September 1993

AFRRI

93-6 TECHNICAL REPORT

Time-Dependent and Light-Induced Fading in Victoreen Model 2600-80 Aluminium Oxide Thermoluminescence Dosemeters

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AFRRI TR93-6

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REPORT DOCUMENTATION PAGE

Form Approved
OMB No 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	September 1993	Technical Report

4. TITLE AND SUBTITLE
Time-Dependent and Light-Induced Fading in Victoreen Model 2600-80 Aluminium Oxide Thermoluminescence Dosemeters

5. FUNDING NUMBERS
PE: QAXM
WU: 4610

6. AUTHOR(S)
Musk, J. H.

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Armed Forces Radiobiology Research Institute
8901 Wisconsin Ave.
Bethesda, Md. 20889-5603

8. PERFORMING ORGANIZATION REPORT NUMBER
TR93-6

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Defense Nuclear Agency
6801 Telegraph Road
Alexandria, Va. 22310-3398

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

14. SUBJECT TERMS

15. NUMBER OF PAGES
8

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UL

SECURITY CLASSIFICATION OF THIS PAGE

CLASSIFIED BY:

DECLASSIFY ON:

SECURITY CLASSIFICATION OF THIS PAGE

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Cleared for public release; distribution unlimited

Radiation Protection Dosimetry
Vol 47 No. 1/4 pp 247–249 (1993)
Nuclear Technology Publishing

TIME-DEPENDENT AND LIGHT-INDUCED FADING IN VICTOREEN MODEL 2600–80 ALUMINIUM OXIDE THERMOLUMINESCENCE DOSEMETERS

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Abstract — In the absence of light, the thermoluminescence (TL) signal of irradiated aluminium oxide TL dosemeters (TLD) faded by 21% in 3 months. When exposed to low intensity incandescent light, the TL signal decreased by 25% in 6 h. High intensity fluorescent light caused the TL signal to fade by more than 90% in 6 h.

INTRODUCTION

Time-dependent and light-induced fading of various forms of photon irradiated aluminium oxide thermoluminescence dosemeters (TLDs) have been studied in the past. McDougall and Rudin[1] found that ceramic type aluminium oxide TLDs stored in the dark faded by 20% in the first few days after irradiation and 5% more in the following 2 months. Mehta and Sengupta[2] determined that when stored at room temperature, the two low temperature peaks in the thermoluminescence (TL) glow curve of aluminium oxide TLDs faded by 20% and 12% respectively in the 2 week period after irradiation. Mehta and Sengupta used TL dosimetric grade powder and pellets made from both pure and commercially available aluminium oxide. Akselrod *et al*[3] found light-induced fading in excess of 20% in 20 min for single-crystal aluminium oxide TLDs stored in 300 lx illumination daylight.

In the present investigation, the fading characteristics of Victoreen Model 2600-80 single-crystal aluminium oxide TLDs were studied. Time-dependent fading experiments similar to those performed by McDougall and Rudin were conducted for the time period 0–90 d. In addition, the light-induced fading investigated by Akselrod *et al* was extended to include 6 h exposures to both incandescent and fluorescent light.

MATERIALS AND METHODS

A Harshaw single-chip TLD reader system (Solon Technologies, Inc., Harshaw/QS Dosimetry Products, Solon, Ohio) was used to read the TLDs used in this study. This system consisted of a Harshaw Model 2000A TL detector and a Harshaw Model 2080 TL analyser. The acquisition time was set at 40 s, and the heating time at 30 s. The preheat temperature and heating rate recommended by Victoreen was used to read the TLDs. The heating cycle used consisted of a rapid heating to the preheat temperature of 100°C, followed by a constant heating at a rate of 10°C.s^{-1} to a maximum temperature of 250°C. Each time TLDs were read, reference light readings were made as a check of system functions. These reference light readings were also used to normalise TLD responses for small variations in the reading system.

Victoreen Model 2600-80 single-crystal aluminium oxide TLDs were used. After TLDs were read, they were run through three additional read cycles in order to minimise any residual TL signal left on the chips. This procedure permitted the chips to be used repeatedly. When the TLDs were not in use, they were stored at room temperature in a temperature controlled, light free environment.

All irradiations were performed with ^{137}Cs using a Shepherd Model 89 Shielded Calibrator (J. L. Shepherd and Associates, Glendale, California) and using a nominal dose rate of 120 mGy.h^{-1}. The field was uniform across the TLD array to within ± 5%. Doses were delivered by varying the time of irradiation in a field of known dose rate. All doses quoted are to water.

