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Effects of time-temperature profiles on glow curves of germanium-doped optical fibre

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HIGHLIGHTS

- This research addresses the TTP parameters to the determination of the kinetic parameters of the glow curve.
- The commercial and tailored made Ge-doped silica optical fibres were used in this study.
- The glow curve responses were explored and the kinetic parameters were analysed.
- This study revealed the possible relationship between TTP parameters and the kinetic parameters of TL glow curves.

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ABSTRACT

The Germanium (Ge) doped silica optical fibres have demonstrated the great potential to be developed as a thermoluminescent (TL) dosimeter that can be used in various applications in radiotherapy, diagnostic radiology, UV dosimetry system and food irradiation industry. Different time-temperature profile (TTP) parameters of the TL reader have been employed by many researchers in various of TL studies. Nevertheless, none of those studies adequately addressed the effects of the reader's preheat temperature and heating rate on the kinetic parameters of the TL glow curve specifically, the Ge-doped silica optical fibres. This research addresses the issue of TTP parameters with special attention to the determination of the kinetic parameters of the glow curve. The glow curve responses were explored and the kinetic parameters were analyzed by the WinGCF software, to show the effect of the preheat temperature and heating rate of the reader on Ge-doped fibre irradiated with 18 Gy of 6 MV photons radiation. The effect of TTP parameters was discussed and compared against the commercial fibre and tailored made fibre of 6 mol% Ge-doped of flat and cylindrical shape. The deconvolution of glow peaks and the kinetic parameters were obtained by the WinGCF software. This enables to fit accurately ($1.5\% < \text{FOM} < 5.0\%$) for all measured glow curves. A positive, moderate linear relationship exists between the TL response and the heating rate when the specific preheat temperature was used to read commercial fibre (50 °C) and cylindrical fibre (80 °C and 160 °C). It is found that the glow peaks of cylindrical fibre exhibit the highest peak integral as compared to flat and commercial fibres. This study revealed the possible relationship between the reader's TTP parameters and the kinetic parameters of TL glow curves for the commercial and tailored made Ge-doped silica optical fibres.

1. Introduction

The Germanium (Ge) doped silica optical fibres have demonstrated considerable potential to be developed as a thermoluminescent (TL) dosimeter that can be utilized in various applications, such as in radiotherapy, environmental dosimetry system, diagnostic radiology and food irradiation industry (Abdul Rahman et al., 2014; Bradley et al., 2012; Mohd Noor et al., 2015). The desirable features of the commercially available doped silica optical fibres have initiated the intention of developing the tailor-made doped silica optical fibres with specific TL dosimetry applications by using modified chemical vapour deposition (MCVD) method and fibre-pulling facilities (Bradley et al., 2014a, 2014b). However, the time-temperature profile (TTP) parameters employed by a number of researchers were varied in the readout of TL dosimeters, particularly for the recent development of tailor-made Ge-

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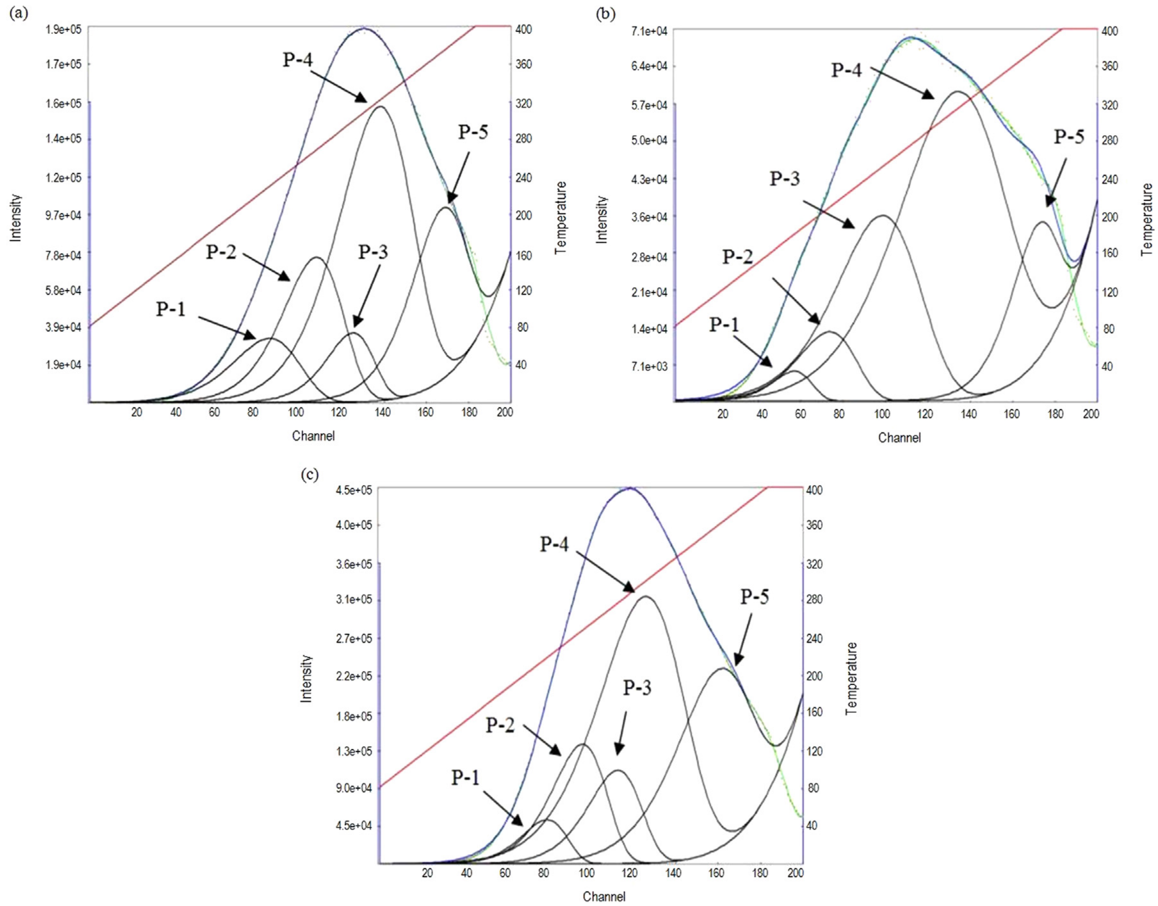

