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Optically Stimulated Luminescence (OSL) properties of CaF_2: Ce phosphor for radiation dosimetry

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ABSTRACT

OSL technique is a now well-developed for its application in radiation dosimetry. Antonov Romanovskii *et al.* were firstly suggested use of OSL for personal dosimetry. However compared to thermoluminescence (TL) technique, Optically Stimulated Luminescence (OSL) is becoming more popular in radiation dosimetry. The polycrystalline CaF_2:Ce phosphor was successfully synthesized via Reactive Atmosphere Process (RAP). The structural properties of prepared phosphors were evaluated X-ray diffraction (XRD) technique. The XRD pattern of prepared phosphor well match with ICDD (International centers for diffraction data) file and synthesis methods were not affected on XRD pattern. The $CaF_2:Ce^{3+}$ phosphor show good CW-OSL response under γ irradiation. The CW-OSL decay pattern of prepared $CaF_2:Ce^{3+}$ phosphor is similar to the CW-OSL decay pattern of commercially available α-Al_2O_3:C phosphor. The photoluminescence (PL) excitation and emission spectra were observed at 305 nm and 338 nm, respectively. The effective atomic number (Z_{eff}) of $CaF_2:Ce^{3+}$ is 16.3 and the phosphor is a candidate for radiation dosimetry.

Keywords : Reactive Atmosphere Process, Γ Irradiation, Effective Atomic Number, $Caf_2:Ce^{3+}$ Phosphor.

I. INTRODUCTION

The OSL is one of the class of measurements known as stimulated phenomena. Such phenomena may be stimulated thermally (thermally stimulated phenomena or TSP) or optically (optically stimulated phenomena or OSP).

The use of OSL for radiation dosimetry was first suggested in 1955 by Antonov Romanovskii *et al.* [1]. It was later used by Braunlich *et al.* (1965) and Sanborn and Beard (1965) [2, 3]. The OSL technique had not been used widely in radiation dosimetry until 1965, because of the lack of superior OSL materials. In 1990 Akselrod *et al.* reported TL properties of α-Al_2O_3:C crystal and found that TL sensitivity of α-Al_2O_3:C crystal was 50 times than LiF:Mg,Ti phosphor. Also α-Al_2O_3:C crystal showed excellent dosimetry properties such as low fading, dose threshold (μGy), a single peak at 460 K, emission band at 420 nm [4].

The OSL technique brought attention of scientific community for personnel dosimetry after the development of α-Al_2O_3:C because of its excellent OSL properties and introduction of the pulsed OSL (POSL) method [5, 6]. The α-Al_2O_3:C crystal was mainly grown by Czochralski method in Landauer, Inc. Kulkarni *et al.* prepared α-Al_2O_3:C phosphor in presence of graphite and this approach is an alternative method for obtaining dosimetry grade α-Al_2O_3:C [7]. However is still limited to artificially grown Al_2O_3:C phosphor and some problem in synthesis method reported by Dhabekar et al. [8].

Several efforts have been made to prepare other promising OSL materials, like $Li_2B_4O_7$:Cu-Ag [9], CaB_4O_7:Ce [10], $LiMgPO_4$:Tb-B [11], $CaSO_4$:Ce [12], Li_3PO_4:Tb^{3+} [13], $LiBaPO_4$:Tb [14], $KMgPO_4$:Tb [15], $CaSiO_3$:Ce [16], $LiCaPO_4$:Ce [17], $NaCaPO_4$:Ce [18], $KCaPO_4$:Ce [19], MgB_4O_7:Ag [20] $KSrPO_4$:Eu [21], SrB_4O_7:Eu [22], $CaSO_4$:Ce [23], $SrSO_4$:Eu [24], $MCaPO_4$:Ce [25]. In the present report we developed CaF_2:Ce phosphor via Reactive Atmosphere Process (RAP) for radiation dosimetry application.

II. EXPERIMENTAL

The polycrystalline CaF2:Ce3+ phosphor was successfully synthesized by using Reactive Atmosphere Process (RAP) [26]. Phase purity of the final products was checked by X-ray diffraction (XRD) using a Rigaku miniflex II diffractometer with Cu Kα (λ= 1.5405 Å) operating at 5 kV. Irradiation of 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 200-450 nm with spectral slit width of 1 nm and PMT voltage at 700V and room temperature.

III. RESULTS AND DISCUSSION

3.1 XRD (X-ray diffraction) Pattern

In order to determine the phase purity, chemical nature of the phosphor, X-ray diffraction (XRD) analysis was carried out. Fig. 1 shows the XRD pattern of CaF_2:Ce^{3+} phosphor along with the standard XRD pattern (International Centre for Diffraction Data (ICDD) Card no. 00-004-0864).

