Types of OSL

1. *Continuous Wave OSL* ***(CW-OSL)***: the stimulation intensity is kept constant throughout the duration of the experiment, with simultaneous monitoring of the signal.
2. *Linearly Modulated OSL* ***(LM-OSL):*** the stimulation intensity is linearly increased with time, with simultaneous monitoring of the signal.
3. *Non-linearly Modulated OSL* ***(NLM-OSL):*** the stimulation intensity is non-linearly increased (parabolically, hyperbolically, etc) with time, with simultaneous monitoring of the signal.
4. *Pulsed OSL* ***(P-OSL):*** the sample is exposed to stimulation pulses, while monitoring of the signal takes place when stimulation mode is off ***(NO FILTERS REQUIRED)***.

Lambert Beer Law

$$I(\lambda,x) = I_0(\lambda)\exp\{-\alpha(\lambda)x\}$$

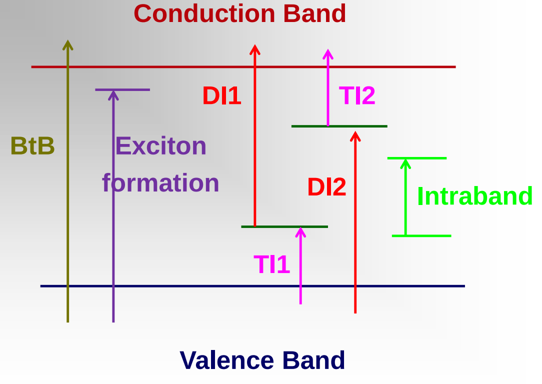
$\alpha(\lambda)$ = absorption coefficient

$I(\lambda,x)$ = intensity at position x

$I_0(\lambda)$ = incident intensity

Excitation = ionizing radiation

Stimulation = electromagnetic radiation



Dependences

$$\alpha\,(hf) = n(E_0)\,\sigma(hf, E_0)$$

$\alpha(hf)$ = absorption coefficient

$n(E_0)$ = concentration of traps/defects

$\sigma(hf, E_0)$ = photo-ionization cross section

$$\sigma(hf, E_0) \sim \frac{(hf - E_0)^{\frac{3}{2}}}{(hf)^5}$$

E_0 = optical ionization threshold energy

Caution

E_0 = optical ionization threshold energy in OSL

≠

E = activation energy, trap depth in TL

The theory of OSL is not related to the corresponding TL theory = the trap depth/activation energy is not considered in the photo-ionization theory.

Simultaneous thermal and optical stimulation

$$p_{total} = p_{thermal} + p_{optical} = s\cdot\exp\left(-\frac{E_o}{k\cdot T}\right) + \sigma(E_o)\cdot\varphi$$

1. Case of CW-OSL

$$L(t) = n_0\cdot\left(s\cdot\exp\left(-\frac{E}{k\cdot T}\right)+\sigma\cdot\varphi\right)\cdot\exp\left(-s\cdot t\cdot\exp\left(-\frac{E}{k\cdot T}\right)\right)\cdot\exp(-\sigma\cdot\varphi\cdot t)$$

2. Case of LM-OSL

$$L = L_m\cdot\left(1-\sqrt{\sigma\cdot q}\,(t_m-t)\right)\cdot\exp\left[\sqrt{\sigma\cdot q}\,(t_m-t)+\sigma\cdot q\cdot t_m\cdot t-\frac{\sigma\cdot q}{2}\cdot\left(t_m^2+t^2\right)\right]$$

σ estimation: fitting of CW-OSL 1

$$I(t) = I_0\left[1+(b-1)\,\frac{t}{\tau}\right]^{-\frac{b}{b-1}}$$

- Fitting parameters

1. b = kinetic order (ranging between 1 and 2)
2. τ = decay lifetime of the OSL component
3. I_0 = maximum intensity of the OSL component

Independent variable: time t (s)

$$\tau = (\sigma\cdot\varphi)^{-1}$$

φ = instrumental parameter expressed in units of W/cm^2
→ should be converted in units of photons per cm^2

