TCAD modeling of radiation induced defects in 4H-SiC diodes and LGADs

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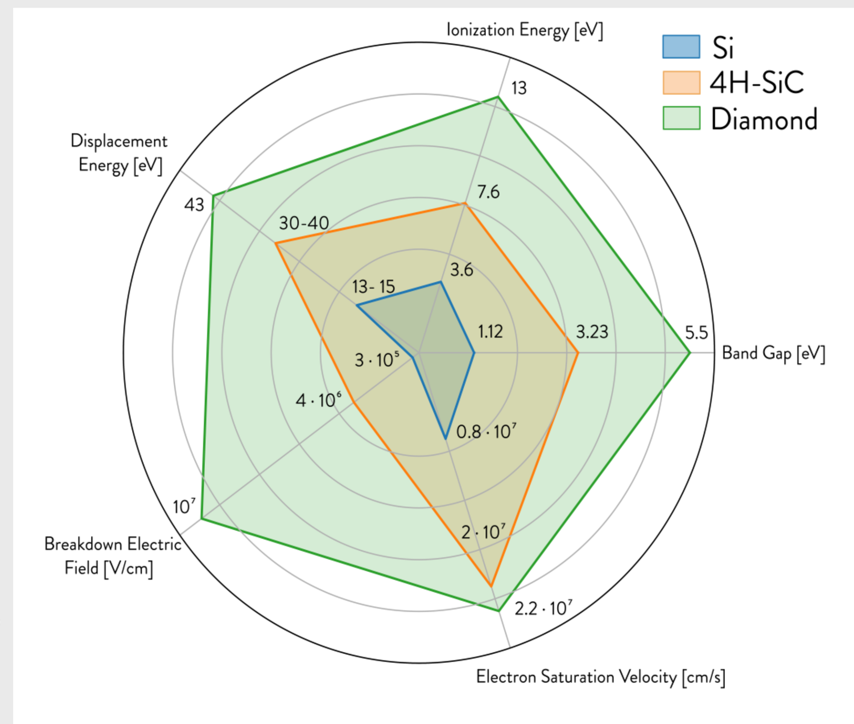
4H Silicon Carbide (SiC)

Advantages[1]:
- Low leakage currents
- Fast signals
- Insensitive to light
- Radiation tolerance

Drawbacks:
- Limited epi-thickness
- High E_{ion} [2]

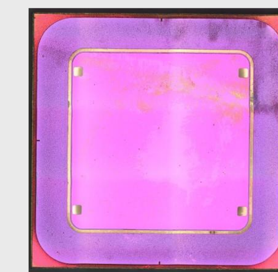


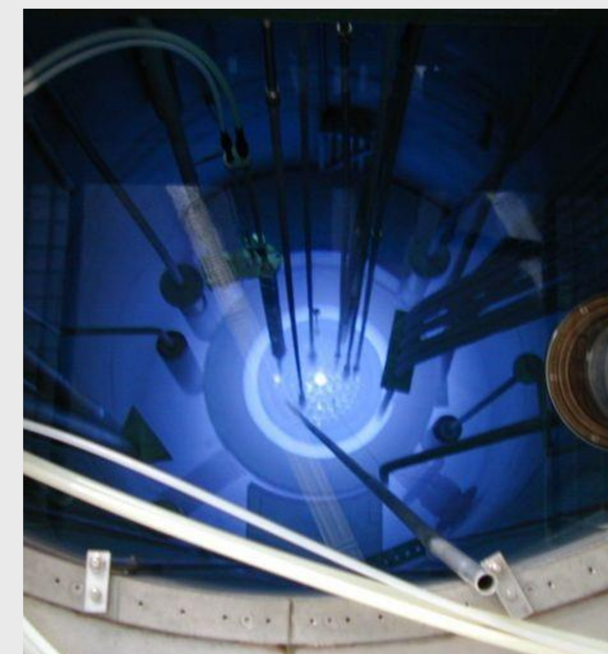
Samples & Irradiation

- Planar diodes
- 50 µm n-epi
- 3 x 3 mm² area
- $1.5 \cdot 10^{14}$ cm^{-3} N_{eff}
- V_{dep} : 325V
- Run 13575 IMB-CNM-CSIC [3]

Neutron Irradiation at ATI Vienna [4]

- Fluences: $5 \cdot 10^{14}$ n_{eq}/cm^2
  $1 \cdot 10^{15}$ n_{eq}/cm^2
  $5 \cdot 10^{15}$ n_{eq}/cm^2
  $1 \cdot 10^{16}$ n_{eq}/cm^2


