LIGHT SENSITIVITY OF SOME COMMON THERMOLUMINESCENCE DOSIMETRY PHOSPHORS

J.W.N. Tuyn and A.R. Lakshmanan

CERN, Geneva, Switzerland

ABSTRACT

The light-induced fading of radiation-induced thermoluminescence and the sensitivity characteristics of LiF , $\text{CaF}_2\text{:Dy}$, and $\text{CaSO}_4\text{:Dy}$ doseimeters to a daylight fluorescent lamp have been studied in order to see if they meet the stipulations of the ISO/IEC draft standard.

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INTRODUCTION

One of the requirements of an ideal personnel or environmental dosimeter for ionizing radiations is its insensitivity to room light or sunlight. In recognition of this, the ISO/IEC draft standard⁽¹⁾ on personnel and environmental thermoluminescence dosimeters (TLDs) stipulates that: i) the exposure of irradiated (to ionizing radiations) dosimeters to 10,000 lux (1m/m^2) of artificial sunlight for one week shall not alter the readout value by more than 10% for both personnel and environmental dosimeters; ii) for unirradiated dosimeters, a similar exposure to sunlight shall not change the zero point reading by more than 10, 100, and 500 μGy for environmental, personnel whole-body, and skin dosimeters, respectively. However, it has been reported in the literature that apart from the background increase, sunlight or fluorescent light can cause significant fading of radiation-induced TL in some TLD phosphors⁽²⁻⁶⁾. Hence it is important to study the fading and the sensitivity characteristics of common TLD phosphors to sunlight or a fluorescent lamp, and to see if they meet the stipulations of the above draft standard.

MATERIALS AND METHODS

The TLD materials chosen for this study were LiF TLD-700 chips and $\text{CaF}_2:\text{Dy}$ chips, both $3 \times 3 \times 0.9 \text{ mm}^3$ *), and CaSO_4 Teflon discs, 13 mm dia. and 0.8 mm thick**). These dosimeters were given the following pre-irradiation annealing treatments: LiF, 1 h at 400 °C + 2 h at 100 °C; $\text{CaF}_2:\text{Dy}$, 1 h at 400 °C; $\text{CaSO}_4:\text{Dy}$, 1 h at 300 °C.

The power of the fluorescent-tube light and the distance between it and the dosimeters were chosen so that the dosimeters will receive an illumination of 10,000 lux (as measured by a luxmeter). During this process, the temperature of the dosimeters did not exceed 30 °C.

*) Both manufactured by Harshaw, USA.

**) Made by D.R.P., BARC, India.

Both irradiated (to 0.01 Gy of ^{60}Co gamma radiation) and unirradiated dose-meters (a total of 30 for each class) were exposed to 10,000 lux for a period ranging from one hour to five days. About 10 dosimeters in each class were kept in the dark for comparison.

$\text{CaF}_2\text{:Dy}$ and LiF chips were given a pre-read annealing treatment in an oven at 100 °C for 10 min. For TL measurements of the chips, the Harshaw TL detector (model 2000 D) and a TL analyser (model 2080) were used. A heated laminar flow of nitrogen gas (flow rate = 2 l/min) maintained at 340 °C was used to heat the TLD chips, and the glow curve area was integrated. For $\text{CaSO}_4\text{:Dy}$ Teflon discs, the Teledyne Isotopes reader (model TLD 7300) having clamping facilities for pre-heating (130 °C), reading (245 °C) and annealing (300 °C) was used. The TL was integrated during the read phase of the heating cycle.

RESULTS

Figure 1 shows the light-induced fading of the radiation-induced TL in the dosimeters as a function of exposure duration. Of the three, $\text{CaSO}_4\text{:Dy}$ shows maximum fading and LiF minimum. After the exposure to light for five days, the fading of the TL signal in LiF , $\text{CaF}_2\text{:Dy}$, and $\text{CaSO}_4\text{:Dy}$ was 25%, 70%, and 95%, respectively. Fluctuations in the TL readings of the dosimeters after the light exposure were found to be highest for the $\text{CaF}_2\text{:Dy}$ chips. From the literature it is seen that other dosimeters such as $\text{Mg}_2\text{SiO}_4\text{:Tb}$, $\text{Li}_2\text{B}_4\text{O}_7\text{:Cu}$, $\text{Li}_2\text{B}_4\text{O}_7\text{:Ag}$, and $\text{MgB}_4\text{O}_7\text{:Dy}$ also show significant fading on exposure to fluorescent light or sunlight⁽²⁻⁷⁾; $\text{Li}_2\text{B}_4\text{O}_7\text{:Mn}$ has recently been found to be an exception⁽⁸⁾. From Table 1 it is seen that from the point of view of a light-induced TL signal, all the dosimeters used in this work almost satisfy the ISO/IEC draft standard requirements for a personnel dosimeter. However, only $\text{CaF}_2\text{:Dy}$ meets the standard for environmental dosimeters. The maximum light-induced (at 10,000 lux level) TL signal in all these dosimeters was found to lie between 6 and 200 μGy equivalent in five days. For all virgin dosimeters, the light-induced TL signal passes through the maximum and then declines with increasing exposure duration.

