

# RADIATION DOSIMETRY: FROM THERMOLUMINESCENCE DOSIMETER (TLD) TO OPTICALLY STIMULATED LUMINESCENCE DOSIMETER (OSLD)

Maseeh uz Zaman,<sup>1,3</sup> Nosheen Fatima,<sup>2,3</sup> Mansoor Naqvi,<sup>1</sup> Riffat Parveen,<sup>1</sup> Zafar Sajjad<sup>1</sup>

<sup>1</sup> Department of Radiology, The Aga Khan University Hospital, Karachi, Pakistan.

<sup>2</sup> Karachi Institute of Radiotherapy And Nuclear Medicine (KIRAN), Karachi, Pakistan.

<sup>3</sup> Karachi Institute of Heart Diseases (KIHD), Karachi, Pakistan.

PJR July - September 2011; 21(3): 107-109

In medicine, radiation dosimetry is an important and regulatory requirement for surveillance of radiation workers in radiology, nuclear medicine and radiation oncology. It is also required for quality assurance (i.e. precise estimation of delivered dose to patient) in external beam radiation therapy and brachytherapy as well. In this review we will discuss types of dosimeters used in medical physics, principles of luminescence, comparison of thermoluminescent detectors (TLD) and optically stimulated luminescence (OSL).

**Types of Dosimeters:** Can be broadly classified as active or passive according to their design.

1) **Active dosimeters** measure exposure in real time. These instruments have an analog or digital readout of the immediate reading, the cumulative reading, or both. Some active dosimeters will store a history of dosage in a recoverable memory. Common active dosimeters are:

- a) **Electronic Dosimeters:** it includes Geiger-Muller or semiconductor detectors and can detect X-rays and gamma radiations. These are relatively expensive, usually quite rugged and reusable too.
- b) **Quartz Fiber Electroscope (QFE):** it consists of a small ionization chamber with a quartz fiber which is deflected by ionization caused by radiation interaction displayed in the eyepiece lens. However, it is very delicate and easily damaged if dropped or roughly handled.

2) **Passive dosimeters** do not provide immediate feedback to the user. Additional analyses or calculation are required to determine the dose. It includes:

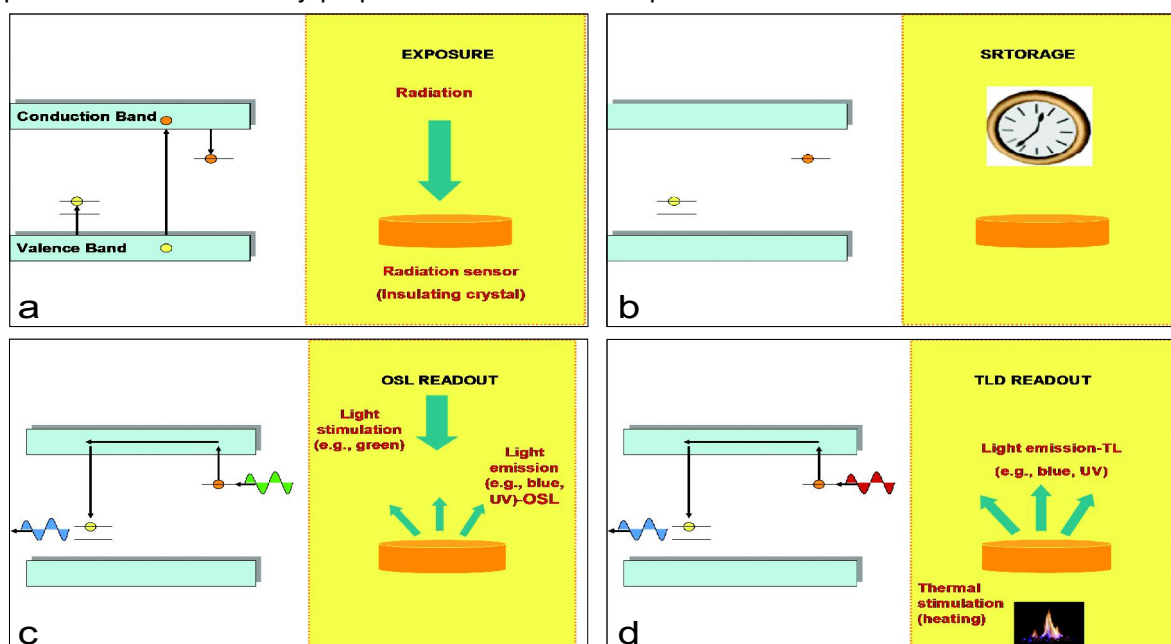
- a) **Film badges:** Use highly sensitivity silver halide film with a range of filters to distinguish exposures from beta, X-ray, gamma and thermal neutrons. Dose is determined by degree of blackening (optical density) and comparing it with calibrated films. Provides permanent record of an individual's dose. Their drawbacks are shorter shelf life, adverse effects of light and heat and require dark room facilities.
- b) **Thermoluminescence dosimeter (TLD) and optically stimulated luminescence dosimeters (OSLD).**

