THERMOLUMINESCENCE RESPONSE OF Ge-, Al- AND Nd- DOPED OPTICAL FIBERS BY $6\,MeV$- ELECTRON AND $6\,MV$- PHOTON IRRADIATIONS

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In this paper, we report the prediction of thermoluminescence responses of Neodymium-doped SiO_2 optical fibre with various dose ranges from $0.5\,Gy$ to $4.0\,Gy$ by $6\,MeV$- electron irradiations without requirement for experimental measurements. A technique has been developed to calculate prediction of $6\,MeV$- electron response of Neodymium-doped SiO_2 optical fibre by observing the measured TL response of $6\,MV$- photon and the ratio of known measured photon/electron yield ratio distribution for Ge-doped, Al-doped optical fibre and standard $TLD\,100$ dosimeter. The samples were kept in gelatin capsule an 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. We found the average response ratio of $6\,MV$- photon and $6\,MeV$- electron in Ge-doped, Al-doped optical fibre and standard $TLD-100$ dosimeter are 0.83(3). Observing the measured value of $6\,MV$- photon irradiation this average ratio is useful to find the prediction of thermoluminescence responses by $6\,MeV$- electron irradiation of Neodymium-doped SiO_2 optical fibre by the requirement for experimental measurements with various dose ranges from $0.5\,Gy$ to $4.0\,Gy$ by $6\,MV$- photon irradiations.

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1. INTRODUCTION

The study of the thermoluminescence (TL) response of optical fibres to ionizing photon and electron radiation is of great practical importance for dosimetric applications [1, 2] because it has TLD phosphor whose atomic properties are almost equal to atomic properties of the human tissues. In regard to the TL response of doped SiO_2 optical fibres, such materials have attracted attention due to their possible application as radiation dosimeters, as they offer a higher chemical stability and a relatively lower effective atomic number than for instance films. The presence of impurities or the addition of dopants to SiO_2 can greatly enhance the sensitivity of the medium to ionizing radiation and indeed even to ultraviolet radiation by providing an increased number of traps. In addition, new defects and absorption bands are formed [3].

Recently, we have started to use doped SiO_2 optical fibers as a radiation dosimeter in order to measure absorbed doses in radiotherapy patients, seeking to overcome a number of limitations of existing dosimetry system [1, 4-7]. 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 [8-10]. 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. Based on the previous studies, this study is very important to find the prediction of TL response of commercially $Nd-107$ doped silica fiber by $6\,MeV$ electron irradiations. This material is irradiated at doses from $(0.5...4.0)\,Gy$ using photons of $6\,MV$ energy to measure the TL response.

2. MATERIAL AND METHODS

2.1. Nd-doped SiO_2 optical fibres

Silicon dioxide, also known as silica, is an amorphous material, devoid of long-range periodic order. In the current research, we focus on the TL response of doped SiO_2 commercially available optical fibre. The doped SiO_2 optical fibres have an outer diameter of $124.7 \pm 0.1\,\mu m$ and a doped core diameter of $9\,\mu m$. In fibre optics, doping with selected atoms permits

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the creation of a refractive index radial profile that leads to total internal reflection. This is essential for an optical guide [1]. In this study, neodymium has been chosen due to their high sensitivity exhibition to irradiations and has low attenuation. We cut the fibres into individual lengths of $5\,mm$ and accommodated the variations in actual length by normalizing the TL response to unit mass of the TL medium. The details of Ge-doped and Al-doped optical fibre and $TLD-100$ were presented [1].

3. EXPERIMENTAL PROCEDURE

For this experiment, the TL materials were kept in a suitable container to avoid the places of high temperature and ultraviolet radiation. The $Nd-107$ doped fiber and $TLD-100$ were placed in the gelatin capsule for routine storage, handling, and for irradiations. Each capsule contained 5 pieces of $Nd-107$ doped fiber, each capsule contained 1 chip. The experimental details was presented [4, 5]. 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. Before starting the annealing process, Time Temperature Profile (TTP) for $Nd-107$ doped silica fibers were set at the computer and fibers were placed in a planchet which was placed inside the annealing oven.

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 $10\,cm \times 10\,cm$. 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. 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.

