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RADIATION CHEMISTRY

Thermoluminescence Response of Multimode Fluorine-Doped SiO_2 Optical Fibers and TLD 100 with 6 Mega Volt Photon Irradiation[1]

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Abstract—This study investigates and compares the results of thermoluminescence responses, its linearity, sensitivity with various dose ranges and TL glow curve of Fluorine-doped silica fiber and TLD-100 materials. The TL responses of the Fl-doped silica fibers and TLD 100 were kept in gelatin capsule and irradiated with 6-MV photon at the dose range from 0.5 Gy to 4.0 Gy. Siemens model Primus 3368 linear accelerator located at Hospital Sultan Ismail; Johor Bahru has been used to deliver the photon beam to the samples. The TL-signal of TLD 100 media exhibits a significant linear dose to signal relationship with an increase in doses. The sensitivity of Fl-doped optical fiber is negligible to TLD 100 media.

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The phenomenon of thermoluminescence (TL) was first discovered by Robert Boyle while conducting an experiment to warm a diamond in the dark and found strange glimmering light [1]. Thermoluminescence dosimetry (TLD) system is suitable for dosimetry of workers because it has TLD phosphor whose atomic properties are almost equal to atomic properties of the human tissues. Besides that, TLD is also used to measure the radiotherapy absorbed dose and surface entrance dose for the diagnostic imaging procedure in medical. Radiotherapy is one of the main methods to eliminate or destroy the cancer tissues, and this treatment is done to maximize the probability of fully destroying tumor by giving high radiation dose to the cancer tissue [2].

To use a thermoluminescence (TL) material for dosimetric purposes, it supposes to has characteristics such as high sensitivity, long term stability to store dosimetric information at room temperature concerning thermal and optical fading, large linearity between the TL signal and dose, and also energy dependence [3]. There are many phosphor materials that show the TL properties, and some of them have been used to detect ionizing radiation. These materials have been doped with the suitable activators to use in TL dosimeter. Knowledge about the general properties of TL materials is needed to determine the choice of this material that is very suitable and optimum [2].

Most of the TL materials have their dose range where the response to the radiation dose is linear. The supralinearity properties can be a function of linear energy transfer (LET), where the properties supralinear dose limits is higher for high LET particles [2].

Recently, SiO_2 optical fibers as a radiation dosimeter were studied to measure the absorbed dose to patients for in vivo dosimetry, in order to overcome spatial resolution limitations of existing dosimetry systems [4–9]. Thermoluminescence response of Germanium and Aluminum doped optical fibers subject to photon and electron irradiation has been investigated. These TLDs are also impervious to water to the extent that in some instances it becomes possible to locate the fiber dosimeter within a particular tissue of interest [10–12]. These optical fibers are also able to maintain a consistent TL response after repeated exposures. The SiO_2 commercial optical fiber demonstrates useful TL properties and is an excellent candidate for use in TL dosimetry of ionizing radiation.

Seeking for further results and based on the previous studies, this study is very important to investigate thermoluminescence properties of commercially Fl-doped optical fiber comparer to TLD 100 media. These materials are irradiated at doses from (0.5–4) Gy using photons of 6-MV energy to measure the TL response.

MATERIAL AND METHODS

To determine the TL response of multimode Fluorine-doped silica fibers and TLD 100 media by 6-MV-photon irradiation, eight capsules for each sample were prepared. The samples were prepared accordingly before irradiating the TL material so that it will be suitable for the purpose of the study.

[1] The article is published in the original.

Prior to irradiation, the outer polymer layer of Fl-doped silica fiber was removed using fiber stripper. Then, a cotton cloth was dampened into ethanol to clean all the fiber's core to avoid any presence of remnant polymer cladding. Subsequently, the fibers were then cut into lengths of approximately 5.0 ± 1.0 mm using a fiber cleaver and the mass of every piece of fibers was weighed using an electronic balance.

Storage and handling is very important because it can affect the TL sensitivity, stability and precision [13]. The factors of concern in TLD routine storage include environmental factors such as temperature, humidity, ultraviolet and visible radiation. For this experiment, the TL materials were kept in a suitable container to avoid the places of high temperature and ultraviolet radiation. During handling, it was ensured that the TL materials were not scratched or touched by hands. The Fl-doped fiber and TLD 100 media were placed in a gelatin capsule for routine storage, handling, and for irradiations. Each capsule was different for different material.

