# Chapter 1
# INTRODUCTION TO LUMINESCENCE SIGNALS AND MODELS

**Abstract** In this introductory chapter we introduce two types of thermally and optically stimulated luminescence signals, which are commonly used for luminescence dosimetry and luminescence dating. Phenomena like thermoluminescence (TL), optically stimulated luminescence (OSL) and radioluminescence (RL), usually take place in a time scales of seconds, while time-resolved (TR) luminescence phenomena usually take place in a ms or $\mu$s scale. We provide an overview of commonly used luminescence models, based on delocalized and localized transitions, and discuss optical absorption (OA) and Electron Spin Resonance experiments (ESR), and their connection and importance in luminescence dosimetry. This chapter concludes with a brief discussion of what types of information researchers typically extract from the experimental data described in this chapter.

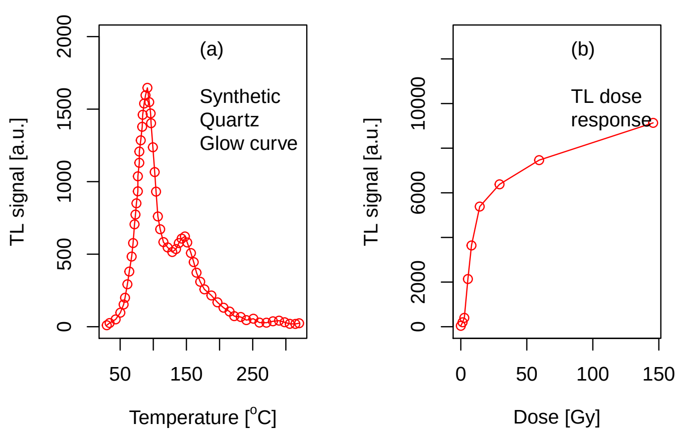

**Fig. 1.1:** (a) Example of a TL glow curve for synthetic quartz, after irradiation with a beta dose of 2 Gy. (b) The TL dose response of this quartz sample, obtained by plotting the maximum intensity of the TL signal as a function of the irradiation dose. For more details see Kitis et al. [15].

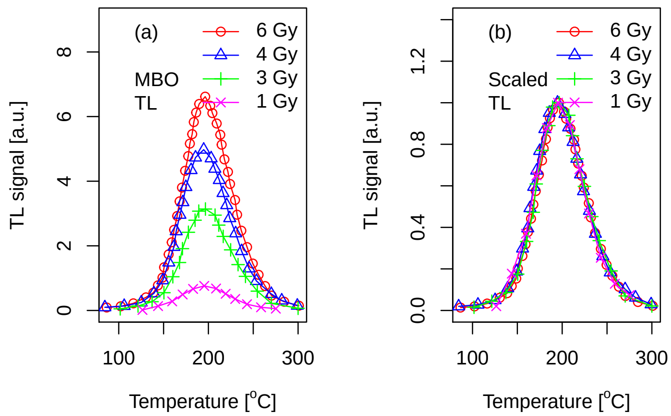


**Fig. 1.2:** (a) Example of a series of TL glow curves for sample MBO, at different beta doses. (b) The data in (a) is normalized to the maximum TL height. For more details see Pagonis et al. [32].

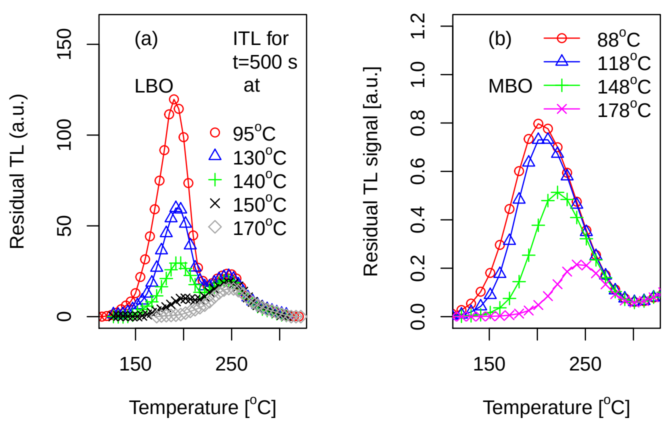

**Fig. 1.3:** (a) Example of a series of TL glow curves for sample LBO, after irradiation and heating up to the temperatures indicated in the legends, and (b) A very similar series of TL glow curves for sample MBO. The different behaviors of these two samples indicate that different luminescence mechanisms are involved in each case. For more details see Kitis et al. [18].

