THE ASSESSMENT OF TAILOR-MADE OPTICAL FIBRE SUBJECTED TO IONIZING RADIATION

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I dedicate this work

To my lovely dear parents
Che Omar Bin Ibrahim
Siti Eshah Binti Che Mat
Whose love, kindness, patience and prayer have brought me this far

To my siblings
Siti Nur Hadis and Khairul Anuar, Muhammad Tasyriq and Nur Syuhanis, Siti Shafiyyah, Muhammad Askari, Siti Nur Salwah and Muhammad Ali Fariddatul
For their love, understanding and support through my endeavor

To my grandparents
Ibrahim Ariffin and Siti Rahmah
Whose always prayer for me

To my niece
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Whose presence fills my life with joy

To my friends
For their endless laughs and tears

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ABSTRACT

The dosimetric properties of thermoluminescence (TL) dosimeter such as dose response, linearity, sensitivity, fading, minimum detectable dose (MDD), glow curve and reproducibility of optical fibres in comparison with TLD-100 (rod types) have been investigated. The samples used were Dummy Flat Fibre (DFF), Flat Fibre (FF), Photonic Crystal Fibre (PCF), Multi Photonic Crystal Fibre (MPCF) of 2 mm and 220 μm diameter, Photosensitive Flat Fibre (PFF), Single Mode Optical Fibre (SMF), Germanium - doped (Ge), Erbium - doped (Er) and Aluminum doped Thulium (Al: Tm). The TL samples were placed in solid phantom and irradiated with 6, 9 and 12 MeV electrons beam with dose ranging from 1.0 Gy to 4.0 Gy by using linear accelerator (LINAC) machine. Investigations were also conducted for X - rays with mean energies of 30, 60 and 70 kV, and gamma rays (^{60}Co) from 1.0 mGy up to 24.0 Gy. The glow curves were observed between 155 °C to 287 °C. The results of TL dosimeter subjected to 6, 9 and 12 MeV electrons clearly showed that PFF was superior in terms of TL response and sensitivity. This was followed by Ge, DFF, TLD-100, FF, PCF, Er, Al: Tm, MPCF 2 mm and MPCF 220 μm. For X-ray irradiation, the SMF showed 10 and 8 times more sensitive than TLD-100. The MDD obtained from optical fibres subjected to electron irradiation were between 0.53- 0.60 mGy for PFF, 0.78-0.81 mGy for TLD-100, 1.00-1.26 mGy for Ge and 1.44-1.64 mGy for DFF. The results showed that PFF and SMF have great potential to be considered as a radiation dosimeter.

ABSTRAK

Sifat dosimetri bagi dosimeter luminesens terma (TL) seperti sambutan dos, kelinearan, kepekaan, kepudaran, dos minima berkesan (MDD), lengkung berbara dan kebolehulangan bagi gentian optik telah dibandingkan dengan TLD-100 (jenis rod) telah dikaji. Sampel yang digunakan adalah Gentian Datar Palsu (DFF), Gentian Datar (FF), Gentian Hablur Fotonik (PCF), Gentian Hablur Fotonik Berbilang (MPCF) berdiameter 2 mm dan 220 µm, Gentian Fotosensitif Datar (PFF), Gentian Optik Mod Tunggal (SMF), Germanium terdop (Ge), Erbium terdop (Er) dan Aluminium terdop Thulium (Al: Tm). Sampel TL diletakkan di fantom pepejal dan disinar dengan alur elektron bertenaga 6, 9 dan 12 MeV mempunyai julat dos dari 1.0 Gy ke 4.0 Gy dengan menggunakan mesin pemecut linear (LINAC). Kajian turut dijalankan bagi sinaran - X dengan tenaga purata 30, 60 dan 70 kV, dan sinar gamma (^{60}Co) dari 1.0 mGy hingga 24.0 Gy. Lengkung berbara dicerap di antara 155 °C – 287 °C. Dapatan bagi dosimeter TL tertakluk kepada 6, 9 dan 12 MeV elektron jelas menunjukkan bahawa PFF adalah baik dari segi sambutan TL dan kepekaan. Ini diikuti oleh Ge, DFF, TLD-100, FF, PCF, Er, Al: Tm, MPCF 2 mm dan MPCF 220 µm. Bagi dedahan kepada sinar - X, SMF menunjukkan 10 dan 8 kali ganda lebih peka berbanding TLD-100. MDD yang diperoleh daripada gentian optik tertakluk kepada sinar elektron adalah di antara 0.53 – 0.60 mGy bagi PFF, 0.78 - 0.81 mGy bagi TLD-100, 1.00 - 1.26 mGy bagi Ge dan 1.44 - 1.64 mGy bagi DFF. Dapatan menunjukkan bahawa PFF dan SMF mempunyai potensi besar untuk dipertimbangkan sebagai dosimeter sinaran.

