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Synthesis & Photoluminescence study of LaPO4: Eu, Tb Phosphor

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ABSTRACT

The present paper reports the Photoluminescence (PL) of the $LaPO_4$ phosphor doped with Eu and Tb rare-earth ions, keeping Eu concentration constant and varying Tb concentration as 0.1, 0.5 and 1.5% is described. The phosphors were synthesized using the standard solid state reaction technique and ground using mortar and pestle, fired at 1200^oC for 1 hour in a muffle furnace. We have studied the effect of dopants on the Photoluminescent $LaPO_4$ phosphor was observed at 470 nm. Under the excitation of 254nm wavelength, PL properties of the samples using Spectrofluorophotometer at room temperature. PL emission of doped $LaPO_4$ phosphor shows peaks at 589, 596, 614 and 622nm with good intensity. As the Tb concentration increases the PL intensity also increases.

Keywords: Photoluminescence;XRD; phosphor rare-earth ions; solid state reaction technique;

INTRODUCTION

The useful applications of rare earth element compounds, especially lanthanide phosphate doped inorganic materials, have been touched upon broadly. Over the past a few years, they have been applied in many fields, such as optical display panels, cathode ray tubes, optoelectronic, sensitive device, nanoscale electronic and plasma display panels[1−4] due to their special chemical and physical properties. Phosphors are widely used in displays and lighting devices. Various solution-phase routes, including solid state reaction, sol-gel, precipitation, water oil microemulsion, polyol-mediated process, ultrasonification, hydrothermal, and mechanochemical method[5-8], have been tried to lower the reaction temperature and obtain high-quality $LaPO_4$ based nanoparticles. However, the simple and mass fabrication of LaPO4 nanocrystals with narrow grain size distribution and uniform morphology still remains a challenge. We adopted the

standard solid state reaction technique to prepare $LaPO_4$ with good morphologies and fine crystal structures; and its emission and intensity of luminescence were also studied. The present paper reports the Photoluminescence (PL) of the $LaPO_4$ phosphor doped with Eu and Tb rare-earth ions, keeping Eu concentration constant and varying Tb concentration.

MATERIALS AND METHODS

$LaPO_4$ phosphor doped with Eu and Tb rare-earth ions, keeping Eu concentration constant and varying Tb concentration as 0.1, 0.5 and 1.5% were prepared using solid state synthesis method. Stoichiometric proportions of raw materials namely, Lanthanum Oxide (La_2O_3), Diammonium Hydrogen Phosphate [$(NH_4)_2$ H PO_4), Cerium Oxide (Ce_2O_3) and Terbium Oxide (Tb_4O_7) were grinded in an agate motor and mixed and compressed into a crucible and heated at 1200^0C for 4 hour in a muffle furnace at the rate of 300^0C per hour. The prepared samples were again powdered for taking the measurements. Photoluminescence (PL) of the $LaPO_4$ phosphor doped with Eu and Tb rare-earth ions were recorded with Spectrofluorophotometer at room temperature.

RESULTS AND DISCUSSION

X-ray diffraction study (Phase purity and structure):-

The crystallinity and phase purity of the product were firstly examined by XRD analysis. Fig 1&2 shows the typical X-ray diffraction (XRD) patterns of synthesized samples of pure $LaPO_4$ and $LaPO_4$ dopped with Eu, Tb. As shown XRD patterns of nanocrystals are in good agreement with the values from JCPDS no.35-731of $LaPO_4$, which shows that all the products are monazite $LaPO_4$ with monoclinic structure. The main peak was found around 28.5^0 corresponding to a d-value of about $3.11A^0$, followed by other less intense peaks corresponds to the monoclinic system of crystal structure of Lanthanum Phosphate[5-7]. All diffraction patterns were obtained using CuKα radiation ($\lambda = 1.540598\ A^0$) at 40 kv and 30 mA, and divergence slit fixed at 1.52 mm. Measurements were made from $2\theta = 10^0$ to 80^0 with steps of 0.008356^0.

When crystallites are less than approximately 100 nm in size, appreciable broadening in X-ray diffraction lines occurs. The crystallite size of particles of powder sample were calculated by using Scherer equation

$$D= 0.9\ \lambda / \beta\cos\theta$$

Where β represents full width at half maximum (FWHM) of XRD lines
λ = Wavelength of the X-rays.(0.154 nm in the present case)
θ = Braggs angle of the XRD peak.

The average crystallite size of LaPO4 phosphors is 62 nm and when doped with RE dopants, the crystallite size becomes 85 nm.

