

Photoluminescence study of Tb, Eu co-doped $Gd_3Al_5O_{12}$ phosphor

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Abstract - The present paper reports the synthesis of 2.5 mol% Terbium and 2 mol% Europium doped $Gd_3Al_5O_{12}$ phosphor, via hydrothermal method. The Phosphor was prepared at a pressure of 14 bar with 150°C temperature. The obtained phosphor was reheated at a calcinating temperature of 1200°C in a muffle furnace in open air atmosphere. The phosphor was white in color. The photoluminescence emission was studied at 275nm excitation. The excitation spectrum was monitored at 615nm, which spreads from 220 to 300nm with a sharp and prominent peak at 275nm. That why the emission spectrum was studied at 275nm excitation. The emission spectrum spreads from 350 to 650nm with prominent and significant sharp peaks at green, orange red and red regions with 544, 592, 594, 599, 616 and 628nm wavelengths. All the emissions are allowed and are due to transitions of Europium and Terbium ions in the host crystal.

1. INTRODUCTION

The production of visible photons in solid-state systems has attracted considerable research interest in recent years. Trivalent lanthanide (Ln^{3+}) doped luminescent nanomaterials are particularly attractive from both a practical and fundamental viewpoint owing to their unique optical properties arising from intra 4f transitions, which gives strong and sharp emissions. These characteristics make them a good alternative to quantum dots for the development of optoelectronic devices, electroluminescent devices and biological applications [1–3].

The luminescence performance of a material can be enhanced significantly by the suitable selection of host material. Ln^{3+} doped nanocrystalline Gd_2O_3 has attracted considerable interest as a host material owing to its high chemical durability, thermal stability and potential application in fluorescent lamps, projection TV systems and field emission systems [4, 5]. Moreover, similarities in the chemical properties and ionic radius highlight Gd_2O_3 as an excellent host for doping with rare-earth ions, making it a promising material for a range of industrial applications. According to the relevant literature, Gd_2O_3 based materials have been extensively studied as potential magnetic resonance imaging (MRI) contrast agents. For example, small Tb^{3+} doped Gd_2O_3 nanocrystals were investigated by Petoral et al. [6] as a bifunctional material with combined fluorescent labeling for living cells and MRI contrast agent

properties. Setua et al. [7] and Li et al. [8] showed that Eu^{3+} and Gd^{3+} doped Y_2O_3 nanocrystals exhibiting both paramagnetism and bright red luminescence that enables magnetic resonance imaging and cells labeling. However, Gd_2O_3 exhibits weaker stability than Y_2O_3 against atmospheric CO_2 and H_2O (known as luminescence killers), owing to its higher basicity [8].

Therefore, it is of great interest to increase the luminescent properties of Gd_2O_3 based phosphors. The incorporation of metal ions in phosphors can be considered as an effective route in order to attain improved luminescence emission. For example, Bai et al. reported the significant upconversion enhancement by introducing the Li^+ into Ho^{3+}/Yb^{3+} co-doped Y_2O_3 nanocrystals [9]. Chen et al. gained about 25 order of magnitude enhancement of the visible upconversion radiation in $Y_2O_3:Er^{3+}/Yb^{3+}$ nanocrystals by tridoping with Li^+ ions [10]. A similar strategy was also used to enhance the luminescent properties of $CaYBO_4:Tb^{3+}$ phosphors for plasma display panels (PDP) by codoping with Al^{3+} ions [11]. Obviously, Li^+ and Al^{3+} ions have smaller cationic radius than rare-earths, which is favorable for their movement and site occupation in the host lattice. These advantages make them attractive for use in tailoring of the host lattice crystal field. The precise manipulation of nano/microcrystals with a welldefined morphology and accurately tunable size remains a major research focus and a challenging issue because the properties of materials are strongly associated with

geometrical factors, such as shape, dimensionality, size, etc. [12]. On the other hand, the emission wavelength of lanthanide-doped host nanoparticles is independent of the particle size. Hence, monodispersity is less crucial, leading to lower synthesis cost [13]. To date, the final Nanoparticles in most studies were agglomerated and irregular in shape and size, which can affect their luminescence properties. However, low light scattering can be obtained using spherical-shaped particles.

To the best of author's knowledge, luminescence enhancement of $Gd_3Al_5O_{12}$ based phosphor materials by codoping with Eu^{3+} synthesized by hydrothermal method have not been reported so far. This study reports the simple photoluminescence study and observed the effect of the co-dopant ion.

2. EXPERIMENTAL

The phosphor is synthesized by hydrothermal method for nanosize particles. Gd_2O_3 and Al_2O_3 were taken as raw materials for the host and Tb_4O_7 and Eu_2O_3 were taken at 2.5 mol% and 2 mol% as activator ions. The Phosphor was prepared at a pressure of 14 bar pressure at $150^\circ C$ temperature. The obtained phosphor was reheated at a calcinating temperature of $1200^\circ C$ in a muffle furnace in open air atmosphere. The final phosphor was white in color.