Most of the TLDs, however, will still meet the ISO/IEC draft standard, which stipulates $< 10\%$ fading and $< 10 \mu\text{Gy}$ equivalent-induced TL in seven days at a 10,000 lux level of fluorescent light for personnel and environmental TLDs, respectively, provided that they are protected from light exposure. Hence it is necessary to ensure that the dosimeters in TLD badges (especially in open window position) are protected from room light and sunlight by, for example, black paper or a black polyethylene wrapper. It is also preferable to carry out TL measurements in diffused room light. The TLDs should not be exposed directly to the light from krypton lamps or UV lamps, since this was found to induce intense TL signals especially in LiF chips.

The TL sensitivities of LiF TLD-700 chips and $\text{CaF}_2:\text{Dy}$ chips to light radiations from UV and krypton lamps are given in Table 2. For UV (253.7 nm) irradiations, a 30 W (90 cm length) germicidal mercury tube light was used. The sample-to-lamp distance was 18 cm and the duration of the UV irradiations was 3 min. Irradiations were also carried out with a 60 W krypton table lamp. The sample-to-lamp distance was 30 cm and the duration of light exposure was 10 min. All the samples were pre-read annealed at 100°C for 10 min. From Table 2, it can be seen that the TL sensitivity of ^7LiF chips to UV and krypton light, and chip-to-chip variation in light sensitivity, are significant. The magnitude and the chip-to-chip variation in light sensitivity of $\text{CaF}_2:\text{Dy}$ are considerably low compared to those of ^7LiF .

CONCLUSIONS

Most of the common TLD phosphors show a significant fading of radiation-induced TL on exposure to sunlight or fluorescent light. All these TLDs will still meet the ISO/IEC draft standard for personnel and environmental dosimeters provided that they are protected from light exposure. It is hence necessary to ensure that the dosimeters in TLD badges (especially in open window position) are protected from room light and sunlight by, for example, black paper or a black polyethylene wrapper.

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Table 1

Fluorescent light-induced (10,000 lux) TL signal
as a function of exposure duration in virgin TLD phosphors

Exposure duration (h)	TL signal in equivalent μGy of ^{60}Co gamma rays		
	^7LiF	$\text{CaF}_2:\text{Dy}$	$\text{CaSO}_4:\text{Dy}$
1	20.5 ± 10	3.6 ± 0.2	38.5 ± 10
5.2	111.4 ± 10	6.1 ± 0.2	89.7 ± 10
16.5	68.2 ± 3.5	6.1 ± 0.1	108.0 ± 8
48.3	111.4 ± 20	4.6 ± 0.5	73.0 ± 15
113.7	185.8 ± 208	3.5 ± 0.3	59.8 ± 12
137.7	71.6 ± 4.7	0.0	42.7 ± 5

Table 2

A comparison of intrinsic TL sensitivities of LiF TLD-700 and
 $\text{CaF}_2:\text{Dy}$ chips to exposure from UV and krypton lamps

TLD	Light sensitivity in equivalent mGy	
	UV lamp	Krypton lamp
^7LiF	0.22 to 12	0.05 to 0.6
$\text{CaF}_2:\text{Dy}$	0.05 ± 0.02	0.01 ± 0.01

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Figure caption

Fig. 1 : Fluorescent light-induced (10,000 lux) fading of gamma radiation-induced (0.01 Gy) TL in LiF TLD-700 (-o-), $\text{CaF}_2\text{:Dy}$ (-●-), and $\text{CaSO}_4\text{:Dy}$ (-Δ-) as a function of exposure duration.

Fig. 1