Device under microscope


ATI Triga Mark II reactor in Vienna [5]

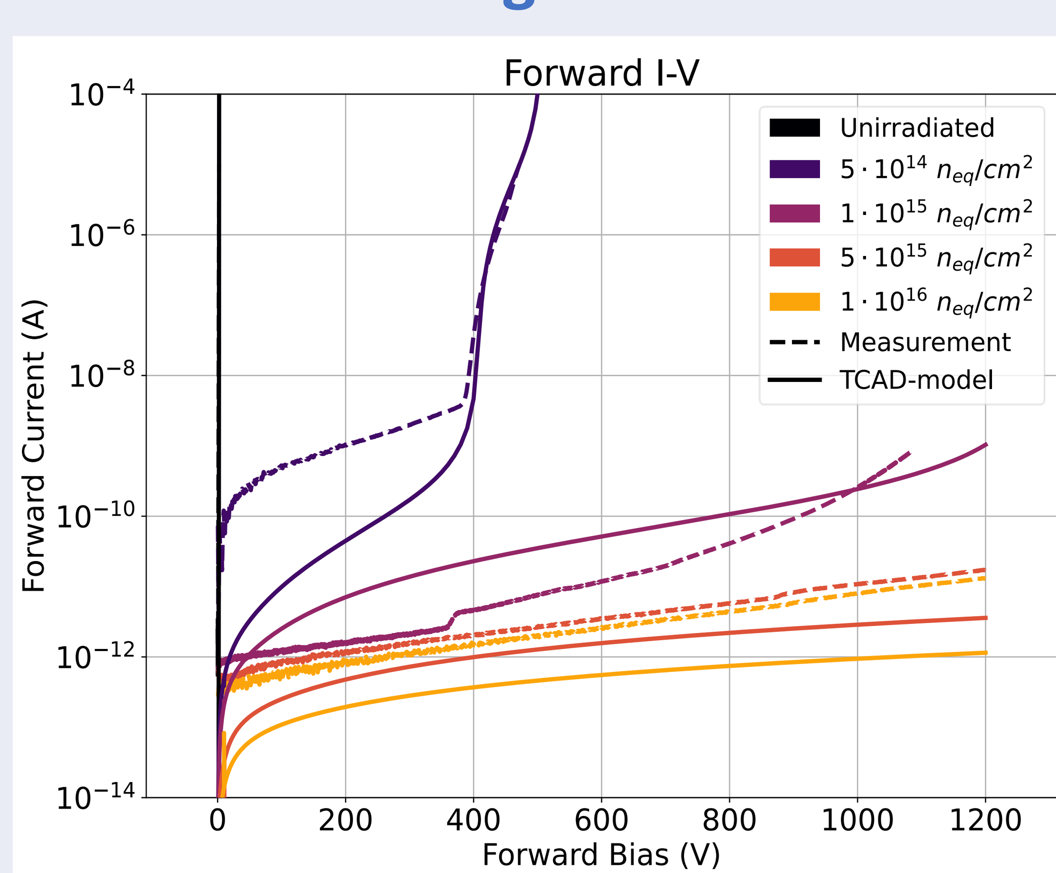
Radiation-induced trap model for TCAD simulation

