Luminescence characteristics of some common polyester fabrics: application to emergency dosimetry

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Abstract

A set of garment polyester-mix fabrics were tested for their potential suitability as surrogate dosimetry materials using optically and thermally stimulated luminescence techniques. A strong native blue-stimulated optically stimulated luminescence and thermoluminescence signal was observed with unirradiated samples, but this could be avoided by measurement of infra-red stimulated luminescence, and a sample of blue polyester-cotton mix fabric exhibited particularly high sensitivity to radiation dose. However, near complete fading at room temperature within several hours and rapid bleaching of the signal when exposed to daylight limit the deployment of this mode of measurement. The fading behaviour is critically dependent on the atmosphere in which the material is measured and on the storage conditions, where a reduction in oxygen significantly reduces the rate of fading. A cathodoluminescence study of the samples performed in a scanning electron microscope revealed complex emission spectra obtained with spatially integrated measurements and, in one fabric examined in more detail, the spatially resolved emission was found to vary in intensity and wavelength within the polyester fibre filaments which is likely to be associated with differences in crystallinity.

Keywords: Emergency dosimetry, OSL, TL, Polymers, Polyester fabrics

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1. Introduction

Emergency dosimetry techniques aim to perform direct dose evaluations for affected members of the public in the event of a catastrophic radiation incident. Individuals exposed in these circumstances are unlikely to possess a dosimeter of the type issued to monitored radiation workers, and hence a primary objective in developing experimental techniques for emergency dosimetry is to identify suitable surrogate materials that potentially can be used to perform the function of cumulative external dose measurement to support rapid medical triage (e.g., Ainsbury et al., 2010; Bailiff et al., 2016). While progress has been made in the application of thermoluminescence (TL) and optically stimulated luminescence (OSL) techniques to ceramic substrates found within mobile phones for this purpose (Woda et al., 2009), other materials are being actively sought to widen the range of positions on the human body where dose determinations could be performed, including various types of polymers that are found in many types of clothing (Sholom et al., 2011; Sholom and McKeever, 2014). In the case of garment fabrics, they observed both a “native” signal and fading, with a loss at ambient temperatures in one week being ca 75% and 25%, depending on the sample.

In this paper we describe an investigation of the luminescence characteristics of a set of 26 fabrics sampled from a range of garment fabrics woven with natural, polyester and mixed fibres of differing colours with the aim

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of obtaining more detailed information regarding the nature of the luminescence using experimental approaches similar to those applied to alumina substrates by Kouroukla et al. (2014), and with the broader objective of examining their suitability for application to emergency dosimetry. We also draw upon the results of earlier research in which the TL properties of polymeric materials were investigated (e.g., Partridge, 1972; Aramu et al., 1971) below room temperature, together with more recent investigations (e.g., Tardieu et al., 2001).

2. Material and instrumentation

Samples of cotton, linen, polyester (polyethylene terephthalate), viscose and mixed fibre fabrics, produced for garments, were tested (further details in Supplementary Material, Table 1). Each type of measurement (i.e., OSL dose response, TL dose response, fading, sensitization) was performed on a fresh sample to measure the native signal, minimise sensitization effects and reduce potential molecular changes in the structure caused by repeated heating to elevated temperatures or exposure to intense light. All OSL, IRSL and TL measurements were performed with a standard configuration Risø model 12 reader (DTU Nutech, Denmark) with a Sr^{90}/Y^{90} β source irradiator delivering an estimated dose rate to fabric samples of 0.44 Gy min^{-1}. Since the primary calibration of the β source dose rate is related to quartz grains, radiation transport simulations were performed to obtain a conversion factor from quartz to polymer. The reader contained standard blue (470 nm) and IR (850 nm) LED arrays used as stimulation sources; a UV (250-350 nm; Schott U-340 filter) detection window was inserted when measuring blue stimulated OSL and a broad-band detection window (350-700 nm; Schott BG39 filter) when measuring IRSL. Unless stated otherwise, none of the samples were preheated and IRSL/OSL measurements were performed with the sample maintained at a temperature of 50°C. TL measurements were performed using a heating rate of $5^{\circ}C.s^{-1}$ to a maximum temperature of 230°C, which lies below the theoretical ignition temperature of most fabrics, and with either a Schott BG-39 filter or a fused silica window inserted in the detection system. A Hitachi SU-70 scanning electron microscope (SEM) with a beam energy of 10 kV and a current of 10 mA was used to analyse the topography of the fabric samples and spatially- and spectrally-resolved cathodoluminescence (CL) spectra were measured using a MonoCL3 spectrometer (Gatan Ltd, Oxford) incorporating a Hamamatsu R374 PMT detector operated in single photon counting mode. The spectra recorded were corrected for instrument response within the SEM analytical software.