3. RESULTS AND DISCUSSION

3.1 Excitation study

Fig.1 shows the excitation spectrum monitored at 615nm wavelength consists of broad excitation band starts from 220 – 285nm with a peak at 275nm which can be attributed to CT band.

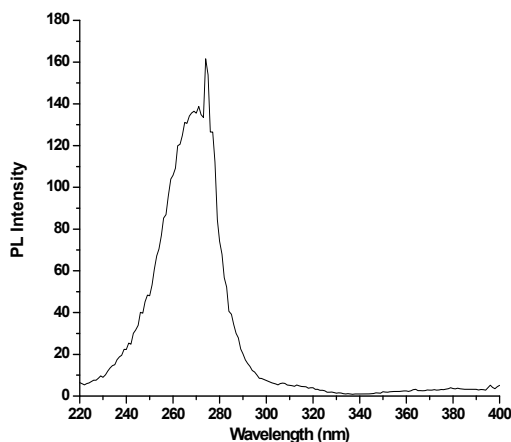


Fig.1: Excitation spectrum of $Gd_3Al_5O_{12}:Tb2.5\%, Eu2\%$ monitored at 615 nm

3.2 Emission study

Fig.2 shows the emission spectrum at 275nm excitation wavelength consists of several sharp peaks starts from 450nm – 650nm peaks at 493, 544, 594, 599, 616 and 628nm. The 544nm (green)

peak is attributed to Tb^{3+} ion and 594nm and 616nm peaks are attributed to Eu^{3+} ion. The 594nm is M.D transition and 616nm is E.D transition of Eu^{3+} ion, among these two transitions the E.D peak is little bit stronger than M.D peak. When compared to Tb^{3+} ion peak the Eu^{3+} ion peaks are stronger therefore the phosphor finally emits yellow colour.

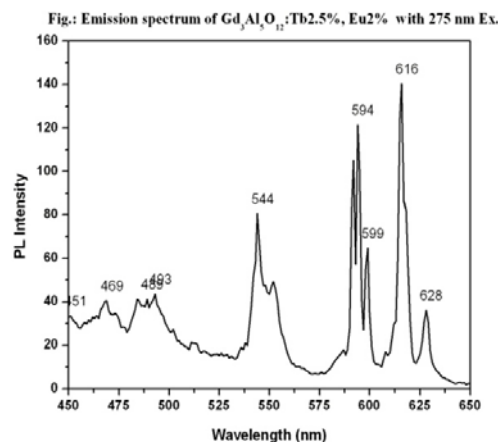


Figure 2

The author's are compared this result with the others result of Tb^{3+} ion doped phosphor only and the emission spectrum is as shown in the figure 3 given below at 276nm excitation wavelength. The characteristic emission of Tb^{3+} ion peak at 545nm ($^5D_4 - ^7F_5$ transition) is stronger than other transitions.

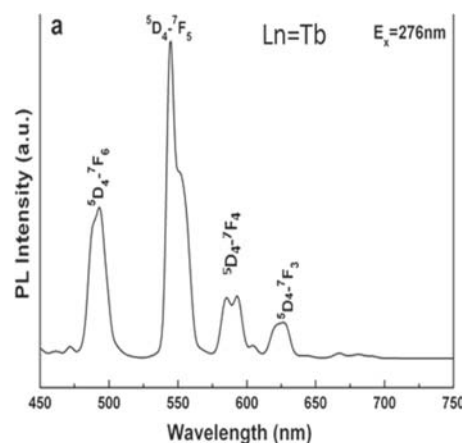


Figure 3

The Tb, Eu co-doped $Gd_3Al_5O_{12}$ phosphor shows both green and red emissions confirms the synthesized phosphor enhanced the emission in red wavelength region due to the incorporation Eu ion as co-dopant by keeping the Tb ion emission.

3.3 CIE co-ordinates study

Fig.4 shows the CIE diagram of prepared phosphor under 275 nm excitation wavelength. The colour co-ordinates of the Eu co-doped phosphor under 275nm are $x=0.388$, $y=0.535$. From the figure the phosphor emitting yellow colour and are useful in producing white light in the field of lamps and display devices. The calculated correlated colour temperature (CCT) of the phosphor is 4534K.

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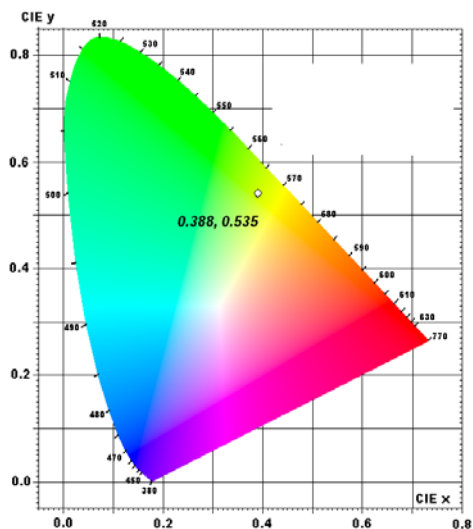


Figure 4

CONCLUSIONS

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