FRPT
FLASH RADIOTHERAPY & PARTICLE THERAPY 2022

SILICON CARBIDE DIODES FOR ULTRA-HIGH DOSE RATE DOSIMETRY

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EMPIR EURAMET
The EMPIR initiative is co-funded by the European Union's Horizon 2020 research and innovation programme and the EMPIR Participating States

Disclosure

- Rafael Kranzer is a PTW employee.

- This work has received funding from:
  - Grant RTC-2017-6369-3 (GRACE) by MCIN/AEI/10.13039/501100011033 and ERDF “A way of making Europe”.
  - The EMPIR programme cofinanced by the Participating States and from the European Union's Horizon 2020 research and innovation program under project 18HLT04-UHDpulse.

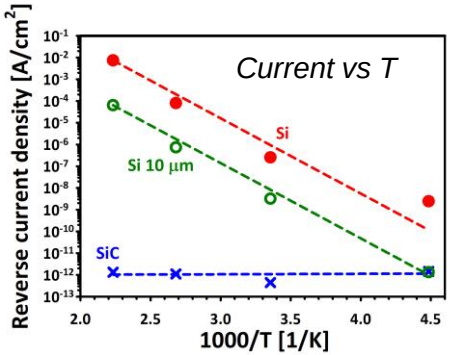
Silicon carbide diodes as real-time radiation dosimeters

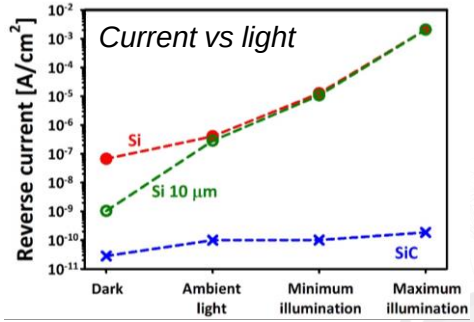
Why SiC? **Wide bandgap semiconductors** (SiC and diamond), **compared to silicon**, have:

- Lower dark current
- Higher radiation hardness
- Tolerance to visible light and temperature variations

In addition, **SiC compared to diamond** has:

- More mature technology allowing to produce complex structures
- High quality substrate material available up to 200 mm wafers at a reasonable cost: good price-performance ratio



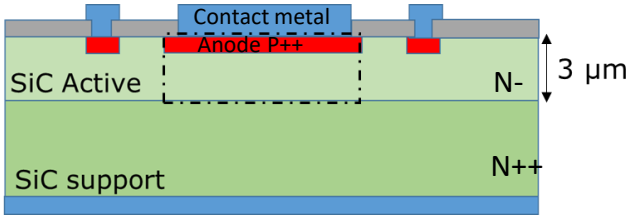


J. M. Rafí et al. JINST 13 C01045 (2018); IEEE Trans.Nucl.Sci. 67 (2020)

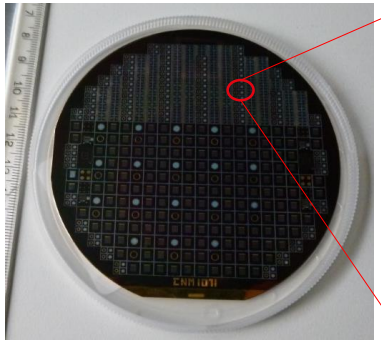
Devices

- Circular 1 mm diameter PiN diodes on 3µm epitaxial 4H-SiC
- Designed and fabricated by IMB-CNM-CSIC (EU Patent pending)
- Encapsulated by PTW with their microSilicon housing for electrical connectivity