3. Experimental results

3.1. Material characterisation : SEM and CL analysis

The fabric samples were coated with a thin platinum layer to enable optical measurements to be performed (CL). The woven structure of the fabric shown in more detail under SEM examination contains filaments within the threads of about 20 μm diameter. A representative CL polychromatic image (Fig. 1) for a blue polyester-mix fabric (F# 3, 65% polyester and 35% cotton) reveals a mixture of luminescing filaments of varying brightness with some comparatively dull, presumed to be non-luminescent within the spectral range of the detection system (350-550 nm). Bright spots within some of the fibres are evident and further investigation using selected spectral windows (e.g., 470 ± 50 nm) indicated that, in additional to a broadly modulated emission from the bulk of the fibres, there are bright regions of roughly circular form within filaments. Elemental analysis within these and other bright regions has not yet been performed. (Further details given in Supplementary Material, Fig.2).

Fig. 1. Polychromatic cathodoluminescence (CL) image of the blue polyester-mix fabric showing the distribution of emission. Electron beam voltage, 10 keV.

The spatially-averaged CL emission spectra measured from five fabrics are shown in Fig. 2; they have been superimposed to enable qualitative identification of common bands.

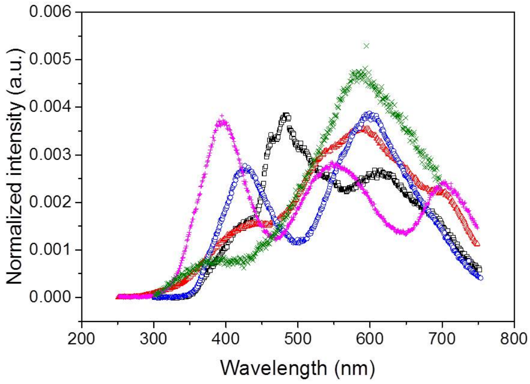


Fig. 2. Spatially integrated CL emission spectrum of different fabric samples: blue polyester-cotton mix F# 3 (□); beige polyester-viscose mix F# 9 (○); blue polyamide F# 25 (△); duck-egg blue polyester F# 12 (+); dark grey polyester F# 14(×). The spectra have been corrected for instrument response.

These spectra illustrate the diversity of emission bands detected in fabrics, although which of the numerous CL bands present in the spectra contribute to optically stimulated recombination luminescence is not yet clear. However, common to all the fabrics tested, except F# 12 and F# 14, is a weak emission in the UV region, where OSL is commonly detected using blue stimulation sources. Of particular interest is the blue polyester-cotton mix (F # 3), which was selected for more detailed investigation because of its favourable luminescence characteristics. In this fabric, several comparatively narrow emission bands in the region 450-500 nm, are relatively weak or do not appear in the spectra for the other fabrics, and emission in this wavelength region may be associated with the luminescence characteristics of this sample that set it apart from the other fabrics tested.

