การศึกษาความเป็นไปได้ในการนำอุปกรณ์ตัวต้านทานชนิดเซอร์เฟสเม้าท์ เพื่อใช้ในการสืบหาปริมาณรังสีย้อนหลังในกรณีเกิดอุบัติเหตุทางรังสี

The study of possibility to use Surface Mount Device Resistor for determination of accidental dose

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Received: Nov 23, 2018

Revised: Aug 27, 2019

Accepted: Oct 10, 2019

บทคัดย่อ

เมื่อเกิดอุบัติเหตุทางรังสีสิ่งที่สำคัญคือการสืบหาปริมาณรังสีย้อนหลังในบริเวณที่มีการเปรอะเปื้อน โดยของใช้ที่หาได้ทั่วไปบางอย่างสามารถใช้เป็นอุปกรณ์วัดปริมาณรังสีได้ ซึ่งในงานวิจัยนี้จะศึกษาความเป็นไปได้ที่จะใช้ตัวต้านทานในแผงวงจรอิเล็กทรอนิกส์ของคอมพิวเตอร์ส่วนตัวเป็นอุปกรณ์วัดปริมาณรังสีย้อนหลังโดยอาศัยหลักการทางเทอร์โมลูมิเนสเซนซ์ ส่วนประกอบของตัวต้านทานชนิดเซอร์เฟสเม้าท์ที่มีคุณสมบัติทางเทอร์โมลูมิเนสเซนซ์คืออะลูมินาพอร์ซเลนซับเสตรท เมื่อตัวต้านทานถูกฉายด้วยรังสีเอกซ์ที่พลังงาน 160 กิโลอิเล็กตรอนโวลต์ พบว่าความสัมพันธ์ระหว่างปริมาณแสงกับปริมาณรังสีมีความเป็นเชิงเส้นตั้งแต่ปริมาณรังสี 10-80 มิลลิเกรย์ มีการจางหายไปของสัญญาณแสงประมาณ 40 เปอร์เซนต์ต่อเดือน และสามารถวัดปริมาณรังสีได้ต่ำสุดที่ 0.2 มิลลิเกรย์ จากผลการทดลองที่กล่าวมานี้ทำให้ตัวต้านทานชนิดเซอร์เฟสเม้าท์ดังกล่าวสามารถนำไปใช้เป็นเครื่องมือวัดปริมาณรังสีที่มีปริมาณรังสีน้อยๆหลังเกิดอุบัติเหตุทางรังสีได้

คำสำคัญ: เทอร์โมลูมิเนสเซนซ์ ตัวต้านทานชนิดเซอร์เฟสเม้าท์ ปริมาณรังสีย้อนหลัง

Abstract

In case of accidental radiation exposure of population, retrospective dosimetry is one of the most important techniques for measuring the irradiated dose in contaminated areas. Many common materials can be used as an accidental dosimeter. The present paper studied the possibility to use Surface Mount Devices (SMD) resistors in the electronic circuit boards of personal computer by exploiting their thermoluminescence (TL) properties. was The TL sensitive component of SMD is the alumina porcelain substrate. It was observed that the resistor irradiated with 160 keV X-ray exhibits a linear dose response in the dose range of 10 to 80 mGy, a proper glow curve peaks at about 150°C, a 40% fading of TL signal after storing for one month at room temperature and a very low minimum detectable dose of about 0.2 mGy. The result shows that SMD resistor can be used as an accidental dosimeter in case of small leakage accidental radiation.

Keywords: Thermoluminescence; Surface mount device; Accidental dosimeter.

1. Introduction

The risk of an accidental radiation exposure of population requires a quick determination of the absorbed dose of individuals, who have been in the area at the moment of unexpected radiological events,

Moreover, the electronic components of cell phones, pagers, portable computers, music and video players, cameras, and USB flash drive have been considered as a suitable accidental dosimeters for optically stimulated luminescence (OSL) or thermoluminescence (TL) methods [5], [6], [7], [8], [9], [10].