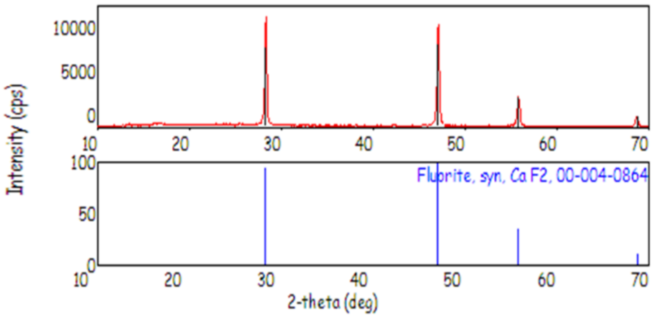

Fig. 1. XRD diffraction patterns of CaF_2:Ce^{3+} phosphor compared with the ICDD file with card no. 00-004-0864.

3.2 Photoluminescence (PL) Properties

The excitation and emission spectra of CaF_2:Ce^{3+} phosphor is shown in Fig. 2. The excitation and emission spectra were observed at 338 and 305 nm, respectively.

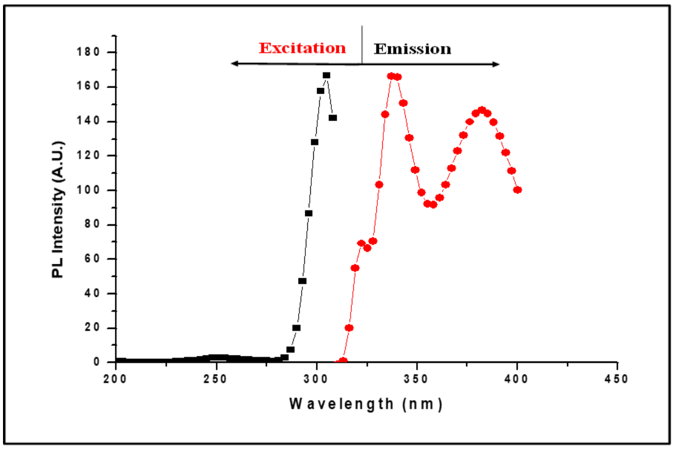

Fig. 2 Excitation and Emission spectra of CaF_2:Ce^{3+}phosphor

3.3 Optically stimulated luminescence (OSL)

The sample was studied for its Continuous-wave OSL (CW-OSL) response using blue LED stimulation (470 nm). The CW-OSL response of $Ca_{(1-x)}F_2:Ce^{3+}$ (X=0.01,0.02) under γ irradiation was shown in Fig 3. The CW-OSL decay pattern of prepared $CaF_2:Ce^{3+}$ phosphor is similar to the CW-OSL decay pattern of commercially available α-Al_2O_3:C phosphor.

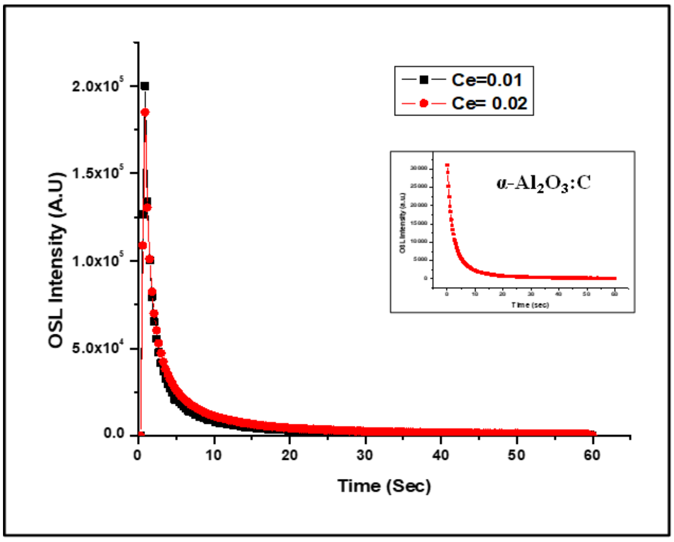

Fig. 3. CW-OSL responsed of $Ca_{(1-x)}F_2:Ce^{3+}$ phopshors under γ irradiation

IV. CONCLUSION

In this report $Ca_{(1-x)}F_2:Ce^{3+}$ (X=0.01,0.02) phosphor was synthesized via Reactive Atmosphere Process (RAP) and discussed its OSL and PL properties. The X-ray diffraction patterns well match with ICDD card number 00-004-0864. The PL excitation and emission spectra of prepared $Ca_{(1-x)}F_2:Ce^{3+}$ were observed at 305 and 338 nm, respectively. The CW-OSL measurements were carried out under the blue stimulation at λ = 470 nm and The OSL decay patterns of the $Ca_{(1-x)}F_2:Ce^{3+}$ phosphor were faster than the OSL decay patterns of the a- Al_2O_3:C (BARC) phosphor. The effective atomic number (Z_{eff}) of prepared CaF_2:Ce phosphor is 16.3 and phosphor show excellent CW-OSL response under γ irradiation. Hence, prepared $Ca_{(1-x)}F_2:Ce^{3+}$ phosphor can be applicable for radiation dosimetry.

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