3.2. OSL characteristics

A measurement sample (ca 3×3 mm) of each fabric type tested was initially cut from a swatch or garment, and a second sample was taken from a different area of the fabric to test for uniformity of response. Where favourable characteristics were found, further tests were performed. In the case of fabric #3 that was examined in more detail (discussed further in Section 3.2) , additional samples were taken from different areas of the donor garment (a lightweight warehouse coat): from the pockets, sleeves and front and back sections of two different coats of the same type produced by the same manufacturer. For each set of characterisation measurements performed, a minimum of three samples were tested and the samples showed good reproducibility, generally within type A measurement uncertainties (±5%). The variation in response to dose (i.e., sensitivity) for different samples of fabric #3 of nominally the same size was within a factor of 2, with a relative range of 0.65-1.25 (expressed as a proportion of the mean value of the luminescence intensity) measured with nine samples to which the same dose have been administered.

All the fabrics tested exhibited a native blue stimulated OSL (BOSL) signal on first measurement that was strong, relative to that measured following β irradiation. The shape of the native BOSL and the β-induced decay curves differ, the former exhibiting a decay that is more reminiscent of long-lived phosphorescence and the latter being comparatively rapid, (ca 50% reduction within 100 ms; Fig. 3), although it is only discernible at relatively high β dose (7.5 Gy) because of strongly supralinear behaviour of the dose response. The intensity of the BOSL signals varied widely between different types and colours of fabric, but a systematic correlation of dye colour and radiation sensitivity was not evident.

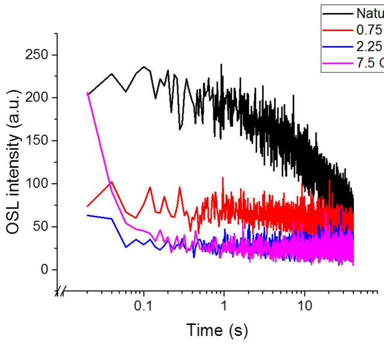


Fig. 3. Typical example of (blue) optically stimulated luminescence (BOSL) decay curves measured with a polyester fabric, showing the native decay curve and the decay curves measured following the administration of increasing β doses (0.75, 2.25 and 7.5 Gy). Detection window: U340.

In contrast, the native signal measured under IR stimulation was negligible for the fabric samples tested. However, with one exception, the IRSL signal measured after β irradiation steadily increased with stimulation time (Fig. 4). Following termination of the stimulation the IRSL signal returned to its initial value, suggesting that the increasing emission detected could partly be connected with a dynamic process involving the movement of mobile ions activated by near-IR photon absorption and/or thermal stimulation during the IRSL measurement. As found with BOSL, there is, with one exception, an indication of strong supralinearity and, at higher dose (10.5 Gy), a conventional decay curve is also discernible, but with a slight dose dependence in the rising tail of IRSL at longer stimulation times. The rates of decay for the two examples are not directly comparable since the incident power of the stimulation sources differ. As suggested by the rapidity of decay of the IRSL, a few minutes of exposure to bright daylight is sufficient to fully bleach the initial part of the IRSL decay curve. The exception mentioned above - a blue polyester-mix fabric (F# 3) - was found to possess IRSL characteristics that were more favourable.

3.2.1. Blue polyester-mix fabric

The blue polyester-mix sample (F# 3) exhibited the highest sensitivity to β radiation and a rising IRSL emission with stimulation time was absent (Fig. 5a). The dose response characteristic (Fig. 5b; corrected for fading and sensitization) is linear within the range of dose of interest for emergency dosimetry (0.75 -15 Gy).