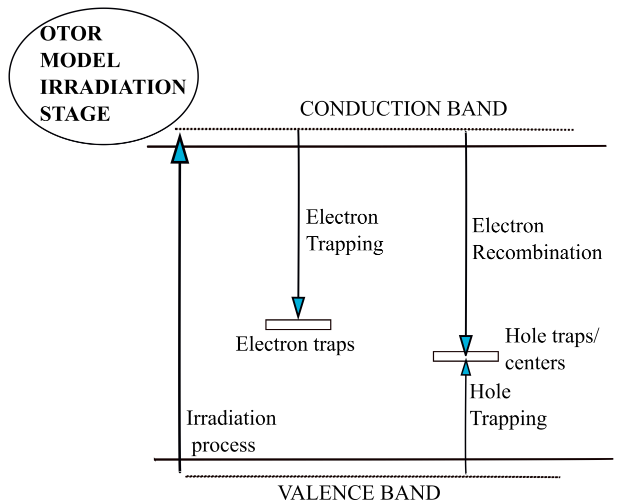


**Fig. 1.4:** The simplest OTOR model, showing the various electronic transitions during the irradiation stage. Irradiation creates electrons and holes in the conduction and valence bands, respectively. Electrons in the conduction band can subsequently either be trapped in electron traps, or they can recombine with holes at the recombination centers/hole traps. Holes in the valence band can be trapped in the same recombination centers/hole traps.

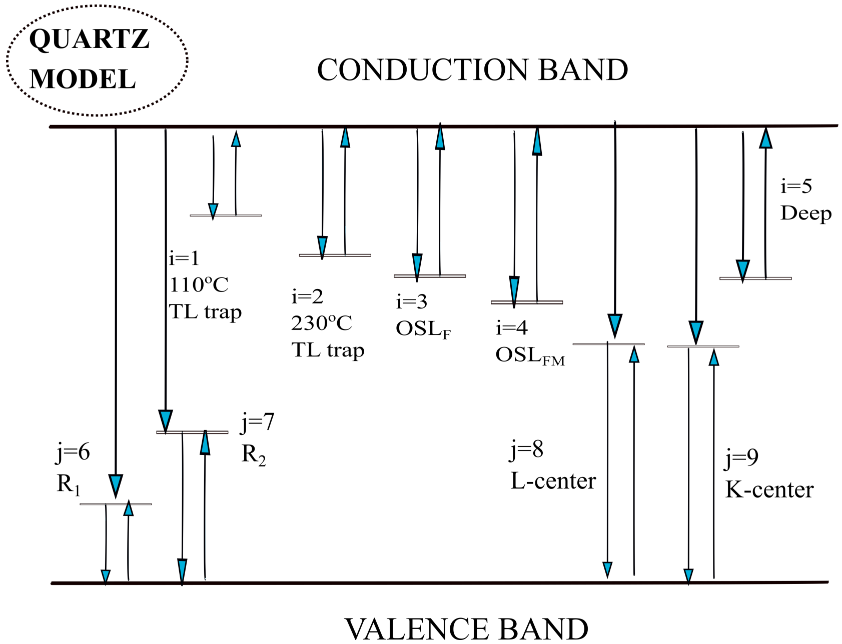


**Fig. 1.5:** Example of a complex *delocalized model* for quartz, involving multiple traps and centers (after Bailey [1]). Each arrow represents a transition between energy levels and the conduction and valence bands. These arrows also represent a mathematical term in a system of differential equations, as discussed in Chapter 11.