**Principle of Luminescence:** The phenomenon of luminescence follows a model of two energy bands, the valence and conduction, separated by a forbidden gap. Defects purposely introduced into the material during fabrication act as local energy bands with levels within the forbidden gap, called traps. When ionizing radiation is introduced to the material it creates electron-hole pairs, and excites electrons up to the conduction band and holes move to the valence band. From here, electrons can travel amongst the crystal lattice until one of two things happen. The electron can cross back towards the valence band and recombine with a hole. However, if near a defect, it can fall into the energy trap. The electron is now prevented from recombining with a hole until it can gain enough energy to once again reach the conduction band. This stimulation is

**Correspondence :** Dr. Maseeh uz Zaman  
Section of Nuclear Medicine,  
Department of Radiology, Aga Khan University Hospital,  
Stadium Road, P.O. Box 3500, Karachi 74800  
Pakistan. Tel. No: 34930051 - Ext. 2020  
E-mail: maseeh.uzzaman@aku.edu

accomplished by either introducing heat, causing TL, or optical photons, causing OSL (Fig. 1). The number of trapped electrons is normally proportional to the

amount of ionizing radiation received. This is the concept that makes crystals with defects a viable passive dosimeter.<sup>1</sup>



**Figure 1:** Principle of Luminescence (TLD and OSLD).

- a. Exposure
- b. Storage
- c. OSL readout
- d. TLD readout

**Thermoluminescent Dosimeters (TLD):** For a number of decades, thermoluminescent dosimeters (TLD) have been the passive detector of choice, able to perform in vivo dosimetry as well as remote quality assurance checks of radiation therapy delivery systems.<sup>2</sup> For personal dosimetry, Lithium (LiF:Mn) based TLDs are used as they are tissue-equivalent. Drawbacks of TLD include a necessary post-irradiation wait period, energy dependence, careful heating techniques to avoid fading, and destruction of signal after one reading.

**Optically stimulated luminescent dosimetry (OSLD):** In recent years, new materials and methods have been proposed to improve passive dosimetry. One of these includes optically stimulated luminescence (OSL), which is based on the underlying physics phenomena similar to TLDs, but is able to overcome a number of drawbacks inherent to the TLD. Aluminum oxide with carbon doping (Al<sub>2</sub>O<sub>3</sub>:C) is the currently substance in use although there are other materials being tested.<sup>3,4</sup> Al<sub>2</sub>O<sub>3</sub>:C was originally designed as a TL dosimeter, noted for its high sensitivity. However,

when it was found to be affected by exposure to light, it was investigated as an OSLD.<sup>5</sup> OSLDs have the same possibilities of applications that TLDs do and can thus be used for in vivo, independent, and even real-time dosimetry. The largest difference in the dosimetry process is the readout technique. TLDs are carefully heated while OSLDs are stimulated via optical methods (Tab.1).

	TLD	OSLD
Dose range (rad)	0-1,000	0-1,000
Lowest Limit of Detection (rad)	<0.001	0.0001
Sensitivity	High	Very high
Results	Days	Days
Reusable	Yes	Yes
Size	Small	Small
Shock	Sturdy	Sturdy
Radiation	Most	Most
Archiving	No	Yes
Dynamic & static exposure	No	Yes

**Table 1:** Comparison of TLD and OSLD.

### Benefits of OSLD:<sup>6</sup>

- 1) Significantly faster process in comparison with TLD.
- 2) The light exposure can be controlled with very high precision.
- 3) Accuracy of dosimetric measurements is high.
- 4) Allows for multiple readouts.
- 5) Only a fraction of the radiation exposure signal contained in the  $\text{Al}_2\text{O}_3$  material is depleted upon stimulation with the green light.
- 6) The retention of dose enables archiving of the detector for future dose evaluations.
- 7) High degree of environmental stability (heat, humidity, or chemical solvents do not affect the detector).
- 8) A special digital image processing technique allows for two-dimensional quantitative analysis and qualitative image review to differentiate between static and dynamic exposures.
- 9) Accurately measures low and high-energy photons, and beta particles.

### References

1. AS Pradhan, JI Lee, JL Kim. Recent developments of optically stimulated luminescence materials and techniques for radiation dosimetry and clinical applications. J Med Phy 2008; **33(3)**: 85-99.
2. TH Kirby, W F Hanson, R J Gastorf, C H Chu, R J Shalek. Mailable TLD system for photon and electron therapy beams. Int J Radiat Oncol Biol Phys 1986; **12(2)**: 261-5.
3. AJJ Bos. High sensitivity thermoluminescence dosimetry." Nucl Instrum Methods Phys Res B 2001; **184**: 3-28.
4. EM Yoshimura, E. G. Yukiara. Optically stimulated luminescence of magnesium aluminate ( $\text{MgAl}_2\text{O}_4$ ) spinel." Radiation Measurements 2006; **41**: 163-9.
5. MS Akselrod, V S. Kortov, E A. Gorelova. Preparation and Properties of  $\text{Al}_2\text{O}_3\text{:C}$ . Radiation Protection Dosimetry 1993; **47**: 159-64.
6. <http://www.osldosimetry.com/contact>