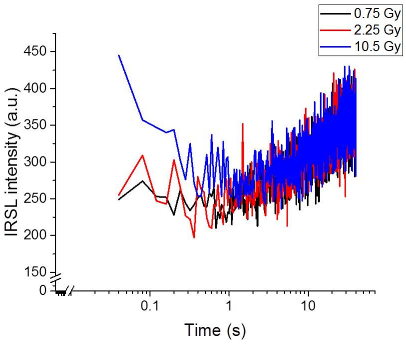
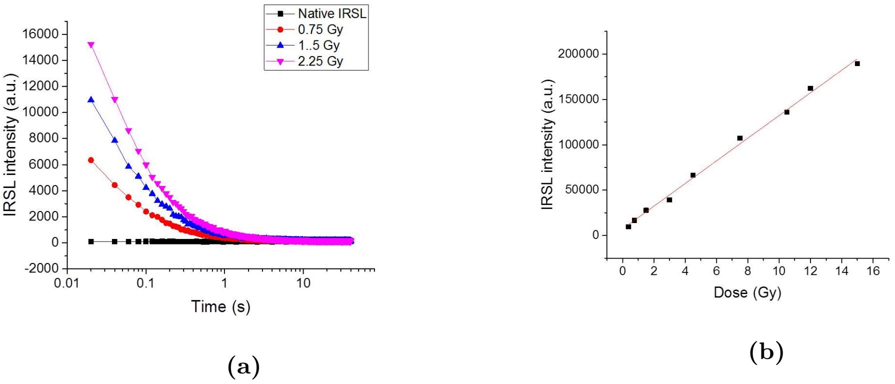


Fig. 4. Typical example of infrared stimulated luminescence (IRSL) decay curves measured with a polyester fabric (excepting the blue polyester-mix fabric), showing decay curves measured following the administration of increasing β doses (0.75, 2.25 and 10.5 Gy). The native decay curve was not significantly above the background signal. Detection window: BG-39.



(a)

(b)

Fig. 5. a) IRSL decay curves measured with a sample of blue polyester-mix fabric (F# 3) showing the initial (native) response and those measured following each of a sequence of β doses (0.75, 1.5 and 2.25 Gy). Detection window: BG-39.
b) Dose response characteristic obtained with the blue polyester-mix fabric (F# 3). The IRSL intensity corresponds to photon counts recorded during the initial 5 channels (20 ms per channel) less a "late" background obtained using the average count from the final 5 signal channels recorded in the decay curve measurement, scaled to the initial time interval. The measured signals were corrected for sensitization and fading effects. The statistical uncertainty in the signal values is less than ±2%. Detection window: BG-39.

The form of the IRSL decay curve was analysed for five levels of absorbed dose administrated (Fig. 6; 12 Gy measurement shown), using a deconvolution procedure that employed a Levenberg-Marquardt iteration algorithm to fit a kinetics function to the experimental data (further details in Supplementary Material, Section 2). The best agreement was obtained using a combined function with a general kinetics term and a tunnelling term, as proposed by Jain et al. (2012), to account for localised electronic recombination via tunnelling between donor-acceptor pairs in crystalline inorganic phosphors. The values of the main function parameters calculated by the fitting procedure are given in Table 1; from these, the initial intensities, I_0, suggest a dominant tunnelling process and the value of b indicates second order kinetics with fast retrapping (τ_{GO}).

The combined function was fitted to the set of measured decay curves that had provided the data for the dose response characteristic (β dose ranging from 0.75 to 15 Gy), using common values for the parameters b, ρ and τ_T given in Table 1. The fitting yielded a value of τ_{GO} for each level of β dose administered. It can been seen in Fig. 7 that there is a strong, monotonic and approximately linear dependence of the parameter τ_{GO} with β dose. If we assume that the tunnelling parameters (ρ and τ_T in Table 1) are more likely to remain invariant over the range of applied dose investigated, these results suggest that the conventional delocalised

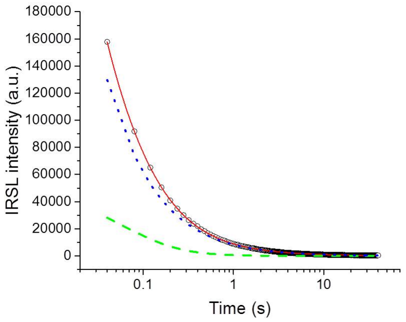


Fig. 6. Curve fitting to IRSL decay curve measured following the administration of a β dose of 12 Gy using a function combining (open circles) a general-order kinetics (GOK) term (dashed line) and a tunnelling (T) term (dotted line), as discussed in the main text.