The ceramic substrate of Surface Mount Device (SMD) resistors have been found as a retrospective dosimeter and their main advantage is the availability in many common electronic devices [11]. The investigation on the thermoluminescence (TL) properties of SMD resistors has shown that SMD resister is a reliable dosimeter in the doses range of 100 mGy to 1.5 Gy by irradiated with the beta source (^{90}Sr-^{90}Y). Moreover, it exhibits a minimum detectable dose above 10 mGy [1].

The objective of this work is to investigate the thermoluminescence properties such as glow curve feature, TL response, lower detection limit and fading of SMD resistor in the electronic circuit board of computer for retrospective dosimetry purposes in order to evaluate the absorbed doses after irradiated with X-ray photon energy at 160keV.

2. Materials and Methods

The investigations were carried out on SMD resistors number 472 in the electronic circuit boards of computer (Figure 1). The TL sensitive component of SMD-472 resistor is the alumina porcelain substrate (Figure 2).

No sample treatment was applied on SMD-472 resistors before irradiation. After the irradiation with X-ray photon energy at 160 keV in the varied dose range of 10 to 80 mGy by varying operating time of X-ray machine, TL light emitted from the resisters was

in order to initiate the proper medical treatment [1]. Previous studies have proved that in this emergency situation, common materials and personal objects of individuals can be used as promising retrospective dosimeters such as the glass display of mobile phones and watch glass [2], [3], [4].

detected by a TLD Reader (Harshaw/Bicron Model 3500 Manual) in order to determine their thermoluminescent dosimetric properties. 5 chips per dose were evaluated. The glow curve was recorded from room temperature up to the maximum temperature of 300 °C with the heating rate of 10 °Cs^{-1}. During the investigation, the nitrogen gas was flowed in order to eliminate the light interference caused by oxidation of dust. A region of interest facility available in the TLD reader was used to evaluate the response of glow peaks by using the CGCD (Computerized Glow Curve Deconvolution) procedure.

3. Results

3.1 Glow curve structures

Figure 3 shows the glow curves of SMD resistor after irradiated by X-ray using the dose ranges of 10 to 80 mGy. The glow curve is characterized as a single peak at the temperature of about 150°C; this temperature is good in terms of no interference of infrared radiation signals that emitted from the planchet of TL Reader. The TL response is found to slightly increase with increasing irradiated dose.

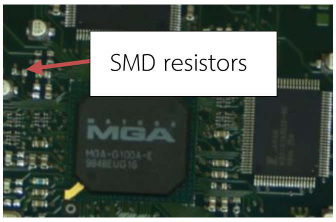

Figure 1 Photograph of electronic circuit board of computer.

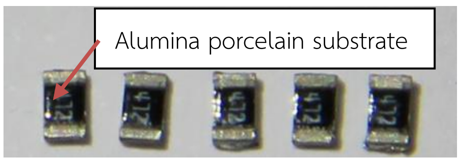

Figure 2 Surface Mount Devices (SMD) resistors.

3.2 Dose Response and Reusability

The study of reusability of SMD resister requires constructing a calibration curve in order to determine an unknown irradiated dose for retrospective dosimetry. After first cycle of irradiation and TL Measurement, the samples were annealed at 300°C for 10 sec in TLD reader and then the second cycle was performed. Figure 4 shows the TL response at the peak as a function of irradiated dose in two irradiation and measurement cycles. Linear TL dose response is found for both cycles. The best fitting straight lines of $y = 2.8421x + 0.0714$ and $y = 2.7251x + 1.447$ with correlation coefficient (R^2) of 0.9919 and 0.9888 are estimated for the first and second cycles, respectively. It can be seen that the fitting lines for the first and the second cycle are identical (within standard deviations). This means after annealing, the samples are reusable and this reproducible linearity of TL dose response enables us to construct a calibration line of SMD resistor for evaluating the absorbed dose at any accidental exposure site.

Calibration factor (Φ_c) is the factor for correcting the TL signal of unknown dose for dose evaluation process. It is given by the ratio of $1/slope$ of dose response curve [12].

