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THERMOLUMINESCENCE DOSIMETRIC PROPERTIES OF Ge- AND Er-DOPED OPTICAL FIBRES AND THEIR APPLICATION IN THE MEASUREMENT OF DEPTH -DOSE IN SOLID WATER PHANTHOM

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Abstract - The dosimetric properties of Ge- and Er-doped optical fibres are studied. The Ge-doped fibre is found to be more sensitive to radiation and there is little fading of TL signal compared with Er-doped fibre. The Ge- and Er-doped fibres showed a linear response over a range of ~ 1 Gy to about 120 Gy and ~ 1Gy to about 250Gy respectively. The Ge-doped fibre is found to be dose-rate independent both for photons and electron beams of energy ranging from 6 to 10 MeV and 6 to 12 MeV respectively. The fibre is energy independent for energy greater than ~ 0.1 MeV for photon or 0.1 MeV for electron beam. From the depth-dose measurement, it was found that the position of maximum dose, dmax , increased with increasing energy ranging from ~2 cm and ~ 2.5 cm for 6 MeV and 10 MeV photons respectively. The central axis percentage depth dose at 10 cm depth was found to be in good agreement with the value obtained using ionization chamber.

INTRODUCTION

Fibre optic cable is used in telecommunication in the 1980s and has since spread rapidly. It has now surpassed the used of communication satellites. Basically optical fibre is silica or simply glass fibre. Dopant such as germanium is added to increase the transmission property of the fibre. Optical fibre consist of two parts, the core and the cladding. Depending on the core size as compare with the wavelength of transmitted light, the fibre is known as single mode or multi-mode if it is smaller or bigger respectively. The multi-mode fibre usually contains higher concentration of dopant. The effect of radiation on optical fibre was studied in the beginning to see if radiation has an adverse effect on the signal transmission properties of the fibre[1]. The formation of defects such as colour centres in the irradiated fibre were suggested as the possible mechanism that reduces its data transmission capability [2]. In radiotherapy, the exact in situ determination of dose to the irradiated part of the body is not possible because of the non-available of suitable size dosemeter. The isodose as a function of depth is usually calculated using a Monte Carlo computer simulation. Due to its size, flexibility and bio-compatibility optical fibre is suggested to be used as in situ thermoluminescence dosemeter (TLD) in radiotherapy. We have studied the thermoluminescence characteristics of germanium and erbium doped optical fibres. Based on these characteristics and it is easily available, we decided to concentrate our study on Ge-doped fibre.

EXPERIMENTAL METHODS

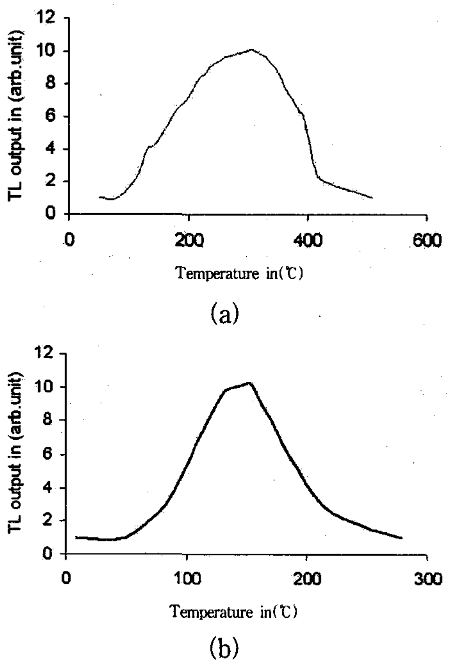
The plastic coating of commercially available

Ge-doped optical fibre is first removed prior to cutting it to ~1.0 cm length and mass of ~0.3 mg. The fibre is then annealed in air at temperature of 400 °C for 1 hour and is then cooled to room temperature. Each piece of fibre is then carefully labeled and its element correction factor obtained by exposing to appropriate radiation, photon or electron beam.

The fibre is then ready to be used for various experiments. The TL glow curve is obtained using TLD reader model 3500 supplied by Harshaw-Bicron.

