Radiation Measurements 81 (2015) 251–256

Contents lists available at ScienceDirect

Radiation Measurements

journal homepage: www.elsevier.com/locate/radmeas

OSL, TL and IRSL emission spectra of sedimentary quartz and feldspar samples

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HIGHLIGHTS

- We have measured OSL, IRSL and TL emission spectra of sedimentary quartz and feldspar samples.
- Spectral analyses were performed at elevated stimulation temperatures.
- Emission spectra show very little variation with stimulation temperatures.

ARTICLE INFO

Article history:
Available online 25 February 2015

Keywords:
Luminescence
OSL
TL
Quartz
Feldspar
Emission spectra

ABSTRACT

This contribution presents a variety of different luminescence emission spectra from sedimentary feldspar and quartz samples under various stimulation modes. These are green stimulated quartz (OSL-) spectra, quartz TL spectra, feldspar IRSL and post-IR IRSL spectra. A focus was set at recording OSL and IRSL spectra at elevated stimulation temperatures such as routinely applied in luminescence dating. This was to test whether optical stimulation at elevated temperatures results in a shift of emission peaks. For OSL emissions of quartz, this has so far not been tested. In case of feldspar emissions, post-IR IRSL conditions, hence IRSL emissions at a low temperature, directly followed by high temperature post-IRSL emissions, are explicitly investigated. All spectra were recorded using a new system incorporated into a Lexsyg luminescence reader. Thus, this study, besides presenting new spectral data, also serves as a feasibility study for this new device. It is shown that (a) the new device is capable of automatically measuring different sorts of spectra, also at elevated temperatures, (b) known thermally and optically stimulated peak emissions of quartz and feldspar are confirmed, (c) obtained IRSL and OSL spectra indicate that there is no significant relation between peak emission and stimulation temperature.

1. Introduction

Luminescence signals are conventionally measured in terms of intensity, i.e., photons are counted through photomultiplier tubes. The wavelength bandwidth of the emission is restricted to relatively narrow emission windows through optical filters. However, the overall luminescence signal consists of a variety of different emission peaks at different wavelengths, providing information on different luminescence centres. Knowledge on the emission wavelengths is vital for choosing optimal filter combinations, which enables a high signal to noise ratio and isolation of thermally stable emissions. Basic work on emission spectra of quartz and feldspar has been carried out in the 1980s–1990s (e.g., Rink et al., 1993; Bøtter-Jensen et al., 1994; Rendell and Wood, 1994; Clarke and Rendell, 1997; Huntley et al., 1988, 1989, 1991, 1996; Krbetschek and Rieser, 1995; Krbetschek et al., 1997; Rieser et al., 1997; Scholefield and Prescott, 1999). Since then, only little further research (e.g., Schilles et al., 2001; Baril, 2002; Martini et al., 2009; Tan et al., 2009; Westaway and Prescott, 2012) was dedicated to luminescence emission spectra, and in particular to optically stimulated luminescence (OSL) and infrared light stimulated luminescence (IRSL) spectra. The reasons for this research deficit appear manifold. Sensitive spectrometers are rare and expensive, it is not easy to block the stimulation light (especially in case of OSL spectra), and possibly, the potential of such measurements has not been appreciated in recent years.

Since 2012, Lexsyg luminescence readers became available, which allow for a comprehensive integration of instrumental

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http://dx.doi.org/10.1016/j.radmeas.2015.02.018
1350-4487/

supplements such as an EM-CCD-camera and/or an optical spectrometer. General descriptions of Lexsyg readers can be found in Richter et al. (2013) and Lomax et al. (2014). The integration of a spectrometer enables automated measurements of thermoluminescence (TL), OSL, IRSL and, if a special ring β-source is available, radiofluorescence (RF) spectra. This enables, for example, spectral analyses of luminescence signals at elevated temperatures, or a combination of spectral TL, RF and OSL/IRSL measurements within one sequence – if an automated detector changer is available. In the present study, quartz and feldspar spectra will be analysed using stimulation by heat (TL-spectra), green light (OSL-spectra) and infrared light (IRSL-spectra). A special focus is set on measurements at elevated OSL and IRSL stimulation temperatures. On the one hand, this will test the capability of the newly developed Lexsyg system to measure such spectra, and one the other hand, will provide new insights into OSL and IRSL spectra using elevated stimulation temperatures. All results are considered as preliminary, as only few samples were investigated.

2. Experimental details

2.1. Instrumental setup

The current set-up uses an Andor Shamrock SR163 spectrograph for the wavelength-dispersion. This Czerny-Turner type spectrograph applies a 300/500 gratin, providing a maximum resolution of 0.77 nm @ 546 nm and a detection bandwidth of ca. 500 nm. The spectrograph has an adjustable entry slit, allowing to choose between maximum signal yield at the cost of spectral resolution (~15 nm at fully opened slit), or vice versa. In the current study, all measurements were carried out with a fully opened slit.