General order kinetics component		*Tunnelling component*	
I_0	$(64 \pm 1)10^3$	I_0	$(88.5 \pm 0.7)10^4$
b	2.0 ± 0.2	ρ'	$(1.66 \pm 0.01)10^{-4}$
τ_{GO} (s)	0.109 ± 0.002	τ_T (s)	$(2.15 \pm 0.05)10^{-5}$

Table 1: Fitting parameters with general order kinetics and a tunnelling component of blue polyester IRSL 12 Gy irradiated. The values of τ are given in seconds.

charge transfer process described by the general kinetics term in this particular polymer environment is very sensitive to changes in absorbed dose compared with the kGy levels applied in the studies of Charlesby and Partridge, for example.

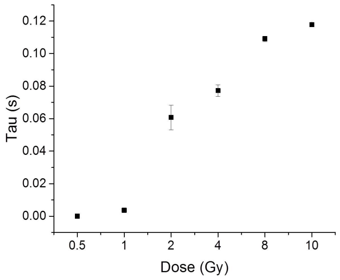


Fig. 7. Values of lifetime tau (τ_{GO}) vs β dose, where the values of τ_{GO} were obtained by deconvolution of IRSL decay curves measured with the blue polyester fabric following the administration of different β doses (0.75 - 10 Gy), as discussed in the main text.

Given the important role of molecular oxygen in the TL of polymers reported by Charlesby and Partridge (1963), we examined its potential effect on the measurement of IRSL above room temperature, in particular fading and sensitization behaviour in ambient air and oxygen-free nitrogen saturated atmospheres.

3.2.2. Fading tests

Fading test procedures with four different forms of pre-treatment and measurement conditions were applied (Supplementary Material, Table 3), although all included the administration of a dose of 6.8 Gy, storage in the dark at ambient temperatures for periods of between 5 and 150 mins and measurement of IRSL at a sample temperature (70°C) below the glass transition temperature ($T_g \sim$ 80°C).

The key differences in procedure were:

1. Untreated. Storage in air and IRSL measurement in air.
2. Pre-treated: initially preheated to 230°C in a nitrogen atmosphere for 60s and cooled to room temperature RT. Storage in air and IRSL measurement in air.
3. Pre-treated: "oxygen depleted" following a procedure applied by Charlesby and Partridge (1963), where the material was subjected a combination of radiation dose (6.8 Gy) and subsequent heating to 230°C to deplete the population of available oxygen molecules in the polythene. Storage in air and IRSL measurement in air.
4. Pre-treated: "oxygen depleted", as above. Storage in nitrogen atmosphere; IRSL measurement in a nitrogen atmosphere.

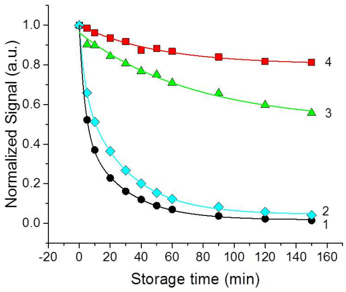


Fig. 8. Fading curves for the IRSL signal measured after storage periods of up to 150 mins following the administration of a β dose to samples of the blue polyester-mix fabric (F# 3), and where 4 procedures were applied, as discussed in the main text: Proc. 1 (filled circles); Proc. 2 (filled diamonds); Proc. 3 (filled triangles); Proc. 4 (filled squares). Detection window: BG-39

