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Parameters influencing the performance of optically stimulated luminescence dosimetry system

Munish Kumar*, Bhushan Dhabekar, M.P. Chougaonkar and Y. S. Mayya

Radiological Physics and Advisory Division, Bhabha Atomic Research Centre, Mumbai – 400 085.

Abstract

Large number of factors affects the performance of the OSL dosimetry system. Some of them are associated with the OSL equipment whereas others are associated with the OSL dosimeter. The paper describes the role of intensity of stimulation on background counts, minimum measurable dose (MMD) and peak intensity of continuous wave optically stimulated luminescence (CWOSL) curves. The effect of parameters such as optical density (OD), self-absorption *etc.* which are associated with the OSL dosimeters are investigated and their role in quality control during large scale batch manufacturing of dosimeters has been described. The optical attenuation coefficient (μ) was also measured for OSL disc dosimeters. The main focus is on the CWOSL recorded using RISO TL/OSL system (TL/OSL-DA-15) and various properties relevant to dosimetry applications are described for Teflon embedded $LiMgPO_4$:Tb, B (LMP) OSL disc dosimeters.

Keywords: Optically stimulated luminescence, optical attenuation coefficient, minimum measurable dose and radiation dosimetery.

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1. INTRODUCTION

Compared to thermoluminescence (TL) dosimetry technique, optically stimulated luminescence (OSL) is becoming popular in radiation dosimetry applications because of (i) faster and multiple readout, (ii) very high sensitivity, (iii) no infra-red/black body radiation, (iv) absence (no role) of thermal quenching effect and (v) possible use of phosphor in plastic (withstanding even low temperature) binders. However the OSL dosimeter assembly must be light tight and should be processed in complete dark [1-2]. In OSL phenomena, the optical stimulation itself introduces background counts as the optical filter never attenuates the stimulating photon intensity perfectly *i.e.* 100%. Also the intensity of the stimulating light can be as high as 10^{18} orders of magnitude stronger than the emitted luminescence [3]. The background signal due to stimulating light is over and above the photomultiplier tube's dark current and noises associated with electronic circuits. There are also evidences indicating the presence of shift in the wavelength of stimulating light ($\lambda \pm \Delta \lambda$), especially for blue LEDs) due to scattering (Raman effect) which can cause variation in the background counts and widening of OSL curves. The commonly used stimulation profiles in OSL are continuous wave (CW; stimulating intensity is constant), linearly modulated (LM; intensity increases linearly with time) and pulsed optically stimulated luminescence and each has its advantage and disadvantage. In CWOSL, the luminescence is recorded very fast and looks like a decay curve. Also in CWOSL, the background count rate or net background is nearly constant. In the case of LMOSL, the recording of luminescence is slow but peak shaped and the background count rate increases (non-linearly) with stimulation time. Well separated multiple peaks can also be obtained if optically sensitive traps having different values of photo ionisation cross-sections are participating in the OSL process. The peak height of the LMOSL curve is decided by the number density of the traps participating in OSL process and the recombination efficiency whereas the peak position is decided by the optical stimulation rate, retrapping and recombination cross-sections and the radiation dose. Due to long recording time, the LMOSL is not useful in dosimetry applications however it is very useful in characterisation of traps participating in OSL process.

In the present paper the main focus is on the CWOSL recorded using RISO TL/OSL system (TL/OSL-DA-15) and various properties relevant to dosimetry applications are described for Teflon embedded $LiMgPO_4$:Tb, B (LMP) OSL discs. The dose delivered to LMP discs was 10 mGy unless

* Corresponding author: Email:drmunishkumar@gmail.com
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otherwise mentioned. CWOSL measurements were performed using RISO TL/OSL system in which a cluster of 42 blue light emitting diodes (λ = 470 ± 30 nm) are used for stimulation. A green long pass GG-420 filter minimizes the directly scattered blue light from reaching the photomultiplier tube (EMI 9235QA). The blue light stimulated signal is detected using a 7.5 mm thick x 35 mm diameter HOYA U-340 (λ_p~340 nm, FWHM~80nm) filter. The LED cluster delivers ~25 mW cm^{-2} (maximum) power to the sample [2, 4]. In the present paper various parameters affecting the performance of the OSL dosimetry system are described. These factors are mainly associated with the OSL equipment and dosimeter/phosphor. Various parameters affecting the performance of OSL dosimetry system are:

2.1. Role of optical stimulation intensity on CWOSL: The OSL intensity from a given phosphor depends on - i) Dose delivered, ii) Energy *i.e.* frequency/wavelength of the stimulating light, iii) The excitation/photo ionization cross-section of the trap and iv) The intensity of stimulating light.

For the parameters described above, the value of the excitation/photo ionization cross-section is decided by the nature of trap/material and it may also show dependence of wavelength. The stimulation wavelength should be such that the value of excitation/photo ionization cross-section at that wavelength is maximum. In fact, OSL phosphors having higher values of excitation/photo ionization cross-section are desirable for dosimetry applications.