Time-dependent fading

To determine the fading characteristics from 0 to 24 h after irradiation, a set of 32 TLDs was irradiated to a dose of 96.6 mGy and read 24 h later. This procedure was repeated three additional times so that each TLD had four separate responses, each at 24 h after irradiation. These same TLDs were again given a dose of 96.6 mGy. This time, however, a subset of four of these TLDs was read immediately after irradiation and at intervals of 1, 2, 4, 6, and 24 h after irradiation. This procedure was also repeated three more times, giving a total of 16 TLD measurements for each time period. The individual TL responses at these different times were normalised to their average responses at 24 h. Each data point represents the average of the 16 individual TLD measurements.

The procedure used to determine the fading from 1 to 90 d was similar to that used in determining the fading from 0 to 24 h. As before, TLDs were exposed four times to a dose of 96.6 mGy and read 24 h later to determine each TLD's average response. Out of these TLDs, a set of four TLDs was chosen as a control group. 24 h before a set of the fading TLDs was read, the control TLDs were run through three read cycles to minimise their residual TL signal and then irradiated to 96.6 mGy. The control TLDs were then read at the same time as the fading TLDs to detect and normalise for any changes in the reading system since the long-term fading TLDs were first irradiated. TLDs were read at 1, 2, 4, 7, 14, 30, 60, and 90 d after irradiation. The data points at 60 and 90 d were based on four TLD measurements, while the remainder were based on eight TLD measurements each. During the entire 90 day period of the experiment, great care was taken to minimise exposure of the TLDs to fluorescent or incandescent lighting. To this end, the TLDs were stored in a light-tight bag inside a light-tight box and kept in a second closed container.

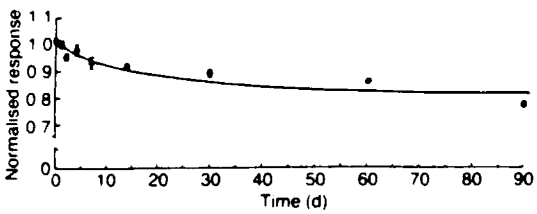

Figure 1. Time-dependent fading of aluminium oxide TLDs. All data points are normalised to the average response at 24 h. Error bars represent ± one standard error of the mean.

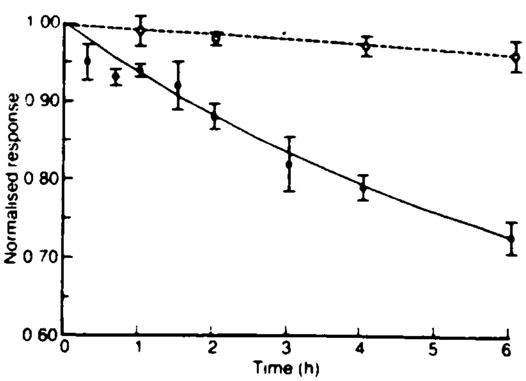

Figure 2. Aluminium oxide TLD fading with exposure to ambient incandescent light. The dashed line shows the time-dependent fading of the same TLDs stored in the dark. Error bars represent ± one standard error of the mean.

Light-induced fading

Three different lighting schemes were used in this study: ambient incandescent light, ambient fluorescent light, and intense fluorescent light. Light intensity was measured using a photographic light meter. The ambient incandescent lighting environment was an otherwise dark laboratory lit by two small incandescent lamps, neither of which shone directly on the TLDs; nominal illumination of this environment was 20 lx. The ambient fluorescent lighting environment was the same lab with the lamps turned off, and the overhead fluorescent lights turned on; nominal illumination was 850 lx. For the intense fluorescent lighting environment, the TLDs were placed 15 cm directly beneath a high intensity fluorescent lamp; nominal illumination was 6000 lx.

The same TLDs that were used for the 0–24 h time-dependent fading studies were used to determine light-induced fading. After irradiation with 96.6 mGy, the TLDs were exposed to either incandescent or fluorescent light for a total of 6 h. One subset of four TLDs was read immediately after irradiation, before any exposure to light. Other subsets were read 20 min, 40 min, 60 min, 90 min, 2 h, 4 h, and 6 h after exposure to light. The individual TLD responses at these various times were normalised to their average responses measured 24 h after irradiation without any exposure to light. The fluorescent light-induced fading experiments were each conducted once. The incandescent light-induced fading experiment was conducted twice and the data points represent the average of the two trials.

RESULTS

The time-dependent fading of aluminium oxide TLDs in the absence of light from 0 - 90 d is shown in Figure 1. In the absence of light, the TL response of aluminium oxide TLDs faded by less than 5% in the first 4 d after irradiation. After 1 month of storage in the dark, however, the signal on the aluminium oxide faded by 11%, and after 3 months, the signal had faded by nearly 21%.

