CHARACTERIZATION OF COMMERCIAL OSL DOSIMETER AS GAMMA AMBIENT DOSIMETER

Karakterisasi Dosimeter OSL Komersial Sebagai Alat Ukur Dosis Ambien Gamma

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Abstrak

The development of OSL dosimeter made from $Al_2O_3:C$ turned out to be able to reduce the limitations of thermoluminescence dosimeter in terms of the heating process, the speed of analysis, and the ability to do a re-reading. This study was conducted to obtain the characteristics of commercial OSL dosimeters which include linearity, fading effect, and reproducibility. Twenty eight environmental OSL dosimeters were annealed and divided into seven groups, each consisting of four dosimeters. Group 1 to 6 were irradiated with ^{137}Cs gamma at various doses, whereas group 7 was as control. Reproducibility testing was done by exposing ten dosimeters by 1 mSv of ^{137}Cs gamma. Results showed that after reading and analyzed, it was obtained the curve of the reading dose to the exposure dose with the equation of $y = 1.0566x - 0.2499$ and the correlation factor $R^2 = 0.9999$. There was no fading effect obtained in the reading dose on the 31st day. While the dose reading on the 70th day was obtained a decrease of 0.12 mSv and 0.34 mSv for exposure doses of 5 mSv and 10 mSv, respectively. The result shows that the average coefficient of dose variation for ten dosimeters that were read once was 9.7% and the average coefficient of variation for 1 dosimeter that was read ten times was 4.2%. The average coefficient of dose variation was greater than the results of previous study which were 2.5% and 1.8%, respectively

Kata kunci: OSL dosimeter, ambient dose, linearity, fading, and reproducibility.

Abstract

Pengembangan dosimeter OSL yang terbuat dari $Al_2O_3:C$ ternyata mampu mengurangi keterbatasan dosimeter termoluminesensi dalam hal proses pemanasan, kecepatan analisis, dan kemampuan untuk melakukan pembacaan ulang. Penelitian ini dilakukan untuk mendapatkan karakteristik dosimeter OSL komersial yang meliputi linearitas, efek fading, dan reproduktibilitas. Dua puluh delapan dosimeter OSL lingkungan di-annealing dan dibagi menjadi tujuh kelompok, masing-masing terdiri dari empat dosimeter. Kelompok 1 sampai dengan 6 di-iradiasi dengan gamma ^{137}Cs pada berbagai dosis, sedangkan kelompok 7 merupakan kontrol. Pengujian reproduktibilitas dilakukan dengan menyinari sepuluh dosimeter pada 1 mSv gamma ^{137}Cs . Hasil penelitian menunjukkan bahwa setelah dibaca dan dianalisis, diperoleh kurva dosis bacaan terhadap dosis pajanan dengan persamaan $y = 1,0566x - 0,2499$ dan faktor korelasi $R^2 = 0,9999$. Tidak ada efek pemudaran yang diperoleh pada pembacaan dosis hari ke-31. Sementara pembacaan dosis pada hari ke-70 diperoleh penurunan 0,12 mSv dan 0,34 mSv untuk dosis paparan masing-masing 5 mSv dan 10 mSv. Hasil penelitian menunjukkan bahwa koefisien rata-rata variasi dosis untuk sepuluh dosimeter yang dibaca satu kali adalah 9,7% dan koefisien rata-rata variasi untuk 1 dosimeter yang dibaca sepuluh kali adalah 4,2%. Koefisien rata-rata variasi dosis tersebut lebih besar dibandingkan dengan hasil studi sebelumnya yang masing-masing besarnya adalah 2,5% dan 1,8%.

Kata kunci: dosimeter OSL, dosis ambien, linieritas, pemudaran, dan reproduktibilitas.

1. INTRODUCTION

Measurement of the environmental dose rate of radiation is traditionally done by using a NaI scintillation detector coupled to multi channel analyzer for minimizing the dependence of the response of difference isotope ratio. Passive solid state detector such as commonly used thermoluminescence (TL) phosphor have also been used to determine the environmental dose rate (Aitken. 1985). The problem using the detector doped with LiF, CaF_2 , and $CaSO_4$ to determine environmental dose is that

they need integration time of the order of months when placed in the field to obtain sufficient measurement accuracy (Jensen, et.al. 1997). The introduction of $Al_2O_3:C$ for TL dosimetry has opened the possibility of several promising applications for ultra high sensitivity particularly for short term exposure in environmental dosimetry (Akselrod et.al. 1990).

