

Mass energy absorption coefficients for 0.2 – 20 MeV Photon in Ge-doped optical fiber and TLD-100 by Monte Carlo n-particle code version 5 (MCNP5)

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This paper demonstrates on mass-energy absorption coefficient of Ge-doped optical fiber and TLD 100 media subjected to photon irradiation by simulation of Monte Carlo n-particle code version 5 (MCNP5). The Ge-doped optical fiber for various photon energies ranging from 20 keV to 20 MeV, were simulated and calculated as energy absorbed in the TL material. The mass energy absorption coefficients of TLD 100 are compared by simulation and calculation.

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1. Introduction

The thermoluminescence dosimeter (TLD) SiO₂ optical fiber has been widely used as personal dosimetric material because of their low energy dependence, high sensitivity, stability and tissue equivalency. The thermoluminescence response of SiO₂ optical fibers have investigated for application as in vivo radiation dosimeters for patient undergoing radiotherapy [1-3]. TL performance of an irradiated optical fiber is depends on the type of fiber and by the radiation parameters. Different impurities in the fiber could give different outcome in the fiber optic performance as TL material. The TL study on commercially available Ge-doped silica based optical fiber has carried out in dose range of 1-1230 Gy[4-5].

Usually SiO₂ optical fibers can be applied as in-vivo dosimeters, doping of germanium would change the luminescence property of optical fiber. We already reported thermoluminescence energy response of TLD-100 and Ge-doped optical fiber using Monte Carlo N-particle transport code version 5 (MCNP5) [6-9]. The mass energy absorption coefficient is very much interest in the estimation of the absorbed dose in medical physics, industrial and agricultural irradiation technology of photon radiation. Information in energy response is very helpful in selecting the filter or any other energy correction method for the TL material [10-12]. The mass energy absorption coefficient was needed in order to have photon energy response of dosimeters. Thus, it is essential to compare mass energy absorption coefficient (MEAC) obtained from calculation, with mass energy absorption coefficient from simulation, $f(E)$. The discussions on a numerical analysis for TL response of Ge-doped optical fiber are very much interesting to understand the luminescence property of optical fiber. At present the mass energy absorption coefficient as a function of photon energy response of Ge-

doped optical fiber and TLD 100 media are compared between calculated and simulation.

2. Materials and methods

This research apply Monte Carlo n-particle code version 5 (MCNP5) as tool to investigate mass energy absorption coefficient as a function of the photon energy of two different TLD material which are TLD 100 and Ge-doped SiO₂ optical fiber.

2.1 Geometry description

The geometry is specified by a phantom, TLD tray and the TLDs. TLD are placed in the plastic tray. A plastic tray contains 50 wells, so 50 TLDs can be held in a single tray. The wells are 1 cm x 1 cm square and 1.0 mm deep. The sizes of the well are large enough to hold the TLDs and small enough to not significantly affect radiation fluency [4]. The phantom is a standard PMMA phantom with external dimensions of 30 cm x 30 cm x 23 cm. There is a rectangular cut-out on the phantom that is sufficient enough to place the TLD tray. For the purpose of simulation, the TLD tray is assumed to be built inside the phantom itself.

Two types of TLD were used in this simulation, which are TLD 100 and Ge-doped silicon dioxide optical fiber. The TLD 100 has a dimension of 3.3mm x 3.3mm square and 0.9 mm thick and it has densities of 2.64 g cm⁻³. For the SiO₂ fibre optic, the initial length is 10 meter long but for this research the fiber was cut into 5mm length. The fiber had 125.0 ± 0.1 μm cores and the mass of each fibre was (0.20 ± 0.02) mg. SiO₂ optical fiber has densities of 2.32 g cm⁻³[1].

2.2 Data card specification

Data card in the MCNP input file contains information such as source, material, tallies and variance reduction. The source and type of radiation particles for an MCNP problem are specified by the SDEF command. Only one SDEF card is allowed in an input file. In this simulation, the source is photon and defined as a point source collimated into a cone of direction. The source energy is between 20 keV (0.02 MeV) to 20 MeV and was placed 100 cm from the phantom surface with each run ending at 10 million histories.

The TLD 100 or LiF: Mg, Ti contains 73.28 % Fluorine, 26.72 % Lithium, 200 ppm Magnesium and approximately 10 ppm of Titanium. Type of fiber used in this research is germanium doped SiO₂ optical fiber. The fibre had average weight fraction as follows: Silica 53.6 %, Oxygen 43.1 % and Germanium 0.3 %.

As mention before, the fiber initial length is 10 m, but for the purpose of this research, the fiber was cut into 50 tiny pieces. Each pieces had 5 mm long. The fractions of elements in each fiber were measured by SEM technique [13]. MCNP provides seven standard tally types. For this research tally F6 was used. According to the MCNP User's Manual, tally F6 is the track heating tallies modified to tally a reaction rate convolved with an energy-dependant heating function instead of flux. The units of this tally are MeV/g. After the input file is completed, the simulation can be run using MCNP5 command prompt. The simulation was terminated after 10 million particle histories were done and it took 9.55 minutes of computer time to complete. After the simulation was done, MCNP5 will generate an output file for each input file.