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CHAPTER 1

INTRODUCTION

1.1 Background of research

Thermoluminescence dosimetry (TLD) is used in radiation dosimetry, especially in the medical field to measure patients' doses. TLD systems utilize TL materials for the measurement of integrated absorbed radiation dose, a fraction of the absorbed energy being conserved in metastable energy levels, either in localised electron bands of ordered media or also non-localised electron traps in the case of amorphous media. The conserved energy is subsequently released by heating, the sum of the light yields being related to the absorbed dose (Yaakob *et al.*, 2011; Bradley *et al.*, 2012). Generally, TLD is used in three different fields, i. e., in personnel dosimetry, environmental dosimetry and medical dosimetry. In medical dosimetry, TLD phosphors are used in radiotherapy treatment and diagnostic X-ray procedures to determine the delivered dose to target volume in patient. Based on the analysis of dose data and evaluation of errors in dose delivery in clinical setting, the International Commission of Radiation Units (ICRU) and International Commission on Radiological Protection (ICRP) recommend the dose delivery to target volume should be within ± 5% accuracy or better in some situations (ICRU, 1976; ICRP, 1996). The accuracy of ± 5% is an uncertainty of 5 % that required in the delivery of absorbed dose to the target volume in radiotherapy. The good clinical requirements for accuracy are based on evidence from dose response (dose effect) curves for tumour control probability (TCP) and normal tissue complication probability (NTCP). The steepness of a given TCP or NTCP curve against dose defines the change in response expected for a given change in delivered dose. The dose ranges for personnel dosimetry (dose estimate in human tissue), environmental dosimetry (dose estimate in air) and medical dosimetry (radiotherapy) are approximately 0.01 – 1.00 mSv, 0.001-0.900 mSv and up to 10 Sv respectively (McKeever, 1985; Podgorsak, 2005).

In this research, the TLD-100 will be compared with many type of doped optical fibre. Optical fibres have several advantages to overcome the limitation of spatial resolution that exists in TL dosimetry system (Hashim, 2009). The percentage dopant in silica can offer advantages in radiation dosimetry as it can increase the radiation sensitivity of the silica by providing a high number of traps (Yaakob *et al.*, 2011).

The potential use of commercially available single mode doped SiO_2 optical fibres has been investigated by a number of workers, for photons (Abdulla *et al.*, 2001; Issa *et al.*, 2011; Abdul Rahman *et al.*, 2011, electrons (Hashim, 2009, Abdul Rahman et al., 2011), protons (Hashim *et al.*, 2006), x-rays (Girard *et al.*, 2004; Bauk *et al.*, 2011; Saeed *et al.*, 2012; Abdul Rahman *et al.*, 2012;) alpha particles (Ramli *et al.*, 2009), fast neutrons (Hashim *et al.*, 2012) and synchrotron radiation (Abdul Rahman *et al.*, 2010). In all such studies the TL performances of irradiated fibres have shown considerable potential for dosimetric applications in radiotherapy.

1.2 Statement of problem

The TLD phosphors used in medicine application are TLD-100 (LiF:Mg,Ti). However, TLD phosphors established now have some drawbacks including being hygroscopic and have poor spatial resolution (Podgorsak, 2005). The TLD is unable to store dose information permanently. Heating the TLD can erase the stored information. Thus, the annealing procedures are required to restore the original sensitivity after irradiation. This is because the sensitivity is unstable after receiving a large dose of radiation. So, the response and sensitivity will be different. Therefore, by investigating each of optical fibre, the result of TL dosimetric can be used to overcome this problem (Hashim *et al.*, 2006).