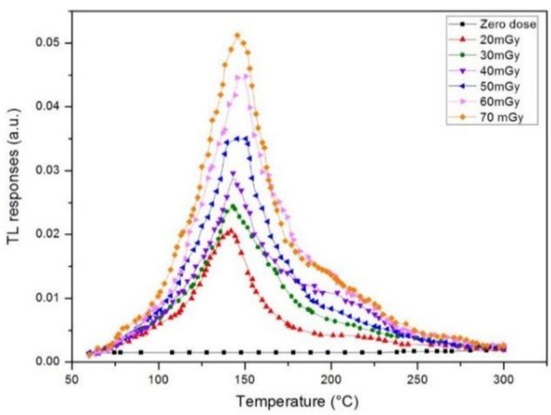

Figure 3 TL glow curves of SMD-472 resistors after X-ray irradiation at different doses.

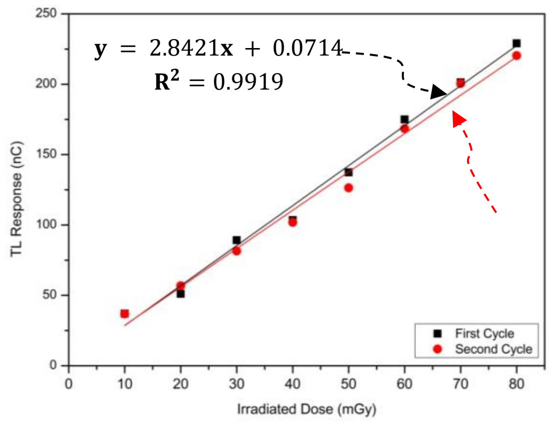

Figure 4 Dose response curve of SMD-472 resistors for the 1st and 2nd cycles of irradiation.

$$\Phi_c = \frac{1}{slope} = \frac{1}{2.7251 \, {}^{nC}/_{mGy}} = 0.367 \frac{mGy}{nC} \qquad (1)$$

3.3 Lower Detection Limit (D_{LDL})

A quantity of interest in the work of SMD resistors is a lower detection limit (D_{LDL}) that is evaluated as the average TL signal of three times the standard deviation of the zero-dose reading ($3\sigma_{BKG}$) [12]:

$$D_{LDL} = (M + 3\sigma_{BKG})\Phi_c = 0.176 \, mGy \qquad (2)$$

Where M is the average zero-dose reading (intrinsic background) of 10 SMD resistors after pre-irradiation at 300°C for 10 sec σ_{BKG} is the standard deviation of M and Φ_c are the calibration factors. The D_{LDL} is typically given in units of the irradiated dose (Gy)

The lower detection limit of SMD-472 resistor, exposed to X-ray photon energy at 160 kV, is 0.176 mGy. This very low minimum detectable dose make the SMD-472 resistor suitable for determining the low radiation dose in the case of small leakage accidental radiation; this usually happens more often than the large leakage radiation. Comparing to the previous research [1] that showed the 10 mGy-detection limit of SMD resister exposed to beta source (^{90}Sr-^{90}Y), the SMD resistor, exposed to X-ray photon energy at 160 kV exhibits the lower detection limit. This demonstrates that the sensitivity observed for photon is higher than that for electron due to the difference of linear energy transfer (LET) of two beams [13], [14], [15], [16]. Therefore, in application of SMD resistor as an accidental dosimeter, we have to regard the energy irradiation.

3.4 Fading factor (λ)

Fading are the loss of the stored TL signal after irradiation over a period of time. Because of this fading effect, the reading of TL signal for the field dosimeter, which is normally carried out after irradiation over a period of times (more than 10 hours and less than 1 month), is incorrect. Therefore, it needs to be corrected by multiplying the TL response with the fading factor. This fading factor evaluates the correct environmental dose over a period of time for retrospective dosimeter [5], [13]. Fading properties was determined by irradiating SMD resistors and storing them in room temperature for different periods of time before evaluating the TL response.

The TL signal in Figure 5 shows that for the first 10 h, the TL response decays by 40% of the original signal. This may be due to the nature of the glow curve structure that the center temperature of main peak (at about 150°C) is rather low [11], [13]. Then it achieves certain stability even after about two months. Therefore, the fading factor of SMD resistor is about 40%.

