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

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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 by 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. Similarly to heavy ion therapy, in deep space environments, where high energy heavy ions are observed, their linear energy transfer (LET) spectrum is important to be characterized and monitored due to their adverse effects on human health as well as electronic components. Microdosimetry involves the measurement of the energy deposition spectrum in micro-sized volumes and from this measured spectrum both the biological and electronic impact from the radiation field can be predicted.

Microdosimetric measurements are traditionally performed using tissue equivalent proportion counters (TEPCs). However, due to their poor spatial resolution they are not well suited to the sharp dose gradients associated with the distal edge of the BP. Additionally, due to their bulky size and complex operation make them challenging for onboard spacecraft use. To address the drawbacks of TEPCs, the Centre for Medical Radiation Physics (CMRP) has developed silicon-on-insulator (SOI) microdosimeters over many years. The latest CMRP SOI microdosimeters are called the “Bridge” and “Mushroom”, both have fully 3D micron sized sensitive volumes (SVs), mimicking the dimensions of cells.

The silicon microdosimeters provide extremely high spatial resolution and were used to measure the dose mean lineal energy and estimate the RBE_{10} using the microdosimetric kinetic model (MKM) for 290 MeV/u ^{12}C, 180 MeV/u ^{14}N and 400 MeV/u ^{16}O ions at Heavy Ion Medical Accelerator in Chiba (HIMAC), Japan. The SOI microdosimeters have also been used to measure the LET of different ions with low energies at the ANU Heavy Ion accelerator including 52 MeV ^{7}Li, 70 MeV ^{12}C, 118 MeV ^{16}O and 170 MeV ^{48}Ti. The study of LET at ANU was to determine the applicability of silicon microdosimeters for high LET ions typical of space. Good agreement between the measured LET was observed with Geant4 and SRIM calculations. This confirmed that the CMRP SOI microdosimeters are not affected by plasma recombination up to LETs of approximately 1300 keV/μm in Si. The microdosimetric spectra obtained for low energy ^{12}C and ^{16}O ions were compared to the microdosimetric spectra measured at the distal part of the Bragg peak for therapeutic ^{12}C and ^{16}O ion beam that allows separate the contributions of the primary ion beam and secondaries.

The measurements performed over the years with the CMRP SOI devices have shown that they are well suited for characterising heavy ion therapy beam and for low energy heavy ions typical for space radiation environment inside of spacecrafts.