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The Thermoluminescence Performance of Ge- Doped Optical Fibres To 6 Mv Photon Irradiations

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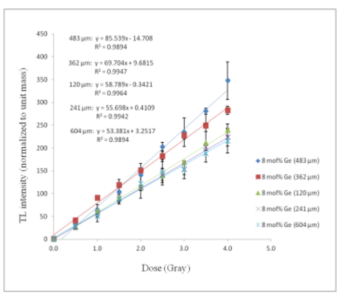
Graphical abstract



Abstract

The study focus on thermoluminescence (TL) response of five different diameters ~120, 241, 362, 483 and 604 µm of 8 mol% Ge-doped optical fibres. The irradiation was performed using Linear Accelerator (LINAC) Model Primus MLC Siemens provided by the Hospital Sultan Ismail, Johor Bahru at 6 MV photon irradiation with delivered doses ranging from 0.5 – 4.0 Gy. The results show the linear dose response against TL signals up to 4 Gy. The diameter of 483 µm optical fibre shows the highest in TL dose response and sensitivity compared to other fibres. The sensitivity of 483 µm optical fibre are almost 1.6 times more than 604 µm. The linear dose response at low dose makes this optical fibre suitable to be used in radiation dosimetry application.
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Keywords: Radiation dosimeter; Ge-doped optical fibre; Thermoluminescence (TL); Photon; Dose Response

Abstrak

Kajian tertumpu kepada sambutan luminesens terma terhadap lima jenis diameter berbeza ~120, 241, 362, 483 dan 604 µm bagi 8 mol% Ge dopan serabut optik. Penyinaran telah dilakukan menggunakan sumber dari pemecut alur linear Model Primus MLC Siemens di Hospital Sultan Ismail, Johor Bahru pada tenaga foton 6 MV dengan dos yang diberikan dari 0.5 – 4.0 Gy. Dapatan menunjukkan sambutan dos adalah berkadar langsung dengan isyarat TL sehingga 4 Gy. Serabut optik berdiameter 483 µm menunjukkan sambutan dos TL dan kepekaan yang tinggi berbanding serabut optik yang lain. Kepekaan serabut optik 483 µm adalah 1.6 kali lebih tinggi berbanding 604 µm. Sambutan dos yang linear pada dos rendah membolehkan serabut optik ini sesuai digunakan dalam aplikasi dosimetri sinaran.

Kata kunci: Dosimeter radiasi; Ge dopan serabut optik; Luminesens terma (TL); Foton; Sambutan dos

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■1.0 INTRODUCTION

Thermoluminescent dosimetry (TLD) is a basic tool for radiation protection which indicates the amount of absorbed dose received by the radiation workers. It is widely used in different ionizing radiation field such as personal dosimeter, environmental monitoring, industry and medical purposes. Several thermoluminescence (TL) phosphors are available for dosimetry and have different properties depending on their application. Recently, a number of research groups have started to use doped SiO_2 optical fibres as a radiation dosimeter by using various types of ionizing radiation[1-4]. The ability to manufacture silica fibres of relatively small diameter (several tens of mm) provides the possibility of producing a TL dosimeter offering high spatial resolution. There are a number of added advantages of doped SiO_2 optical fibre dosimeters. Unlike the conventional TLDs, the fibres are impervious to water; in some instances, it then becomes possible to locate the fibre dosimeter within a particular tissue of interest[5]. In the present work, we report the results of of 8 mol% Ge- doped SiO_2 optical fibres with five different diameters (120 µm, 241 µm, 362 µm, 483 µm and 604 µm) subjected to 6 MV photon irradiation with doses ranging from 0.5 Gy to 4.0 Gy. A comparison in terms of their sensitivity at various doses have been made to the above-mentioned optical fibre samples.

Table 1 Five types of Ge-doped optical fibres

No	Diameter (μm)	Mass (± 0.02 mg)	Length (± 1.0 mm)
1	120	0.16	5.0
2	241	0.58	5.0
3	362	1.06	5.0
4	483	2.07	5.0
5	604	3.08	5.0

2.0 EXPERIMENTAL

2.1 Sample Preparation

Present research has focused on the TL response of commercial produced single-mode telecommunication optical fibres. The 8 mol% Ge-doped optical fibre with different diameter were investigated. A tailor-made optical fibres were fabricated through Modified Chemical Vapour Deposition (MCVD) at Telekom Malaysia Research and Development (TMR&D), Multimedia University and were pulled at Faculty of Engineering, Universiti Malaya, as shown in Table 1.