Annealing is a process to remove all residuals of TL signal, to establish the TL sensitivity and to eliminate the unstable low-temperature glow peaks. In annealing, the TL materials were put in a furnace. The furnace was connected to a computer, and Thermosoft software was used to control the process in the furnace. For different TL materials, the annealing characteristics might vary. During annealing, TL materials were heated to a certain temperature for a certain length of time. The temperature and time for annealing is called Time Temperature Profile (TTP). Before starting the annealing process, Fl-doped fiber and TLD 100 were set at the computer, and those were placed in a planchet that was placed inside the annealing oven.

All the samples were exposed to 6 MV photon by using Siemens model Primus 3368 linear accelerator located in the Department of Radiotherapy and Oncology, Hospital Sultan Ismail, Johor Bahru, Malaysia. The dose delivered by the LINAC machine was 20–400 MU (monitor unit) with a field size of 10 cm × 10 cm.

By using TLD Reader and WinREMS software, readings were obtained after irradiation. In this research, Harshaw 3500 TLD Reader with hot nitrogen gas as a heat transfer medium was used. To measure the TL response of optical fibers were placed on the planchet in the TLD reader drawer. Acquisition setup was performed by using WinREMS software. Pre-heat temperature was 50°C, and the maximum temperature during data acquisition was 300°C. To acquire temperature, the rate was 10°C per second.

RESULT AND DISCUSSION

A set of glow curves measured with an equal experimental geometry for Fl-doped fibrin TLD 100 media were carried out by 6 MV photon with dose 2 Gy. Figures 1, 2 show the glow curve for Fl-doped fiber and TLD 100 respectively. It can be seen from those figures that the shape of glow curves are different and depend strongly on the types of materials. The TLD 100 media presents a glow peak which is clearly observable compared to glow curve Fl-doped optical fiber.

Table 1. TL yield for 6 MV photon irradiation of Fl-doped multimode optical fiber

Sample	Dose (Gy)	TL reading (nC)	Mass of fiber (mg)	TL response (nC/mg)
1	0.5	6914	23.1	299.4372
2	1.0	13280	22.1	600.9050
3	1.5	22880	23.4	977.7778
4	2.0	30190	23.7	1273.8397
5	2.5	38010	23.7	1603.7975
6	3.0	–	23.6	–
7	3.5	50680	23.6	2147.4576
8	4.0	66310	23.2	2858.1896

Table 2. TL yield for 6 MV photon irradiation of TLD-100 chip

Sample	Dose (Gy)	TL reading (nC)	Mass of fiber (mg)	TL response (nC/mg)
1	0.5	0.4803	0.9	0.5337
2	1.0	0.4248	1.0	0.4248
3	1.5	0.4071	0.6	0.6785
4	2.0	0.5646	1.0	0.5646
5	2.5	1.3960	1.0	1.3960
6	3.0	1.8080	1.0	1.8080
7	3.5	0.4309	0.7	0.6156
8	4.0	0.3967	1.0	0.3967

For this present investigation the sample of Fl-doped multimode silica fiber and TLD-100 were subjected to 6 MV photons irradiation with dose range of 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5 and 4.0 present as shown in Table 1 and 2. From the Table 2, some data points not available for dose 3.0 Gy. This happened because WinREMS software suddenly turns off during the reading process. So the TL response for TLD-100 could not be obtained. Figure 3 shows thermoluminescence response for TLD 100 and Fl-doped silica fibers. Using 6MV photon irradiation, both materials normalized to unit mass and TL response as a function of the dose range 0.5–4.0 Gy are plotted in figure 3. It shows that the TL response for TLD 100 media linearly increases with increasing dose. TL response for Fl-doped silica fibers has negligible effect on doses compared to TLD 100. It is noted that there is no fluctuation for the response of Fl-doped throughout the given dose range.

