EVALUATION OF SILICON AND DIAMOND BASED MICRODOSIMETRY FOR BORON NEUTRON CAPTURE THERAPY APPLICATIONS

James Vohradsky[1], Jeremy A. Davis[1,2], Anatoly B. Rosenfeld[1], Susanna Guatelli[1]
[1] Centre for Medical Radiation Physics, University of Wollongong, Australia
[2] Illawarra Health and Medical Research Institute, University of Wollongong, Australia

Introduction: The shift from reactor to accelerator based neutron production has created a renewed interested in Boron Neutron Capture Therapy (BNCT). This method is typically used to treat inoperable brain tumours (glioblastoma [1]) that cannot be treated by traditional forms of radiotherapy or chemotherapy [2]. BNCT is reliant upon the favourable uptake of boron-10 by tumour cells along with the interaction with neutrons to produce high LET fragments (He^{2+} & Li^{3+}) that deposit energy locally within the tumour site. As with any radiation based treatment, Quality Assurance (QA) by means of dosimetric measurements is crucial in terms of patient safety. This study extends previous work regarding the application of solid state microdosimetry in the field of BNCT by means of a dedicated Monte Carlo simulation [3].

Materials and Methods: Geant4 was used to model and optimise the design of silicon on insulator and diamond based microdosimeters [4] [5] [6]. The CMRP Bridge microdosimeter was studied extensively. Detector optimisation in this context, pertains to the geometry and materials (i.e., sensitive volume size and probability of neutron activation) to be used in the construction of detectors. The applicability of previously determined correction factors to match the energy deposition response of charged particles within silicon/diamond to water was evaluated within the context of BNCT by analysis of microdosimetric spectra [7] [8].

Results: The study has shown conclusively that the materials currently used in the available silicon and diamond-based CMRP microdosimeters do not pose any radiation protection risk with the typical exposure times of BNCT. However, there are changes with respect to the sensitive volume thickness that must be addressed.

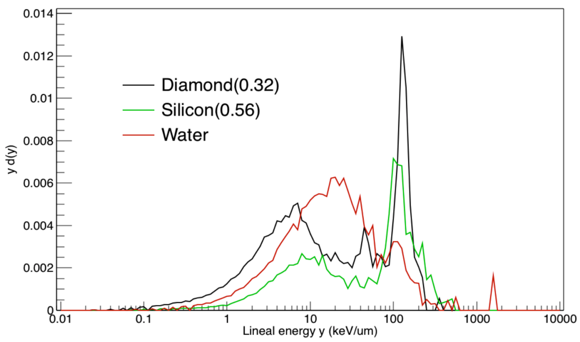

Figure 1. Comparison of microdosimetric spectra obtained with 0.1 μm thick SVs in the case of 25ppm ^{10}B concentration in the tumour volume.

Reduced SV thickness resulted in a higher rate of BNC products crossing the SV. The study of water equivalence conversion in BNCT using the current geometric scaling factors published for silicon, 0.56 [7], and diamond, 0.32 [8], produced a suitable result for high-LET radiation fields.

Conclusion: Three dedicated Geant4 applications were developed to characterise the BNCT radiation field, provide analysis of neutron activation and to obtain the microdosimetric response of optimised detector designs. Unfortunately, in the context of this project, it was not possible to validate the simulation against experimental measurements. With a 10 μm thick SV, the number of alpha particles classified as stoppers is about 96%. This is due to the short range of the alpha particles and ^{7}Li nuclei in comparison to the Bridge SV mean chord length. As the projected range of a 1.5 MeV alpha particle in silicon is 5.26 μm [9], thinner SVs are required to allow BNC products to cross the SV. The study of the water equivalence conversion concluded their suitability for high-LET radiation fields. However, it was found that their ability diminished in the lower lineal energy range where most events were due to stoppers. As the majority of particles in BNCT are stoppers, these correction factors do not provide a well-approximated water equivalent response for low-LET events. The solution is to develop thin SVs to have more crossers and eventually develop an ad hoc conversion factor for BNC. The results have shown that a Bridge microdosimeter fabricated with thinner SVs would provide a very suitable detector for dedicated BNCT QA for epithermal neutron sources, such as existing facilities at Tokai and KURRI in Japan.

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