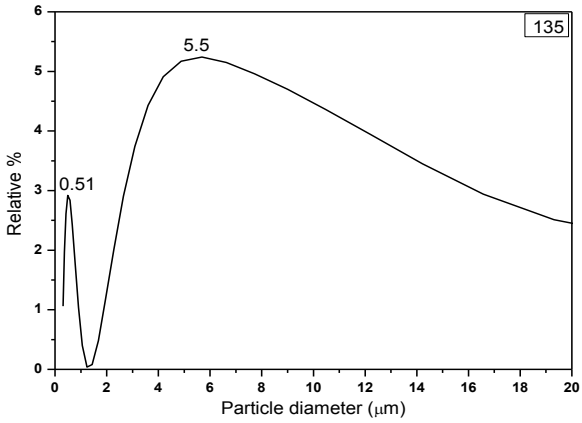

Fig. 7: Particle size histogram of 1.5% Tb doped $YGdB_2O_6$ phosphor

From fig.7 it is observed the sub micron particles apart from 5.5 micron average particles are found.

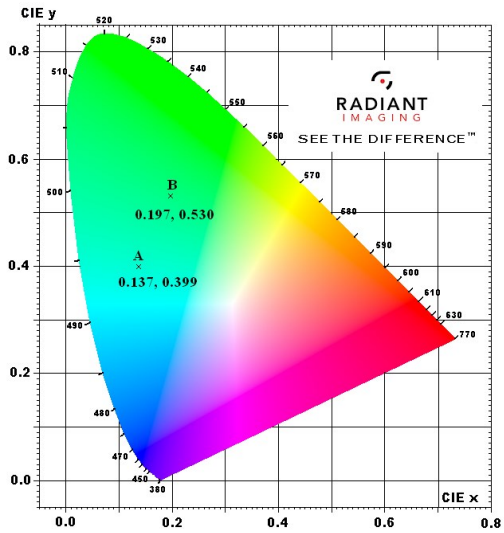

Fig. 8: CIE colour co-ordinates of GdB_2O_6:Tb(1.5%) phosphor A) Under 254nm Ex. B) under 275nm Ex.

From Fig.8 it is found the green dominated emission is observed in the present studied phosphpor.

4. CONCLUSIONS

Tb^{3+}(1.5 mol %) doped $YGdB_2O_6$ phosphor displayed three bands at 480-500, 540-560 and 580-600 nm, blue, green and low intensity yellow bands. Among all the four phosphors studied this will be best phosphor suitable for blue-green emission (cyan) decorative lamps. The quenching effect of all the PL emissions in 2% Tb doped $YGdB_2O_6$ phosphor is due to more Tb^{3+} ions nearby (adjacent) in the host leads opposite coulomb attraction. Due to that the standard luminescence quenching is marginally observed in 2% Tb doped $YGdB_2O_6$ phosphor.

The $YGdB_2O_6$:Tb(1.5 mol %) emissions versus transitions and energy is presented for better comparison.

When the phosphor is excited with 275nm all the observed emission intensities in the $YGdB_2O_6$: Tb(1.5 mol %) increase by 20 – 40%. This is may be due the resonance energy transfer from Gd-Tb ions in the phosphor. The particle size observed for Tb doped $YGdB_2O_6$ is 3.9 and 5.5microns and the surface area are 2.881 and 2.121 M^2 per gram.

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