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scCVD Diamond Membrane based Microdosimeter for Hadron Therapy

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Hadron therapy (protons and carbon ions) is an innovative mode of radiation therapy for cancer treatment which enables tumour cells to be more effectively destroyed than conventional radiation therapy using photons. Knowledge of the high linear energy transfer¹ (LET) of particles is used as a fundamental parameter in the prediction of the relative biological efficiency¹ (RBE) of particle beams in hadron therapy. Therefore, it is a key quantity to be considered in ensuring that a safe dose is delivered to patients in treatment planning.

Based on single-crystal CVD (scCVD) super-thin diamond membranes obtained using deep Ar/O plasma etching², a prototype of a solid-state microdosimeter for LET measurements was produced at the Diamond Sensors Laboratory of CEA-LIST. A p⁺-i junction was created by a CVD growth of thin 400 nm boron-doped scCVD layer on top of an intrinsic 4 μm thick diamond membrane. Multiple square microdosimetric sensitive volumes (μSVs) with side lengths of 120, 60 and 30 μm (Figure 1) were formed on the membrane surface using projection photolithography, followed by local plasma etching of the p⁺ diamond layer². The characteristic behaviour of the micro p⁺-i junction was determined by a 1.8 V built-in potential which resulted in full depletion of the device at zero-bias.

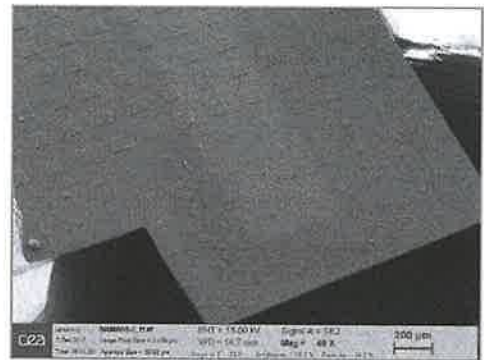


Figure 1: Scanning electron microscope (SEM) image of the scCVD diamond membrane based microdosimeter prototype with different micro-sensitive volumes.

The response of the diamond membrane microdosimeter to single projectiles was investigated in ion micro-beams. The active μSVs of the microdosimeter were irradiated using a raster scanning method and the charge transport properties of the device were determined with sub-micron precision by measuring the charge collection efficiency (CCE), the μSVs 3D spatial definition and the pulse-height spectra. Preliminary, this novel microdosimeter was tested in a 100 MeV therapeutic proton beam at Institut Curie – Proton Therapy Center in Orsay and the experimental data compared to Monte Carlo simulation. The results show a great potential of this device to be used for studies of the RBE in clinical applications.

References

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