Gamma response characterizations of optically stimulated luminescence (OSL) affects personal dosimetry

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Abstract. Optically Stimulated Luminescence (OSL) is the current technique of personal dosimetry changed by Nuclear Technology Service Center instead of Thermoluminescence dosimetry (TLD) because OSL has more advantages, such as repeat reading and elimination of heating process. In this study, OSL was used to test the gamma response characterizations. Detailed OSL investigation on personal dosimetry was carried out in the dose range of 0.2 – 3.0 mSv. The batch homogeneity was 7.66%. R² value of the linear regression was 0.9997. The difference ratio of angular dependence at ± 60° was 8.7%. Fading of the reading was about 3%.

1. Introduction
Radiation protection theory is initially limited for occupational and public exposure. Therefore, the measuring exact radiation dose is very important. At present, optically stimulated luminescence (OSL) is the technique for radiation dose assessment. It has been variously used in radiation dosimetry fields, such as space dosimetry, medical dosimetry, environmental dosimetry and personal dosimetry. This technique is a related phenomenon in which the luminescence is stimulated by the absorption of optical energy, rather than thermal energy [1].

The objective of this study is to evaluate the batch homogeneity, dose linearity, angular dependence and fading of OSL for gamma response characterizations.

2. Materials and Methods

2.1. Gamma radiation
OSL dosimeters were irradiated with 137Cs gamma rays by Secondary Standard Dosimetry Laboratory (SSDL) of Office of Atom for Peace (OAP), delivered doses of 0.2, 0.4, 0.6, 0.8, 1.0, 1.5, 2.0 and 3.0 mSv.

2.2. Calibration
The InLight Automatic reader (Landauer, Glenwood, IL, USA) was calibrated with calibrate set of Landauer calibration facility. It is directly traceable to the National Institute of Standards and Technology (NIST).

2.3. Radiation dosimeter
A commercial InLight Automatic reader, which uses OSL technology, measures radiation exposure with aluminum oxide doped with carbon (Al₂O₃:C). The read out process uses the green light of 532 nm wavelength produced by light emitting diode (LED) arrays to stimulate the detectors, and the blue
light of 420-440 nm wavelength emitted by the OSL material is detected and measured by the photomultiplier tube (PMT) of the OSL reader, as shown in figure 1. The amount of light released during optical stimulation is directly proportional to the absorbed radiation dose and the intensity of stimulation light. A dose calculation algorithm is applied for determination of personal equivalent dose.

![Figure 1. The read out process (Landauer, Inc.).](image)

2.4. Batch homogeneity
Twenty-four dosimeters were used for testing the batch homogeneity. All dosimeters were irradiated with 2.0 mSv. The batch homogeneity of evaluated personal equivalent dose was calculated from

$$\text{Batch homogeneity (\%) = \frac{(E_{\text{max}} - E_{\text{min}})}{(E_{\text{max}})} \times 100}$$  \hspace{1cm} (1)

where $E_{\text{max}}$ and $E_{\text{min}}$ are the maximum and minimum evaluated values of the batch, respectively. The evaluated value for any one dosimeter in a batch shall not differ from the evaluated value of any other dosimeter in the batch by more than 30% [2].

2.5. Dose linearity
Ninety-six dosimeters were used for testing the dose linearity and divided into eight groups of twelve. The personal equivalent dose was calculated from the average dose with the evaluation of $Hp(10)$, at a depth equivalent to 1,000 mg/cm² or about 1.0 cm deep below the ICRU phantom surface.

2.6. Angular dependence
Twenty-one dosimeters were used for testing the angular dependence and divided into seven groups of three. The dosimeters were mounted on a 30 × 30 × 15 cm PMMA ISO water phantom and were exposed in vertical centerline of the phantom face to the proper angle for irradiation from seven different angles (-60°, -45°, -30°, 0°, 30°, 45° and 60°). The personal equivalent dose was calculated from the average dose. The relative response value was obtained by normalized the response for each angle to the response at an incidence angle of 0°.

2.7. Fading of the reading
Thirty-six dosimeters were used for testing the fading of the reading and divided into nine groups of four. The effect of storage time over the period of 1-365 days after irradiation were investigated. The dosimeters were irradiated with 3.0 mSv and were kept in the dark. The personal equivalent dose was calculated from the average dose.
3. Results and Discussion

3.1. Batch homogeneity
The result of batch homogeneity test is shown in figure 2. The batch homogeneity was 7.66%, complying with the acceptance limit and the error was less than ±5%.

![Figure 2. The result of batch homogeneity test.](image)

3.2. Dose linearity
The dose linearity of OSL as a function of radiation dose was given in figure 3. It is shown that the reported dose increases linearly with the delivered dose ranging from 0.2 – 3 mSv. The dosimeter shows a very high linearity indicated by the $R^2$ value of linear regression is 0.9997 ($P < 0.0001$). The function of linear fitting is $Y = 0.9994X + 0.0135$ where $X$ and $Y$ stand for personal equivalent dose (mSv) from SSDL and the reader, respectively.

![Figure 3. The reported dose as a function of delivered dose. The $R^2$ value of linear regression is 0.9997 ($P < 0.0001$).](image)
3.3. **Angular dependence**

The angular dependence of dosimeters was measured by irradiated with 2.0 mSv from seven different angles. The results of radiation incident angles of -60°, -45°, -30°, 0°, 30°, 45° and 60° were 0.92, 0.97, 0.99, 1.00, 0.99, 0.96 and 0.91, respectively. Figure 4 shows the data of relative response of OSL. The difference ratio of angular dependence at ± 60° was 8.7%.

![Figure 4. The relative response as a function of incident angle.](image)

3.4. **Fading of the reading**

For these measurements the dosimeters were irradiated and readings were begun within nine different periods (1, 7, 30, 60, 90, 120, 150, 180 and 365 days) after irradiation. The result of fading test is shown in figure 5. Fading of the reading was about 3%.

![Figure 5. Fading of the reading.](image)
4. Conclusions
In this study show that OSL dosimeters can response to the radiation doses with high precision and accuracy. It may be useful for occupational and public exposure. Nevertheless, personal dosimeters should be aligned in the vertical direction because they measure the exact dose value at this alignment [3]. Fading of the reading was about 3% over different time periods of up to 365 days after irradiation. These results are in accordance with the previous results that fading is generally quoted 3-5% per year [1].

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