# Combustion Synthesis and Luminescence Characterization of $K_2SrP_2O_7$: Eu Phosphor

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**Abstract**

In this paper photoluminescence property of $K_2SrP_2O_7$:$Eu^{3+}$ phosphor is presented for the first time. $K_2SrP_2O_7$:$RE^{3+}$ phosphor activated with the trivalent rare earth ions was synthesized by combustion method. Phosphor was characterized for phase purity, morphology and luminescence properties. The emission and excitation spectra were followed to explore the luminescence attributes. The as prepared powders of $Eu^{3+}$ doped $K_2SrP_2O_7$ emit red light due to *f-f* transitions. The study is novel as no such luminescence data are available for this compound.

**Keywords:** Combustion, Phosphor, Luminescence, Solid State Lighting.

## 1. Introduction

Nowadays the use of phosphors presents a fast growing industry due to the wide range of applications: light emitting diodes (LEDs), field emission displays (FEDs), cathode ray tubes (CRTs), vacuum fluorescent displays (VFDs), plasma display panels (PDPs) and Scintillators. Phosphate based phosphors have gained interest owing to their better thermal and chemical stability compared with sulfides, which are currently used in the screen of FEDs. White light-emitting diodes (LEDs) offer many advantages such as long service lifetime, thermal resistance, and high efficiency. Therefore, white LEDs are expected to be a new light source in the illumination field. Currently, the most common and simple method to produce white light is to combine a blue LED chip with a yellow light emitting phosphor YAG:Ce. However, YAG:Ce emits a greenish yellow light is deficient in a red spectral region, which leads to the fact that the white LED has a poor colour rendering property **[1-4]**. In order to solve this problem, the compensating red phosphors were introduced. Moreover, the other methods to achieve white LEDs are suggested, for example, they can be obtained by combining a tri-colour (red, green, and blue) phosphor or a single-phase white emitting phosphor with an ultraviolet or near-ultraviolet (UV) LED **[5-9]**. The latter method yields white light with better spectral characteristics and colour rendering property. Therefore, more attention has been paid to the development of new tri-colour or white emitting phosphor that can be excited in the range of UV or NUV light due to the necessity of increasing the efficiency of white LED. Some green, blue and red emitting phosphors excited by NUV chip have been prepared and extensively studied along these lines. Terbium, europium and dysprosium activators have tremendous applications in lighting technology. As an important family of luminescent materials, phosphates have drawn considerable attention because of their many important chemical & physical properties. In this context luminescence studies on phosphate phosphors were undertaken **[10, 11]**. Recently, rare earth ions activated $Na_2CaP_2O_7$ diphosphates were reported **[12]**. However, to the best of our knowledge, no attention has been paid to the luminescent properties of $Eu^{3+}$ doped $K_2SrP_2O_7$ diphosphate phosphor. Therefore, in the present paper, the luminescent characteristics, structural properties and morphology of $Eu^{3+}$ activated $K_2SrP_2O_7$ phosphor are investigated.

## 2. Experimental

The samples were synthesized by a time and energy saving combustion method. According to the molecular formula $K_2Sr_{1-x}P_2O_7{:}xRE^{3+}$(x = concentration of rare earth ion), the raw materials $KNO_3$, $Sr(NO_3)_2$, $(NH_4)H_2PO_4$, urea, $Tb_4O_7$, $Eu_2O_3$ and $Dy_2O_3$ (all materials are of analytical grade) were measured and mixed stoichiometrically in an agate mortar for few minutes till a paste was formed. The paste so formed was and transferred to crucible and put into a muffle furnace preheated at 550 °C to set in the combustion process. Likewise procedure was adopted for other two dopant ions as well as for all concentrations to prepare a series of $RE^{3+}$ activated $K_2SrP_2O_7$ phosphors. Finally all samples prepared in this way were pulverized for few minutes to yield a fine powder. The final phase formation of the host compound was identified by powder X-ray diffraction (XRD) (X'-Pert. PRO-ANNALYTICAL X-ray Diffractometer with Cu Kα = 1.5406 Å at 40 kV and 30 mA) at a scanning step of 0.001, in the 2θ range from 10 to 70°. Excitation and emission spectra were measured using RF-5301PC Shimadzu Spectrofluorophotometer with slit width 1.5 nm. All the measurements were performed at room temperature.

