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Thermoluminescence investigations on tobacco dust as an emergency dosimeter

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HIGHLIGHTS

- Spectral measurements indicate main emissions may be from feldspar.
- Terminating the glow curve at 300 °C avoids changes in the TL sensitivity.
- Dose response, optical stability and fading of the TL signal were characterized.
- Irradiation trials showed agreement between given and measured doses within 20%.

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ABSTRACT

Silicates extracted from tobacco dust in cigarettes were investigated for their suitability as an emergency dosimeter in accidental situation using thermoluminescence technique. A typical glow curve (at a heating rate of 2 °C s^{-1}) of irradiated dust silicates in the transmission window between 300 and 500 nm has two prominent peaks at about 83 °C and 137 °C and a weak one at about 181 °C which were all distinguishable from the natural thermoluminescence. The TL spectrum of highly irradiated dust samples showed the existence of three dominant emissions at 1.66 eV (745 nm), 2.2 eV (560 nm) and 2.81 eV (440 nm), which are similar to those reported for feldspar. Repeated irradiation and TL measurement did not affect the sensitivity of the 137 °C peak, if the glow curve is terminated at 300 °C. A linear dose response of the TL signal was observed for doses between 0.1 and 10 Gy. A preheat temperature of 110 °C was found to be optimal for the emptying of the low temperature peak which is not stable. The TL signal is not stable but fades with time since irradiation. Furthermore it can be bleached by daylight but the dust seemed to be sufficiently light shielded in intact cigarettes. Based on the experimental dosimetric properties, a measurement protocol for the detection of absorbed radiation dose was developed. The result of a dose recovery test showed a reasonable agreement between fading corrected dose and given dose.

1. Introduction

It is well known that silicates can detect ionizing radiation through the emission of stimulated luminescence which allows their use as dosimetric material in different scenarios. Quartz extracted from building materials (bricks and tiles), for example, has been widely used for retrospective dosimetry in contaminated areas for the estimation of local doses using either thermoluminescence (TL) or optically stimulated luminescence (OSL) techniques (ICRU, 2002; Woda et al., 2011; Bailiff et al., 2016). On the other hand, dust containing a mixture of minerals (mostly feldspars and quartz) has also been shown to be a radiation sensitive material. This has been investigated by collecting dust from local objects such as a closed cupboard (Wieser et al., 1994) and more recently from personal objects such as jewels, watches, keys, tobacco and coins (Bortolin et al., 2010, 2011). The latter has the advantage of directly estimating an individual dose of the person carrying the

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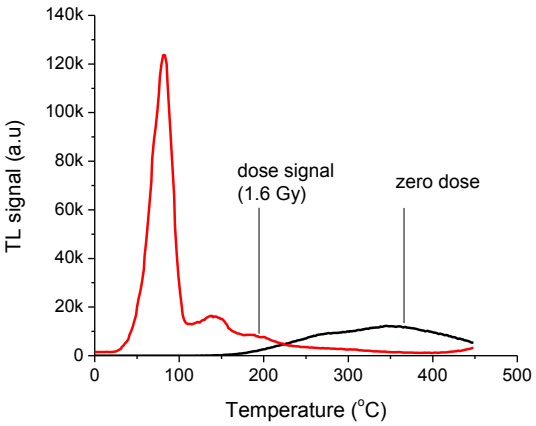

Fig. 1. TL glow curves of natural (unirradiated) and irradiated signals.

objects, which greatly reduces the uncertainty arising from the translation of local dose to person specific dose. The success of the preliminary tests carried out on minerals separated from personal belongings and irradiated at 10 Gy (Bortolin et al., 2010) encouraged further investigation to confirm the applicability of this material in accidental situations. In Bortolin et al., 2011, the dose range 0.1–5.0 Gy was tested on silicates extracted from objects yielding a relatively high amount of sample material. In Della Monaca et al., 2013, the integration interval of the TL glow curve was optimized to 210–250 °C and a linear dose response was found between 0.5 and 5 Gy for mineral silicates extracted from herbs. While these studies clearly demonstrate the general potential of using dust from personal objects as an individual emergency dosimeter, more work is needed for a fundamental understanding and a further characterization of the materials. Moreover all published results were obtained by a single laboratory which necessitates independent confirmation. This study focuses on dust extracted from cigarette tobacco with the aim of studying the emission spectra and investigating the dosimetric properties of the TL signal relevant for emergency dosimetry (dose response, thermal and optical stability, fading, dose recovery).

