SIMULTANEOUS SENSITISATION AND RE-ESTIMATION IN THERMOLUMINESCENT LiF

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There is a continuing need for thermoluminescent (TL) phosphors of high sensitivity and approximate tissue equivalence for a variety of dosimetry applications in radiological protection. Lithium fluoride (TL) has been widely used for many years but has relatively low sensitivity for some applications such as environmental, skin and interface dosimetry. It is possible however to increase the sensitivity by a process of radiation sensitisation.

RADIATION SENSITISATION

It has been known for some time that if LiF is subjected to radiation doses of approximately 10^3Gy and a subsequent thermal anneal (300°C for 1 hour for example) the sensitivity is increased by a factor of up to six (1). Unfortunately this process of radiation sensitisation produces a high residual background signal which precludes its use for low dose measurements. Mayhugh and Fullerton (2) suggested a modified procedure for sensitisation to overcome this problem which involved an annealing procedure which incorporated simultaneous UV exposure and heat treatment. Their study did not however contain an analysis of the statistical fluctuations in the remaining background, which dictates the minimum detectable dose.

RE-ESTIMATION

In addition to the measurement of low doses it is often desirable to be able to re-estimate (confirm) the measured dose, perhaps because of instrument malfunction or suspected over exposure of personnel. Re-estimation involves the transfer of tightly bound trapped electrons, which remain after the initial read out, to the less stable TL traps. This is normally achieved by subjecting the phosphor to UV radiation, often at elevated temperatures. Bartlett and Sandford (3) studied the re-estimation capability of sensitised LiF using both conventional and UV/thermal annealing procedures and concluded that simultaneous sensitisation and re-estimation was <u>not</u> possible. Their data extended only to doses of 1Gy and used lower UV intensities than in the study reported here. This paper outlines and extends our previous studies of radiation sensitisation and re-estimation (4, 5) and shows that the two processes are definitely <u>not</u> incompatible.

SIMULTANEOUS SENSITISATION AND RE-ESTIMATION - THEORY AND PRACTICE

In an attempt to understand the reason for the effectiveness of UV/thermal annealing procedures an absorption spectra study was carried out using Harshaw ^{7}LiF chips (0.9 mm thick). Figure 1a illustrates typical spectra for chips which have received sensitising doses of 2 x 10^3Gy and then been subjected to conventional and UV/ thermal annealing. Following the conventional anneal a broad absorption band remains at about 225 nm which has been associated with a Mg^{++}-F centre pair - a so-called Z_3 centre (6). The reduced intensity of this band following the UV/thermal anneal is quantitatively correlated with the reduction in background which this treatment provides. The removal of this band is associated with only a small reduction in sensitisation, as pointed out also by Stoebe and Watanabe (7). Sensitisation is presumably associated with deep traps which can only be observed by absorption measurements below 200 nm.

Figure 1b illustrates the changes in absorption spectra which take place following re-estimation. After an initial read out the Z_2 band ($Mg^{++}-F^-$) at about 310 nm is considerably reduced. Following re-estimation these centres are repopulated at the expense of F, and possibly Z_3, centres.

Since the radiation sensitisation and UV re-estimation are associated with different trapping centres the two processes should be mutually compatible. Figure 2 shows the results of simultaneous sensitisation and re-estimation with Harshaw ^{7}LiF chips (0.9 mm thick). For sensitised chips the statistical fluctuation in the re-estimation background is such that the minimum re-estimatable dose (2σ) is $\sim$ 0.2Gy as compared to $\lesssim$ 0.01Gy for unsensitised LiF chips. The high UV re-estimation background may be due to remaining Z_3 centres. This limitation is not prohibitive since re-estimation is most important for the confirmation of high doses. It is possible that the background signal may be reduced by a judicious choice of the UV wavelength for both the annealing and re-estimation exposures. The intense 254 nm line of the low pressure mercury lamp has been widely used, in studies such as these, purely as a matter of convenience and is unlikely to be the optimum choice. Our work is continuing in this direction with the use of a high intensity UV monochromator factility.

Figure 3 shows the dependence of re-estimation (expressed as a percentage of the initial read out signal) on UV exposure time, temperature and UV intensity. The complex relationship between these parameters explains why so many different values of re-estimation have been reported in the literature. It is clear too that if the results of different workers are to be compared it is necessary to measure UV intensities as accurately as possible. This is not an easy task in the 200-250 nm region. Calculated intensities, based on manufacturers specifications are very unreliable. Calibrated thermopiles and similar detectors, together with filters to cut out stray light, are essential for reliable UV dosimetry.