3.5 Residual signal

The residual signal is defined as the percentage ratio of the second readout to the first readout by exactly the same reading program and without any sample treatment between them. Table 1 (column 1&2) shows the residual signal of SMD resistor irradiated with X-ray at dose of 40 mGy.

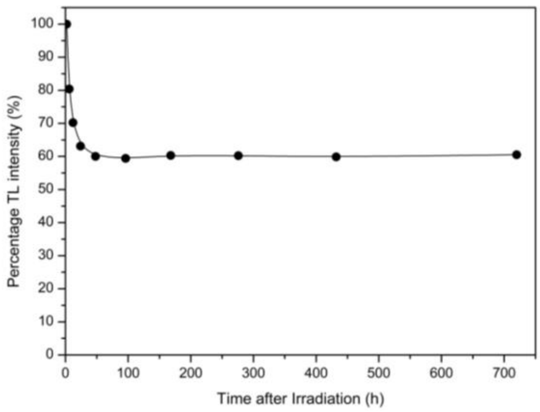

Figure 5 Fading of TL signal of SMD-472 resistors after irradiated with 20 mGy X-ray for 2 months.

Table 1 The residual signal and intrinsic background of SMD resistor after irradiated with 40 mGy X-ray

Readout No.	TL signal (nC)	Intrinsic Background (nC)
1	1.2330	-
2	0.4350	0.4080
3	0.3669	0.3675
4	0.3760	0.3623
5	0.3551	0.3018
6	0.3309	0.3361
7	0.3371	0.3918
8	0.3149	0.3729
9	0.3219	0.3549
10	0.3436	0.3483
11	0.3178	0.3170
X ± SD	0.3499±0.0344	0.3561±0.0306
%SD	9.83%	8.59%

The percentage ratio of the second readout (0.4350 nC) to the first readout (1.2330 nC) is about 35 %, and the residual TL signal of readout number 2-11 remains nearly constant. The average and percentage standard deviation of TL signal is 0.3499 nC and 9.83% , respectively. The TL signal of unexposed SMD-472 resistor after annealing at 300°C for 10 sec, shown in column 3 of table 1, is defined as intrinsic background. The data shows that the intrinsic background is in a good agreement with residual signals of exposed SMD-472. This means after the first readout, the absorbed dosed are all released. Therefore this temperature profile, which is preheat at 60ºC and a following heat up to the maximum temperature of 300 ℃ with the heating rate 10 ℃/s, is suitable for monitoring the absorbed dose of SMD resistor.

4. Discussion

From the results, we can determine the absorbed doses of SMD resistor from the accidental irradiation by the following procedures:

1) Remove SMD-472 resistors from electronic circuit board of computer that exposed to the accidental irradiation. The SMD-472 resistors are then divided into two groups: Group I (at least 10 pieces) for constructing the calibration curve and Group II (at least 3 pieces) for evaluating the unknown absorbed dose.
2) Anneal samples in Group I by heating at 300℃ for 10 sec to release the absorbed dose.
3) Irradiate the SMD-472 resistors in Group I with the known dose, then immediately measure TL intensity and repeat step 2 and 3 using different irradiation doses until approximately 8-10 different doses are obtained. After that, plot the calibration curve and calculate the calibration factor (Φ_c).
4) Measure TL response of SMD-472 resistor in Group II with the same temperature profile of TL Reader as in step 3
5) Determine the irradiation dose from the accidental radiation of the samples in Group II by multiplying the measured TL response in step 4 with calibration factor (Φ_c) and fading factor (λ).

For practical use, absorbed dose should be corrected by multiplying with attenuation correction factor due to dose attenuation by computer case and other components.

5. Conclusion

The results discussed in this paper show that the SMD-472 resistors seem to be a potential retrospective dosimeter for X-ray radiological accident due to its outstanding properties including no sample preparation, high TL responses, proper TL glow curve structure, good linearity of TL response in the dose range of 10 - 80 mGy and low minimum detectable dose.

Acknowledgments

The authors would like to thank science achievement scholarship of Thailand; Ministry of Science and Technology for financial support and Glass Technology Excellent Center, Ubonratchathani University for instrument support.

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