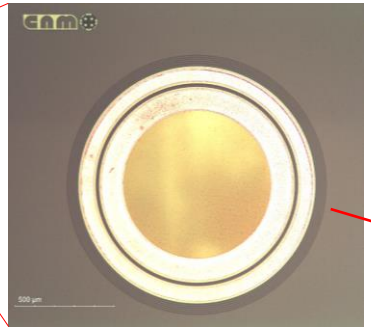
SiC diode schematic cross section



4" SiC wafer



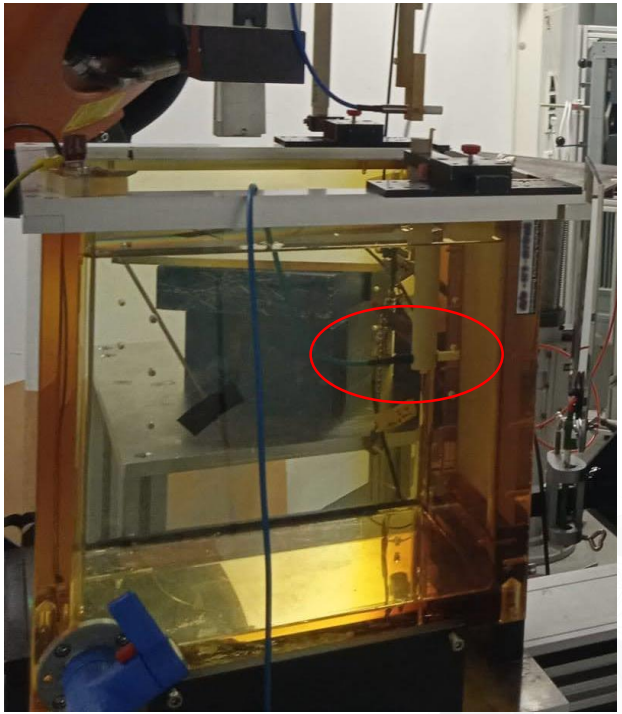
1 mm diode



Encapsulation

Tests with electron beams at PTB

- Measurements at PTB UHDPP electron beam
- Electron energy 20 MeV
- Repetition rate 5 Hz, pulse duration 0.6, 1.6 and 2.9 µs
- Measurements in PMMA water tank with a motorized positioning system
- Reference dosimetry provided by Alanine and prototype flashDiamond*
- SiC diode operated **without external bias**



SiC diode in water phantom at PTB

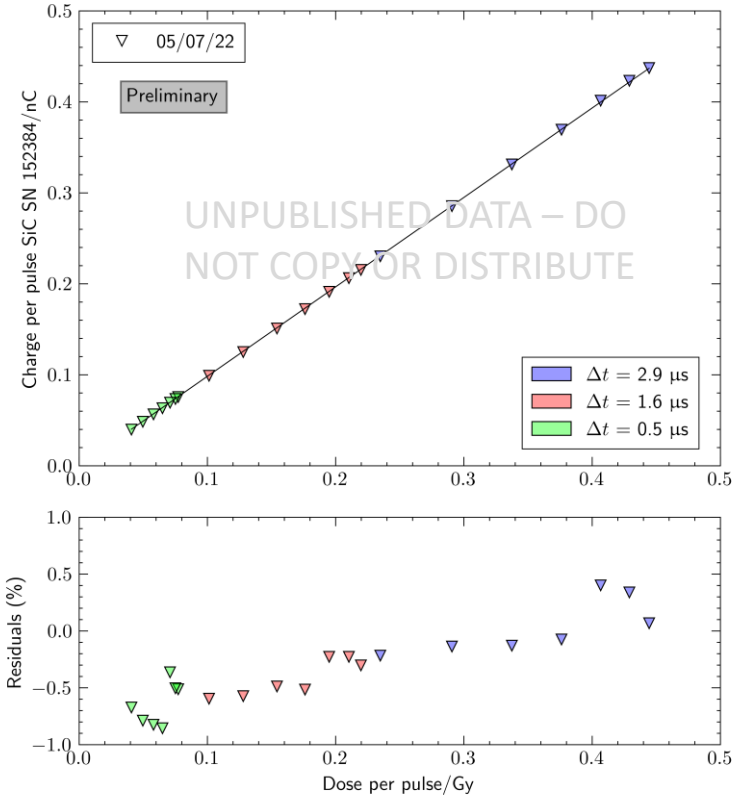
(*) M. Marinelli et al. “Design, realization and characterization of a novel diamond detector prototype for FLASH radiotherapy dosimetry” Med Phys. 2022;49:1902–1910

