Luminescence characteristics of some common polymers for application to emergency dosimetry : supplementary material

1. List of samples

Fabric #	Colour	Composition
1	White	Cotton
2	Red	95% viscose 5% elastane
3	Blue	65% polyester 35% cotton
4	Yellow	Linen
5	White satin	95% polyester 5% elastane
6	Purple	42% viscose 32% cotton 21% polyamide
7	Yellow	Polyester
8	Blue	Polyester
9	Beige	80% polyester 20% viscose
10	Light blue	41% acrylic 31% polyester 28% cotton
11	Grey	100% polyester fleece
12	"Duck egg" blue	100% polyester
13	Blue	80% cotton 20% polyester fleece
14	Dark grey	100% polyester
15	White "linen"	100% polyester
16	White "jersey"	100% polyester
17	Black	Fabric 17 black 85% viscose 15% wool
18	Brown	65% polyester 30% viscose 5% elasthane
19	Green	100% polyester (F#16), dyed in lab
20	Blue	100% polyester (F#16), dyed in lab
21	Red	100% polyester (F#16), dyed in lab
22	Blue/dark	100% polyester
23	Black	Wax cotton
24	Brown	100% wool
25	Blue	Cotton/polyamide
26	Blue	Polyester with waterproof laminate side

Table 1: List of samples with details of colour, composition and lab reference number

2. Sample imaging

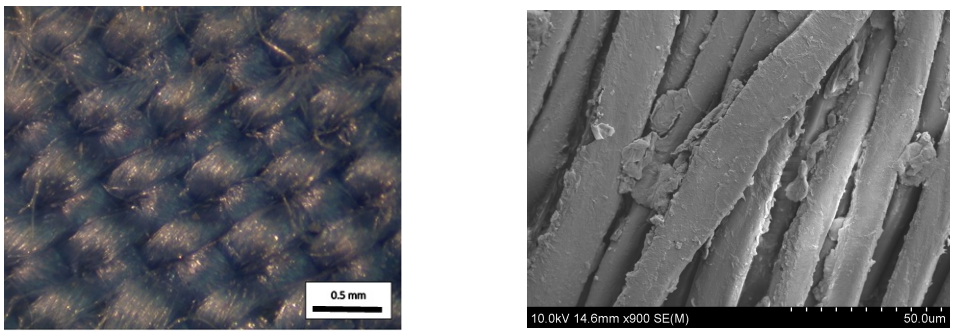
Fig. 1 shows the woven threads forming the blue polyester-mix fabric F#3 (Fig. 1a) and filaments of $\sim 20\mu$m diameter (SEM image, Fig. 1b). The CL spectral image of the polyester-mix fabric F#3 (Fig. 2) reveals circular brighter blue region in the filaments in the region of emission 470 nm δ= 100 nm.

3. IRSL deconvolution

The IRSL curves were deconvoluted using a Levenberg Marquardt iteration algorithm and the best fit was obtained using a general order kinetics component (1) and a tunnelling component (2) such as :

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

$$L \propto I_0 \frac{\rho'}{\tau} \left[\left(\ln(z\frac{t}{\tau}+1)\right)^2 \frac{\exp\left(-\rho'\left(\ln(z\frac{t}{\tau}+1)\right)^3\right)}{z\frac{t}{\tau}+1}\right] \tag{2}$$



(a) (b)

Figure 1: a) Image of a piece of blue polyester-mix fabric (F#3) showing the woven structure and filaments within each thread; b) Blue polyester-mix (F#3) showing filaments (x900 magnification)

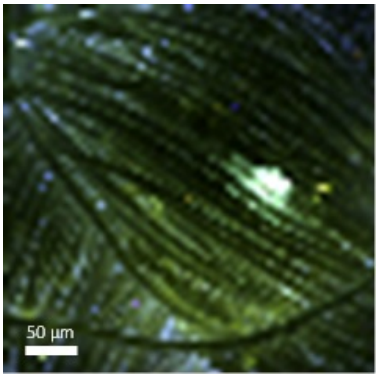


Figure 2: Cathodoluminescence (CL) images of the blue polyester-mix fabric with a blue spectral window (470 nm central wavelength, δ= 100 nm). Electron beam voltage, 10 keV.

where I_0 (a.u.) is the initial intensity, τ (s) the lifetime, b the order of kinetic, ρ' the dimensionless number density of acceptors and z a constant set equal to 1.8. The lifetime τ associated to eq. 1 and 2 are labelled τ_{GO} and τ_T respectively in the text.

4. Fading procedures

The details of the fading procedures with different forms of pretreatment and measurement condition are summarized in Table 2.

5. Sensitization

The sensitization of F#3 (Fig. 3), showing a strong dependence on the measurement atmospheric conditions.

6. TL glow curve fitting

The TL glow curves were deconvoluted using the analytical expression developed by Kitis (Kitis, G., J. M. Gomez-Ros, and J. W. N. Tuyn. "Thermoluminescence glow-curve deconvolution functions for first, second and general orders of kinetics" *Journal of Physics D: Applied Physics* 31.19 (1998): 2636.) such as:

$$I(T) = I_m b^{\frac{b}{b-1}} \exp\left(\frac{E}{kT}\frac{T-T_m}{T_m}\right) \times \left[(b-1)(1-\Delta)\frac{T^2}{T_m^2}\exp\left(\frac{E}{kT}\frac{T-T_m}{T_m}\right) + Z_m\right]^{-\frac{b}{b-1}} \quad (3)$$

Where $\Delta = 2kT/E$, $Z_m = 1 + (b-1)\Delta_m$ and $\Delta_m = 2kT_m/E$. I_m (a.u.) is the maximum intensity, T_m (K) the temperature at peak maximum, b the order of kinetics and E (eV) the activation energy. The parameters extracted from the deconvolution are listed in Table 3.

