

Radiation Damage Studies of 4H-SiC LGADs

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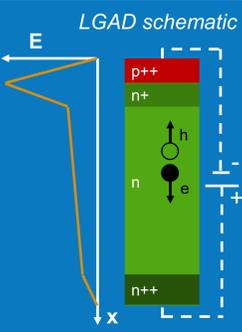
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Introduction and motivation

- 4H-SiC should offer high radiation tolerance and temperature stability, making it a strong candidate for the next-generation detectors
- Lower signal yield and limited sensor thickness are addressed by forming Low-Gain Avalanche Detectors (LGAD) [1,2]
- We show first proton irradiation results of previously tested high gain 4H-SiC LGADs [3]



— Silicon
— 4H-SiC
— Diamond

Bandgap [eV]

Electron Saturation Velocity [10^7 cm/s]

Ionization Energy [eV]

Displacement Energy [eV]

Breakdown Field [MV/cm]

Sensor specification:

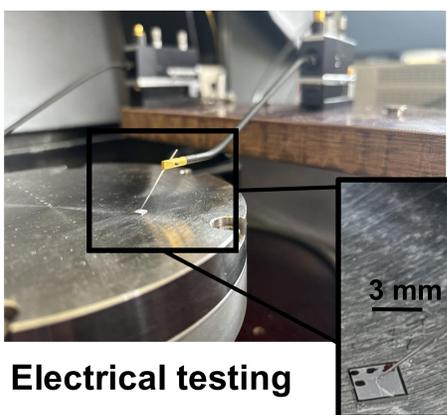
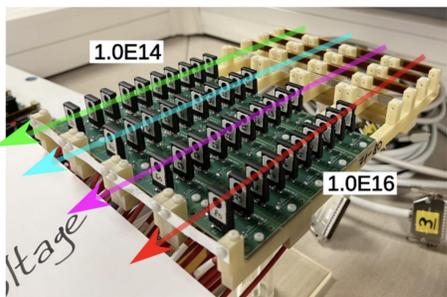
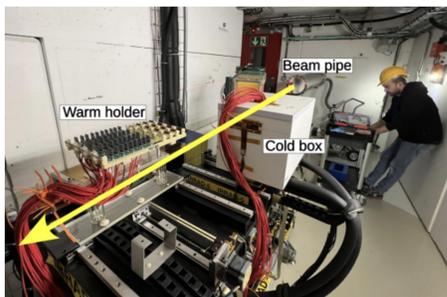
- Low doped N-type epi on high doped 6-inch substrate wafer
- W16 (30 μ m), W17 (50 μ m), W19 (50 μ m)
- LGAD layer: from $1.65E13$ to $1.75E13$ ion/cm²
- P+ dose: from $0.4E14$ to $8E14$ ion/cm²

TCT setup

- ELI Beamlines
- Beam spot $\sim 2 \mu$ m
- Top side illumination
- Pulse duration ~ 50 fs
- High accuracy positioning
- Tuneable wavelength, 370nm used
- High-bandwidth oscilloscope readout

Irradiation campaign

- CERN IRRAD facility
- 24 GeV/c protons, $\sim 12 \times 12$ mm² FWHM
- Irradiated at +20 °C and -20 °C
- Biased MOSFETs irradiated in parallel
- Samples from W16, W17 & W19
- PN, LGAD1 & LGAD2
- 4 - 7 dies per type & fluence
- Total fluences (1 MeV neq/cm²)
 - $7.4E13$
 - $9.9E14$
 - $4.3E15$
 - $5.2E15$