The fading curves obtained are shown in Fig. 8. The rate of fading with procedure 1, aiming to be loosely similar to an emergency scenario, is the fastest with a 98% loss of the signal within 2.5 hours; procedure 2 resulted in comparable behaviour. The application of the third and fourth procedures gave rise to a significant reduction in the fading observed. In procedure 3, where there was the opportunity for oxygen to diffuse back into the polyester filaments of the fabric, the fading was reduced, but not as effectively as in the case of procedure 4 where flushing of the measurement chamber with nitrogen was maintained throughout the storage period, giving rise to only a 20% loss in 2.5 hours. Analysis of the fading curves obtained using procedures 1 and 2 indicates that a good fit to the experimental data can be obtained with a double exponential function comprising fast (3.6 mins) and slow (28 mins) component lifetimes, and this may reflect a combination of charge (electron) transfer and slower ionic movements within the polymer structure. The timescale over which these fading measurements were performed (procedures 3 and 4) is not sufficient to fully characterise the fading behaviour at large storage times, but within the first 2.5 h, a single function, of either exponential or Bequerel decay form, could be satisfactorily fitted to this restricted dataset. Consequently these results suggest that the presence of mobile oxygen within the polymer structure has a significant influence on fading behaviour above room temperature.

3.2.3. Sensitization

Samples subjected to repeated cycles of irradiation (6 Gy) and measurement of IRSL (sample temperature, 70°C) exhibited sensitization effects in air and in an atmosphere of nitrogen. For both treatments, the IRSL signal increases linearly with measurement cycle, but the rate of increase per cycle changes substantially from 8% in air to 50% in nitrogen (further data given in Supplementary Material). The presence of oxygen appears to have a significant effect on luminescence behaviour, and in these tests the introduction of nitrogen into the measurement chamber may suppress a quenching effect of mobile oxygen ions.

3.3. TL characteristics

Typically all the fabric samples tested exhibited a strong native TL signal with a glow curve peak centred at 180°C, and in subsequent measurements following β irradiation this TL peak disappears leaving two broad peaks with maxima located at 100°C and 25°C (Fig. 9). The native TL peak at 180°C was not significantly bleached by exposure to light (sun, blue or IR) and was found to have regenerated following the initial glow curve measurement after storage for several weeks at RT in the dark. Similar results were obtained using both detection windows.

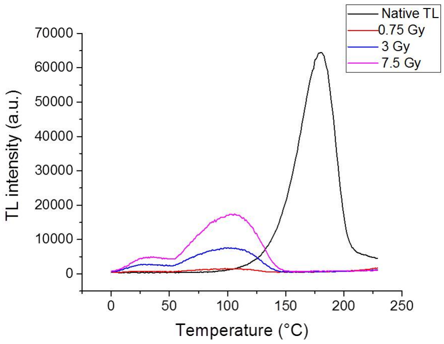


Fig. 9. Thermoluminescence (TL) glow curves measured with blue polyester-mix (F# 3) sample: including the native glow curve and the β-TL glow curves measured following the administration of three levels of β dose (0.75, 3 and 7.5 Gy). Detection window: fused silica.

The kinetic parameters of both native and β induced TL peaks measured with the blue polyester fabric were analysed using curve fitting procedures and peak shape criteria. Despite the dissimilarity of the position and shape of the native and β-induced peaks, the values of the shape parameter μ_g are the same (0.41), indicating a first order kinetic process in both cases. The estimates of the activation energy, E, obtained were ~ 1 eV and ~ 0.6 eV for the native and 100°C β-induced TL peak respectively. Glow curve deconvolution analysis, using equations for general order kinetics, also yields values of E and order of kinetics that agree with the peak shape analysis. However, the value of the frequency factor, s, obtained for the native TL peak (1.06×10^6 s^{-1}) is anomalously low (Chen et al., 2016) and the estimate of mean lifetime of 6.7 years likely to be unreliable; the mean lifetime estimated for the 100°C TL peak at ambient temperatures was 44 min.

A more detailed examination of the trap depths was performed by applying the T_{max}-T_{stop} method. The analysis of the glow curves yielded the values of activation energy, E, plotted against T_{stop} in Fig.10. The significant shift in T_{max} between 70 and 80 °C may reflect two distinct trapping levels, but it also coincides with the region of the glass transition temperature (T_g) above which structural movements at a molecular level are expected to be activated in the amorphous regions of the polymer. For higher values of T_{stop}, the values of E steadily increase, but there is evidence of a plateau in the region of 100°C, corresponding to the position of the second β-induced TL peak, with an average value of E of 0.75 ± 0.01 eV (and for the lower peak, $E = 0.68 \pm 0.01$ eV, details of calculation can be found in the Supplementary Materials).

