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SHORT COMMUNICATION

Precision of Low-Dose Response of LiF:Mg, Ti Dosimeters Exposed to 80 kVp X-Rays

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Abstract: *The low-dose response of a LiF:Mg, Ti thermoluminescent dosimeter (TLD-100) was studied by exposing the TLDs to 80 kVp X-rays to different doses. There was no evidence of non-linearity in the dose range studied. The standard deviation was less than 10% at 0.3 mGy, the lowest thermoluminescent (TL) dose before the uncertainty in the TL reading became very large, which reached approximately 60%.*

Keywords: TL-dose response, diagnostic x-ray, low dose

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Abstrak: *Sambutan dos rendah meterdos pendarkilau LiF:Mg,Ti (TLD-100) telah dikaji dengan mendedahkannya kepada sinar-X 80 kVp pada dos yang berlainan. Tidak terdapat bukti ketaklinearan dalam julat dos yang dikaji. Dos terendah dengan bacaan TL yang mempunyai peratusan sisihan piawai kurang daripada 10% ialah 0.3 mGy. Di bawah nilai dos ini ketakpastian dalam bacaan TL adalah besar hingga mencapai kira-kira 60%.*

Kata kunci: sambutan TL-dos, sinar x diagnosis, dos rendah

1. INTRODUCTION

The response of a thermoluminescent dosimeter (TLD) phosphor would ideally be linear over a range of doses. Linearity would make calibration straightforward. A linear thermoluminescent (TL) signal-dose relationship starting from dose zero is preferred for many applications. The TL dose response is defined as[1] follows:

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$$f(D) = \frac{\frac{Q(D)}{D}}{\frac{Q(D_1)}{D_1}} \tag{1}$$

where $Q(D)$ is the TL signal measured as a function of dose D and $Q(D_1)$ is the TL signal measured at a low dose, D_1. An ideal TL detector should satisfy the criterion $f(D) = 1$.

A TLD is not an absolute dosimeter. The TLD dose measurements are obtained by comparing the TL signal of an exposed TLD against the true dose values measured by a reference dosimeter, which is exposed to the same radiation beam. A linear dose response curve would result in an easy calibration. A few authors have reported linearity of response using the very low dose region of 0.1 to 10 mGy with LiF powder.[2,3] Watson[4] had analysed a few references on linearity of dose response curves of TLDs. He found that dose response curves obtained by various authors ranged from linear to completely non-linear. He suggested that a non-linear response may be expected with some readout devices.[4,5]

The zero-dose reading is calculated from the TL signal obtained when an unirradiated TLD is read. It defines the lowest detection limit. The detection threshold, the smallest dose that can be distinguished significantly from a zero-dose, can be taken as three times the standard derivation of the zero-dose readings, expressed in units of absorbed dose. The lower limit of the detectable doses depends on the amount of background signal caused by the dark current of the photo-multiplier tube (PMT), the black-body radiation from the heated planchet and phosphor, and any non-radiation-induced thermoluminescence.[5,6]

Additionally, it varies with residual signals from the annealing and irradiation history of the dosimeter. Other stimuli, such as friction, grinding, chemical reactions and even static electricity, also affect low-dose readings. Jones and Bjarngard[9] concluded that variations in background signal and the absolute value of this background limit the measurement of lower doses. Some authors[6–8] have suggested ways to reduce the effects of PMT dark current on dosimeters. All of the mentioned factors cause the precision of TL dosimetry measurements at low doses to drop rapidly. The overall precision is given as:

$$\frac{\sigma D}{D} = \sqrt{\left(\frac{\sigma_{BG}}{D}\right)^2 + \sigma_s^2} \tag{2}$$

where σ_s is the standard deviation of the sensitivity variations of TLDs, σ_{BG} the standard deviation of the background variations and D the dose given. At small doses, σ_{BG}/D dominates.

Most recent work by other authors analysed doses greater than 5 mGy.[10–12] In most diagnostic procedures, radiation measurements are in the microGray (μGy) region. Our concern is on the use of LiF:Mg, Ti dosimeters in experiments involving diagnostic X-ray machines. For example, the typical entrance dose in a chest posterior-anterior (PA) X-ray procedure for a 23 cm thick patient is approximately 0.14 mGy.[13] Hence, it is imperative to know the precision and the reproducibility of the TL readings in this dose region.

2. MATERIALS AND METHOD

The TLDs used consisted of LiF:Mg, Ti chips (3.2 × 3.2 × 0.89 mm). The TLDs were annealed at 400°C for 1 h using a Nabertherm furnace followed by 20 h at 80°C using a Memmert oven.

An X-ray machine was used to irradiate the TLDs at source-to-skin distance (SSD) of 50 cm at a field size of 10 × 10 cm^2. The TLDs were placed on a piece of paper in air to reduce the effect of scattering. The crystals were arranged at the centre of the X-ray field. All irradiations were performed at 80 kVp, which was the suggested voltage for non-grid chest X-rays.[14] The current and timer settings were varied to obtain different exposures. The effective energy of the X-ray beam at 80 kVp was 28 keV. The dose output of the X-ray machine was determined using a PTW 77337 parallel plate thin window ion chamber connected to a PTW UNIDOS electrometer. Its calibration was consistent with the Secondary Standard Dosimetry Laboratory, Malaysian Nuclear Agency.