RESULTS AND DISCUSSION

The typical TL glow curves for Ge-doped and Er-doped optical fibres are shown in Fig. 1(a) and 1(b) respectively. The heating rate is 15 °C/s and is carried out in nitrogen atmosphere. The TL glow curve for Er-doped is characterized by having one peak at temperature 150 °C while the Ge-doped has a broad peak centered at temperature of 250 °C.



(a)

(b)

Fig. 1. A typical TL glow curve for Ge-doped (a) and Er-doped (b) optical fibre

Several types of TL dosimetric properties are investigated as stated below:

1. Reproducibility and Linearity Test

Using a single piece of fibre, 6 repeated cycles of annealing-irradiation-readout are carried out. Fig. 2 shows the TL response after each cycle. Clearly the fibre has a very good reproducibility with a standard deviation of only ±1.4%.

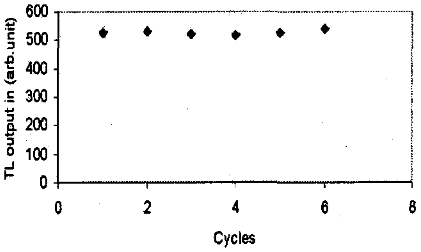
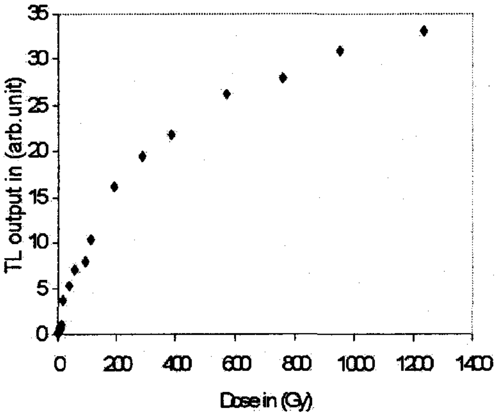
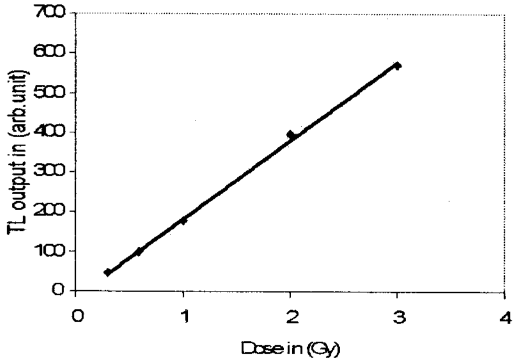


Fig. 2. A plot of TL output as a function cycle times. A standard dose of 7.9 Gy is used in this test

For a linearity test, the fibres are also subjected to various type of radiation ranging from photon to electron beam. Fig. 3 shows the TL response as a function of dose for (a) Co-60 gamma and (b) 100 keV superficial X-ray. Clearly the response is linear up to the dose of ~120 Gy for gamma radiation. The response tends to be sub-linear at doses higher then ~150 Gy. Similarly for 100 keV X-ray, the response is linear up to the dose of 3 Gy.



(a)

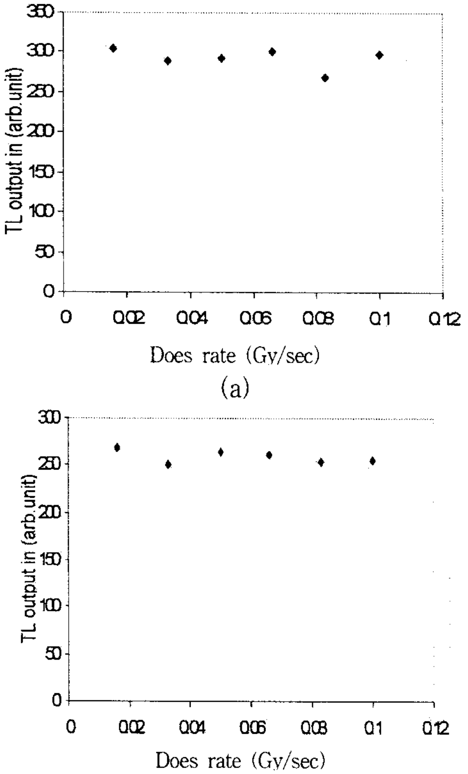


(b)

