Optically Stimulated Luminescence Dosimeters (OSLDs) & Thermoluminescence Dosimeters (TLDs)

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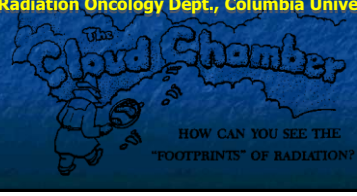


Thermoluminescence (TL)

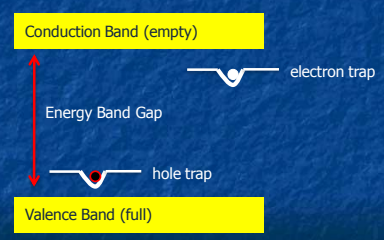
- the process of stimulating, using thermal energy, the emission of luminescence from a substance following the absorption of energy from an external source by that substance.

Picture taken by Larry. A. DeWerd
Courtesy of Prof. DeWerd, UW-Madison

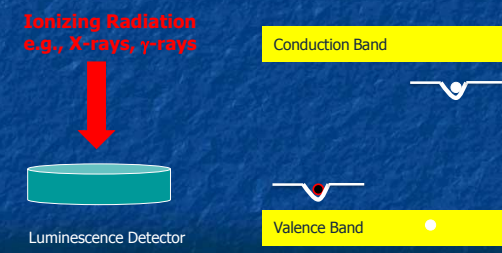
Optically Stimulated Luminescence (OSL)

- the process of stimulating, using optical energy, the emission of luminescence from a substance following the absorption of energy from an external source by that substance.

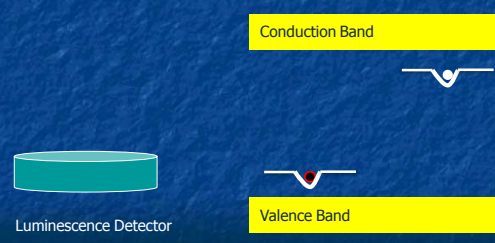
Luminescent Material
(Insulator)



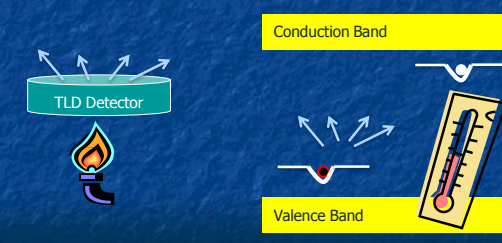
1st Stage Involved in the Luminescence Process
Excitation by ionizing radiation



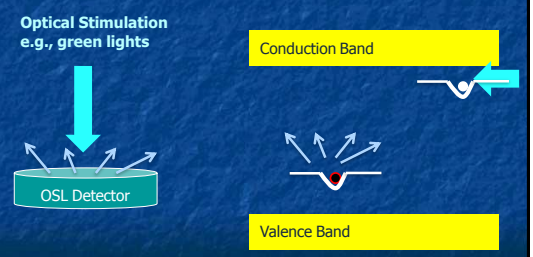
2nd Stage Involved in the Luminescence Process
Latent Period



3rd Stage Involved in the Luminescence Process
Readout: heating for TLD



3rd Stage Involved in the Luminescence Process
Readout: optical stimulation for OSL



Background

- **Both thermoluminescence and optically stimulated luminescence have been known for many years.**
- **TLD has a long track record as a successful method for radiation dosimetry, from LiF: Mg, Ti emerged in 50s to the recent LiF:Mg, Cu, P as a new TL material.**
- **OSLD for radiation dosimetry was more recent. Al_2O_3:C was developed in 90s. The future of OSLD is bright.**

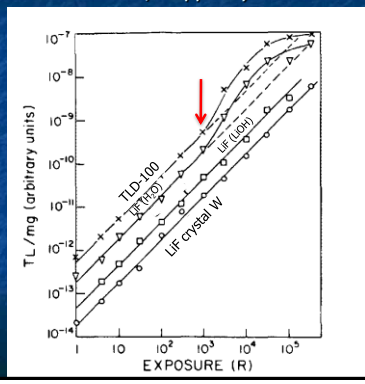
Example of OSL Instrumentation

Comparison of TLD & OSLD

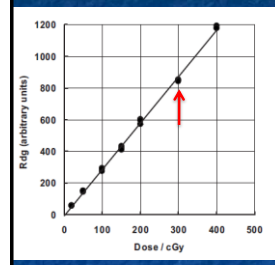
- **Dose linearity**
- Energy response
- Angle dependence
- Temperature dependence
- Transient signal and fading