## 3. Results and Discussion

### 3.1 X-ray powder diffraction pattern

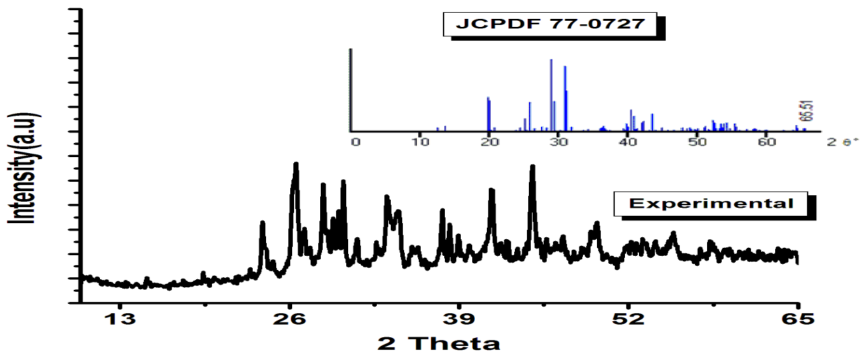


**Fig.1 X-ray powder diffraction patterns of $K_2SrP_2O_7$ and its standard JCPDS file.**

To verify the phase formation, crystalline nature and to clarify whether this compound has any standard data available, powder X-ray diffraction test of $K_2SrP_2O_7$ was carried out. The powder X-ray diffraction test was carried out by X'-Pert PRO ANALYTICAL X-ray Diffractometer with Cu Kα = 1.5406 angstrom. The XRD pattern of $K_2SrP_2O_7$ reported in this work is shown in **Fig.1**.We searched its standard data file in JCPDS data and a file with card number JCPDF 77-0727 was available there. While comparing with the standard data file, as prepared



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compound exhibited well match (**Fig.1**). The phosphate compound $K_2SrP_2O_7$ was reported to crystallize in a monoclinic structure comprised of the space group $P2_1/c(14)$ with lattice parameters a= 9.168, b=5.712, c=14.720 and β=105.79.

### 3.2 Morphology and Energy dispersive spectroscopy (EDS) Studies of $K_2SrP_2O_7$ matrix

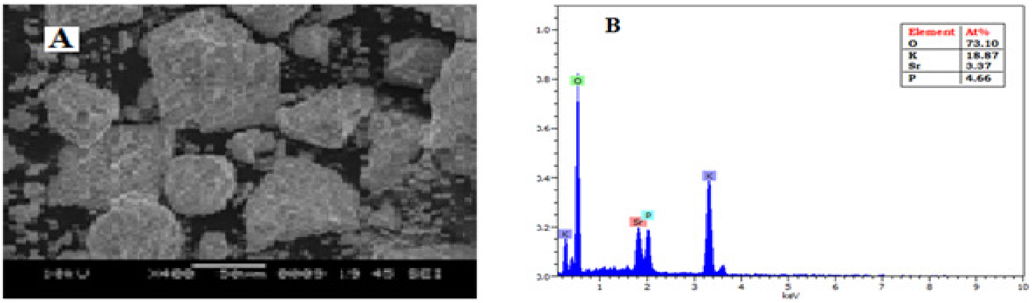


**Fig.2 SEM image and EDS spectrum of K2SrP2O7**

The scanning electron microscopic (SEM) image of $K_2SrP_2O_7$ phosphor is shown in **Fig.2(A)**. The morphological studies were carried out by the JEOL, 6380A scanning electron microscope. The (SEM) characterization showed that the prepared phosphor has micron (50μm) size particles. These particles are identical to each other and powders of these particles seem to be homogeneous. To determine the composition of the prepared product, an EDS was carried out and presented in **Fig. 2(B)**. It is found that the host matrix is composed of K, Sr, P, and O.