Fig. 3. A TL response of Ge-doped fibre as a function of dose from (a) Co-60 gamma and (b) a 100 kV X-ray

2. Dose-rate and Energy Dependent

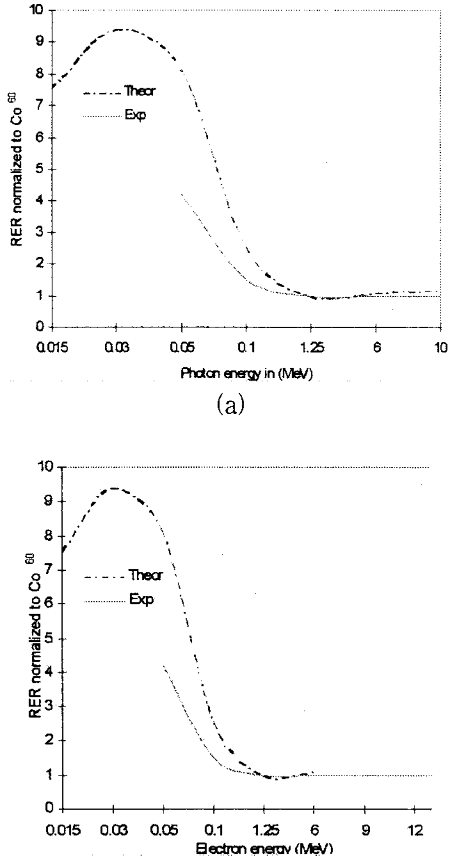
The fibre is irradiated with photons and electron beams of various energy and dose rate. Fig. 4(a) and (b) show a typical dose rate response for 10 MeV photon and 9 MeV electron beam respectively. Clearly, within the range of dose rate studied (0.016 to 0.1 Gy/sec), the fibre is found to be independent of dose rate effect.



(b)

Fig. 4. The Ge-doped fibre shows no effect of dose rate as shown by flat response to (a) 10 MV photon and (b) 9 MeV electron beam of various dose rate.

Like most of TLD materials, the fibre also has a flat energy response at high energy of greater than ~0.1 MeV as shown in Fig. 5 for (a) photon and (b) electron. The relative energy response normalized to Co-60 gamma energy is also calculated using formula developed by McKinley [3]. The effective atomic number of the fibre has also being obtained [4].

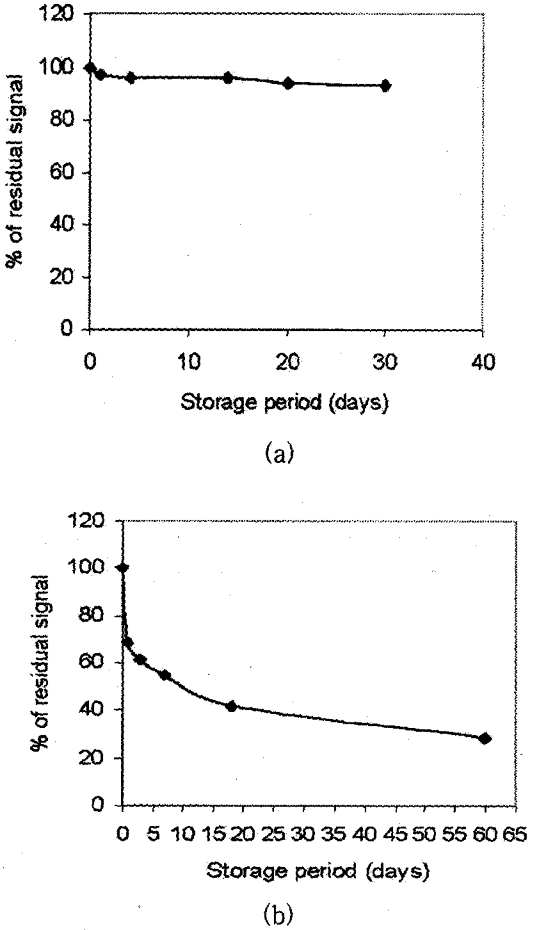


(b)

Fig. 5. The relative energy response, normalized to Co-60 average gamma energy for (a) photon and (b) electron beam.