TLD Dose Linearity

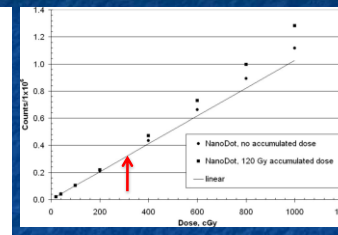
(TG Stoebe and LA DeWerd, J Appl Phys 57:2217-2220, 1985)



OSLD Dose Linearity

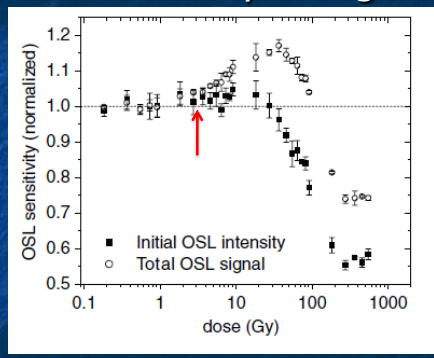


Viamonte A, Med. Phys. 35(4), 1261-1266, 2008



Jursinic PA, Med. Phys. 37(1), 132-140, 2010

OSLD Sensitivity Changes



Yukihara EG and McKeever SWS, Phys. Med. Biol. 53, R351-R379, 2008.

Dose Linearity: TLD & OSLD

TLD (LiF:Mg,Ti)

- Supralinear at high accumulated doses (>10Gy)

(*TG Stoebe and LA DeWerd, J Appl Phys 57:2217-2220, 1985*)

OSLD (Al_2O_3:C)

- Supralinear at high accumulated doses (>3Gy)
- The characteristics needs to be considered and controlled in order to make precise measurements in single-use protocol or multiple-use protocol.

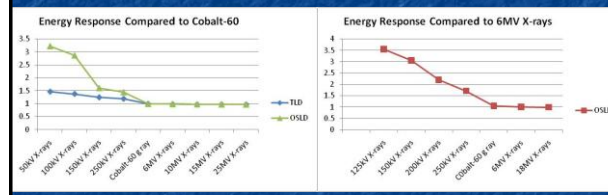
(*Jursinic PA, Med. Phys. 37(1), 132-140, 2010*)

Comparison of TLD & OSLD

- Dose linearity
- **Energy response**
- Angle dependence
- Temperature dependence
- Transient signal and fading

Energy Response: OSLD

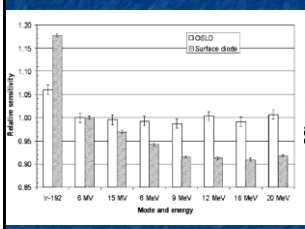
Z_{water} = 7.4; $Z_{Al_2O_3}$ ~ 11.28

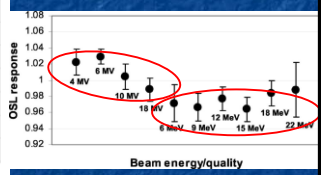


Graphed based upon Monte Carlo simulation results from Mobit et al, *Radiat. Prot. Dosim.* 119, 497-499, 2006.

Graphed based upon measured results from Reft, *Med. Phys.* 36(5), 1690-1699, 2009.

Energy Response in Radiation Therapy: OSLD



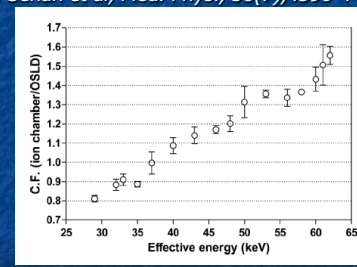


No significant variation for OSLD in therapy energy range.
Jursinic PA, Med. Phys. 34(12), 4594-4604, 2007

3.7% difference in OSL response between the photon beam and electron beam responses.
Schembri V, et al, Med. Phys. 34(6), 2113-2118, 2007

OSLD Energy Correction Factors in Diagnostic Energy Range

(RM Al-Senan et al, Med. Phys., 38(7),4396-4405,2011)



It is important to determine the beam energy and to use the correction factor for dose estimation.

Energy Response: TLD & OSLD

Z_{water} = 7.4; $Z_{Al_2O_3}$ ~ 11.28

- Both TLD and OSLD have energy response.
- Correction factors are needed.
- Particularly for OSLD applied in diagnostic energy range, beam quality needs to be carefully defined in order to reduce errors.

Comparison of TLD & OSLD

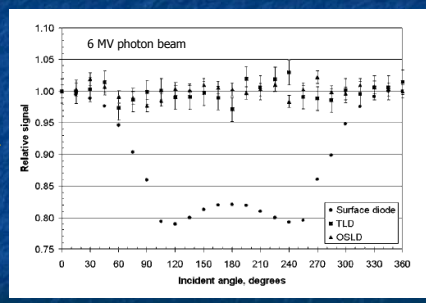
- Dose linearity
- Energy response
- **Angle dependence**
- Temperature dependence
- Transient signal and fading

Angle Dependence: TLD & OSLD

(Jursinic, Med. Phys. 34(12), 4594-4604, 2007)

Cylindrical phantom:
•3.6 cm diameter;
•5 cm length.

