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# Synthesis & PL 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 with 0.5 mole percentage. The phosphors were synthesized using the standard solid state reaction technique and ground using mortar and pestle, fired at 1200°C for 1 hour in a muffle furnace. The produced materials were analyzed by XRD,FTIR and PL. We have studied the effect of dopants on the Photoluminescent $LaPO_4$ phosphor. Under the excitation of 254 nm 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.*

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

## INTRODUCTION

Phosphors are widely used in displays and lighting devices. The phosphor particles must have good characteristics such as their high brightness, fine size and narrow size distribution for application in PDP. We adopted the standard solid state reaction technique to prepare $LaPO_4$ with good morphologies and fine crystal structures.

## MATERIALS AND METHOD

$LaPO_4$ phosphor doped with Eu, Tb rare-earth ions with concentration of 0.5% 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 $PO_4$), and Terbium Oxide ($Tb_4O_7$) were grinded in an agate motor and mixed and compressed into a crucible and heated at $1200^0$C for 4 hour in a muffle furnace at the rate of $300^0$C per hour. The prepared samples were again powdered for taking the measurements. The crystalline structure and phase purity of the sample were studied by XRD analysis. FTIR measurements were carried out with pure KBr tablet cell as a background spectrum and spectra were collected at resolution of 1 $cm^{-1}$ over the wave number range of 4000-400 $cm^{-1}$. To record IR spectra, the mixture of the sample with pure and dry KBr was ground in agate mortar and heated. Then the mixture was compressed in to thin sample cell with tablet pressed under 12 ton pressure for 1 minute. 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):-

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.

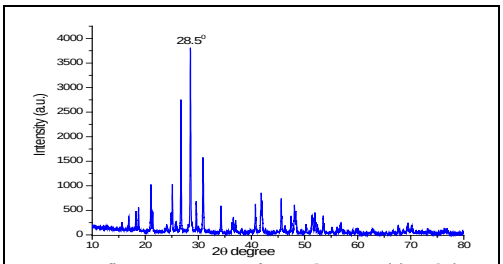


fig.1. XRD Pattern of Base Compound (LaPO4)

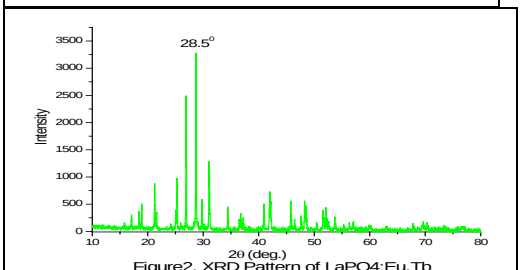
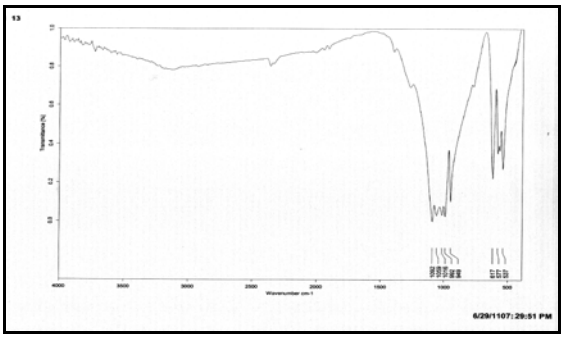


Figure2. XRD Pattern of LaPO4:Eu,Tb

FOURIER TRANSFORMS INFRARED SPECTOSCOPY:-

The FT-IR technique has been used to identify the reaction between solids, by monitoring the vibrational and rotational motion of the molecules during the reaction. The FTIR spectrum of $LaPO_4$ doped Eu and $LaPO_4$ doped Eu, Tb synthesized at $1200^0$C for 4 hours has been depicted in fig.3. The most of the bands are characteristics of vibration of phosphate group. So the characteristics of monoclinic phase of three bands located at 537, 577, 617 $cm^{-1}$ are found in $\nu_4$ region and five peaks at 949, 992, 1016, 1059, 1092 $cm^{-1}$appear in $\nu_3$ region [11]. This observation indicates that monoclinic $LaPO_4$: Eu, Tb exists in the specimen.



FT-IR Spectra of LaPO4:Eu(0.5%),Tb(0.5%)

Photo luminescence study:-

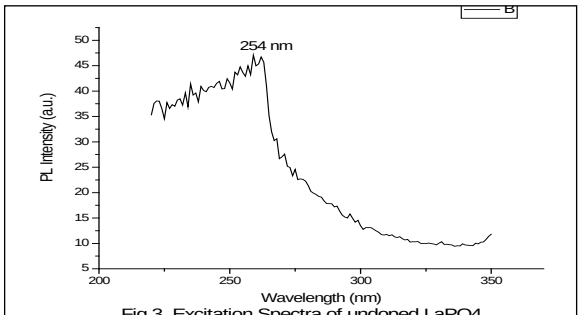


Fig.3. Excitation Spectra of undoped LaPO4

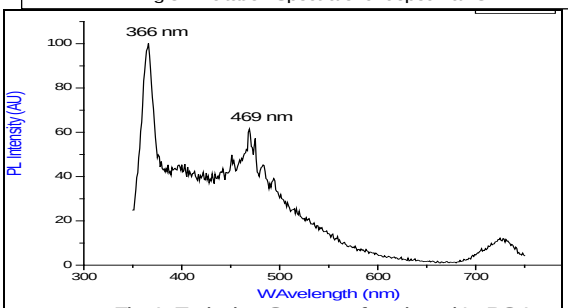


Fig.4. Emission Spectra of undoped LaPO4

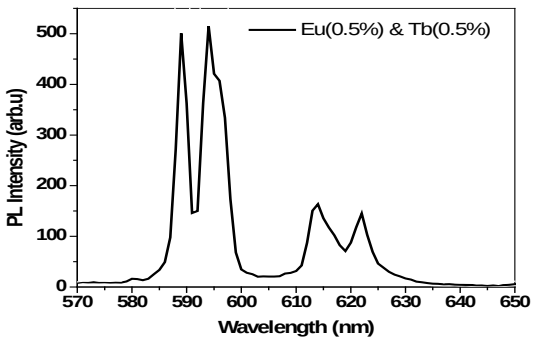



Fig.5.**Emission spectrum of $LaPO_4$: Eu & Tb at 254nm Excitation**

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.

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 which are the primary emissions of $Eu^{3+}$ due to electrical and magnetic dipoles. 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].

## CONCLUSIONS

$LaPO_4$ phosphor doped with Eu, Tb rare-earth ions with concentration of 0.5% 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. The PL intensity is very high. Therefore, $LaPO_4$: Eu, Tb phosphors can be considered for red emission phosphor in the lamps. The $LaPO_4$:Eu, Tb phosphors can be easily applied in various types of lamp and display.

## ACKNOLEDGEMENT

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