Development of optical stimulated luminescence dosimeter made from $Al_2O_3:C$ can eliminate the limitations of the TL dosimeter in the heating process, the speed of the process and the ability to do repetitive analysis

(Kobayashi *et.al.* 2012). Landauer has even tested the OSL dosimeter on several parameters, such as linearity and reproducibility tests to determine the performance of this dosimeter (Ford *et.al.* 2007). Testing of the ambient dose response for irradiation ≤ 1 mSv conducted by Jumpeno *et.al.* (2019) on commercial OSL dosimeters showed a linear curve with a correlation factor of 0.97-0.98.

Dosimeter OSL is a radiation dose detection tool by utilizing light to stimulate dose information stored in dosimeter material. The dosimeter made from $\text{Al}_2\text{O}_3:\text{C}$ material is able to detect photon and beta. To detect neutron, the $\text{Al}_2\text{O}_3:\text{C}$ material is coated with $^6\text{Li}_2\text{CO}_3$ [Landauer Inc. 2009]. Dosimeter OSL used to monitor gamma/beta can be divided into three types, namely personnel dosimeter, environmental dosimeter and medical dosimeter. In this study, the characteristics of commercial OSL dosimeters as gamma ambient dosimeter were tested. The parameters tested include linearity, effect of fading and reproducibility.

2. MATERIAL AND METHODS

A. Material

Optically stimulated luminescence (OSL) referred to emission of luminescence from irradiated semiconductor when exposed to light. The OSL environmental dosimeter is designed for environmental radiation exposure. It has four elements of $\text{Al}_2\text{O}_3:\text{C}$ with different filters as shown in Figure 1. OSL dosimeter has characteristics that influence dosimeter response to gamma dose, namely linearity, fading, reproducibility, energy dependence, light penetration, directional dependence and uniformity.

Figure 1. OSL environmental dosimeter

Information dose was read using a microStar reader that is designed to be operated manually. This OSL reader has dimension of 32.7 cm x 23 cm x 11 cm with a total weight of 15 kg. This reader was integrated with a portable computer and a scanner as shown in Figure 2.

To operate the microStar reader, the inlight microStar system was installed.

Figure 2. MicroStar reader device

B. Method

Twenty eight dosimeters were annealed and the ambient dose was confirmed to be 0. The dosimeters were wrapped in aluminum foil to prevent $\text{Al}_2\text{O}_3:\text{C}$ element from being exposed to light. The available dosimeters are divided into seven groups, namely Group 1 to 6 and Control. Each of them consists of four OSL dosimeters and was labeled a, b, c, and d. Group 1 to 6 were irradiated with ^{137}Cs gamma of 0.25 mSv; 0.5 mSv; 1 mSv, 2.5 mSv, 5 mSv and 10 mSv. The distance of the dosimeter to the source of ^{137}Cs was 200 cm. Each dose level was irradiated simultaneously. Each dosimeter was read three times.

The fading effect was tested by re-reading the dosimeter that was irradiated with ^{137}Cs gamma. The readings were carried out on the 1st, 31st and 70th day after irradiation.

Reproducibility characteristics were obtained by irradiating ^{137}Cs gamma of 1 mSv on ten dosimeters that had been annealed and wrapped in aluminum foil. Each dosimeter was re-read up to ten times.

3. RESULT AND DISCUSSION

1. Linearity

Irradiation of gamma was carried out at the OB 85 Calibration Facility which utilizes ^{137}Cs sources with activity of 740 GBq / March 1985. This radiation calibration facility has been accredited by National Accreditation Committee since February 2013. Table 1 showed response of the reading dose to exposure dose.

Table 1. Response dose of OSL dosimeter to exposure dose.

No.	Ambient Dose (mSv)	
	Exposure dose	Reading Dose
1	0.25	0
2	0.5	0.22
3	1	0.82
4	2.5	2.43
5	5	5.09
6	10	10.28

Meanwhile the curve of reading dose response to the exposure dose as standard dose can be seen in Figure 3.

Figure 3. The curve of reading dose to exposure dose on the environmental OSL dosimeter

After the dose measurement data was analyzed, the curve of reading dose response to the exposure dose shows a linear tendency with a correlation factor (R^2) ~ 1 for the exposure dose ≤ 10 mSv. The linearity response is in accordance with the results of research by Pinto *et.al* (2008), Jain *et.al.* (2017), and Hashim *et.al.* (2018). Landauer Inc. (2007) in *Environmental Dosimeter Type Testing* described that the linearity curve slope was 1.029 with a value of $R^2 = 0.998$ for 0.5 mSv up to 10 mSv exposure dose.