Optimized trap model parameters

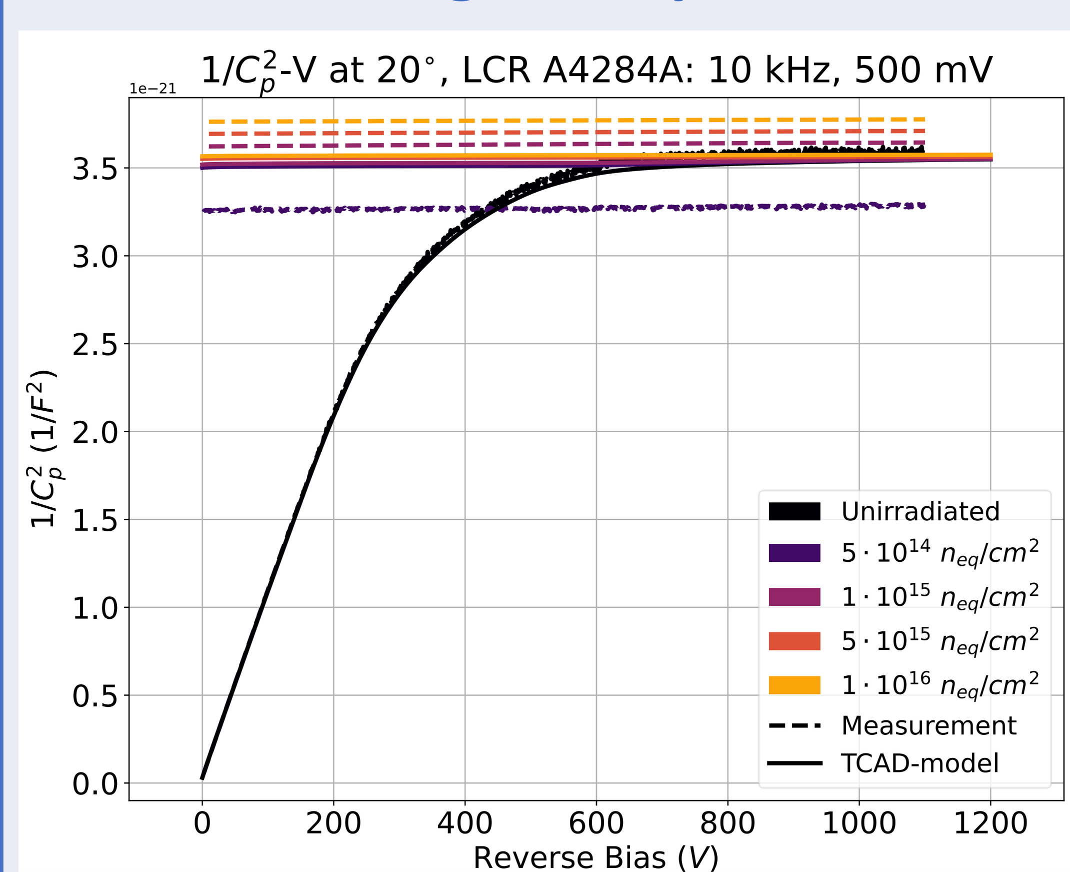
Trap	Type	Energy [eV]	σ_e [cm²]	σ_h [cm²]	N [cm^{-3}]
$Z_{1,2}$	Acceptor	E_C - 0.67 [6]	$2.0 \cdot 10^{-14}$ [6]	$3.5 \cdot 10^{-14}$ [6]	$5.0 \cdot \Phi$ [7]
$EH_{6,7}$	Donor [8]	E_C - 1.60 [9, 10]	$9.0 \cdot 10^{-12}$ [10]	$3.8 \cdot 10^{-14}$ [9, 10]	$1.6 \cdot \Phi$ [7]
EH_4 [11, 12]	Acceptor	E_C - 1.03 [11, 12]	$5.0 \cdot 10^{-13}$ [12]	$5.0 \cdot 10^{-14}$ [12]	$2.4 \cdot \Phi$ [7]
B [13]	Donor	E_V + 0.28 [14]	$2.0 \cdot 10^{-15}$ [15]	$2.0 \cdot 10^{-14}$ [7]	$1.0 \cdot 10^{14}$
D [13]	Donor	E_V + 0.54 [14]	$2.0 \cdot 10^{-15}$ [15]	$2.0 \cdot 10^{-14}$ [7]	$1.0 \cdot 10^{14}$

- 4H-SiC simulation challenging:
  → Low $N_{Carrier}$ (Bad convergence)
  → Unestablished model parameters
- Irradiated epi becomes intrinsic due to introduced traps [16-19]
- Software: Sentaurus TCAD [10]
- Initial guesses using literature
- Trap parameters optimized to fit experimental results (IV, CV, CCE)
- Broader irradiation studies pending