In the study on various optical fibres presented herein, the results of dose response, linearity, sensitivity, fading, glow curve, MDD and reproducibility must be determined to know the performance of TL response of each fibre. The TL results are compared with commercially available TLD phosphors (TLD-100). Findings from these studies may pave the way to conduct more comprehensive investigation of TL from tailor-made doped optical fibres.

1.3 Objectives

i. To investigate TL response in term of dose response, linearity, sensitivity, fading, minimum detectable dose, glow curves and reproducibility of doped SiO_2 optical fibres subjected to ionizing radiation.

ii. To determine effective atomic number (Z_{eff}) of doped optical fibres using Scanning Electron Microscope (SEM) and energy dispersive x-ray (EDX).

iii. To compare TL properties of tailor-made optical fibres with TLD-100.

1.4 Significance of research

These researches were focused on the dosimetric properties due to new optical fibre. This fibre also can measure the dose response, linearity, sensitivity, fading, MDD, glow curves and reproducibility. Also, it have a small size, high sensitivity and accuracy, comprehensive, safe and easy to use and calibrate, provides the absorbed dose in real-time, wide dose range and good stability under varying environmental conditions. In propose of effective atomic number (Z_{eff}) to acquire the composition of the element inside the optical fibre, the TLD is expected to have close value of Z_{eff} with the biological value (soft-tissue equivalent is 7.4). However, the investigation of Z_{eff} for optical fibre almost equal to bone value (Z_{eff} of bone is in range of 11.6-13.8). These values are important to investigate the possible linear response between absorbed dose and TL intensity over a wide dose range, in particular over the range of interest for the clinical application. Given that optical fibres are non - tissue equivalent, therefore the investigation of dose deposition in such media would need to be correction for an expected over-response. However, since the value of Z_{eff} is within the range of bone value, it makes the optical fibre as a strong candidate for use in skeletal radiation dosimetry. Thus, the dosimetric properties of TL dosimeter can provide the optical fibre as a new TLD in personal dosimeter, environmental dosimeter and radiotherapy application to overcome the problem of hygroscopic and poor resolution from the present commercially available phosphor dosimeter i. e TLD-100.

1.5 Scope of study

In this research, the 10 types of optical fibres and TLD-100 are showed in Table 1.1. All samples mentioned are investigated to obtain their dosimetric properties such as effective atomic number (Z_{eff}), linearity and sensitivity with respect to dose response, TL glow curve, fading and reproducibility of each optical fibre. This result will be compared with TLD-100 which is widely used as individual and occupational dosimeter.

Table 1.1: List of optical fibres and TLD-100 and the manufacturer

Manufacturer	Type	TL Materials
TM R&D and UM	Circular	Ge
		Er
		Al: Tm
	Flat	PFF
		DFF
		FF
	Circular	PCF
		MPCF 2 mm
		MPCF 220 µm
		SMF
HARSHAW	Rod	TLD-100 (LiF: Mg, Ti)

The sample that exposed to electron beam, x-ray and gamma rays is read by using Harshaw TLD 3500. From the TLD reader, the raw data of glow curve is obtained and the results of dosimetric properties of TL dosimeter are analyzed by using Microsoft Office Excel.

1.6 Thesis outline

The following paragraph describes five main chapters in this research:

Chapter 1. INTRODUCTION: This chapter provides a brief introduction of the research study. It includes the background of research, statement of problem, objectives, significance of research and scope of study.

Chapter 2. LITERATURE REVIEW: This chapter provides a review of the background and knowledge about radiation dosimetry, theory of TL and TLD related to optical fibre as a function of TLD material.

Chapter 3. RESEARCH METHODOLOGY: This chapter outlines the experimental procedures that have being conducted. This includes a detail of optical fibre preparation, flow chart of an experimental works and the apparatus involved.

Chapter 4. RESULTS AND DISCUSSION: The result of the experimental work will be presented in this chapter. It also includes the main finding of this research investigation such as TL glow curve, dose response, sensitivity, minimum detectable dose, linearity, fading, reproducibility and effective atomic number subjected to ionizing radiation will be presented. The dosimetric properties of all optical fibres will be compared to that of TLD-100.

Chapter 5. CONCLUSION: This chapter includes brief conclusion and recommendation in future research. This research will be discussed the experimental work.

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