3. Results and discussion

The mass energy absorption coefficient for a mixture of materials was calculated using Eq. 1

$$\left(\frac{\mu_{en}}{\rho}\right)_{\text{material}} = \sum_i \left(\frac{\mu_{en}}{\rho}\right)_i W_i \quad (1)$$

Here, W_i indicate the weight fraction of elements

The mass energy absorption coefficients of each element in the Ge doped optical fiber and TLD 100 was taken from tables of X-rays[14].

Twenty two input files were run by MCNP5 with each of the file contain same information except for the source energy to find the mass energy absorption coefficient of TLD 100 and optical fiber by simulation. The energy used were 20, 30, 40, 50, 60, 80, 100, 150, 200, 300, 400, 500, 600, 800 keV and 1, 1.25, 2, 3, 6, 10, 15 and 20 MeV. Tally F6 was utilized to generate the photon energy response of TLD. The output data from the simulation contains much information that can be used, but the value retrieved from the file is energy absorbed normalized to a unit mass of the material, E_{abs} .

The value of mass absorption coefficient $f(E)$ of TLD 100 is an average fraction of energy deposited in TL material obtained from MCNP simulation. The result extract from MCNP is in unit of MeV/g and it means average energy deposited from a particle to a unit gram of the dosimeter, E_{abs} . The following equation was used to obtain mass energy absorption coefficient of the dosimeter by simulation.

$$f(E) = E_{abs} \times \frac{1 \text{ cm}^2}{E_{\text{MeV}}} \quad (2)$$

where $f(E)$ = average fraction of energy deposited in TL material, for any given energy ($\text{cm}^2 \text{g}^{-1}$)

E_{abs} = Energy absorbed normalized to unit mass (MeV g^{-1})

And E_{MeV} = Incident photon energy (MeV).

Fig. 1 shows that value of $f(E)$ is slightly higher than MEAC except for energy of 20 keV. It is common for a result from MCNP slightly higher than calculated since in MCNP there are a few simplifying assumption made from the actual model. This simplifying assumption could be a factor for a difference value between calculation and simulation.

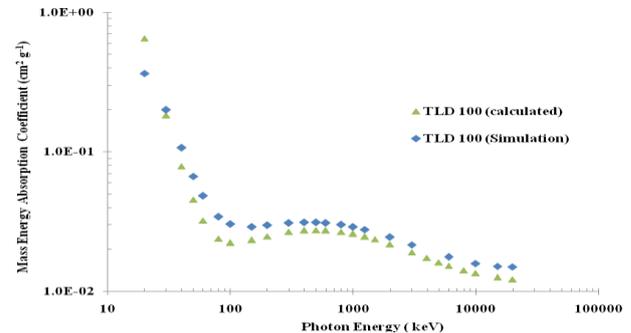


Fig. 1. Calculation and simulation of mass energy absorption coefficient of TLD 100.

For the response of optical fiber by simulation, same procedures were applied in order to obtain mass energy absorption coefficient as a function of photon energy response. Fig. 2 depicts mass energy absorption coefficient of optical fiber with comparison between calculation and simulation. Both results of mass energy absorption coefficient for TLD 100 and optical fiber show similarity. From Fig. 2, just like TLD 100, $f(E)$ of optical fiber is slightly higher than MEAC except for energy of 20 keV. As TLD 100, difference values between calculation and simulation could be due to simplifying assumption in generating simulation. It is shown that the mass energy absorption coefficient ($\text{cm}^2 \text{g}^{-1}$) show same pattern of response from each material. Both figures show that mass energy absorption coefficient as a function of photon energies for optical fiber, and TLD 100 materials decrease rapidly from 20 keV to 100 keV and then remain slowly

decrease until 20 MeV. Theoretical calculations of photon energy responses of both dosimeters for mass energy absorption coefficient are good agreement with Monte Carlo Simulation.

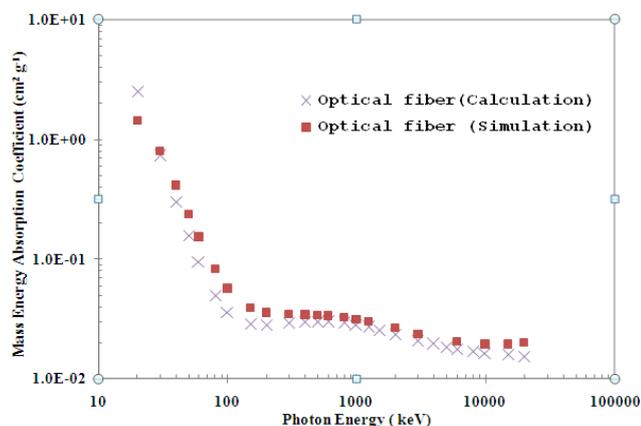


Fig. 2. Calculation and simulation of mass energy absorption coefficient of Ge-doped optical fiber.

4. Conclusions

This research for mass energy absorption coefficient has successfully utilized MCNP simulation in determines photon energy ranges from 20 keV – 20 MeV of Ge-doped optical fibers and TLD 100 media. Using tally F6, MCNP5 simulate photon energy deposited in both dosimeter. Output results generated by MCNP5 were analyzed and being used to calculate mass absorption coefficients for different gamma rays energies. Simulation results and theoretical calculations are good agreement to both dosimeters. The mass energy absorption coefficient of commercially available optical fiber show larger than TLD 100 at lower energy range 20 keV to 100 keV. In addition, mass absorption coefficients of optical fibers have a good relative response and are providing comparable response to that of TLD100.

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