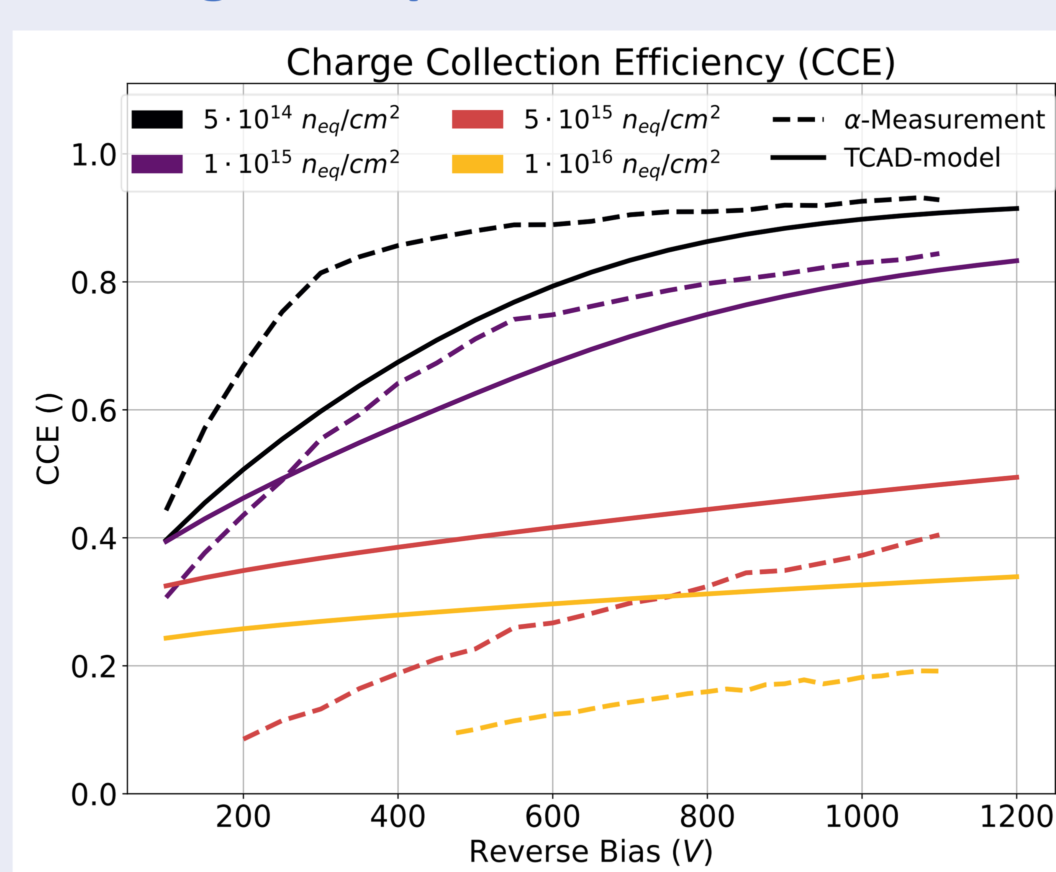
Forward biasing after irradiation



"Flattening" of capacitance

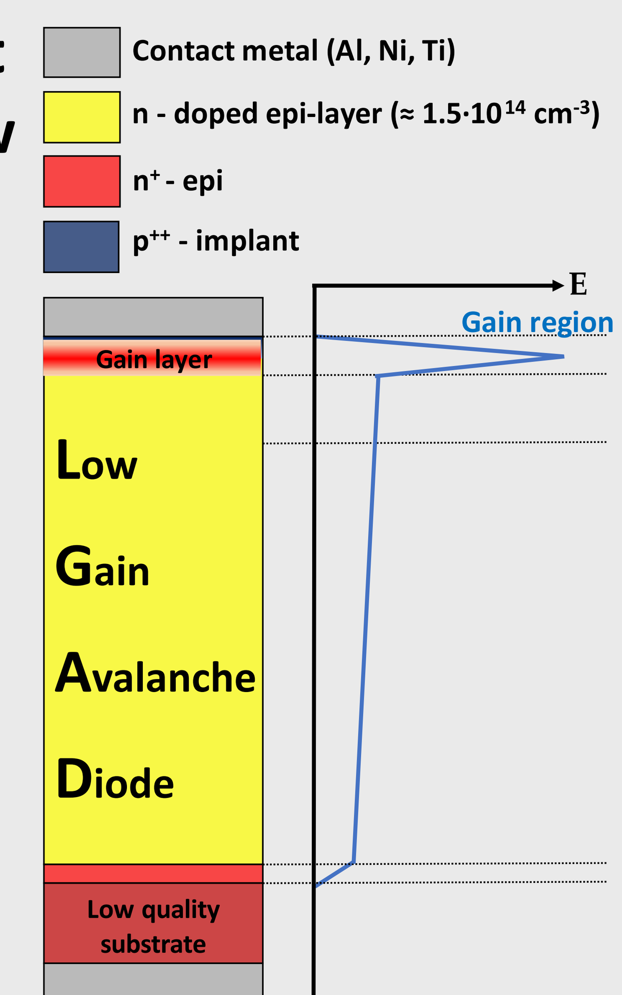


Signals up to Φ = 10^{16} cm^{-2}

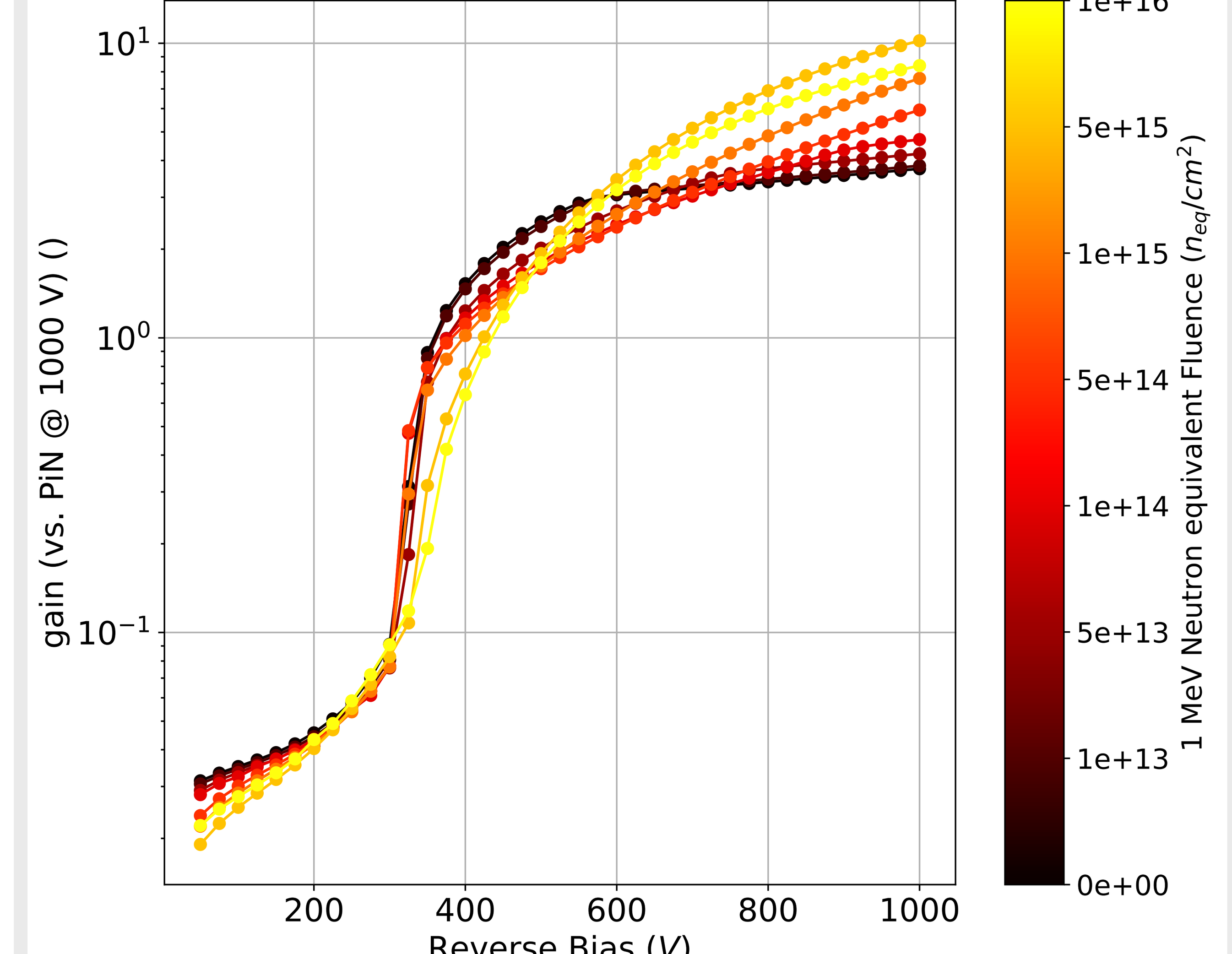


4H-SiC LGADs

- Epi-thickness of current 4H-SiC diodes is too low to measure MIPs
- LGADs increase signal via internal charge amplification
- TCAD design for RD50 common project [20]
- Expected gain: 2-10
- Processing end of 2024



- Applied developed radiation model to current LGAD-design
- Peak field at gain region increases with irradiation
- Slight increase of signal gain predicted



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