The protective polymer layer of the optical fibre was removed from the fibres using a fibre stripper (Fremont Inc., USA). A moist cotton cloth dipped into ethanol was used to clean the doped SiO_2 optical fibre core to minimize the possibility of any remnant polymer cladding. Subsequently, the fibre was cut to lengths of 5.0 ± 1.0 mm using an optical fibre cleaver (Fujikura Ltd., Japan). The mass of each fibre was measured using an electronic balance (PAG, Switzerland). This allowed TL yield to be normalized to unit mass of the fibre. Vacuum tweezers (Dymax 5 – Charles Austen pump Ltd) were used for handing and grouping of the TL materials.

2.2 Annealing

Annealing is the thermal treatment used to remove any irradiation memory from the TL material, stabilizing the trap structure and restoring the dosimeter to initial conditions prior to irradiation [6]. The fibres were annealed at 300 °C for a period of 1 hour in order to erase all possible remaining information. During an annealing, about 24 hours is taken for cooling down inside the oven to avoid thermal stress[4]. The fibres were equilibrated at room temperature in the end of annealing process. After annealing, the samples were placed inside capsules and kept in an opaque plastic container to minimize environmental exposure such as humidity, temperature and visible light.

2.3 Sample Irradiation

The Ge-doped SiO_2 optical fiber which grouped in different diameters were placed at the surface of a solid phantom and were irradiated with 6 MV photon, delivered by a Model Primus MLC Siemens Linear accelerator (LINAC), with doses from 0.5 Gy to 4.0 Gy at Department of Radiotherapy and Oncology, Hospital Sultan Ismail, Johor Bahru, Malaysia. The field size used to deliver the dose by LINAC is 10×10 cm^2 and 100 cm as a setting for source to skin distance (SSD).

2.4 Thermoluminescence Measurement

After each set of exposures, the fibres were left for 24 h to allow uniform control of thermal fading. The optical fiber TL yield was readout using instrument Harshaw 3500 TL reader and WinREMS software for displaying TL glow curve and TL response values at Nuclear Lab, Faculty of Science, Universiti Teknologi Malaysia (UTM). The time temperature profile (TTP) was set at preheat temperature of 50°C for 8 s; acquisition temperature 300°C for 13.3 s; heating rate cycle of 25°C per seconds [7]. Nitrogen atmosphere was used to suppress spurious light signals from triboluminesence and also to reduce oxidation of the heating element.

3.0 RESULTS AND DISCUSSION

The intensity of luminescence as a function of temperature is called the thermoluminescent glow curve. This glow curve varies with the mode of heating and the heating temperature[5]. Figure 1 shows the TL glow curve yield for a 8 mol% Ge-doped optical fibre of five different diameters.

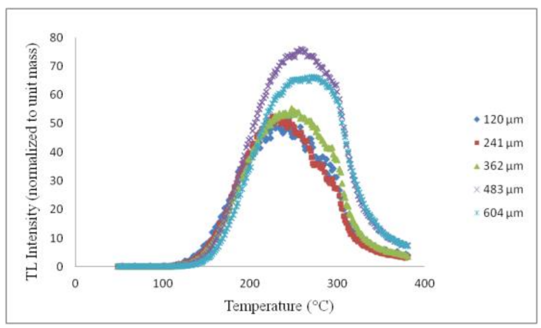

Figure 1 TL Glow curve for 8 mol% Ge-doped optical fibre of five different diameters following 4.0 Gy dose of 6 MV photon irradiation.

Based on the figure, it shows 483 µm optical fibre has a greater intensity after normalizing to unit mass compared to other fibres. The TL glow peak for these five diameters are found to be in the range of 226 - 274 °C. TL yields as a function of temperature (i.e. the glow curves) were recorded using a heating rate of 25 °C/sec. The readout temperature was 300 °C from the time-temperature profile setup for the TLD reader. The area under the curve represents the radiation energy deposited to the TL samples. The TL glow curve for 483µm diameter Ge-doped optical fibre subjected to different radiation doses of 0 - 4 Gy from 6 MV photon irradiation are shown in Figure 2.

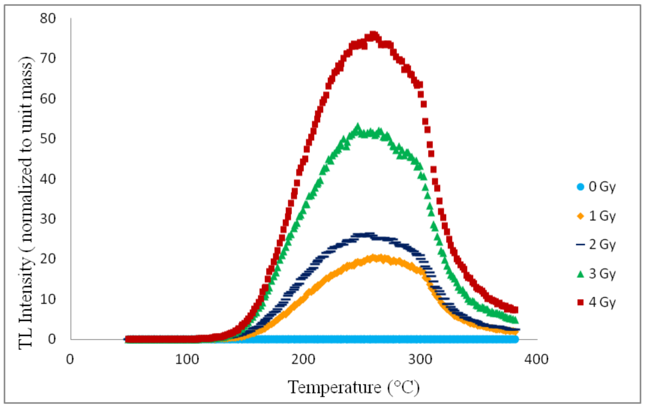

Figure 2 TL Glow curve for the Ge-doped optical fibre with 483µm diameter subjected to various radiation doses.

