Silicon carbide detectors for dosimetry and monitoring of ultra-high dose rate beams

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The saturation effects experienced with the standard dosimeters, such as ionization chambers, at Ultra-high dose rates (UHDR) have prompted the exploration for alternative dose-rate independent detectors that can be utilized for dosimetry and beam monitoring for FLASH radiotherapy [1]. Solid-state detectors, such as silicon carbide detectors (SiC) have emerged as a promising solution for such applications [2]. The collaboration between ST-Lab, a startup company in Catania, and INFN Catania division has recently led to the development of novel SiC detectors of various thicknesses (0.2-20 μm) and active areas (1-10 mm^2). Moreover, a unique configuration based on ultra-thin "free standing membranes" where the substrate is completely removed, was also produced to improve the transparency of the sensor, and is being currently investigated. SiC detectors (with active thickness of 10 μm, a radius of 1 mm, and a 370 μm thick substrate) were characterized using UHDR electron beams accelerated with the ElectronFLASH LINAC developed by SIT Sordina company at the Aprilia SIT location and at the Centro Pisano for the FLASH Radiotherapy (CPFR) in Pisa (founded by the Fondazione Pisa). The SiC detector was placed downstream a final applicator (40 mm radius) and the irradiation was carried out at energies of 7 MeV and 9 MeV, varying the dose per pulse (DPP). Alanine detectors placed at the same position as the SiC were irradiated for each configuration as the SiC for reference. The measurements were conducted with the SiC detector positioned in air at the position of the maximum dose in depth for 9 MeV electrons (equivalent to 13 mm water depth). The signal arising from the single electron pulse (shown in figure 1a) was acquired by directly connecting the detector to a fast oscilloscope. The corresponding charge was obtained by integrating the current signal in time. The SiC response in charge was then measured as a function of the delivered DPP ranging from few cGy up to 5 Gy corresponding to an average instantaneous dose rate up to 1.2 MGy/s (pulse width=4 us).

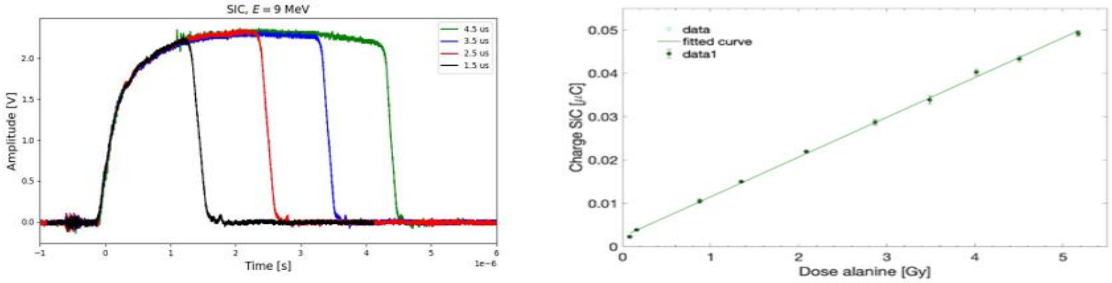

Figure 1 (a) Temporal structure of a single electron pulse at energy of 9 MeV for different pulse widths (up to 4.5 μs) measured at the Aprilia SIT Company facility. (b) SiC response in charge as a function of the DPP measured with the alanine detectors employed as a dose rate independent reference for the measurement of the delivered dose at the CPFR.

The results, that will be discussed in detail in this contribution, clearly demonstrated the dose-rate independence of the novel SiC detectors at FLASH regime and their capability to provide real-time monitoring of the single electron pulse.

References

[1] F. Romano, C. Bailat, P. G. Jorge, M. L. F. Lerch, and A. Darafsheh, 'Ultra-high dose rate dosimetry: Challenges and opportunities for FLASH radiation therapy', *Med Phys*, vol. 49, no. 7, pp. 4912–4932, Jul. 2022, doi: 10.1002/mp.15649.

[2] F. Romano *et al.*, 'First Characterization of Novel Silicon Carbide Detectors with Ultra-High Dose Rate Electron Beams for FLASH Radiotherapy', *Applied Sciences*, vol. 13, no. 5, p. 2986, Feb. 2023, doi: 10.3390/app13052986.