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PRELIMINARY OSL STUDIES OF NaCaPO₄:Ce PHOSPHOR FOR RADIATION
DOSIMETRY

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ABSTRACT

The polycrystalline NaCaPO₄:Ce phosphor sample was successfully synthesized by solid state diffusion (SSD) method. The structural properties of prepared phosphor was evaluated X-ray diffraction (XRD) technique. The XRD patterns well match with ICDD (International centers for diffraction data) file with card No. 00-029-1193. The NaCaPO₄:Ce phosphor show excellent CW-Optically Stimulated Luminescence (OSL) properties under γ irradiation. The photoluminescence (PL) excitation and emission spectra were observed at 383 and 321 nm, respectively. The prepared phosphor is a candidate for radiation dosimetry.

Keywords: Solid state method (SSD); γ irradiation; OSL; NaCaPO₄:Ce phosphor.

I. INTRODUCTION

Radiation dosimetric methods are used for the estimation of dose absorbed by radiation in a detector material. These methods are required for estimation of absorbed dose in various applications of radiation, such as personnel and environmental dosimetry, retrospective/ accidental, dosimetry and medical applications of radiation [1].

Optically stimulated luminescence (OSL) is a well-established technique in personal and medical dosimetry, particularly in conjunction with Al₂O₃:C OSL detectors [2]. The OSL technique provides fast readouts, re-evaluation of dose with same dosimeter and simple analysis as compared with thermoluminescence (TL).

The compounds ABPO₄ [A=Li, Na, Ka& B= Mg, Ca, Sr, Ba] have visible as main optical materials because of the excellent thermal and hydrolytic stabilities [3]. Jeonget *al.* reported on green emitting NaCaPO₄:Eu phosphor for White-light UV-LEDs applications and this phosphor was prepared using high temperature solid state method [4]. Game *et al.* reported on red and green emitting NaCaPO₄:Eu³⁺/Eu²⁺ phosphors for W-LEDs and these phosphors were synthesized using pechini (citrate gel) method [5]. Palanet *al.* reported Rare Earth (RE) activated ABPO₄ phosphors for radiation dosimetry [6-11].

In this report to study preliminary OSL study of NaCaPO₄:Ce phosphor via solid state method and its OSL properties were investigated.

II. EXPERIMENTAL DETAILS

The polycrystalline NaCa_(1-x)PO₄:xCe (x=0.001) phosphor was successfully synthesized by using a solid-state diffusion method[12]. Phase purity of the final products was checked by X-ray diffraction (XRD) using a Rigakuminiflex II diffractometer with Cu K α (λ = 1.5405 Å) operating at 5 kV. Irradiation of all samples was performed at room temperature using a calibrated γ (⁶⁰Co) source at Department of chemistry of RTM University, Nagpur. The dose rate was 0.3712KGy/hr. The OSL measurements were carried out using PC CONTROLLED TL/OSL-1008 reader. The PL and PL excitation (PLE) spectra were measured on (Hitachi F-7000) fluorescence spectrophotometer with a 450W xenon lamp in the range of 200-550 nm with spectral slit width of 1 nm and PMT voltage at 700V and room temperature.

III. RESULTS AND DISCUSSION

In order to determine the phase purity of the phosphor X-ray diffraction (XRD) analysis was carried out. Fig. 1 shows the XRD pattern of $\text{NaCaPO}_4:\text{Ce}$ phosphor along with the standard XRD pattern (ICDD 00-029-1193). The structure of prepared $\text{NaCaPO}_4:\text{Ce}$ phosphor was found to be Orthorhombic with Pmnb(62) space group having lattice parameter $a=6.7970$, $b=9.1650$, $c=5.4060$ Å and $\alpha=\beta=\gamma=90$. The XRD pattern shows the formation of pure NaCaPO_4 phase. The addition of the dopant Ce does not seem to have effect on the XRD pattern which suggests that the dopant was incorporated in the lattice.