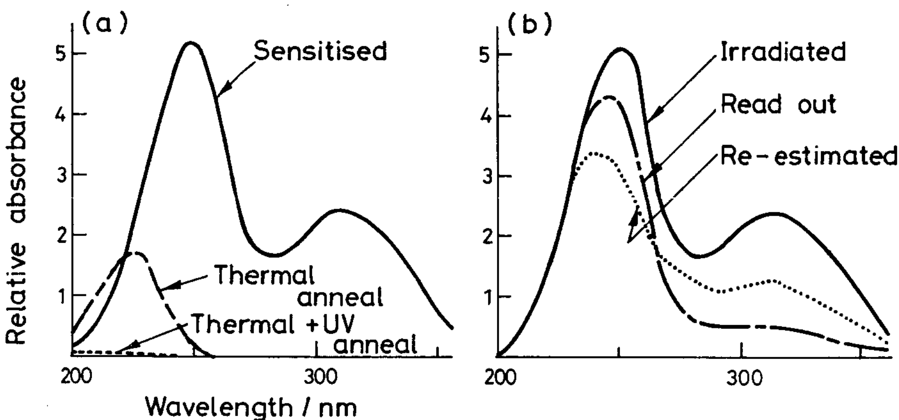

Figure 1. Absorption spectra for 0.9 mm Harshaw ^7LiF chips.
(a) Sensitised at $2x10^3$Gy ——; sensitised + thermal anneal (300°C, 1 hour); sensitised + simultaneous thermal/UV anneal (300°C, 6 $mWcm^{-2}$ of 254 nm UV, 1 hour).----. (b) Unsensitised, Read out at 260°C, re-estimated at 150°C for 2 minutes using 5 $mWcm^{-2}$ of 254 nm UV.

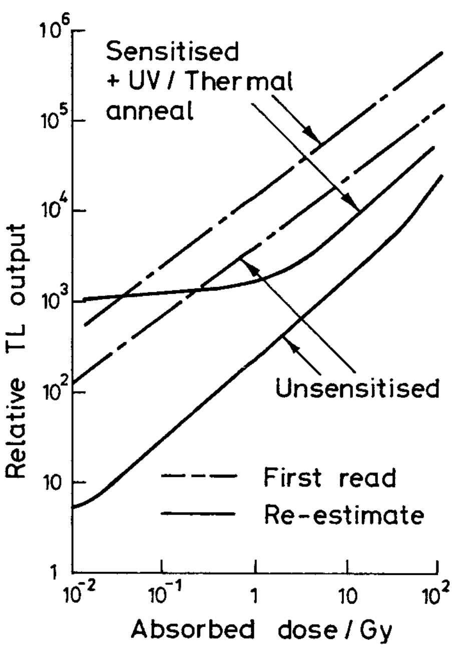

Figure 2. Simultaneous sensitisation and re-estimation in ^7LiF Harshaw chips. Sensitisation data as Fig. 1, re-estimation, 5 $mWcm^{-2}$, 100°C, 5 min.

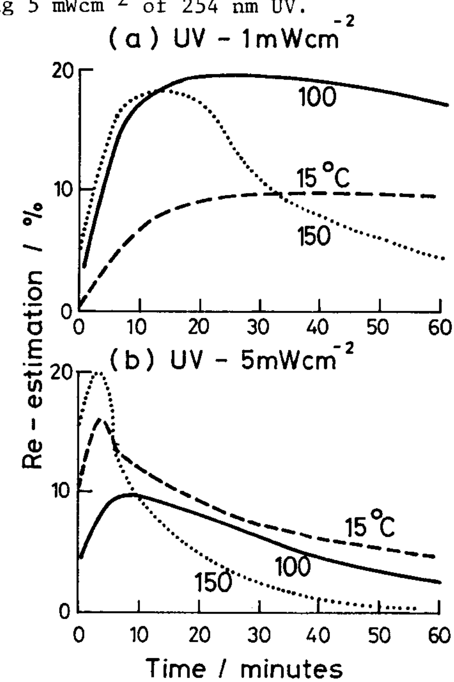

Figure 3. Re-estimation versus UV (254 nm) exposure time for ^7LiF Harshaw chips.

SUMMARY

Radiation sensitisation is a useful technique which can reduce the minimum detectable dose for LiF (TL) by a factor of 3, and retain the possibility of dose re-estimation. Further work is necessary however to reduce the background signal associated with re-estimation. The smallest dose which can be re-estimated with sensitised ^{7}LiF chips (0.9 mm thick) is about 0.2Gy at the present time.

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