4. RESULTS AND DISCUSSION

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. The effects of TL light yield proportionality to dose and by establishing the ability to accurately calculate electron response, the experimental implications of dosimeter TL yield proportionality to dose can be studied without the requirement for experimental measurements. This technique also provides a more detailed characterization of electron response than experimental techniques that rely on the use of multiple radiation sources. To demonstrate this technique, we have calculated the ratio of measured response of Ge-doped, Al-doped optical fibre and $TLD-100$ by $6\,MV$ - photon and $6\,MeV$ - electron irradiation [4].

Fig.1 shows comparative studies of TL response of Ge-doped, Al-doped optical fibre and $TLD-100$ with various dose ranges from $0.2\,Gy$ to $4.0\,Gy$ by $6\,MV$ - photon and $6\,MeV$ - electron irradiation. The TL yield as a function of dose is linear; the response for electron irradiations in each case is greater than that for photon irradiations. The response of Al-doped optical fibre is negligible to $TLD-100$ and distribution of photon and electron response as a function of dose is overlap to each other for Al-doped fibre. We have calculated average ratios of response of $6\,MV$ - photon and $6\,MeV$ - electron irradiation numerically and were found 0.81(3), 0.85(2) and 0.84(3) for $TLD-100$, Ge-doped and Al-doped optical fibre respectively. Therefore the average of response ratios of $6\,MV$ photon and $6\,MeV$ - electron for any dosimeter is 0.83(3). We found that the $Nd-107$ doped optical fibre have a significant linear dose to signal relationship.

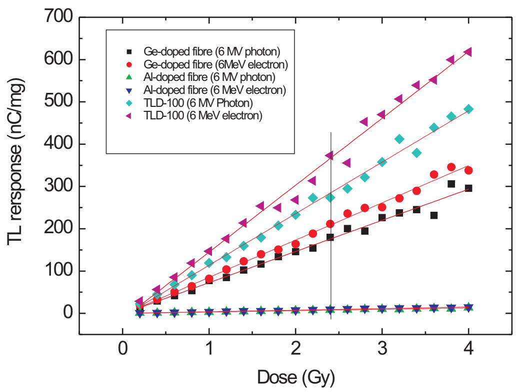

Fig.1. *TL-response (nC/mg) of Ge-and Al-doped optical fibres, and $TLD-100$ rods for $6\,MV$ - photon and $6\,MeV$ - electron irradiation*

Fig.2 shows comparative studies of TL response (arbitrary unit) of Neodymium-doped SiO_2 optical fibre with various dose ranges from $0.5\,Gy$ to $4.0\,Gy$ predicted by $6\,MeV$ - electrons and measured by $6\,MV$ - photon irradiations.

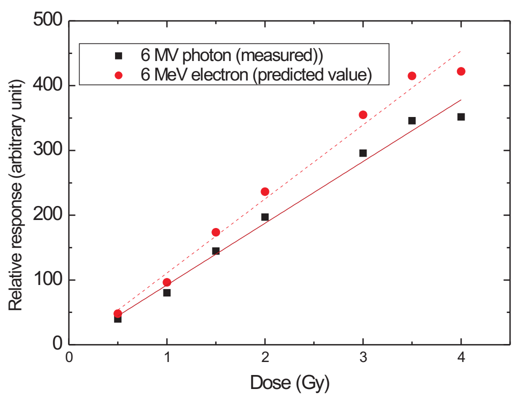

Fig.2. *Relative response of Nd-doped optical fibre by $6\,MV$ - photon (measured) and $6\,MeV$ - electrons (predicted) irradiation*

By comparing previous results of $TLD-100$, Ge-doped and Al-doped optical fibre to both measured photon and electron responses and measured value of Nd-doped optical fibre by photon responses, this technique has been validated for $6\,MeV$ - electron irradiation.

5. CONCLUSIONS

We have demonstrated TL linearity and TL response ratio of $6\,MV$ - photon/ $6\,MeV$ - electron irradiation for Ge-and Al-doped optical fibres, and $TLD-100$. The average response ratio is 0.83(3). The sensitivities of electron response are larger than those of photon irradiation. We have predicted the TL response of $Nd-107$ doped silica fibers by $6\,MeV$ - electron comparer to measured value by $6\,MV$ - photon irradiated with dose range from $0.5\,Gy$ to $4.0\,Gy$.