σ estimation: fitting of CW-OSL 2

For the stimulation light intensity expressed in W/cm^2 one obtains

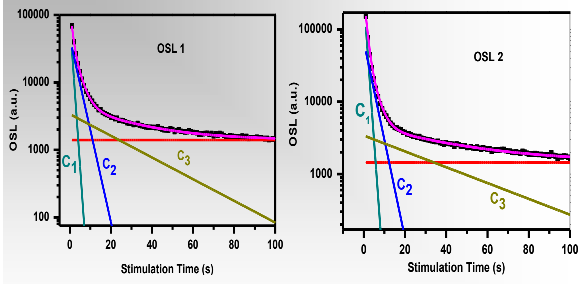
$$c_f = \frac{\text{Joule}}{\text{s cm}^2} = \frac{6.24146\times10^{18}\ \text{eV}}{\text{s cm}^2}. \qquad (9)$$

For a given stimulation photon energy E_ϕ

$$c_f = \frac{6.24146\times10^{18}}{E_\varphi}\left[\frac{\text{eV}}{\text{eV s cm}^2}\right]. \qquad (10)$$

$$\frac{1}{\tau P_{stimW} c_f} = \sigma$$

Deco examples: Quartz



σ estimation: fitting of LM-OSL

$$I(u)=\frac{I_m}{u_m}\cdot u\cdot\left(\frac{\beta-1}{2\cdot\beta}\cdot\frac{u^2}{u_m^2}+\frac{\beta+1}{2\cdot\beta}\right)^{\frac{\beta}{1-\beta}}$$

- Fitting parameters

1. u_m = stimulation time where the signal gets its maximum value
2. β = kinetic order (ranging between 1 and 2)
3. I_m = maximum intensity of the peak

Independent variable: Stimulation time u (s)

$$\sigma=\frac{2P}{c_f\cdot I_0\cdot u_m^2(\beta+1)}. \tag{8}$$

For the stimulation light intensity expressed in W/cm^2 one obtains

$$c_f=\frac{\text{Joule}}{\text{s cm}^2}=\frac{6.24146\times10^{18}\ \text{eV}}{\text{s cm}^2}. \tag{9}$$

For a given stimulation photon energy E_ϕ

$$c_f=\frac{6.24146\times10^{18}}{E_\varphi}\quad\left[\frac{\text{eV}}{\text{eV s cm}^2}\right]. \tag{10}$$

Eventually

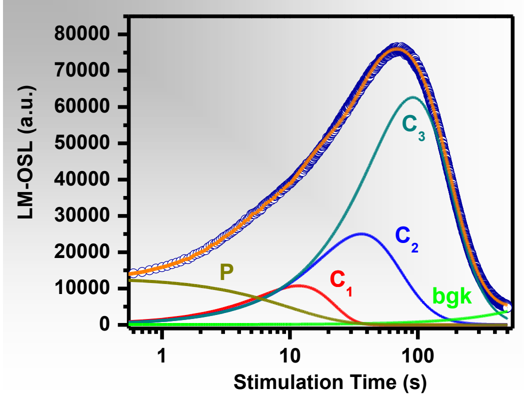
Total measurement time

$$\sigma=\frac{2P\cdot E_\varphi}{6.24146\cdot10^{18}\cdot u_m^2 I_0\cdot(\beta+1)}. \tag{11}$$

Time corresponding to maximum intensity

Maximum stimulation intensity in W/cm^2

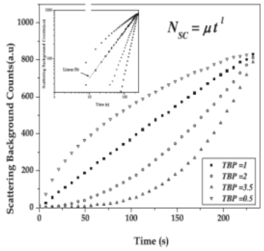
$BaSO_4$:Eu



Non-linearly Modulated OSL **(NLM-OSL)**

$$\varphi(\lambda) = \varphi(\lambda, t, l) = \gamma' t^l \qquad \gamma = \frac{d\varphi(\lambda)}{dt} = \gamma' l t^{l-1}$$

$$_b^l I_{NL-OSL} = \sigma \gamma' n_0 t^l \left[1 + (b-1)\frac{\sigma \gamma' t^{l+1}}{l+1}\right]^{b/1-b}$$



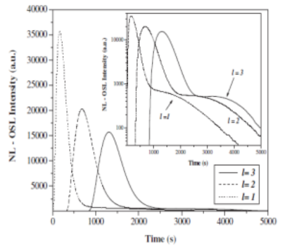


Table 2
Deconvolution results concerning the t_{max} values of all LM-OSL components for both types of irradiation.