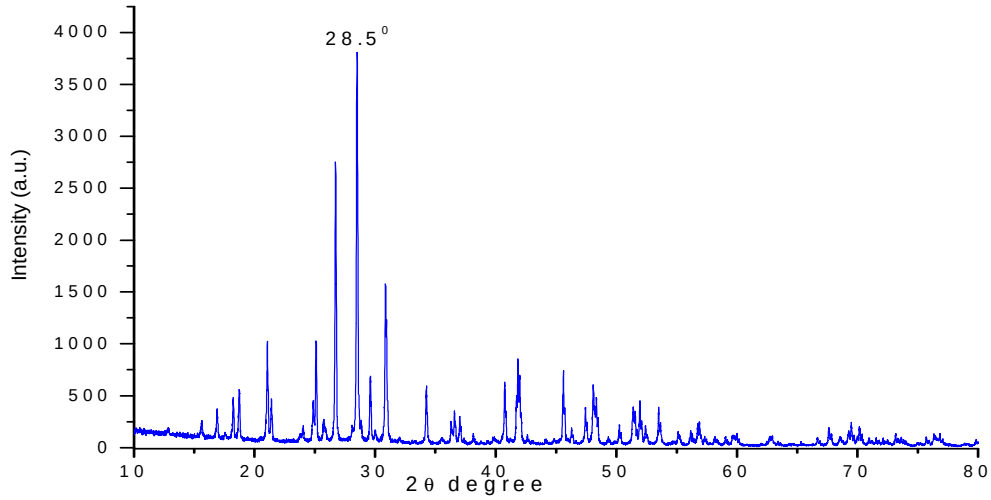

fig.1. XRD Pattern of Base Compound (LaPO4)

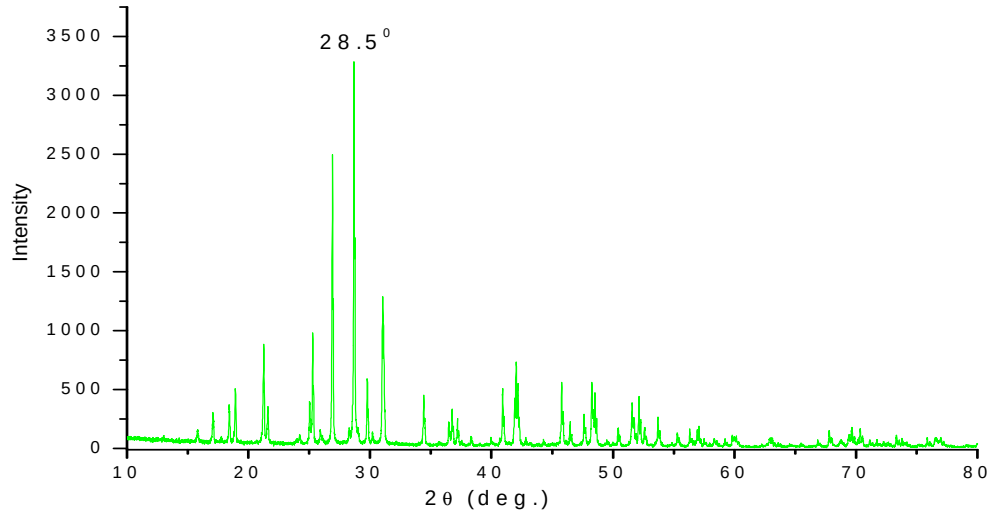

Figure2. XRD Pattern of LaPO4:Eu,Tb

Photo luminescence study:-

Fig.3 shows the excitation spectra of undopped LaPO4 and fig.4 shows the emission spectra of undopped LaPO4 under the excitation of 254 nm. The emission peaks are at 366 nm and 469 nm.

