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RADIATION CHEMISTRY

Thermoluminescence Response of Ytterbium-Doped Silicon Dioxide Fiber[1]

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Abstract—In this study, thermoluminescence properties of Yb-doped of SiO_2 optical fiber such as linearity, sensitivity and dose response have been investigated. Samples were placed in the gelatin capsules to irradiate with photons from Cobalt-60 of the dose range between 10–100 Gy. The beams were provided by Gammacell 220, available at Universiti Kebangsaan Malaysia, Bangi, Malaysia. The glow curves were analyzed to determine various characteristics of the thermoluminescence. The TL response as a function of dose is linear up to 40 Gy. The sensitivity of Yb-doped optical fiber is 0.136 nC mg^{-1} Gy^{-1}.

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The thermoluminescence (TL) properties of doped optical fibers have been under extensive investigations. Thermoluminescence dosimeters (TLD) are used to monitor doses for medical and environmental applications due to its ability to meet the requirements of a good ionizing detector. Several studies have carried out to improve TLD's dosimetry system [1–3]. To use a TL material for dosimetric purposes, the following characteristics such as high sensitivity, long term stability of stored dosimetric information in room temperature that involves thermal and optical fading, large linearity between TL signal and dose as well as energy response are required. TLD should provide rapid retrieval of information. It should be very precise, and possess good environmental stability, good water or tissue equivalence and have a wide range of sensitivities.

Optical fibers have been studied as new TLD materials, because of their small size, flexibility, low cost and good spatial resolution [4–11]. These new TLD materials exhibit a few acceptable TLD characteristics but cannot be recommended as an optimized TL material. This research concerns the suitability of doped optical fiber as ionizing radiation dosimeters. Previous studies encourage us to find TL properties of Ytterbium-doped of silicon dioxide fiber which optical fibers will be more enhance of radiation dosimeter.

EXPERIMENTAL

Yb-doped SiO_2 optical fibers coated layer was removed to detect succesfully and read the signals or response of the thermoluminescence for irradiation process. The outer coating layer was removed by using fibers stripper. T1he optical fiber was cut into approximately 0.5 cm long by using an optical fiber cleaver. To avoid from environmental factors such as temperature, humidity, ultraviolet and visible radiations, the ytterbium doped optical fibers were placed inside the capsules and labeled for dose from 10–100 Gy respectively. The capsules were kept in a black box at room temperature. The mass of each capsule was measured by analytical balance. Annealing process is required to reuse TLDs. Annealing is carried out to stabilize the trap structure.

The ytterbium-doped silicon dioxide optical fibers were exposed to photon (Cobalt-60) from Gammacell 220. They were exposed at the dose of 10, 20, 30, 40, 50, 60, 70, 80, 90 and 100 Gy. After exposure, response was read out by using TLD Reader and WinREMS software. The details of annealing, exposure to radiation, instrumentation are explained to [4–11].

RESULTS AND DISCUSSION

Thermoluminescence light emission phenomenon is commonly called thermoluminescence glow curve. Glow curve presents the intensity of luminescence as a function of temperature. The glow curves are different for different mode of heating and temperatures. Moreover, the stability of response can also be changed if the samples store for a long time. Radiation energy deposited is displayed by the area under the curve. The photon-irradiations have been done for ranges between 10–100 Gy. Figure 1 presents the glow curve of Yb-doped of dose 10 Gy while. Figure 2 is the glow curve for 100 Gy. Red line in the graph shows the readout temperature (300°C) from the time-temperature

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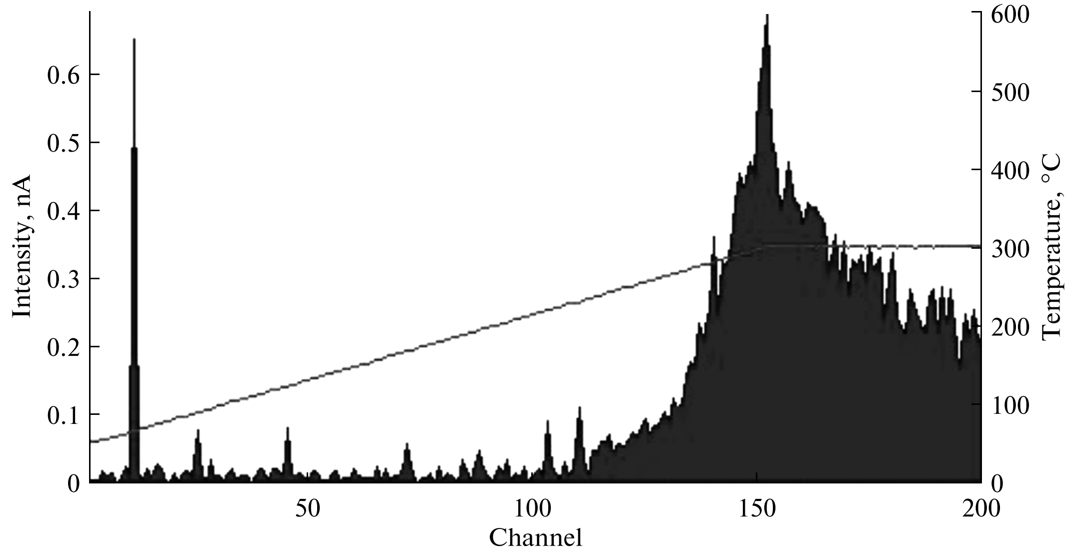

Fig. 1. The glow curve of Yb-doped SiO_2 optical fiber for 10 Gy doses of photon irradiations.