Results

Intermediate DPP range: 0.2 - 0.42 Gy

- Response independent both of DPP and of instantaneous dose rate
- Linearity deviation **< 1 %** *
- SiC diode sensitivity **~1 nC/Gy**

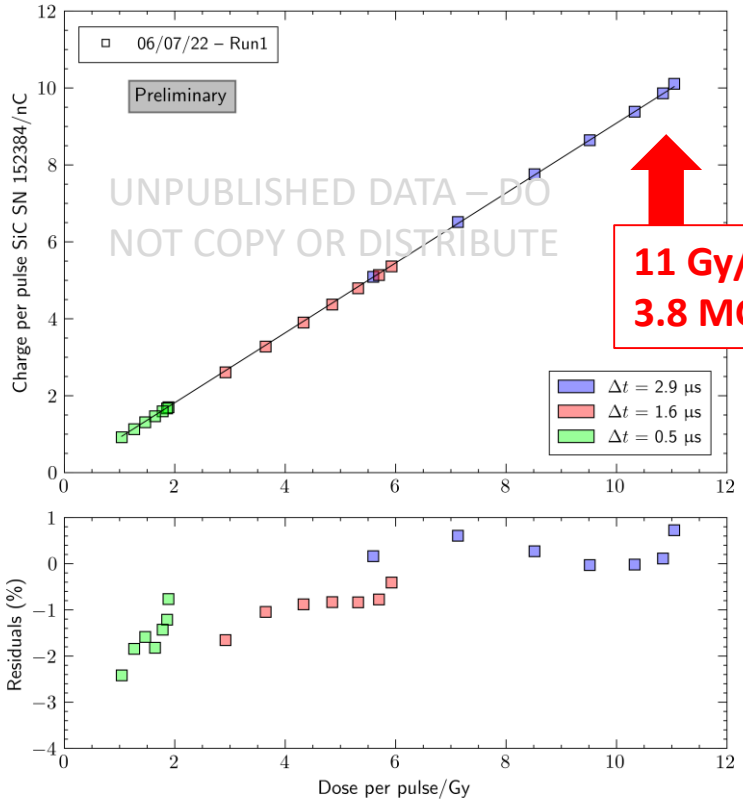
(*) includes uncertainty of reference detector



Results

Ultra-high DPP range: 1 - 11 Gy

- Signal linearity up to at least **11 Gy/pulse (3.8 MGy/s)** with a relative deviation of < 3 %



11 Gy/pulse
3.8 MGy/s

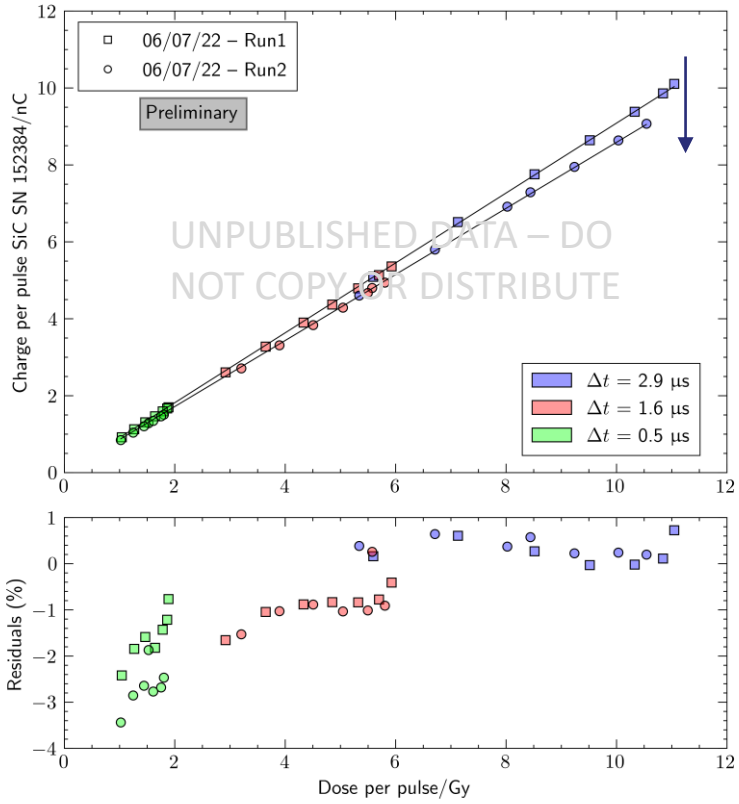
Results

Effect of accumulated dose

- Two runs, around **~16 kGy** accumulated dose between them
- Response linearity not affected
- Sensitivity variation with dose **< 1%/kGy ***