2. Materials and methods

2.1. Sample preparation

Dust from tobacco in five different brands of cigarette was extracted as described by Bortolin et al., 2011:

Tobacco from cigarette was "washed" in ultrapure water for few minutes at room temperature and the adhering minerals loosen using an ultrasound. The tobacco was removed after washing whereas the water with the minerals was left for 5 min to allow the minerals to sediment. The water above the sediment was eliminated leaving the minerals in few milliliters of water. The mineral

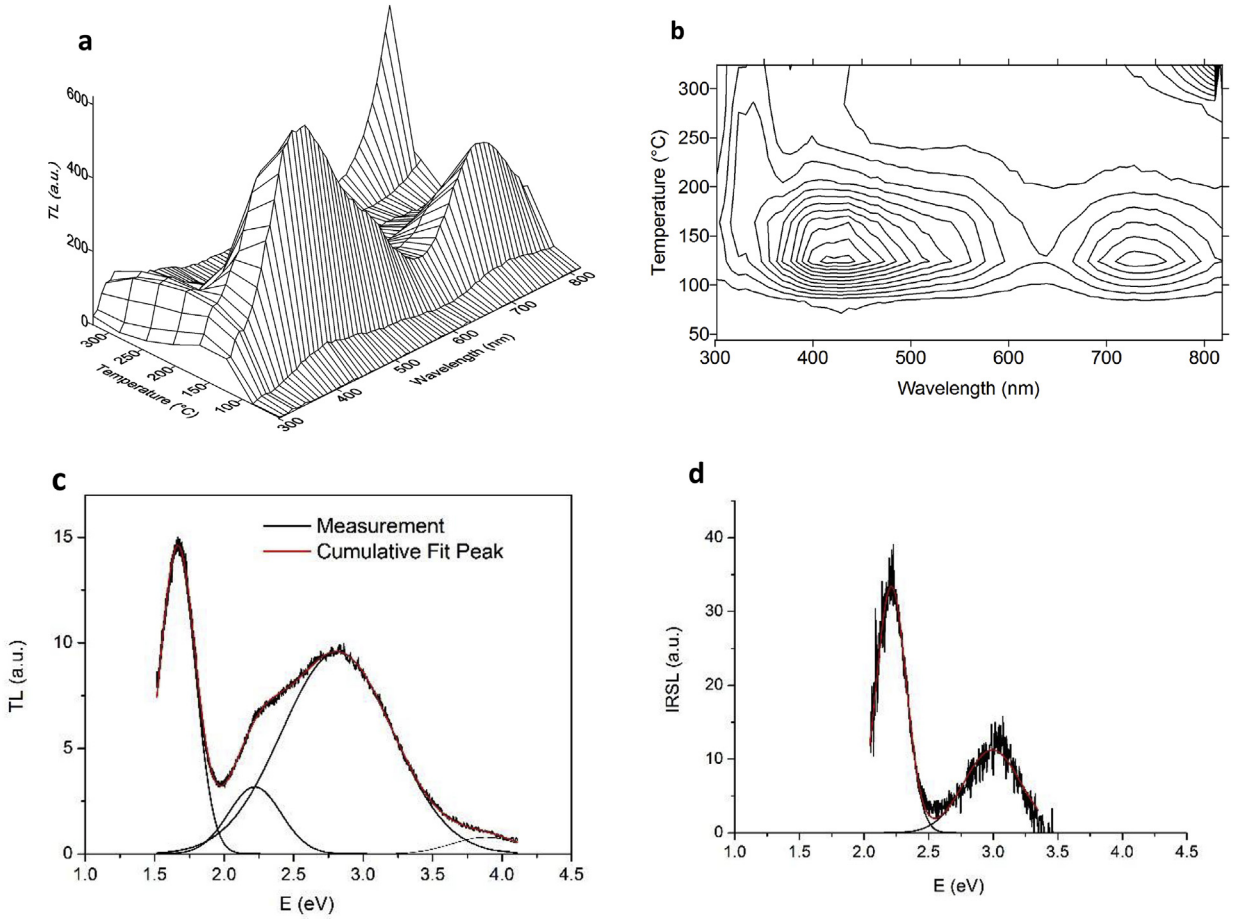

Fig. 2. (a) TL emission spectrum of dust silicates, irradiated with gamma dose of 900 Gy. (b) Contour plot of the emission shown in (a). (c) Fitting of the 120–160 °C part of the spectrum with Gaussian-shaped peak functions. To account for non-uniform distribution of data points with respect to photon energy, the TL intensity was multiplied with λ^2 $(hc)^{-1}$ (Blasse and Grabmaier, 1994), explaining the differences in relative signal intensities between (c) and (a). (d) IRSL spectrum of dust silicates with fitted components.

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