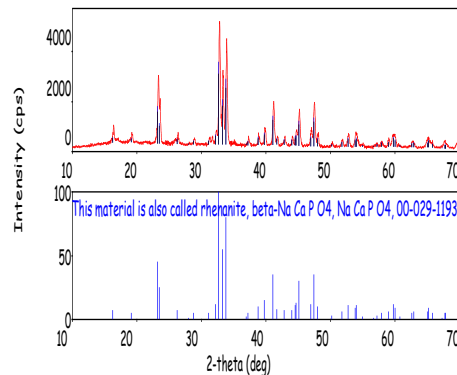


Fig. 1 - XRD pattern of $\text{NaCaPO}_4:\text{Ce}$ Phosphor matched with standard ICDD-00-029-1193

3.1 Optically stimulated luminescence (OSL)

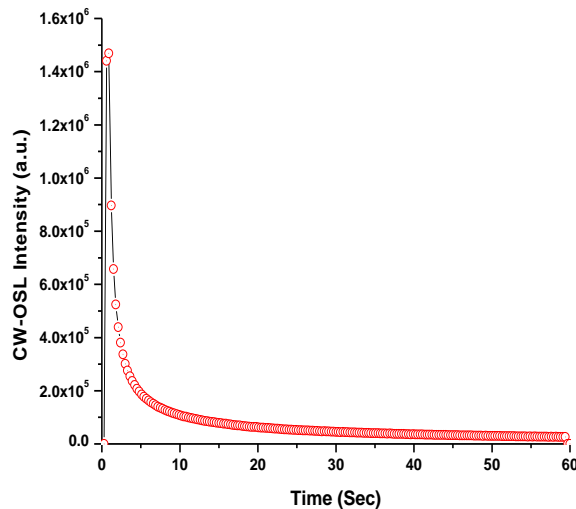


Fig. 2 CW-OSL response of $\text{NaCaPO}_4:\text{Ce}$ under gamma irradiation

Continuous wave OSL (CW-OSL) curves of $\text{NaCa}_{(1-x)}\text{PO}_4:\text{xCe}$ ($x=0.001$) phosphor is shown in Fig.2. The CW-OSL measurements were carried out under the blue stimulation at $\lambda = 470$ nm. The CW-OSL decay pattern of prepared $\text{NaCaPO}_4:\text{Ce}$ phosphor is similar to the CW-OSL decay pattern of commercially available $\alpha\text{-Al}_2\text{O}_3:\text{C}$ phosphor.

3.2 Photoluminescence (PL) properties

The excitation and emission spectra of $\text{NaCaPO}_4:\text{Ce}$ phosphors are shown in Fig. 3. The excitation and emission spectra were observed at 383 and 321 nm, respectively. The excitation spectra consist of broad band ranging from 200 to 350 nm with maximum at 321 nm. The emission spectra possess broad band in the range from 350 to 450 nm

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with maximum at 383 nm. The emission of NaCaPO₄:Ce phosphor was caused by the transitions from the lowest energy level of the Ce³⁺ 5d configuration to the spin-orbit split ²F_{5/2} and ²F_{7/2} levels [13].

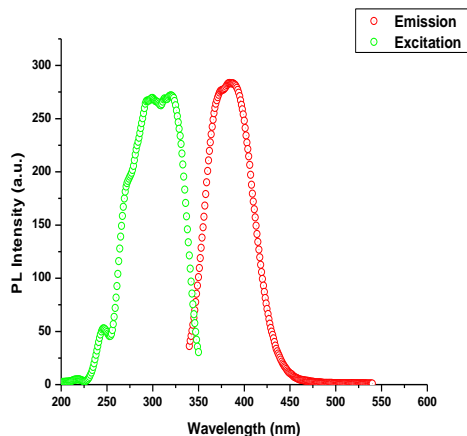


Fig. 3 The combined excitation and emission spectra of NaCaPO₄:Ce phosphor

IV. CONCLUSIONS

In this report NaCaPO₄:Ce phosphor was synthesized via solid state reaction and discussed its PL and OSL properties. The X-ray diffraction patterns well match with ICDD card number 00-029-1193. The PL excitation and emission spectra of prepared NaCaPO₄:Ce were observed at 321 and 383 nm, respectively. The CW-OSL measurements were carried out under the blue stimulation at $\lambda = 470$ nm and The OSL decay patterns of the NaCaPO₄:Ce phosphor were faster than the OSL decay patterns of the α - Al₂O₃:C (BARC) phosphor. The effective atomic number (Z_{eff}) of prepared NaCaPO₄ phosphor is 14.63 and phosphor show excellent CW-OSL response under γ irradiation. Hence, prepared NaCaPO₄:Ce phosphor can be applicable for radiation dosimetry.

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