Component t_{max} σ	β, RT	α, RT	β,125 °C	α,125 °C
C_1	6.8 ± 0.3 (s) 9.1×10^{-15} (cm^2)	7.5 ± 0.4 (s) 1.2×10^{-16} (cm^2)	12.4 ± 0.5 (s) 3.1×10^{-16} (cm^2)	12.4 ± 0.7 (s) 3.1×10^{-16} (cm^2)
C_2	25.6 ± 0.4 (s) 9.3×10^{-16} (cm^2)	30.3 ± 0.5 (s) 2.3×10^{-17} (cm^2)	32.3 ± 0.6 (s) 1.3×10^{-17} (cm^2)	35.3 ± 0.8 (s) 1.1×10^{-17} (cm^2)
C_3	98.3 ± 0.3 (s) 4.7×10^{-18} (cm^2)	86.7 ± 0.6 (s) 7.3×10^{-18} (cm^2)	92.9 ± 0.8(s) 3.4×10^{-18} (cm^2)	88.9 ± 1 (s) 7.1×10^{-18} (cm^2)
C_4	173.1 ± 5 (s) 1.9×10^{-19} (cm^2)	176.4 ± 6 (s) 2.1×10^{-19} (cm^2)	143.8 ± 5.5 (s) 7.2×10^{-19} (cm^2)	138.8 ± 6 (s) 8.1×10^{-19} (cm^2)
C_5	497.8 ± 23 (s) 2.7×10^{-20} (cm^2)	524.8 ± 24 (s) 2.5×10^{-20} (cm^2)	323.7 ± 24.3 (s) 6.8×10^{-20} (cm^2)	293.7 ± 26 (s) 7.7×10^{-20} (cm^2)
C_6	1842.5 ± 75 (s) 2.2×10^{-22} (cm^2)	1659.8 ± 69 (s) 1.3×10^{-22} (cm^2)	1233.6 ± 61 (s) 4.7×10^{-22} (cm^2)	942.5 ± 57(s) 2.3×10^{-21} (cm^2)

The cross-section, σ, values reported in literature vary by over four orders of magnitudes, ranging from $\sim 10^{-17}$ for the "fast" components up to the $\sim 10^{-21}$ cm^2 for the "slow" components.

Values of cross-section for each component in cm^2

Components	Samples			
	alt	atk	pdk	sle
C_1	3.3×10^{-15}	3.1×10^{-15}	2.8×10^{-15}	1.1×10^{-15}
C_2	1.5×10^{-16}	8.0×10^{-17}	1.1×10^{-16}	1.0×10^{-16}
C_3	7.2×10^{-18}	6.6×10^{-18}	9.3×10^{-18}	6.6×10^{-18}
C_4	4.8×10^{-19}	4.7×10^{-19}	4.2×10^{-19}	5.1×10^{-19}
C_5	3.4×10^{-20}	2.9×10^{-20}	3.1×10^{-20}	2.9×10^{-20}
C_6	5.5×10^{-22}	5.9×10^{-22}	5.9×10^{-22}	6.6×10^{-22}

Table 1
OSL characteristics of CaF_2:N

Peak number	u_m (s)	β	σ (10^{-18} cm^2)
1	13.55767	1.56	24.99149
2	80.65983	2	0.60312
3	195.1535	2	0.10304
4	649.29629	1.75	0.01015

Excitation and Luminescence Photon Energies Used in OSL Dating

Mineral	*Energy (wavelength) of excitation photons*	*Energy (wavelength) of luminescence photons*
Quartz (SiO_2)	**2.2 – 2.4 or 2.7 eV (510 – 560 or 470 nm) green-blue**	**3.35 eV (370 nm) ultraviolet**
Potassium Feldspar $KAlSi_3O_8$	**1.4 eV (880 nm) infrared**	**3.1 eV (400 nm) Violet**

Appropriate detection filters required

Excitation and Luminescence Photon Energies Used in OSL Dosimetry

Dosimeter	*Energy (wavelength) of excitation photons*	*Energy (wavelength) of luminescence photons*
Quartz (SiO_2) **Al_2O_3:C, BeO, CaF_2:N, CaF_2:Dy MgO, $BaSO_4$:Eu, KBr:Eu**	**2.2 – 2.4 or 2.7 eV (510 – 560 or 470 nm) green-blue**	**3.35 eV (370 nm) ultraviolet**

Appropriate detection filters required