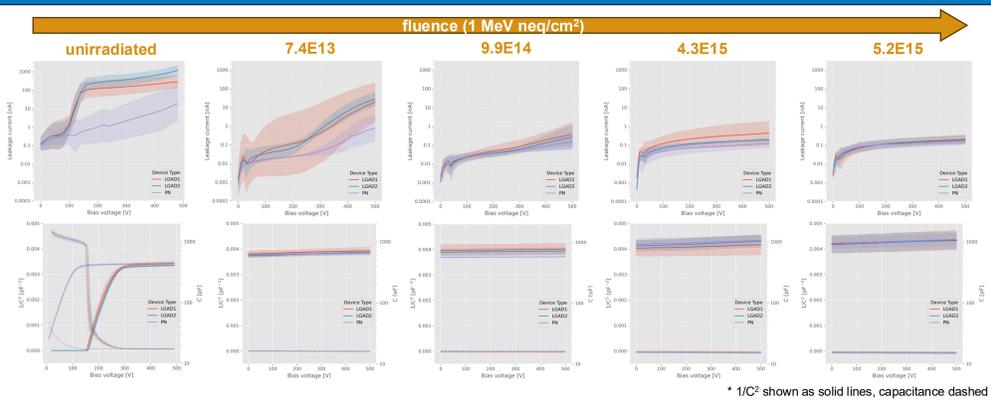
Diodes on each wafer:

- 3 mm x 3 mm size
- PN, LGAD1 & LGAD2 targeting different gains
- Metal "grill" showing lines of bare SiC for UV-TCT tests



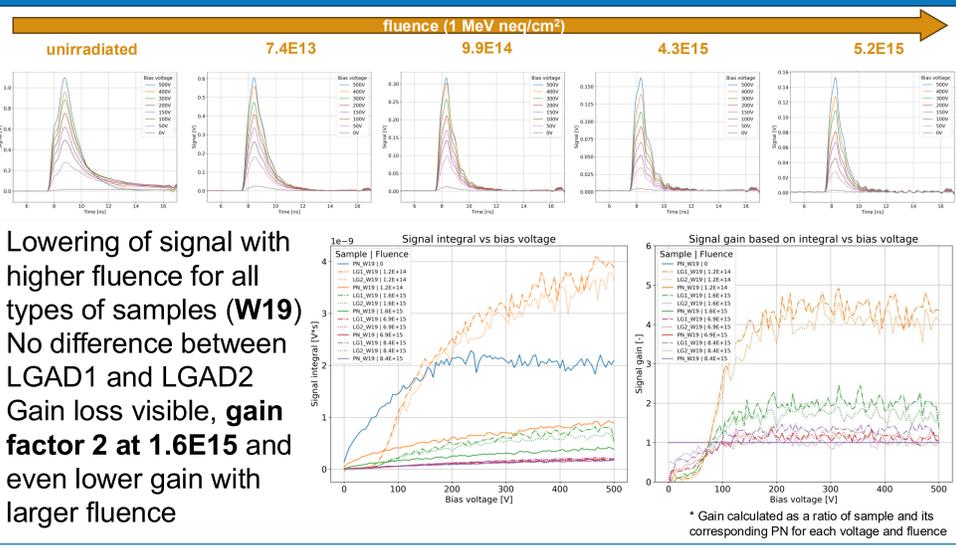
Electrical testing

Current and Capacitance measurements in reverse bias



- Shown for W19, both IV and CV strongly impacted with radiation damage
- Observed lowering of currents with higher fluence, no difference anymore between PN, LGAD1 and LGAD2 for $5.2E15$ 1 MeV neq/cm²
- Capacitance for W19 is constant at around 15pF after any irradiation

TCT measurements in reverse bias



- Lowering of signal with higher fluence for all types of samples (W19)
- No difference between LGAD1 and LGAD2
- Gain loss visible, gain factor 2 at $1.6E15$ and even lower gain with larger fluence

Conclusions and outlook

- Successful irradiation and testing campaign, **observed signal loss** for both PN and LGADs
 - Ongoing annealing studies to understand possible recovery
 - Move towards segmented structures and more detailed TCT / MIP studies



[1] Zhao, S., et. al.: "Electrical Properties and Gain Performance of 4H-SiC LGAD (SICAR)", IEEE, 2024, DOI: 10.1109/TNS.2024.3471863

[2] Novotný, R., et. al.: "First Generation 4H-SiC LGAD production and its performance evaluation", submitted to JINST 2024, DOI: 10.48550/arXiv.2408.12744

[3] Švihra, P., et. al.: "Exploring the design and measurements of next-generation 4H-SiC LGADs", NIM-A, 2025, DOI: 10.1016/j.nima.2025.170742