### 3.3 Photoluminescence property of $K_2SrP_2O_7$: $Eu^{3+}$ phosphor

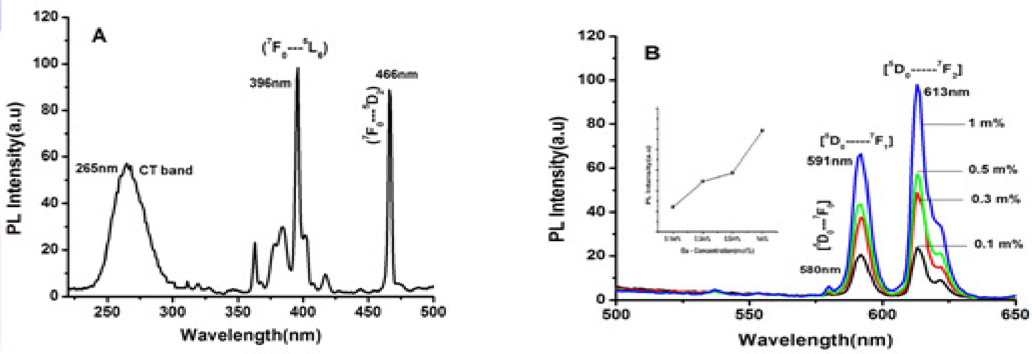


**Fig.4 PL excitation and emission spectra of $K_2SrP_2O_7$:$Eu^{3+}$ phosphor. $\lambda_{exc}$ = 396nm,.$\lambda_{emi}$ = 613nm.**

$Eu^{3+}$ doped $K_2SrP_2O_7$:Eu phosphor exhibits a wide excitation spectrum spanning from CT band to sharp lines in NUV region. The excitation spectrum (**Fig.4A**) of $K_2SrP_2O_7$:Eu phosphor has a broad excitation band in the range 220 -300 nm and 300 nm onwards sharp excitation peaks in the near NUV(320–396 nm) and visible (420– 470 nm ) regions. The broad excitation band peaking at around 265 nm can be attributed to charge transfer (CT) between $O^{2-}$ and $Eu^{3+}$ while the sharp excitation peaks are due to f-f transitions of $Eu^{3+}$ ions **[13,14]**. The strong absorption was seen only at 265nm, 396nm and 466nm as these three wavelengths results in intense orange reddish emission around 591 nm and 613nm respectively. The excitation spectrum was monitored at 613 nm emission wavelength. In the emission spectra (**Fig.4B**) various peaks at 580nm, 591nm and 613nm respectively, were observed under excitation wavelengths 265nm, 396nm and 467nm. In the present case emission spectrum observed at 396nm is shown only. The emission spectrum was dominated by the red and orange peaks at 613nm and 591nm due to the electric dipole and magnetic dipole $^5D_0 \rightarrow {}^5F_2$ and $^5D_0 \rightarrow {}^5F_1$ transitions respectively **[15, 16]**. We also observed that PL intensity varied with change in doping concentration of $Eu^{3+}$ ions in $K_2SrP_2O_7$ phosphor (inset of **Fig.4B**). The highest PL intensity was obtained at 1m% Eu in $K_2SrP_2O_7:Eu^{3+}$ phosphor.

## 4. Conclusion

$K_2SrP_2O_7:Eu^{3+}$ phosphor was synthesised by combustion method at 550 °C. Typical excitation and emission spectra were observed for $Eu^{3+}$ ions doped in $K_2SrP_2O_7$ system. Both magnetic dipole as well as electric dipole transitions are involved in the luminescence behaviour of $Eu^{3+}$ activated $K_2SrP_2O_7$ phosphor. Very strong absorption in NUV region for $K_2SrP_2O_7$: $RE^{3+}$ phosphor indicates that it could be effectively excited by LEDs emitting in the NUV region. Photoluminescence results show that $K_2SrP_2O_7:RE^{3+}$ system could become an important component of pc-WLEDs for solid state lighting applications.

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