Fig. 1. The typical deconvoluted TL glow curves of Ge-doped (a) Commercial fibre, (b) Flat fibre and (c) Cylindrical fibre consist of five individual glow peaks with the FOM of 3.9%, 4.6% and 3.9%, respectively.

doped silica optical fibres with the use of the same type of reader (Alawiah et al., 2015; Begum et al., 2013; Mohd Noor et al., 2015; Zahaimi et al., 2014). It was known that the types of radiation used to irradiate samples and heating rate during the readout of TL dosimeters can affect the number of glow peaks (Cameron et al., 1968). Besides, variable heating rates shifted the glow peak temperature to higher temperature side when the heating rate was increased (Caprile et al., 2013; Daniel et al., 2014; Pradhan et al., 2008). Different heating rates resulted in different TL intensities, which in turn may give rise to a change in the trapping parameters (Ogundare et al., 2005). For a constant dose, the maximum TL intensity is directly proportional to the heating rate (Attix, 2008). To the best of our knowledge, none of those studies adequately addressed the effects of the reader's preheat temperature and heating rate on the kinetic parameters of the TL glow curve specifically, the Ge-doped silica optical fibres. This paper investigates the effects of the preheat temperature and heating rate on the kinetic parameters of TL glow curves of Ge-doped silica optical fibres.

2. Materials and methods

2.1. Ge-doped silica optical fibre

Two main types of Ge-doped silica optical fibres were used: commercial fibre and fabricated fibre. The commercial Ge-doped silica fibres were comprised of a 50 μm core and a cladding of 125 μm (CorActive, Canada) whereas the fabricated Ge-doped silica fibres were made in the form of cylindrical (diameter of 483 μm) and flat shape (dimension of 273×67 μm^2) with 6 mol% Ge dopant using MVCD method. The fibre preform was first fabricated using MVCD method at Department of Engineering, Multimedia University, with subsequent fibre pulling using the fibre drawing tower located in the Department of Electrical Engineering, University of Malaya. The combination of core and cladding of commercial fibres was initially covered with polymer coating of 248 μm in diameter. Prior to use, the protective polymer coat was removed with a fibre stripper (Pro'sKit, Taiwan) without scratching or nicking the fibres. For fabricated fibres, no stripping involved as these fibres were made without polymer coating. The core of the silica fibre was cleaned by using isopropyl alcohol (2-propanol) to remove any remnant of buffer. Subsequently, the fibres were cut into lengths of approximately 3.0 mm and handled with vacuum tweezer (Dymax 5, Surrey, UK). Prior to irradiation, the unscreened fibres placed in a brass plate were thermally treated in a furnace at temperature of 400 °C for 1 h, to eliminate previous irradiation history, standardizing the thermal history as well as erasing the unstable low temperature glow peaks. To minimize thermal stress following annealing, the fibres were retained in the furnace to finally equilibrate at room temperature. After cooling, the fibres were kept in the light-tight box to minimize exposure to light prior to and following irradiation as it could affect the TL responses (Mohd Noor et al., 2012).

2.2. Irradiation setup

The irradiations of all silica fibres were performed at the National Cancer Institute, Putrajaya, using Novalis Tx linear accelerator. The fibres were irradiated in a Perspex phantom with

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