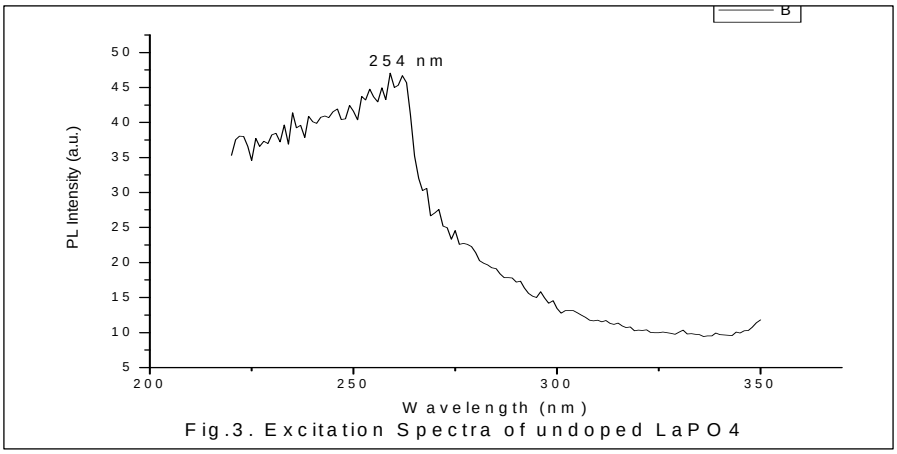

Fig.3. Excitation Spectra of undoped LaPO4

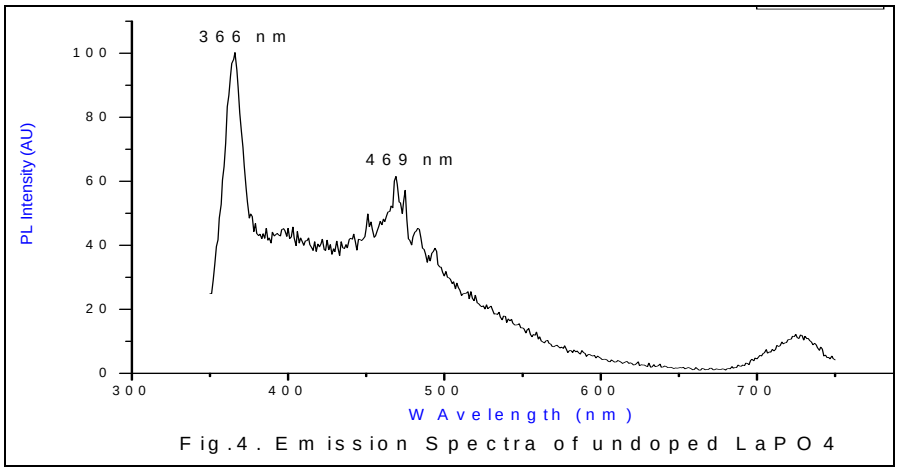

Fig.4. Emission Spectra of undoped LaPO4

The bulk material was doped by Terbium in $LaPO_4$ does not shown any specific emission. However Terbium is known to give a narrow band emission about 541 nm [10]. Figure-4 shows the PL emission of undoped $LaPO_4$ phosphor was observed at 470 nm. Fig. 5 shows that, under the excitation of 254 nm wavelengths, PL emission of doped $LaPO_4$ phosphor shows peaks at 589, 596, 614 and 622 nm with good intensity. As the Tb concentration increases the PL intensity also increases. In the trivalent rare earth ions, the luminescence arises mainly due to transactions within the 4 f shell. The efficiency of emission depends on the number of electrons in the 4f shell. The Tb^{3+} ion has 8 electrons in the 4f shell, which can be excited in the 4f-5d excitation band [7]. The electron in the excited $4f^7$ - 5d state remains at the surface of the ion and comes under the strong influence of the crystal field resulting in the splitting of the excitation band. The excitation Spectra thus has multiple peaks. The excited ion in th $4f^7$ - 5D state decays stepwise from this state to the luminescent levels $5D4f_3$ or $5d4f_4$ by giving up phonons to the lattice. Luminescence emission occurs from either of these states, with the ion returning to the ground state. The emission line in the green region lying at 545 nm is due to the transition $5D_4$ - $7F_6$, 585 nm due to 5D4-7F4 and 620 nm due to 5D4 -7F5 . There are in fact multiple emission lines at each of these due to the crystal field splitting of the ground state of the emitting ions [8].

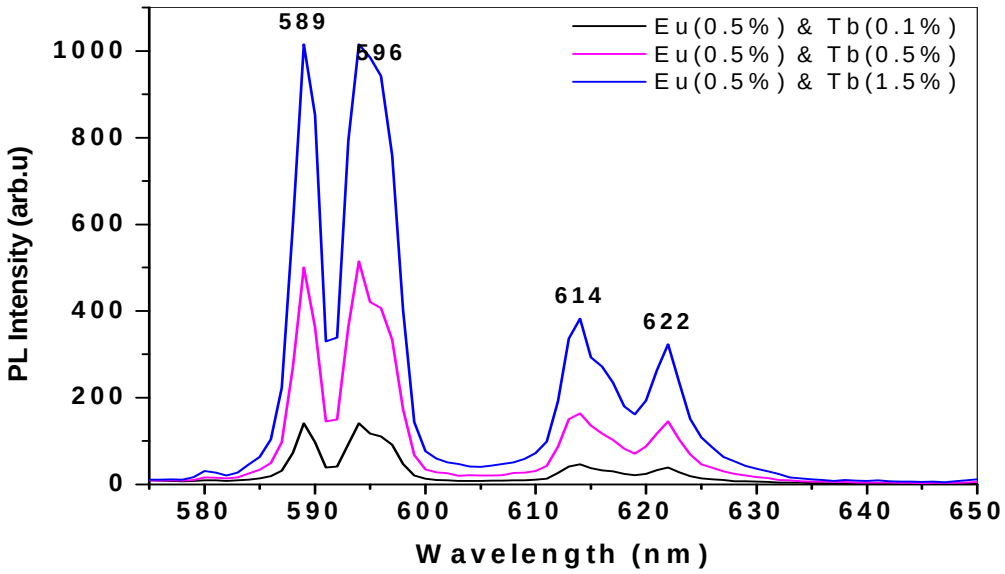

Fig.5. **Emission spectrum of $LaPO_4$: Eu & Tb at 254nm Excitation**

CONCLUSION

$LaPO_4$ phosphor doped with Eu and Tb rare-earth ions, keeping Eu concentration constant and varying Tb concentration as 0.1, 0.5 and 1.5% were prepared using solid state synthesis method are successfully synthesized. The main peak in XRD pattern was found around 28.5^0 corresponding to a d- value of about $3.11A^0$, followed by other less intense peaks corresponds to the monoclinic system of crystal structure of Lanthanum Phosphate. As the Tb concentration increases the PL intensity also increases. The PL intensity is very high therefore; the $LaPO_4$:Eu, Tb phosphors can be easily applied in various types of lamp and display.

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