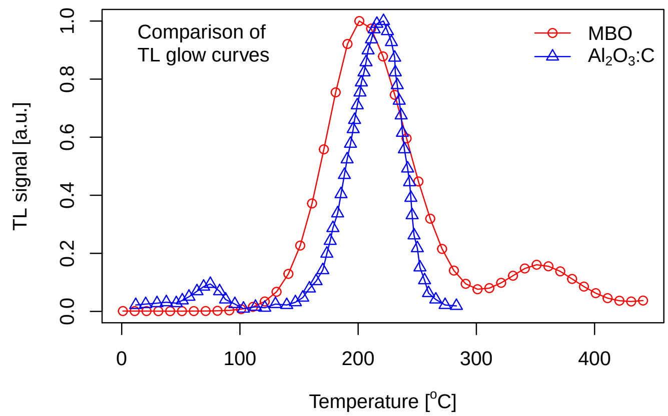


**Fig. 1.6:** Comparison of the TL glow curves MBO and $Al_2O_3$:C. The main dosimetric peak around 200°C for MBO is very nearly symmetric, while for $Al_2O_3$:C the main peak is asymmetric. Notice also the difference between the widths of the main dosimetric peaks in the two materials. For more details see Pagonis et al. [28] and from Kitis et al. [18].

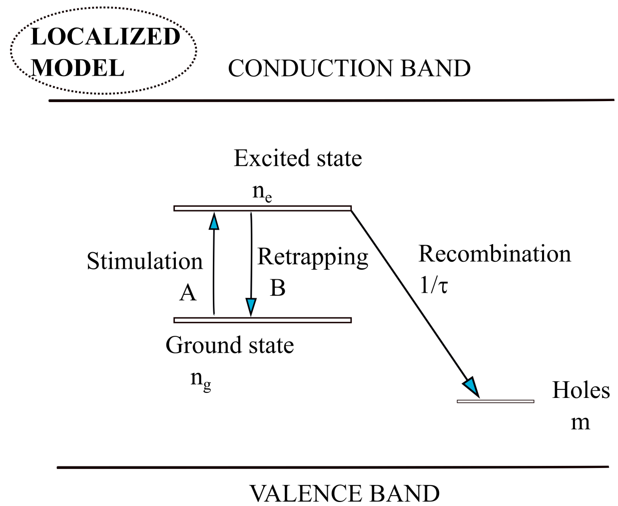


**Fig. 1.7:** A typical *localized transition model*, consisting of the ground state and the excited state of a trapped electron, and an additional energy level associated with a recombination center. Electrons are excited from the ground state ($n_g$) into the excited state ($n_e$ ) of the trap at a rate $A$, and can also relax back into the ground state of the trap at the rate $B$. The transition indicated by the rate $1/\tau$ occurs from the excited state of the trap to an energy level of the recombination center (after Pagonis et al. [36]).