The TLDs were irradiated in three batches with five TLDs in each batch to obtain a reasonable TLD reading. After exposure, the readout of the TLDs was obtained using a Harshaw 3500 TLD reader. The heating rate profile was 10°C/sec, and the acquire temperature was 300°C for 33.3 sec.

3. RESULTS AND DISCUSSION

All TLDs were first screened by determining the relative sensitivity of each TLD to the mean of the batch. Any TLDs with a relative sensitivity value greater that ±10% was rejected. Then the individual sensitivity correction factor of each selected TLD was determined and used for the rest of the study.

Figure 1(a) shows the dose-response curve for an 80 kVp X-ray in the low dose range. The error bars on the graph indicate values to one standard deviation. The curve is linear up to the lowest available dose. Using a linear regression method, the gradient of the curve is 7.86 nC/mGy depicting good linearity (0.999).

The TLD's response to doses below 5 mGy was plotted on a larger scale in Figure 1(b). The gradient of the curve was 7.94 nC/mGy, which is comparable to the gradient in Figure 1(a) and indicates that the dose response linearity is maintained. The slight difference in the gradients of the two figures is not significant considering the uncertainty in this low dose region. Non-linearity, as reported by some authors,[4,5] was not observed.

Variation of the standard deviation percentage of TL readings against dose was also calculated as shown in Figure 2. The standard deviation was very high (above 40%) at doses below 0.3 mGy. This finding indicates that LiF:Mg, Ti TL measurements below 0.3 mGy are no longer precise and reproducible.

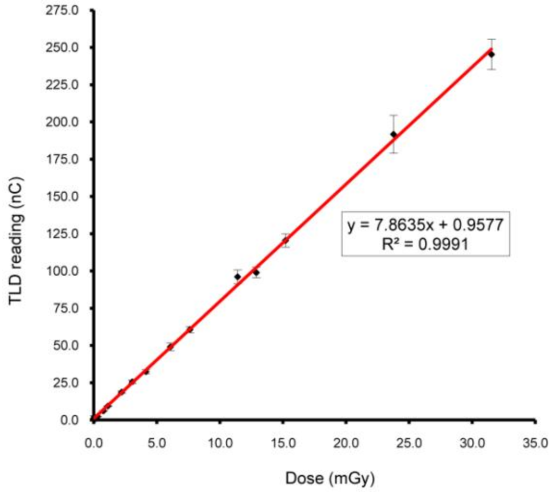

Figure 1(a): TL-dose response of LiF:Mg, Ti chips exposed to 80 kVp x-rays for the dose range of 0.03 to 32 mGy.

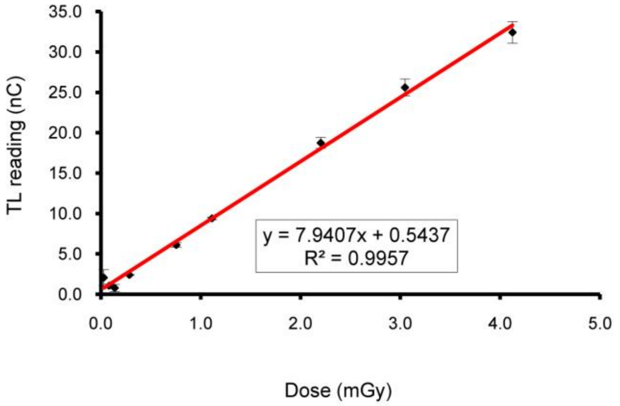

Figure 1(b): Dose-response curve for doses below 5 mGy.

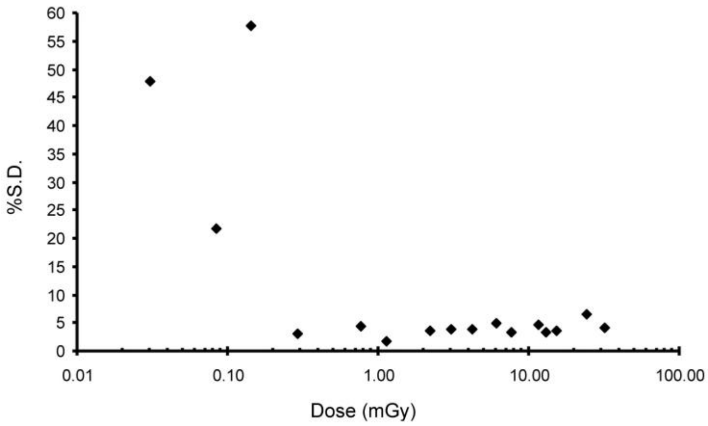

Figure 2: The relationship between the dose (mGy) and the percent standard deviation of LiF:Mg, Ti TL readings exposed to 80 kVp X-rays.

4. CONCLUSION

There is no evidence of non-linearity in the 0.02–32 mGy dose range studied. The lowest detectable dose was 0.3 mGy with a standard deviation of less than 10%. Below 0.3 mGy, the uncertainty in the TL reading was large. These findings are important and should be made available to researchers and medical practitioners using LiF:Mg, Ti dosimeters for low-dose measurements in diagnostic radiology.

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