The spectrograph is attached to an Andor Newton DU920P-BU camera, equipped with a thermoelectrically cooled (down to −80 °C), back-illuminated and UV-enhanced CCD-chip. The maximum quantum efficiency is reached in the wavelength range of 380–410 nm. A disadvantage of the back-illuminated CCD-chips is the phenomenon of etaloning, a distortion of the spectrum at wavelengths > ~ 700 nm. A fused silica light guide connects the light collecting optics with the spectrograph. The light guide has a numerical aperture of around 0.122. The fibres of the light guide form a circular area with a diameter of 2.4 mm at the light entry, and a matching line at the spectrograph's entry slit. The optical light guide can be attached to three different positions in the Lexsyg reader. These are (a) the standard OSL position, where OSL and TL spectra can be recorded and where different filters can be set between the sample and the detector, (b) the RF position above the ring β-source, and (c) an extra TL position.

For any of these positions, a custom-made optic is provided, made of fused silica lenses for maximum UV transmission. The extra TL optic, the RF optic and one of the standard OSL/TL optics have a magnification of 1×, displaying just the inner ~2.4 mm diameter aliquot area. Furthermore, a 0.5× optic (larger detection area, but reduced sensitivity) and a 2× optic (smaller detection area, higher sensitivity) are available for the standard OSL/TL position. For the current study, the 1× OSL optic, compromising best between sensitivity and detection area, was used.

Optical stimulation is carried out using green LEDs (525 nm ± 20 nm, max. power density on sample position 40 mW/cm^2) and IR laser diodes (850 nm ± 3 nm, max. power density on sample position 400 mW/cm^2). For irradiation a ^{90}Sr/^{90}Y ring β-source (Richter et al., 2012), with a dose rate of ca. 0.07 Gy/s for coarse grain quartz on stainless steel cups is used.

2.2. Correction of raw spectra

Several correction procedures were performed in order to correct the raw spectra. These are (1) a removal of cosmic-ray peaks (by applying a smoothing procedure with a running median), (2) background subtraction, and (3) a signal value normalization for the wavelength dependent relative sensitivity of the system; this is, optical transmission of the filters, optics, light guide, spectrometer and the quantum efficiency of the CCD-chip. The difference between a raw spectrum and corrected spectrum is demonstrated in Fig. 1a and b. Filter transmission curves used for the OSL (BG3 + BG39) and IRSL (BG39) spectra are shown in Fig. 1c. Also shown are the emission bands for the green LED and IR laser diodes, which were used as stimulation sources. In case of the green OSL spectra, only a narrow wavelength window ranging from ca.

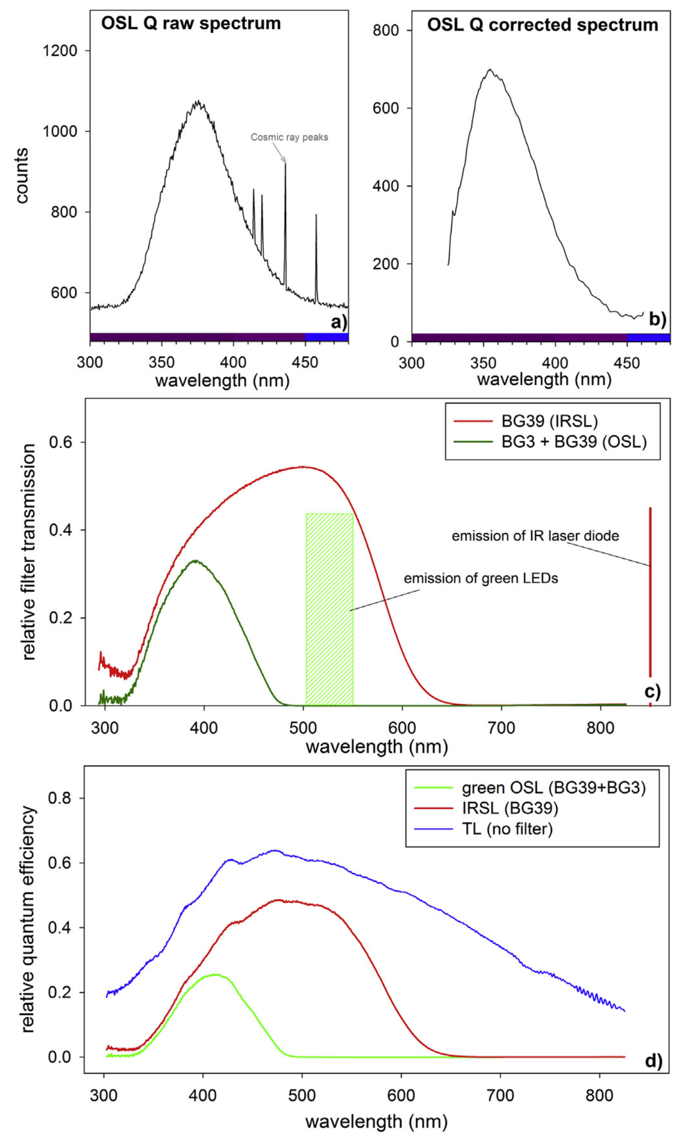

Fig. 1. (a) Example of a raw quartz OSL emission spectrum, and (b) the same spectrum after the correction procedure (cosmic ray removal, background subtraction and efficiency correction). (c) Relative optical transmissions of the filters/filter combinations used for OSL (BG3 + BG39) and IRSL spectra (BG39). Also indicated are the emission of the green LEDs and the IR laser diodes, used as stimulation sources for quartz and feldspar, respectively. (d) Sensitivity of the total spectrometer system (including filters and optics). All calibration measurements were obtained with a Bentham CL6 spectral irradiance system, 200 μm entry slit (nearly closed) and OSL 1× and extra TL 1× optics.