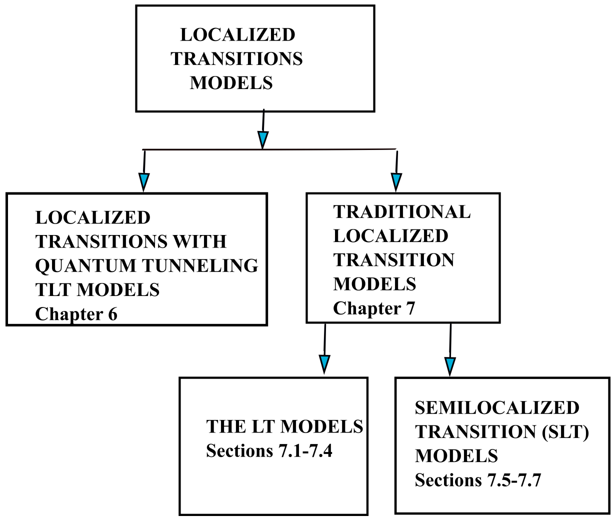


**Fig. 1.8:** The organization of localized transition models in chapters 6 and 7 of this book.

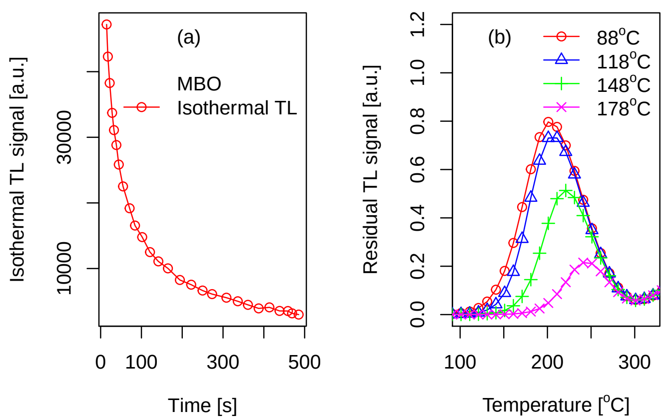


**Fig. 1.9:** (a) Isothermal TL signal for sample MBO and (b) a series of RTL glow curves, measured after an isothermal TL experiment for 500 s at the indicated temperatures. For more details see Kitis et al. ([18]).

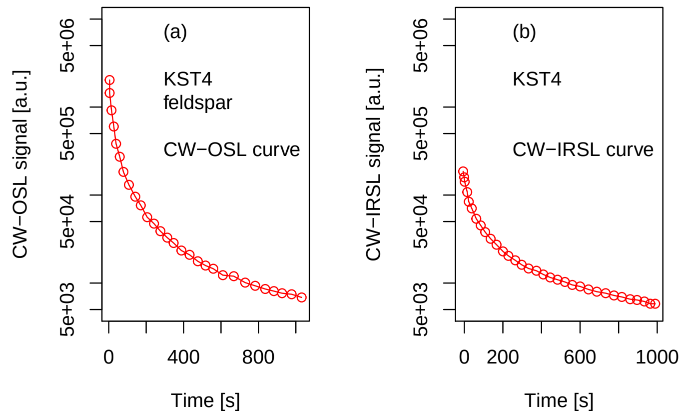


**Fig. 1.10:** Examples of (a) A CW-OSL curve and (b) CW-IRSL curve, from the same geological feldspar sample KST4. For more details see Kitis et al. [17].

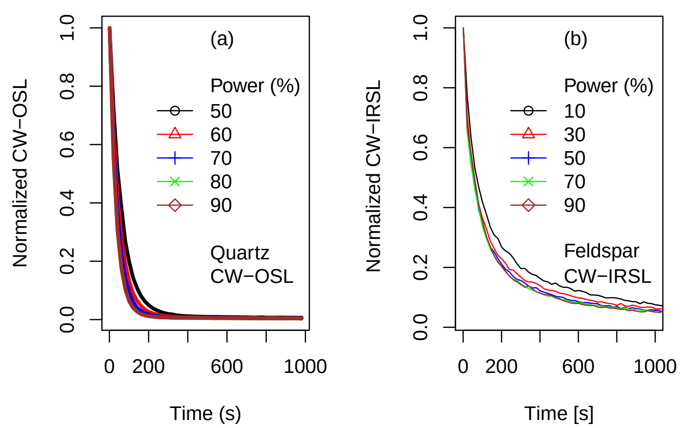


**Fig. 1.11:** (a) CW-OSL for quartz at different illumination powers in the range 50-90% of maximum power. (b) CW-IRSL signal at different illumination powers in the range 50-90% of maximum power, for a feldspar sample (laboratory code KST4). Both sets of data have been normalized to the maximum intensity. The shape of both signals changes with the illumination power. For more details see Pagonis et al. [40] and Polymeris [48].

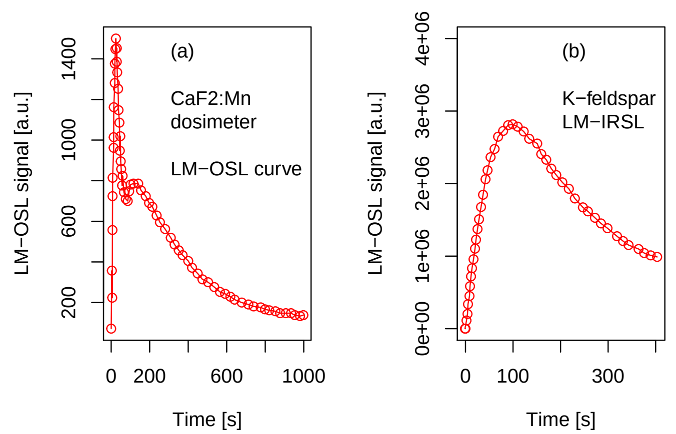


**Fig. 1.12:** Examples of (a) LM-OSL curve for the dosimetric material $CaF_2$:N (Kitis et al. [16]). (b) LM-IRSL for a K-feldspar. For more details see Bulur and Göksu [6].