As can be seen from Fig.2, the TL intensity is directly proportional to the delivered doses, i.e. 4 Gy of dose shows the highest TL response. The increase of radiation doses do not change the pattern of the glow curve of the irradiated optical fibres. It can be observed that the glow curve peaked in a range of 244-274 °C.

Ideally, dosimeters should produce a linear response to the absorbed dose of radiation. However, beyond a certain dose range a non-linearity (sub-linear and supralinear behaviour) sets in. The linearity range and the non- linearity behaviour depend on the type of dosimeter and their physical characteristics [8]. In this study, the five optical fibres with different diameter of 8 mol% Ge-doped optical fibre have shown good linearity to the delivered doses (0.5 Gy – 4.0 Gy) as shown in Figure 3.

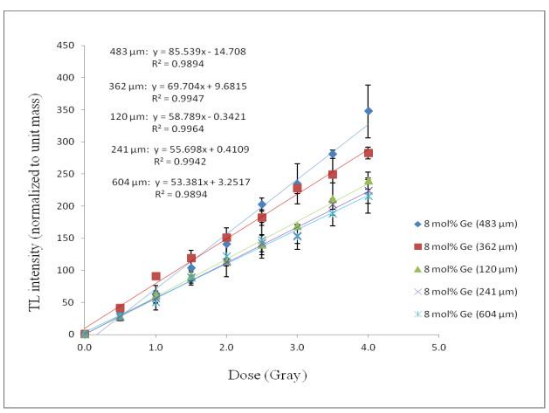

Figure 3 TL response of 8 mol% Ge-doped optical fiber with five different diameter.

The sensitivities of five different diameter optical fibres have been compared based on the slope of the TL response graph (Fig. 3). The 483 µm optical fibre has shown higher sensitivity than any other optical fibre samples. For instance, the sensitivity of 483 µm optical fibre are almost 1.6 times more than 604 µm and 1.5 times more than 120 µm and 241 µm respectively. It is also 1.2 times more sensitive compare to 362 µm.

4.0 CONCLUSION

The study provides useful TL properties of five different diameters of 8 mol% germanium doped optical fiber. These fibers show good linearity i.e. TL response as a function of the absorbed dose from photon irradiation. Among five different diameter optical fiber, 483 µm diameter shows the best result in response and the sensitivity are almost 1.6 times, 1.5 times and 1.2 times more than 120 µm, 241 µm, 362 µm and 604 µm. It very useful to conduct further studies on a tailor-made Ge-doped optical fiber with different level of germanium concentration.

Acknowledgement

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References

[1] Saeed, M.A., Hossain, I., Hida, N. and Wagiran, H. 2013. Thermoluminescent sensitivity of single clad neodymium doped SiO_2 optical fibres measured with 6 MeV photons. *Radiation Physics and Chemistry*. 91: 98–100
[2] Hashim, S., Bradley, D.A., Peng, N., Ramli, A.T., Wagiran, H. 2010. The thermoluminescence response of oxygen-doped optical fibres subjected to photon and electron irradiations. *Nuclear Instruments and Methods in Physics Research A*. 619: 291–294
[3] Issa, F., Abd Latip, N.A., Bradley, D.A., Nisbet, A. 2011. Ge-doped optical fibres as thermoluminescence dosimeters for kilovoltage X-ray therapy irradiations. *Nuclear Instruments and Methods in Physics Research A*. 652: 834–837
[4] Hashim, S., Bradley, D.A., Saripan, M.I., Ramli, A.T., and Wagiran, H. 2010. The thermoluminescence response of doped SiO_2 optical fibres subjected to fast neutrons. *Appl. Radiat. Isot*. 68: 700–703.
[5] Yusoff, A.L., Hugtenburg, R.P. and Bradley, D.A. 2005. Review of development of a silica-based thermoluminescence dosimeter. *Radiation Physics and Chemistry*. 74: 459–481
[6] Che Omar, S.S., Hashim, S., Ibrahim, S.A., Wan Hassan, W.M.S., Mahdiraji, G.A., Md Isa, N., Mad Isa, M.J., Abd Jalil, M.M., and Kadir, A. B. 2014. Thermoluminescenct response of single mode optical fibre to x-ray irradiation. *Journal of Physics: Conference Series*. 546: 012018
[7] Ibrahim, S.A., Che Omar, S.S., Hashim, S., Mahdiraji, G.A., Bradley D. A., Isa, N.M., and Kadir, A.B. 2014. Assessment of Ge-doped optical fibres subjected to x-ray irradiation. *Journal of Physics: Conference Series*. 546: 012017
[8] Podgorsak, E.B. 2005. *Radiation Oncology Physics: A Handbook for Teacher and Student.* International Atomic Energy Agency, Vienna.