2. Fading

To test the fading effect, dose readings on the 1st day after irradiation was repeated on the 31st day and 70th day. In this study, re-read dosimeters were stored in a light-proof container in the OSL Laboratory which was controlled its temperature and humidity condition. There is no provision regarding the timing of OSL dosimeter placement in the field but it is adjusted to the need for dose monitoring. The reading dose response after irradiation is shown in Table 2.

Table 2. Dose response of OSL dosimeter after irradiation

No	Exposure Dose (mSv)	Reading Dose After Irradiation (mSv)		
		1 st day	31 st day	70 th day
1	0.25	0.00	0.00	0.00
2	0.5	0.22	0.26	0.23
3	1	0.82	0.86	0.89
4	2.5	2.43	2.45	2.45
5	5	5.09	5.13	4.97
6	10	10.28	10.29	9.94

Figure 4 illustrates the dose response at day 1, day 31 and day 70 after ^{137}Cs irradiation.

Figure 4. Dose response on day 1, day 31 and day 70 after irradiation.

In the testing, there is no fading effect obtained in the reading dose on the 31st day. While the dose reading on the 70th day was obtained a decrease of 0.12 mSv and 0.34 mSv for exposure doses of 5 mSv and 10 mSv. It was confirmed that no significant effect of fading. Jensen *et.al.* (1997) in their research found that no significant fading of the OSL signal over 85 days at room temperature. According to Gronchi *et.al.* (2007), the fading of $\text{Al}_2\text{O}_3:\text{C}$ is relatively strong when it is exposed to fluorescent light because $\text{Al}_2\text{O}_3:\text{C}$ is very sensitive to light. Therefore the OSL dosimeter used must be protected from light and handled in a dark room.

3. Reproducibility

When ten dosimeters were read once the average coefficient of variation was 9.7%. Meanwhile it was 4.2% when one dosimeter was read ten times. Its repeated readings are shown in Table 3.a

Table 3. Dose response for reproducibility with ten replication

OSLD Code	Re-reading Dose (mSv)										Avg. CV (%)
	1	2	3	4	5	6	7	8	9	10	
OS1	0.64	0.66	0.64	0.65	0.62	0.61	0.64	0.65	0.63	0.60	4.2
OS2	0.63	0.67	0.68	0.67	0.59	0.55	0.57	0.65	0.64	0.61	
OS3	0.65	0.70	0.69	0.63	0.65	0.68	0.69	0.65	0.64	0.65	
OS4	0.66	0.63	0.68	0.72	0.67	0.64	0.64	0.66	0.66	0.67	
OS5	0.58	0.67	0.65	0.64	0.65	0.66	0.65	0.66	0.64	0.69	
OS6	0.78	0.77	0.72	0.74	0.76	0.78	0.75	0.72	0.76	0.76	
OS7	0.80	0.81	0.79	0.80	0.84	0.75	0.76	0.79	0.73	0.80	
OS8	0.78	0.80	0.79	0.82	0.77	0.78	0.74	0.70	0.74	0.74	
OS9	0.76	0.78	0.76	0.79	0.73	0.78	0.73	0.71	0.75	0.73	
OS10	0.82	0.80	0.73	0.83	0.78	0.76	0.74	0.75	0.77	0.73	
Avg. CV (%)	9.7										

Ponmalar et.al. (2017) state that the sensitivity of the OSL dosimeter varies in the production batch so that it affects the dose response. In *The Environmental Dosimeter Type Testing* (2007), the average coefficient of variation for ten dosimeters which were read once and each dosimeter which was read ten times is 2.5% and 1.8% respectively. Figure 5 illustrate

Figure 5. Dose response to environmental OSL dosimeter with ten replications

Compared with the report, the average coefficient of variation in this study was relatively higher. The average coefficient of variation was more than tolerance value of 3%. This might be due to difference or variation of sensitivity for each OSL dosimeter to dose response. The large difference in sensitivity for each dosimeter to radiation led to high difference in the variation of dose response.

5. CONCLUSION

Commercial OSL dosimeter testing for measurement of gamma ambient dose shows a

linear tendency with the equation of $y = 1.0566x - 0.2499$ and a correlation factor (R^2) = 0.9999 for the exposure dose ≤ 10 mSv. There is no fading effect obtained in the reading dose on the 31st day. While the dose reading on the 70th day was obtained a decrease of 0.12 mSv and 0.34 mSv for exposure doses of 5 mSv and 10 mSv. For reproducibility testing, the average coefficient of variation was more than tolerance value of 3%. When ten dosimeters were read once the average coefficient of variation was 9.7%, meanwhile it was 4.2% when one dosimeter was read ten times.

ACKNOWLEDGMENT

Thank you to the Head of Radiation Measurement Calibration Subdivision - NNEA who has permitted to utilize the Gamma Calibration Facility.

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