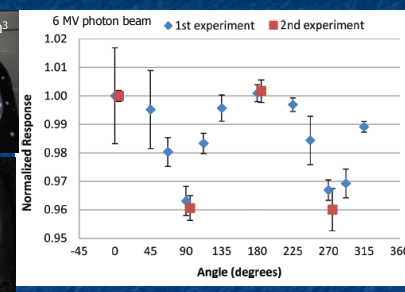
20cm tall block of high-density Styrofoam:
1. To provide an easy way to angle the cylindrical phantom;
2. To avoid inadvertent scatter from the treatment couch.



- TLD and OSLD: no angle dependence.
- Diode (MOSFET): ~ 20% variation.

Angle Dependence: OSLD

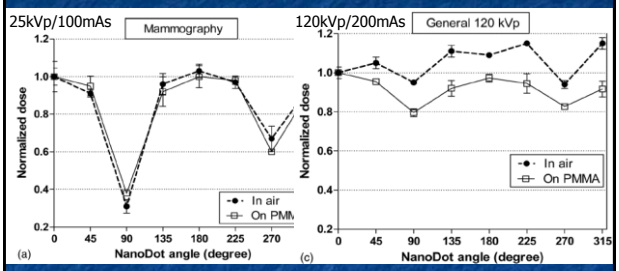
(Kerns et al, Med. Phys. 38(7), 3955-3962, 2011)



- OSL: a nontrivial angular response of 3- 4% was observed at 90°.
- TLD: encapsulated in cylindrical shape, shows no angular dependence.

OLSD Angular Dependence in Diagnostic Energy Range

(RM Al-Senan et al, Med. Phys., 38(7),4396-4405,2011)

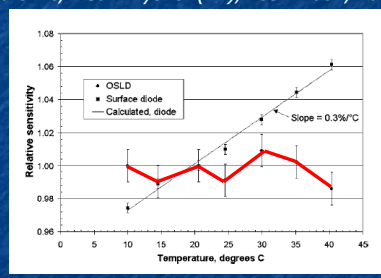


Comparison of TLD & OSLD

- Dose linearity
- Energy response
- Angle dependence
- **Temperature dependence**
- Transient signal and fading

Temperature Dependence at Time of Irradiation: OSLD

(Jursinic, Med. Phys. 34(12), 4594-4604, 2007)



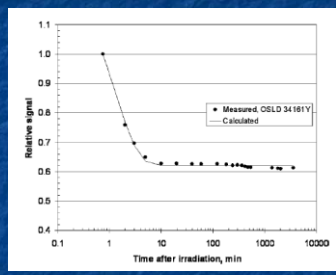
- OSLD: no temperature effect at time of irradiation; thus good for in vivo dosimetry.

Comparison of TLD & OSLD

- Dose linearity
- Energy response
- Angle dependence
- Temperature dependence
- **Fading and transient signal**

Fading and Transient Signal: OSLD

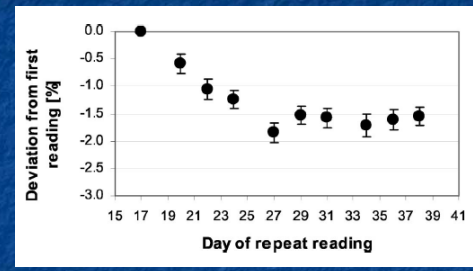
(Jursinic, Med. Phys. 34(12), 4594-4604, 2007)



- OSLD: A wait time in the dark of 8 min after irradiation is adequate to avoid the transient signal.

Fading and Transient Signal: OSLD

(Schembri et al, Med. Phys. 34, 2113-8, 2007)



- Slow fading in a 3-wk period from Day 17 to Day 38.

Summary

- **Both TLD and OSLD are strong and popular tools for radiation dosimetry.**
- **OSLD adds the versatility.**
- **Both TLD and OSLD methods have multiple materials that provide various properties. When we consider pros and cons of the two, we should not only look at LiF and Al_2O_3.**
- **More clinical applications are being developed, e.g., remote fiber optic dosimetry using OSLD.**

References

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L. A. DeWerd *et al*: TLD
J. E. Cygler *et al*: OSLD
Available on AAPM Virtual Library
- "**Introduction to Radiological Physics and Radiation Dosimetry**" by F. H. Attix, Wiley-Interscience, New York, 1986.
- "**Optically Stimulated Luminescence: Fundamentals and Applications**", by E. G. Yukihara and S. W. S. Mckeever, John Wiley & Sons Ltd, 2011.

ANY QUESTIONS?