3. Fading Test

One of the important factor that determined the suitability of a material as a TL dosemeter is the stability of its signal. Fig. 6 shows the fading of the TL signal in the fibre kept in the dark at room temperature. Er-doped fibre is far less stable compared with Ge-doped fibre where almost 40% of the signal is lost after only a few days.

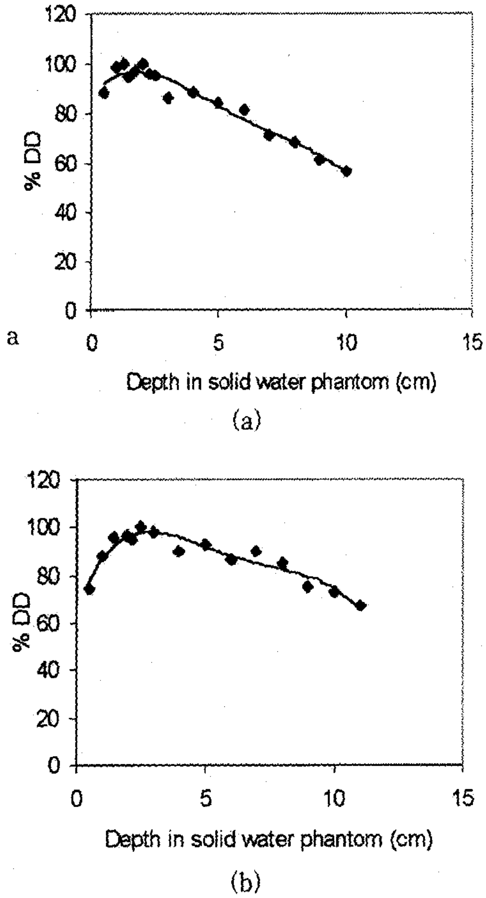


(a)

(b)

Fig. 6. Signal stability as a function of storage period for (a) Ge-doped and (b) Er-doped fibre. The irradiated sample is stored in the dark at room temperature.

After establishing the required TLD parameters, we used the fibre to measure the depth-dose distribution in a solid phantom. The absorbed dose is a function of depth inside the phantom and the exact dose along the depth depends on several factors such as energy, field size and the collimating system. Fig. 7 shows the percentage depth-dose as a function depth for (a) 6 MeV and (b) 10 MeV photons. The field size used is 10×10 cm^2. The percentage depth-dose is defined in percent, as the ratio of absorbed dose at any depth to that of at absorbed dose at some fixed reference depth.



(a)

(b)

Fig. 7. Depth-dose relation in solid phantom subjected to (a) 6 MeV and (b) 10 MeV photon

As the radiation enter the phantom, there is an initial build-up of the dose to a maximum value, d_{max}, before the dose decreases with depth. The build-up region occurs due to the ejected electrons near the surface deposited their energy at a significant distance from their site of origin. As such, the higher the radiation energy, the deeper is d_{max} . Our result supported this argument as the d_{max} is found to be 2 cm and 2.5 cm for photon energy of 6 and 10 MeV respectively. The percentage depth dose at a depth of 10 cm is found to be 61 % and 68.2 % for the above energies photon respectively. The value obtained using ionization chamber is 66.6 % and 73 % respectively.

CONCLUSIONS

The Ge-doped fibre is found to have more favorable properties as thermoluminescence dosimeter. The results of measurement of depth dose distribution in solid phantom using the fibre are in good agreement with that obtained using an ionization chamber.

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