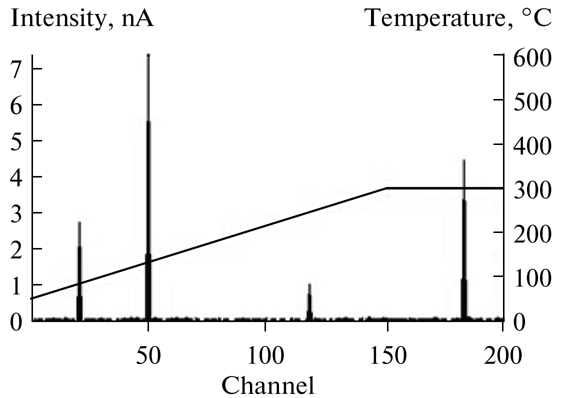

Fig. 1. The glow curve for the Fl-doped multimode silica fiber material following 6 MV photon.

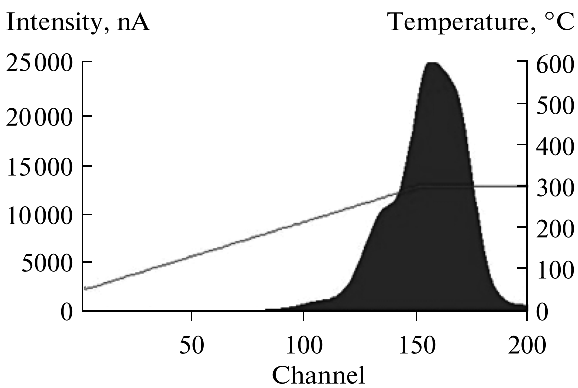

Fig. 2. The glow curve for TLD-100 chips following 6 MV photon irradiations.

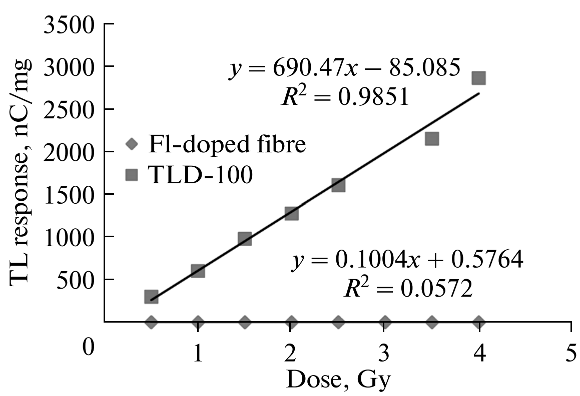

Fig. 3. The graph shows the TL response in (nC/mg) of TLD-100 and Fl-doped optical fiber for 6 MV photon irradiation versus dose in Gy.

In contrast, a response fluctuation was observed after 3.0 Gy dose in TLD-100.

The linearity can be confirmed by another factor, which is the regression coefficient (R^2). The (R^2) number is a measure of how well the data correlate. The closer the number is to one, the more closely correlated the data is. A regression coefficient for TLD 100 is 0.9851, and Fl-doped fiber is 0.0572. This indicates the occurrence of a little scatter in the TL values at these high doses. The Fl-doped silica fibers do not provide good TL responses. This indicates that Fl-doped silica fibers are not useful as a radiation dosimeter.

Thermoluminescence sensitivity is a measure of the amount of TL signal per unit mass produced by a given material after exposure to a radiation dose [14]. Assuming a linear fit, a change in the TL yield per unit absorbed dose for Fl-doped silica is 0.1 mg^{-1} Gy^{-1}, while for TLD 100 it is 690.47 mg^{-1} Gy^{-1}.Fl-doped silica fibers sensitivity is approximately 0.02% of the sensitivity of TLD100. The sensitivity of TLD 100 media at present work is consistent to the previous measurement [15]. This clearly indicates that theTLD-100 has a higher efficiency and capability in producing the luminescence than the Fl-doped silica fibers.

CONCLUSION

This study demonstrates a number of highly desirable features of commercially available Fl-doped SiO_2 optical fibers and TLD 100 chip for TLD including glow curve, linearity and sensitivity. This indicates considerable and possible utility for radiation dosimetry. The TL response of samples has been observed for 6 MV photon irradiated with a dose range from 0.5 to 4.0 Gy. We can conclude that, the thermoluminescence response of multimode Fl-doped silica fibers is negligible compared to TLD 100. The sensitivity of Fl-doped silica fibers is 0.02% of TLD 100 media. The measurement of TLD 100 is consistent to the previous measurement [15].

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