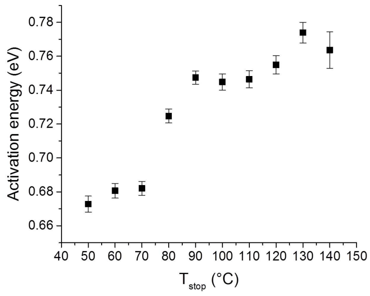


Fig. 10. Activation energy, E, vs T$_{stop}$, where E was calculated by applying the initial rise method to each glow curve recorded.

4. Discussion

Amongst the earlier work by Charlesby and Partridge (1965), TL emission spectra were recorded below room temperature (RT) for a range of polymers, and in the case of polyethylene they identified two broad emission bands located at ~350 nm and ~470 nm. Wavelength-resolved measurements of photoluminescence and recombination induced luminescence (equivalent to phosphorescence) emission from polyethylene by Tardieu et al. (2001) revealed a broad, generally featureless, emission spectrum at RT with a maximum located at ~450 nm, but with several component bands, were better resolved within the range 390- 480 nm by performing measurements at 80 K and applying spectral deconvolution techniques. They associated the phosphorescence with transitions from triplet excited states and identified a 250 nm stimulated fluorescence UV emission band (350 nm) attributed to transition from a singlet excited state. It is notable that the UV emission was generally weak in the CL spectra measured with the fabrics tested in this study, with the exception of a band located at 380 nm (Fig. 2, F# 12 and F# 14). However, preliminary measurements of time-resolved luminescence (using a 532 nm Q-switch pulsed laser and not reported above) from an unirradiated sample of blue polyester-mix fabric (F# 3) detected strong emission and a complex spectrum with recombination lifetimes of less than ~10 ns. The latter is consistent with a fluorescence mechanism and, via an energy transfer process, may account for the high native OSL observed with all the fabrics under blue OSL.

In recent work by Qiao et al. (2016), the broad CL spectrum of polyethylene measured at RT, extending from 300 to 800 nm, was deconvolved into four bands, three of which were assigned to a different luminescence process: fluorescence (328 nm), chemiluminescence (415 nm) and recombination luminescence (505 nm), but a specific luminescence mechanism of the production of the strongest emission band located at 573 nm remained unidentified, except for its attribution to either a by-product of the fabrication process or the result of material degradation. For the blue polyester-mix (F# 3) that has been examined in more detail in this study, the emission bands associated with both recombination luminescence and chemiluminescence (associated with a chemical reaction initiated by electron bombardment) by Qiao et al. are evident in its CL spectrum. Although we do not yet have OSL, IRSL and TL emission spectra, and also noting that the CL measurements were performed in vacuum, it is likely that one or both of these bands contributed to the strong IRSL observed in the blue polyester-mix fabric, and these would have been efficiently transmitted by the BG39 optical filter placed in the detection system. The additional bands observed are likely to be associated with the modification of the polymer by the dyes, amongst which the anthroquinone disperse dyes are known to exhibit strong fluorescence (Koh, 2011). With an estimated band gap of 8.8eV (Hoffman, 1991) for polyethylene, chromophores (e.g., additive, cross-linking by-products, oxidized groups or non-saturated bonds) can introduce potentially deep traps if they possess an electron or hole affinity (Tardieu et al., 2001).

