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INVITED: Recent development of solid state microdosimetry and its applications in particle therapy and space

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Particle therapy has many advantages over conventional photon therapy, particularly for treating deep-seated solid tumours due to its greater conformal energy deposition achieved in the form of the Bragg peak (BP). Successful treatment with protons and heavy ions depends largely on knowledge of the relative biological effectiveness (RBE) of the radiation produced by primary and secondary charged particles. The RBE prediction based on microdosimetric approach using the tissue equivalent proportional counter (TEPC) measurements in 12C therapy has been reported, however large size of commercial TEPC is averaging RBE which dramatically changes close to and in a distal part of the BP that may have clinical impact. Moreover, the TEPC requires high voltage and gas supply that are not always practical for a quality assurance (QA) purpose in a routine clinical setup.

Based on many years of experience in development of silicon-on-insulator (SOI) microdosimeter, the Centre for Medical Radiation Physics, University of Wollongong, has successfully developed a microdosimetric probe which is based on a SOI microdosimeter with 3D micron sized sensitive volumes (SVs) mimicking dimensions of cells, known as the "Bridge"and "Mushroom"microdosimeters, to address the shortcomings of the TEPC [1, 2]. Several designs of high definition 3D SVs fabricated at SINTEF, Norway using 3D MEMS technology were implemented. 3D SVs were fabricated in different sizes and configurations with diameters between 18 and 30μm, thicknesses of 2-50 μm and at a pitch of 50 μm in linear array of single or multiple volumes or matrixes of 20×20 and 50×50 volumes. SVs were segmented into sub-arrays to reduce capacitance and avoid pile up in high dose rate pencil beam scanning applications. Detailed electrical and charge collection charaterisation of these devices will be presented at the conference. The silicon microdosimeters were used to evaluate the RBE of various ions [3] and were successfully utilised for validation of treatment planning system (TPS) in multiple ion therapy at Heavy Ion Medical Accelerator in Chiba (HIMAC), Japan [4]. In multiple ion therapy, the dose and linear energy transfer (LET) distributions can be optimized simultaneously resulting in an improved RBE-weighted dose distribution. By measuring the response of the microdosimeter in a He, C, O and Ne ion spread out BP (SOBP), and applying a dose-weighted summation of the acquired spectra, the combined ion dose mean lineal energy (yD) and cell surviving fraction in MIA PaCa-2 pancreas cells is found for combinations of He+O and C+Ne ions along the SOBP. The survival fraction results are then compared against the in-house TPS showing very good agreement (Fig. 2). These results demonstrate that the 3D SOI microdosimeter is a suitable candidate for the QA system in multiple ion radiotherapy.

Beside application in particle therapy, the SOI microdosimeter is also useful for radiation protection in space. The first study on a comparison of the SOI microdosimeter and the TimePix [5] developed at CERN and currently deployed on the International Space Station (ISS) was performed. Both detectors were placed behind the aluminum plates of various thicknesses to evaluate the radiation field exposed to the astronauts behind shielding. 290 MeV/u 12C, 400 MeV/u 20Ne, 800 MeV/u 28Si and 650 MeV/u 40Ar ions were used in this study. The lineal energy spectra obtained with the SOI microdosimeter and the dE/dX spectra derived with TimePix and converted to tissue are compared and agreed reasonably well. The average quality factor Q of the radiation field obtained with the 2 detectors has shown good agreement for Ar and Ne ions ranging from 1.54% to 11% while some discrepancies between the two detectors of around 15 % were observed for no Al or thin Al wall in case of C, Fe and Si ions. Some discrepancies observed can be related to the fact that the TimePix is measuring dE/dX that is higher than the y due to escaping high energy delta electrons from SV in SOI microdosimeter that is typical for high energy ions like in this experiment. SOI microdosimeter and TimePix can provide the Hp(10) and Q values as well as LET instantly through microdosimetry approach and via data processing of tracks, respectively.

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