Also for a given dose, photo-ionization cross-section and stimulation wavelength, the main factor which decides the OSL output is the stimulation power/intensity. Figure 1 shows the variation of CWOSL signal (integrated) as a function of stimulation power.

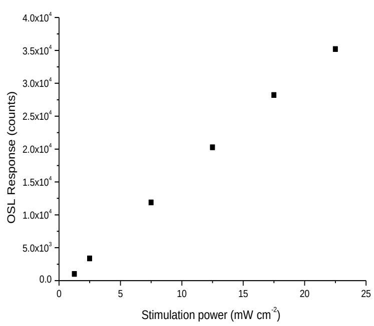

Fig. 1: CWOSL signal (counts) as a function of stimulation power (mW cm^{-2}) using blue LEDs.

Figure 2 shows CWOSL curves recorded at different values of stimulation intensity/power. It has been observed that the i) The maximum intensity/height of the CWOSL curve increases with increase of the value of optical stimulation power/intensity, ii) CWOSL curves are recorded faster, iii) Signal remaining for further readouts (multiple) decreases *i.e.* tail height decreases.

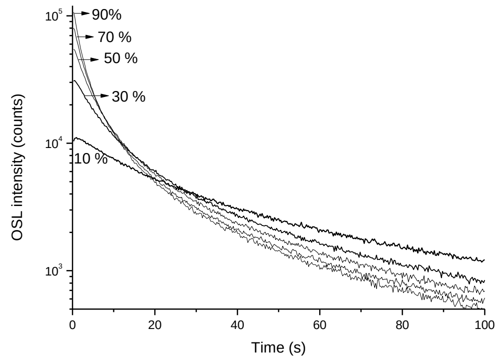

Fig. 2: CWOSL curves recorded at different values of stimulation intensity/power using blue LEDs.

Also for the use of CWOSL for personnel monitoring applications, it is desirable that the CWOSL curve is recorded with sufficient height (maximum intensity) and the ratio of the peak to the tail height should be such that reasonable signal remains for future multiple readouts. If 20 % of the OSL signal is erased in first readout, then the remaining signal can be utilized for future (multiple) readouts. In addition, the acquisition time should be such that the CWOSL curves are recorded very fast as large number of dosimeters needs to be processed. In view of this higher and higher values of optical stimulation intensity/power are required.

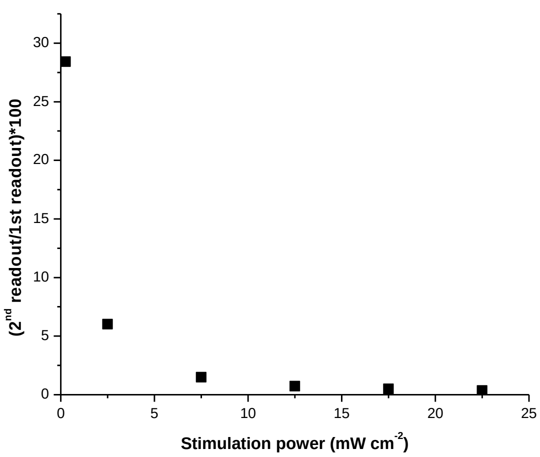

Fig. 3: Variation of ratio of 2nd readout to 1st readout in CWOSL with stimulation intensity/ power (mW cm^{-2}) using blue LEDs.

2.2. Variation of ratio of 2nd readout counts to 1st readout counts with stimulation intensity/ power: The ratio of CWOSL signal of 2nd readout to 1st readout increases with decrease of stimulation power (Figure 3) and the ratio further increases as the dose increases.

2.3. Dependence of background signal/ noise on stimulation intensity/power: The background noise during recording of CWOSL curves is composed of dark current, electronic noise and background signal arising from optical stimulation. In Figure 4, the dark current (counts) and variation of background signal (mainly arising from optical stimulation) is shown. From Figure 4, it follows that the background signal from optical stimulation increases with increase of optical stimulation power/intensity. It may be noted from Figure 4 that the typical background counts are ~20 cps at low stimulation power levels (< 5mW cm^{-2}) whereas at 22.5 mW cm^{-2} *i.e.* 90% of the maximum stimulation power/intensity, the typical background counts are ~94 cps. The above measurements were performed using freshly annealed/bleached discs and the typical MMD value at 90% (22.5 mW cm^{-2}) stimulation intensity/power are < 1μGy.

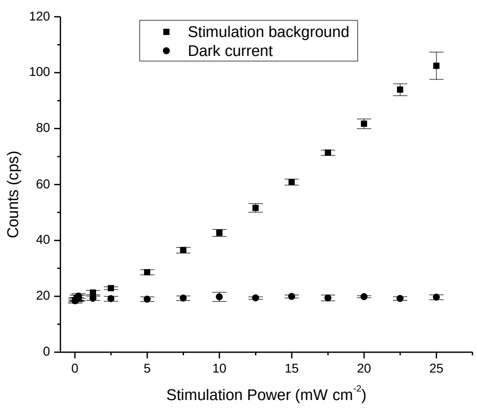

Fig. 4: Variation of background signal (counts) with stimulation intensity/power (mW cm^{-2})

2.4 Dependence of MMD on stimulation intensity: MMD is generally defined as the 3 times the standard deviation (σ) of the readout of freshly annealed / bleached dosimeters. After determining the calibration factor (luminescence signal/μGy), MMD can be measured. Typical MMD value for 0.4 mm thick Teflon embedded LMP discs using RISO reader system at 90% stimulation power/intensity was found to be ~0.14 μGy. It should be noted that for the use of CWOSL in personnel monitoring applications, higher stimulation intensity is desirable not only to reduce the acquisition time but it also increases the signal to noise ratio. In addition, MMD also improves (decreases) with increase in the value of optical stimulation intensity/power.