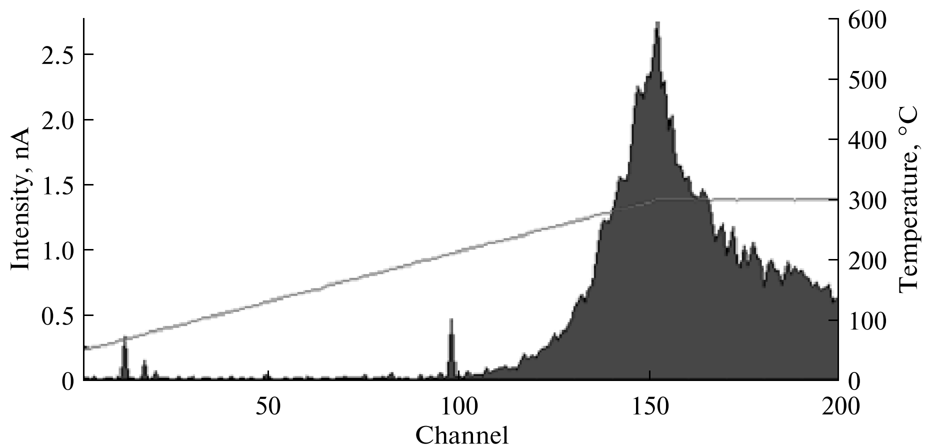

Fig. 2. The glow curve of Yb-doped SiO_2 optical fiber for 100 Gy doses of photon irradiations.

profile setup for the TLD reader. From the figures, we can see the glow peak maximum is at channel 150.

For thermoluminescence dosimetric applications, the response of a TLD should be linear. However, the linearity ranges depend on the thermoluminescence material. In this research, a linear TL response for Yb-doped optical fiber is obtained.

For the present studies, the samples were irradiated for different doses ranging between 10 to 100 Gy of photon by Gammacell 220 Excel. Irradiation time increases as the dose range increases. The TL responses are measured by TLD Reader while the errors are calculated by using Origin software. Before calculating the TL response, the background noise had been taken into consideration.

Figure 3 shows the graph of TL response for Yb-doped SiO_2 optical fiber versus dose, which was irradiated with photons for a dose range from 10–100 Gy. Here, we can see that as the dose increases, the TL response also increases. The linearity is observed

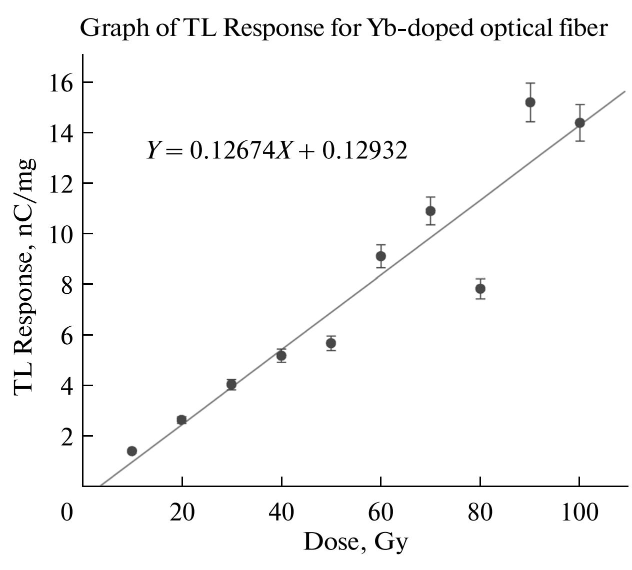

Fig. 3. Graph of TL Response versus Dose for Yb-doped optical fiber.

Yb-doped optical fiber response to photon irradiations

Dose, Gy	TL response, nC	Weight of Yb-doped (±1.0 mg)	Response after Normalization, Nc/mg	Sensitivity, nC mg^{-1} Gy^{-1}
10	2.96	2.1	1.41	0.14
20	5.72	2.0	2.64	0.13
30	7.27	1.8	4.04	0.13
40	11.40	2.2	5.18	0.13
50	11.33	2.0	5.67	0.11
60	16.36	1.8	9.09	0.15
70	19.59	1.8	10.88	0.16
80	17.99	2.3	7.82	0.10
90	28.82	1.9	15.17	0.17
100	28.72	1.8	14.36	0.14
			Average	0.14

up to 40 Gy; TL responses as a function of dose vary from 50 Gy to 90 Gy. The equation of the graph for this Yb-doped is $Y = 0.129 + 0.127 X$. This graph shows the linearity of TL response versus dose. The slope is equal to 0.127 mg^{-1} Gy^{-1}.

The sensitivity is one of the important characteristics of TL material. It can be described in term of TL yield per unit per dose per unit mass of the sample. In this study, the sensitivity is expressed as glow curve area per unit mass of dosimeter and per unit dose (nC mg^{-1} Gy^{-1}). Table 1 shows a summary of the sensitivities of Yb-doped optical fiber.

The average sensitivity of Yb-doped is 0.136 nC mg^{-1} Gy^{-1} for the dose range between 10–100 Gy. This may relate that dose range played a role for the sensitivity of TL response. The sensitivity is determined by dividing the TL response with mass and dose. The results of TL response are summarized in table. These summaries of data have been used in the dose response from Fig. 3.

In this research, the TL response linearity of Yb-doped optical fiber was obtained up to 40 Gy.

CONCLUSIONS

Yb-doped optical fiber yields a linear response against the absorbed dose for photons irradiation despite the difference in the glow curve characteristics and radiation sensitivities. The linearity is observed up to 40 Gy. Yb-doped optical fiber has the potential to be a part in dosimetric material that can be used widely in many applications because of its physical characteristics such as small size, impervious to water and cost-effective.

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