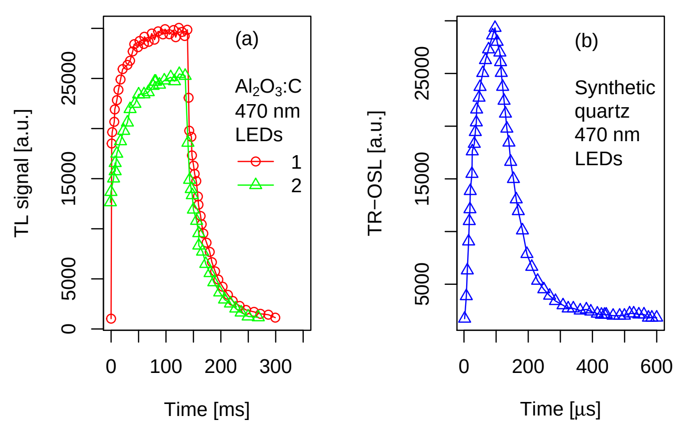


**Fig. 1.13:** Examples of TR-OSL curves for (a) $Al_2O_3$:C and (b) High purity synthetic quartz. Notice the very different time scales on the horizontal axis. The curves labeled 1 and 2 in (a) represent repeated measurements on the same sample, after the trapped electrons have been partially depleted. For more details see Pagonis et al. [43].

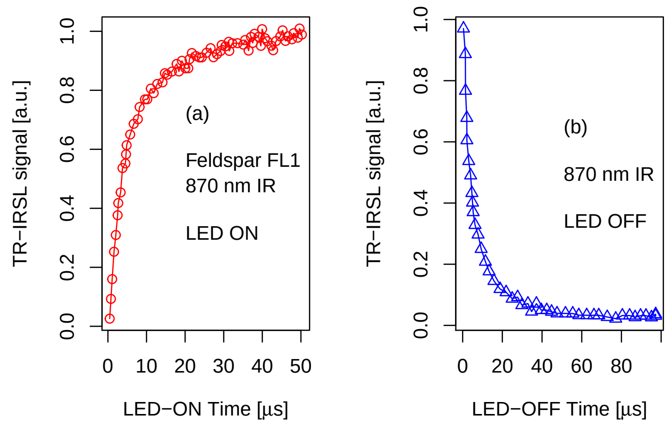


**Fig. 1.14:** Examples of TR-IRSL data for a feldspar sample FL1. (a) The TR-IRSL intensity as a function of the stimulation time during a 50 $\mu$s LED ON pulse. (b) The TR-IRSL intensity as a function of the stimulation time during the 100 $\mu$s LED OFF period. For more details see Pagonis et al. [29].

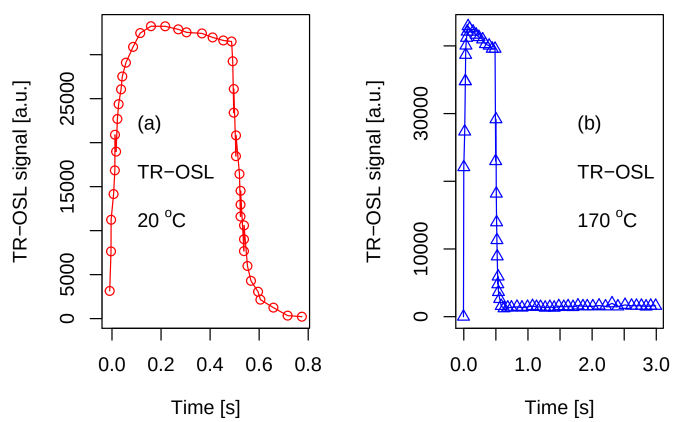


**Fig. 1.15:** Examples of TR-OSL data for $Al_2O_3 : C$ (a) At room temperature 20°C (b) at a stimulation temperature of 170°C. For more details see Pagonis et al. [28].