2.5. Optical density (OD) and attenuation coefficient for disc dosimeters: The high optical transparency of the dosimeters is desired not only for the stimulating light but also for the luminescence emitted. During OSL stimulation, the dosimeter is illuminated with light which nearly penetrates exponentially inside the dosimeter. The surface of the dosimeter is illuminated to maximum stimulation intensity whereas the opposite side of the dosimeter is illuminated to least stimulation intensity. In a similar way, the light emitted in the form of OSL is maximum from the surface of the dosimeter whereas from the opposite side of the dosimeter, the amount of light reaching PMT and contributing towards OSL signal is least/small. The self/re-absorption of the emitted luminescence in the dosimeter may influence the shape of OSL curve and can cause statistical fluctuations in the resultant signal. In our study, the OD for Teflon embedded LMP discs having thickness from 0.1 mm-1.0 mm was measured and the results are shown in Table -1. The OD of 0.4 mm and 0.8 mm thick discs made from Teflon only was also measured and was found to be 0.20 ± 0.01, 0.35 ± 0.02 respectively (Table-1). From these OD values, it has been found that ~36% of OSL (compared to surface contribution) comes from the base of 0.4 mm thick LMP discs whereas the transmission for pure Teflon disc having thickness of 0.4 and 0.8 mm are ~ 63% and 45% respectively. The optical attenuation coefficient (μ) was found to be 1.15 mm^{-1} and 2.53 mm^{-1} for 0.4 mm thick (pure) Teflon and Teflon embedded LMP discs.

Table – 1: OD values for pure Teflon and Teflon embedded LMP disc dosimeters

Type	Thickness (mm)	OD	Transmission %
Teflon embedded LMP	0.1	0.25± 0.03	56.23
	0.2	0.38± 0.04	41.68
	0.3	0.41±0.03	38.90
	0.4	0.44±0.03	36.30
	0.6	0.95±0.05	11.22
	0.8	1.06±0.03	8.71
	1.0	1.35±0.08	4.46
Pure Teflon	0.4	0.20 ± 0.01	63.10
	0.8	0.35 ± 0.02	44.66

OD also plays an important role in ensuring the quality control of dosimeters and it is expected that for a given batch of dosimeters, the OD values should be nearly same.

2.6 Disc to disc variation/batch inhomogeneity: The distribution in grain size of the phosphor leads to the spread in OSL sensitivity of the phosphor in powder form which further increases for Teflon embedded OSL discs and is due to the fact that during bulk mixing of the phosphor and Teflon, the grains of different sizes are disturbed in different discs but on the average it is assumed that amount of phosphor and number of grains of the same size are present in the disc. In addition, slight variation in mass, diameter and thickness in the dosimeter disc can also contribute towards spread in OSL sensitivity. Change in the optical transparency/OD amongst the discs due to repeated use, bleaching *etc.* may further increase the spread in the OSL sensitivity. This becomes a major limitation in dosimetry programmes which use batch calibration rather than individual calibration of dosimeters. Batch to batch variation of $< \pm 8$ % is desirable for use of OSLDs in personnel monitoring applications.

2.7 Spurious luminescence: Inorganic as well as organic impurities deposited on the OSL dosimeter may lead to spurious signal during OSL recording. In view of this, the dosimeters should be free from the external impurities.

3. CONCLUSIONS:

It is clear from the foregoing discussion that the intensity of stimulation affects background counts, minimum measurable dose (MMD), recording time of the CWOSL curves and peak intensity of CWOSL curves. The effect of parameters such as optical density (OD), self-absorption *etc.* which are associated with the OSL dosimeters was also investigated and their role in quality control during large scale batch manufacturing of dosimeters has been described. The optical attenuation coefficient (μ) was also measured and found to be 1.15 mm^{-1} and 2.53 mm^{-1} for 0.4 mm thick Teflon and Teflon embedded LMP disc dosimeters.

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References:

1. S.W.S. McKeever, M. Moscovitch, Radiat. Prot. Dosim. 104 (2003) 263.
2. Guide to the Riso TL/OSL reader, RISO, DTU, Denmark, 2010.
3. Munish Kumar, Bhushan Dhabekar, S.N. Menon, M.P. Chougaonkar and Y.S. Mayya, Nuclear Instruments and Methods in Physics Research B 269 (2011) 1849.
4. M.P. Chougaonkar, B.C. Bhatt, Radiat. Prot. Dosim. 112 (2004) 311.