→ Not as radiation hard as diamond, better than silicon

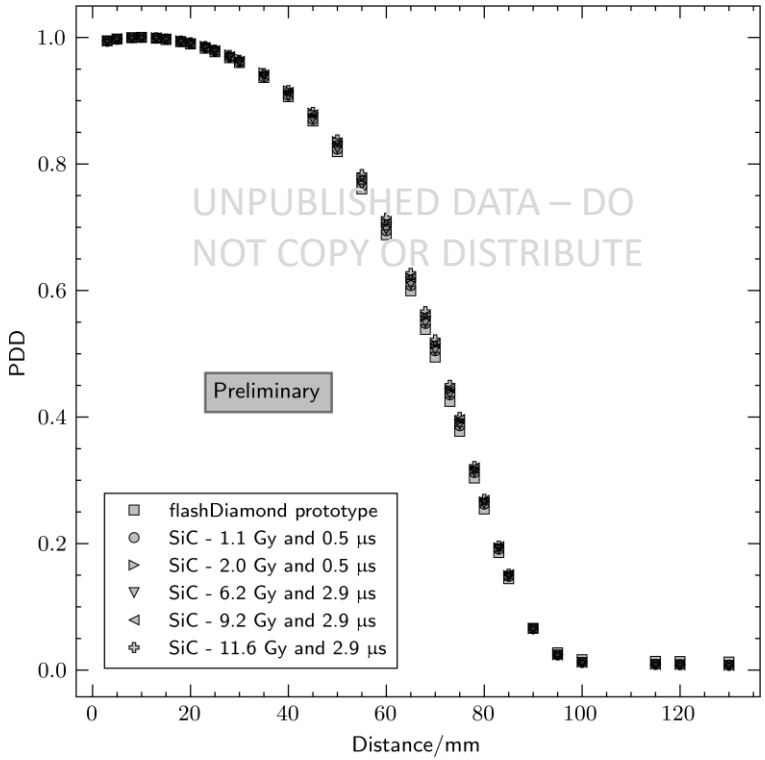
* Worst case (under analysis)



Results

PDD measurement

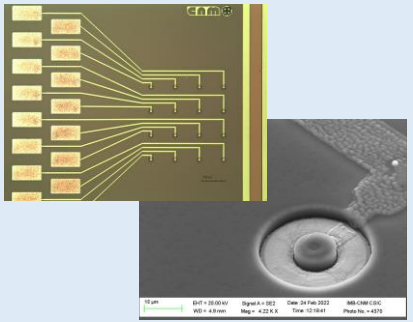
- Several runs of PDD curves obtained with the SiC diode:
  - Max. dose per pulse: 1.1 to 11.6 Gy
  - Pulse duration: 0.5 and 2.9 µs
- Performance comparable to reference flashDiamond



Conclusions and outlook

- **First SiC diodes produced and validated** for relative dosimetry in UHDR pulsed electron beams.
  - ✓ Operation without external bias
  - ✓ Response independent both of DPP and of instantaneous dose rate in the investigated range: up to 11 Gy/pulse, 3.8 MGy/s
  - ✓ Radiation robust: < 1%/kGy sensitivity variation with dose
  - ✓ Performance comparable to flashDiamond in PDD measurement under UHDPP conditions

- Future work:
  - Systematic characterization in a wide range of beam configurations
  - Test other detector structures already fabricated: diodes with sidewalls removed for increased spatial and dose resolution, pixel and strip configurations for 2D dose maps



Thank you!

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