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ТЕРМОЛЮМИНЕСЦЕНТНЫЙ ОТКЛИК ОПТИЧЕСКОГО ВОЛОКНА С ДОБАВЛЕНИЕМ Ge-, Al- И Nd НА ОБЛУЧЕНИЕ 6 МэВ - ЭЛЕКТРОНАМИ И 6 МВ - ФОТОНАМИ

I. Hossain, M. A. Saeed, H. Wagiran, N. Hida, N. H. Yaakob, A. A. Moburak

Мы докладываем предсказания термолюминесцентного отклика SiO_2 оптического волокна с добавлением Неодима при разных дозах облучения 6 МэВ - электронами в интервале доз от $0.5\,Gy$ до $4.0\,Gy$ без необходимости экспериментальной проверки. Была развита техника расчета предсказания термолюминесцентного отклика SiO_2 оптического волокна на 6 МэВ - электроны путем наблюдения термолюминесцентного отклика на 6 МВ - фотоны и известного измеренного отношения photon/electron выходов оптического волокна с добавлением Ge и Al и стандартного $TLD-100$ дозиметра. Образцы были заключены в желатиновые капсулы и облучены $6\,MB$ фотонами в диапазоне доз от $0.5\,Gy$ до $4.0\,Gy$. Линейный ускоритель модели Siemens Primus 3368, расположенный в Hospital Sultan Ismail, Johor Bahru, был использован для облучения образцов фотонами. Мы нашли среднее отношение откликов для 6 МВ - фотонов и 6 МэВ - электронов в оптическом волокне с добавлением Ge и Al и стандартным дозиметром $TLD-100$, равным 0.83(3). Измеренная величина этого усредненного отношения при облучении 6 МВ фотонами является полезной для нахождения ожидаемого термолюминесцентного отклика SiO_2 оптического волокна с добавлением Неодима требуемых для экспериментальных измерений доз в интервале от $0.5\,Gy$ до $4.0\,Gy$ при облучении 6 МэВ - электронами.

ТЕРМОЛЮМІНЕСЦЕНТНИЙ ВІДГУК ОПТИЧНОГО ВОЛОКНА З ДОБАВКАМИ Ge-, Al- І Nd НА ОПРОМІНЕННЯ 6 МеВ - ЕЛЕКТРОНАМИ І 6 МВ - ФОТОНАМИ

I. Hossain, M. A. Saeed, H. Wagiran, N. Hida, N. H. Yaakob, A. A. Moburak

Ми доповідаемо передбачення термолюмінесцентного відгуку SiO_2 оптичного волокна з добавками неодиму при різних дозах опромінення 6 МеВ - електронами в інтервалі доз від $0.5\,Gy$ до $4.0\,Gy$ без необхідності експериментальної перевірки. Була развинута техніка розрахунку передбачення термолюмінесцентного відгуку SiO_2 оптичного волокна на 6 МеВ - електрони шляхом спостереження термолюмінісцентнго відгуку на 6 МВ - фотони і відомогого виміряного відношення photon/electron виходів оптичного волокна з добавками Ge и Al і стандартного $TLD-100$ дозиметра. Зразки були розміщені в желатинових капсулах і опромінені 6 МВ - фотонами в діапазоні доз від $0.5\,Gy$ до $4.0\,Gy$. Лінійний прискорювач моделі Siemens Primus 3368, розміщений в Hospital Sultan Ismail, Johor Bahru, був використаний для опромінення зразків фотонами. Ми знайшли середнє відношення відгуків для 6 МВ - фотонів и 6 МеВ - електронів в оптичному волокні з добавками Ge и Al і стандартним дозиметром $TLD-100$, яке дорівнює 0.83(3). Виміряна величина цього усередненого відношения при опроміненні 6 МВ - фотонами є корисною для знаходження очікуваного термолюмінесцентного відгуку SiO_2 оптичного волокна з добавками неодиму, які потрібні для експериментальних вимірювань доз в інтервалі від $0.5\,Gy$ до $4.0\,Gy$ при опроміненні 6 МеВ - електронами.