The time-dependent fading in the absence of light in the period 0–6 h is shown by the dashed curve in each of Figures 2–4. The solid curve in Figure 2 shows the light-induced fading of aluminium oxide TLDs exposed to ambient incandescent light. The TL signal of the aluminium oxide TLDs exposed to the incandescent light faded much more rapidly than that of the TLDs stored in the dark. When exposed to ambient incandescent light, the signal on the TLDs fell by 25% in 6 h.

Similarly, Figure 3 shows fading under ambient fluorescent light and Figure 4 shows the fading under intense fluorescent light. With exposure to ambient fluorescent light, the TL signal fell to 33% of its original value in 1 h and to under 10% in 6 h. Under intense fluorescent lighting the fading was even more pronounced, with the TL signal falling to 10% in 1 h and to 3.5% in 6 h.

In all figures, standard curve-fitting procedures were used to draw the curves through the data points. Error bars represent one standard error of the mean.

DISCUSSION

The results of this study indicated that after 3 months of storage in the dark, single-crystal aluminium oxide TLDs faded by as much as 21%. This result is in qualitative agreement with both the McDougall and Rudin data and the Mehta and Sengupta data for non-single-crystal forms of aluminium oxide TLDs which both showed significant time-dependent fading.

The observed 25% fading in 6 h under incandescent light (20 lx) is in qualitative agreement with Akselrod *et al.* who found 20% fading in 20 min under 300 lx daylight for the same type of single crystal TLDs used in this study. Given the amount of light-induced fading seen in this experiment, it is clear that when working with aluminium oxide TLDs, great care must be taken to ensure that the exposure of the TLDs to any light, especially fluorescent light, is kept to a minimum.

CONCLUSIONS

Irradiated aluminium oxide TLDs should never be exposed to fluorescent light, and their exposure to incandescent light should be kept to a minimum. While the light-induced fading is significant, it can be minimised by proper handling and storage. The time-dependent fading, however, is more problematic and cannot be avoided by careful handling of the TLDs.

ACKNOWLEDGEMENT

The author thanks Dr Eric Kearsley for his guidance and support throughout this project. This work was supported by the Armed Forces Radiobiology Research Institute, Defense Nuclear Agency, under Work Unit Number 04610.

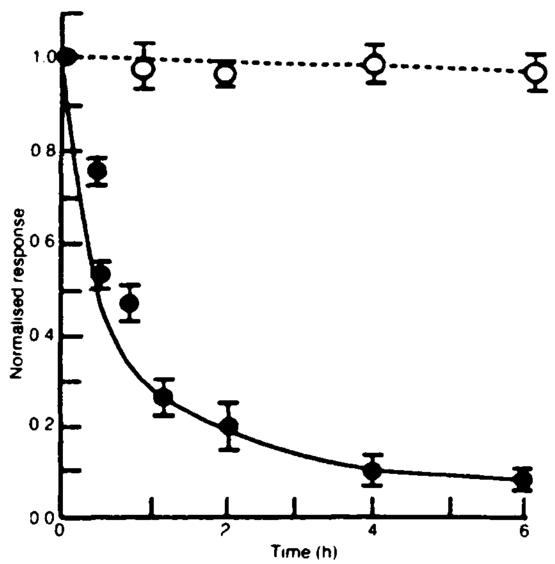

Figure 3. Aluminium oxide TLD fading with exposure to ambient fluorescent light. The dashed line shows the time-dependent fading of the same TLDs stored in the dark. Error bars represent ± one standard error of the mean.

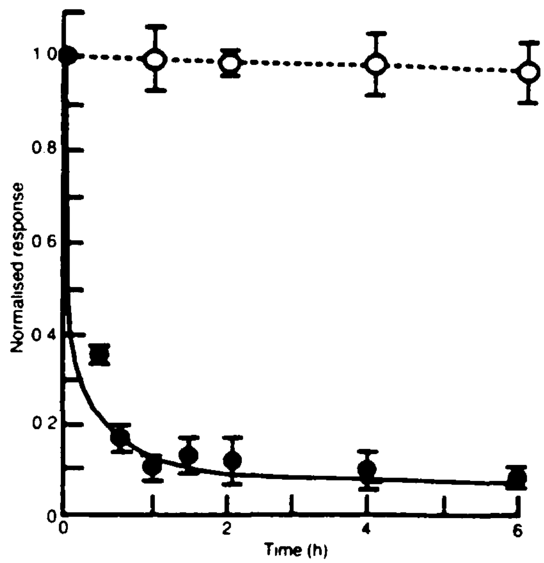

Figure 4. Aluminium oxide TLD fading with exposure to intense fluorescent light. The dashed line shows the time-dependent fading of the same TLDs stored in the dark. Error bars represent ± one standard error of the mean.

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