Procedure	Measurement sequence
1	1. Beta dose (6.8 Gy) 2. Storage at ambient temp. (0-150 min) 3. Record IRSL (40 s, 70 °C sample measurement temp.) 4. Repeat record IRSL (for residual).
2	1. Preheat (250 °C, 60 s, in N_2 atmosphere) 2. Beta dose (6.8 Gy) 3. Storage at ambient temp. (0-150 min) 4. Record IRSL (40 s, 70 °C sample measurement temp.) 5. Repeat record IRSL (for residual).
3	1. Record TL (to 230 °C at 0.5 °C s^{-1} in N_2 atmosphere) 2. Beta dose (6.8 Gy) 3. Record TL (to 230 °C at 0.5 °C s^{-1} in N_2 atmosphere) 4. Beta dose (6.8 Gy) 5. Storage at ambient temp. (0-150 min) 6. Record IRSL (40 s, 70 °C sample measurement temp.) 7. Repeat IRSL (for residual).
4	1. Record TL (to 230 °C at 0.5 °C s^{-1} in N_2 atmosphere) 2. Beta dose (6.8 Gy) 3. Record TL (to 230 °C at 0.5 °C s^{-1} in N_2 atmosphere) 4. Beta dose (6.8 Gy) 5. Storage at ambient temp. with continuous N_2 flow (0-150 min) 6. Record IRSL (40 s, 70 °C sample measurement temp. in N_2 atmosphere) 7. Repeat IRSL (for residual).

Table 2: Fading procedures

	TL native peak		TL β peak 102 ° C		TL β peak 25 ° C	
T_m (K)	452	± 1	373	± 1	299	± 1
b	1.00	± 0.01	1.09	± 0.03	2.0	± 0.6
E_a (eV)	1.20	± 0.01	0.50	± 0.02	0.8	± 0.1

Table 3: Blue polyester TL fitting parameters of the native TL peak and the β induced peak, Risø system, quartz window.

7. Peak shape method for TL glow curves

The native peak and β peaks activation energies were determined using the peak shape method, such as :

$$E_a = c_\alpha(kT_m^2/\alpha) - b_\alpha(2kT_m), \tag{4}$$

where α stands for δ, τ or ω. The relevant coefficients are :

$$\tau = T_m - T_1; \quad \delta = T_2 - T_m; \quad \omega = T_2 - T_1, ; \mu_g = \delta/\omega \tag{5}$$

where T_m (K) is the temperature at peak maximum, T_1 and T_2 (K) the low and high temperatures of half maximum respectively. Hence, c_α and b_α are given by :

$$c_\tau = 1.51 + 3(\mu_g - 0.42); \quad b_\tau = 1.58 + 4.2(\mu_g - 0.42), \tag{6}$$

$$c_\delta = 0.976 + 7.3(\mu_g - 0.42); \quad b_\delta = 0, \tag{7}$$

$$c_\omega = 2.52 + 10.2(\mu_g - 0.42); \quad b_\omega = 1, \tag{8}$$

The parameters obtained for the blue polyester-mix fabric (F#3) are summarised in Table 4.

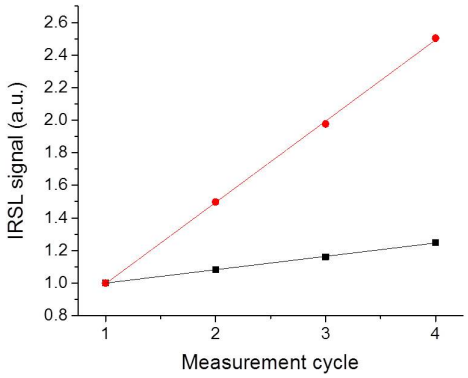


Figure 3: Change in IRSL response with repeated cycles of β irradiation (6 Gy) where the IRSL measurement was performed at a sample temperature of 70 °C and in an atmosphere of air (filled squares) or nitrogen (filled circles). Detection window: BG-39.

	Native TL peak		β TL peak	
μ_g	0.41	$\pm$0.07	0.41	$\pm$0.04
c_τ	1.5	$\pm$0.2	1.5	$\pm$0.1
b_τ	1.5	$\pm$0.3	1.5	$\pm$0.2
c_δ	0.9	$\pm$0.5	0.9	$\pm$0.3
c_ω	2.4	$\pm$0.7	2.4	$\pm$0.4
E_τ (eV)	1.1	$\pm$0.2	0.56	$\pm$0.06
E_δ (eV)	1	$\pm$0.6	0.6	$\pm$0.1
E_ω (eV)	1.1	$\pm$0.4	0.58	$\pm$0.08

Table 4: Blue polyester-mix (F#3) peak shape parameters of the native TL peak and a β induced peak after 7.5 Gy irradiation, detection window : fused silicate.

8. $T_{max} - T_{stop}$ method

The $T_{max} - T_{stop}$ procedure was conducted as follows :

- 6.7 Gy β irradiation
- Measure TL to the maximum temperature $T_{stop} = \{50 - 140\}$ °C
- Measure TL to the maximum temperature $T_{max} = 230$ °C
- Repeat steps incrementing T_{stop} by 10 °C

The activation energies for the set of glow curves were obtained using the initial rise method, assuming that in the initial part of the glow curve, the energy can de approximated by:

$$E = -k\frac{d(\ln(I))}{d(1/T)}, \tag{9}$$

where k (eV.K^{-1}) is the Boltzmann constant, I (a.u.) the intensity and T (K) the temperature.