The bright spots observed within the fibre filaments revealed in the spatially-resolved CL images of the blue polyester-mix (Fig. 1) may be associated with regions of higher crystallinity. The formation of spherical semi-crystalline regions, termed spherulites, have been studied in industrial polyester fibres because of their relevance to the structural properties of polyethylene, and their size found to be dependent on the manufacturing process (Kim and Rhee, 2015). The extent to which these regions participate in optically or thermally stimulated luminescence processes has yet to be established, but the relatively enhanced CL brightness and emission within the blue region would make them of particular interest in the search for stable repositories of trapped charge (i.e., for dosimetry) if they were found to be crystalline. While the crystalline regions within polymers may provide at RT sufficiently stable storage of trapped charge following exposure to ionising radiation, the influence of atmosphere (in particular the presence or absence of oxygen) on the luminescence behaviour observed provides potentially important information concerning the structural regions from which the luminescence originates.

As discussed above, we observed strong effects when oxygen was excluded from the surrounding atmosphere during the measurement of IRSL, or by applying the oxygen depletion procedure of Charlesby and Partridge. If, as argued by Partridge (1972), mobile oxygen molecules can diffuse within the amorphous regions and do not penetrate the crystalline phases of the polymer, this suggests that the source of IRSL is either within the amorphous regions, or near the interface with crystalline regions. In supplementary thermogravimetric analysis (TGA) measurements with the blue polyester-mix fabric (F# 3), the availability of mobile oxygen was indicated in both unirradiated and irradiated sample by detecting its release from RT to beyond 200°C, which increased by a factor of ∼5 within this temperature interval. There is much discussion in the early literature regarding the role of oxygen (e.g., summarized in Partridge, 1972) and its effects on the TL characteristics of polyethylene, from which the dual role of oxygen as an electron trap and as quencher of luminescence is most relevant to measurements above RT. Boustead (1970), studied the effects of oxygen on a TL peak measured at 140 K in different types of polyethylene, which was attributed to electron trapping on oxygen molecules (i.e., forming negative O_2 ions) following exposure to ionising radiation. However, on the basis of the calculation of the electron affinity of oxygen, the position of an “oxygen” TL peak was estimated to be in the range 370 K to 500 K, and the disparity with the results of his experimental measurements was reconciled by arguing for a reduction in the electron affinity resulting from an interaction between the polymer matrix and the oxygen molecules. Consequently it is interesting that for the fabrics we tested, the TL peaks observed were in this temperature range, and the oxygen molecule mechanism may account for the native TL peak that is observed on first measurement of the glow curve (and regenerated in the dark after long storage time). The strong effect of depleting oxygen content in the fading and sensitization tests based on the measurement of IRSL adds further evidence for the involvement of oxygen in the production of IRSL above room temperature.

5. Conclusion

The investigation of a set of randomly selected garment fabrics mostly containing polyester fibres undertaken in this study has confirmed the potential identified in earlier work for deploying materials of this type for emergency dosimetry using OSL techniques. However, a combination of a strong native signal (both BOSL and TL) and supralinear growth of the luminescence signal with dose limited their utility in the dose range of interest (ca 0.1-5 Gy) in the set of fabrics we tested. The use of IR stimulation (IRSL), on the other hand, was found to provide a means of circumventing these problems, the characteristics of one polyester-mix fabric being particularly favourable. Under these measurement conditions the latent signal fades to almost complete reduction within several hours and consequently the lifetime is insufficient for general application to emergency dosimetry. However, as found in earlier studies of the TL of polyethylene and other polymers, the effect of mobile oxygen within the polymer has a very strong effect on the luminescence characteristics, and its depletion appears to cause a dramatic reduction in the rate of fading. While such effects related to the presence of oxygen at a post-irradiation stage do not appear to be feasible on the basis of the observations made in this study, further investigation of this aspect of luminescence behaviour may yield a better understanding of the physical mechanisms responsible for fading and clarification of the roles of charge trapping and ionic movements in the fading process. Although optical fading by exposure to daylight is another issue to be anticipated when attempting to use fibres, the multi-layered construction of many garments has the potential provide shielded locations from which suitable fibres can be extracted for analysis. The luminescence properties of polymer filaments in woven fabrics are clearly complex, but may yet offer a means of dosimetry suitable for general application to emergency dosimetry.

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