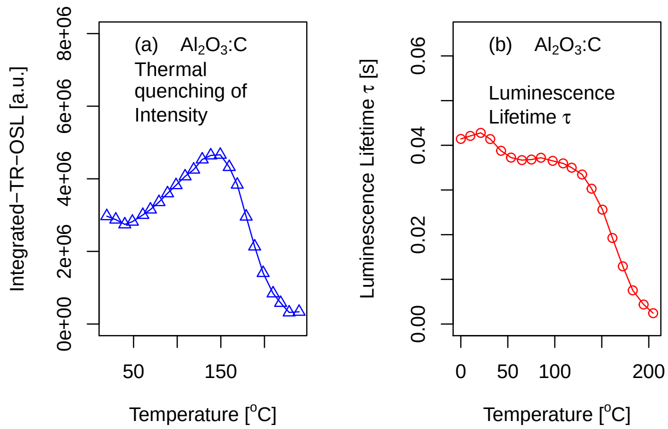


**Fig. 1.16:** Examples of TR-OSL data for $Al_2O_3$:C, showing the phenomenon of thermal quenching. (a) The integrated TR-OSL intensity as a function of the stimulation temperature. (b) The luminescence lifetime parameter $\tau$ as a function of the stimulation temperature. For more details see Pagonis et al. [28].

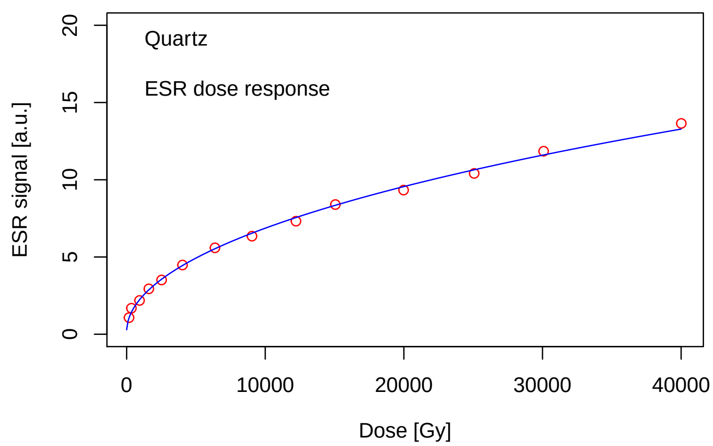


**Fig. 1.17:** Example of the dose response of ESR data from quartz. Redrawn from Pagonis et al. [38], original data from Duval [9].

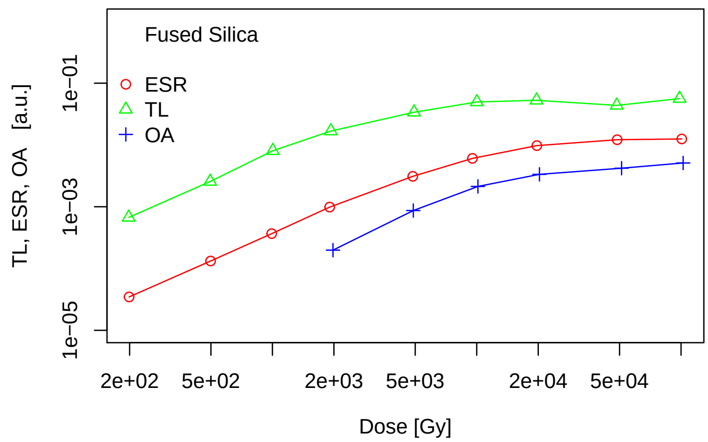


**Fig. 1.18:** Measurements of TL, ESR and OA signals as a function of the irradiation dose, from a single sample of fused silica. Note the log scale in both axes. For more details see Pagonis et al. [39], original data from Wieser et al. [53].