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Silicon sensor qualification and electric field simulations for the BCM1F detector at CMS

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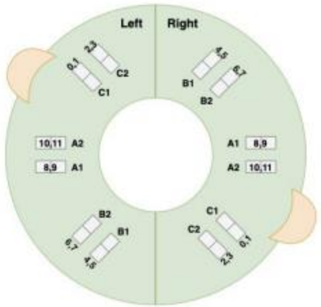
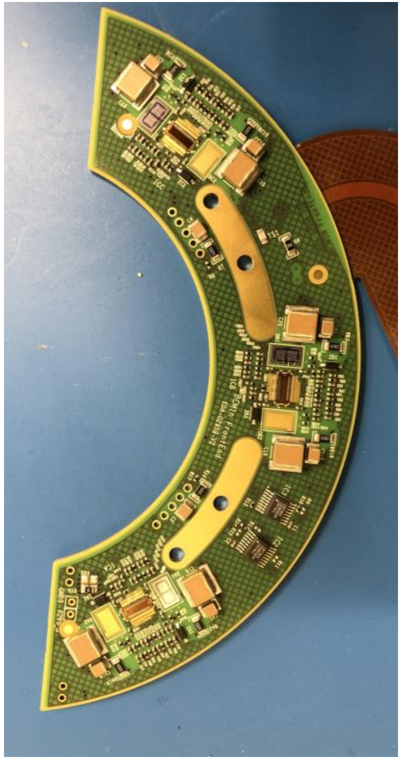
Fast Beam Condition Monitor /BCM1F

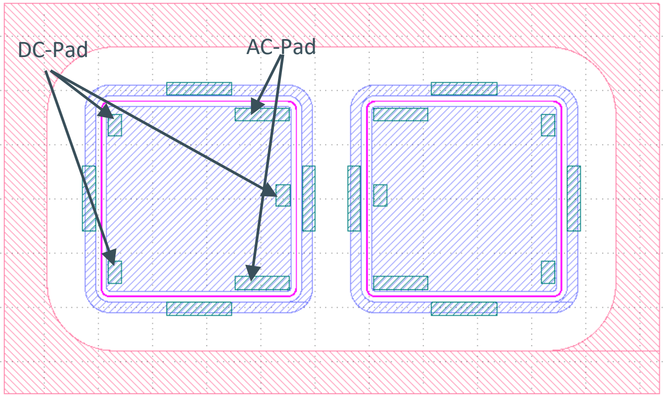
- Detector dedicated to the luminosity measurement and monitoring of beam induced backround
- 24 Si-double-sensors mounted on two rings around the beampipe
- 1.8m from interaction point

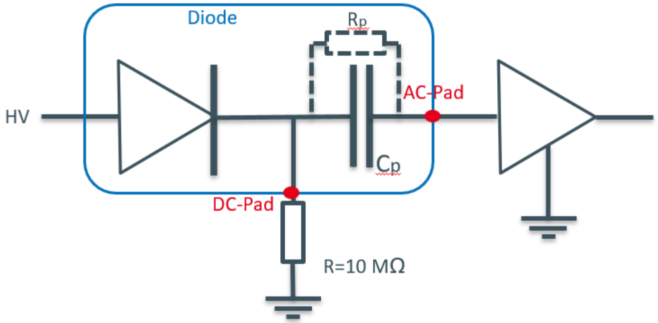




Sensor design

- n-on-p sensor
- 1.7x1.7 mm² sensor area
- Produced as part of the CMS phase-2 tracker wafer.





Task

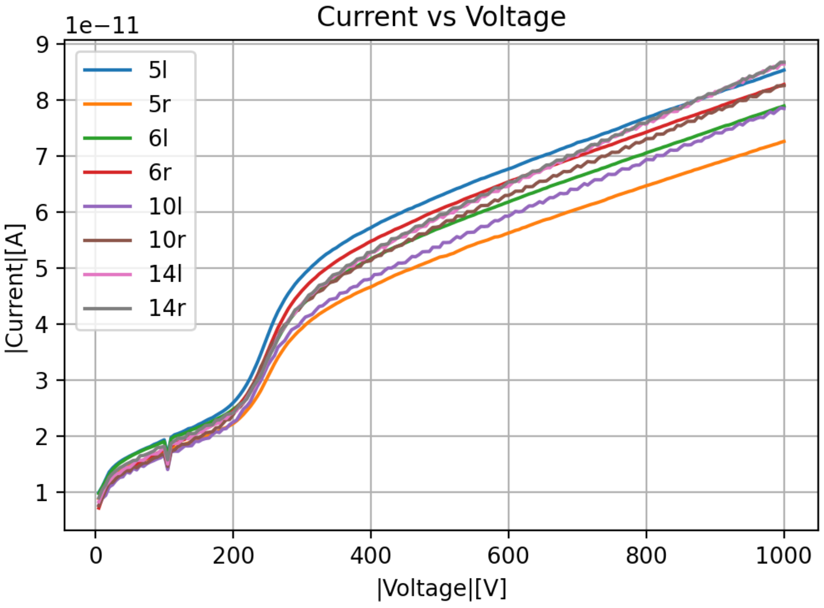
- Inspection of 30 newly produced siliconsensors as backup for the currently installed BCM1F-system

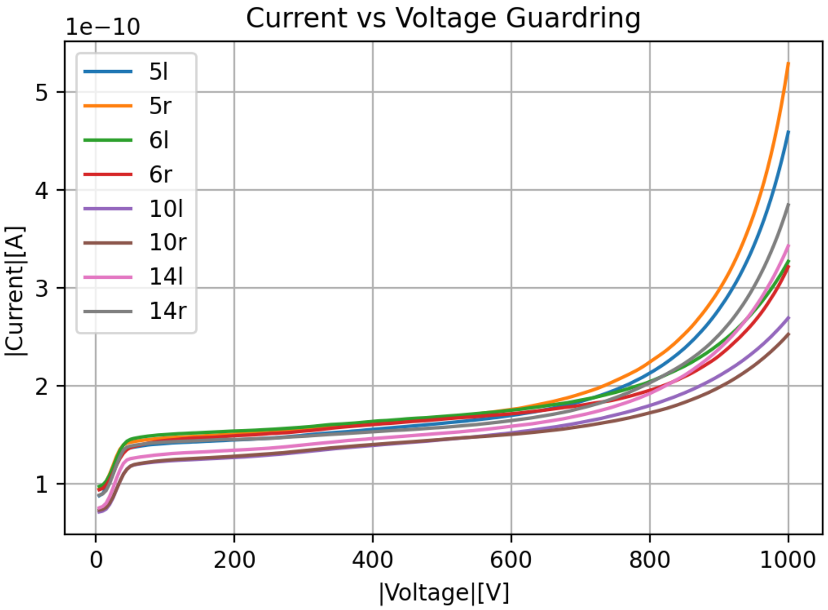
Therefore the following properties were measured:

- Current vs Voltage
- Capacitance vs Voltage
- Capacitance and Resistance between the AC and DC-Pad

Current vs Voltage

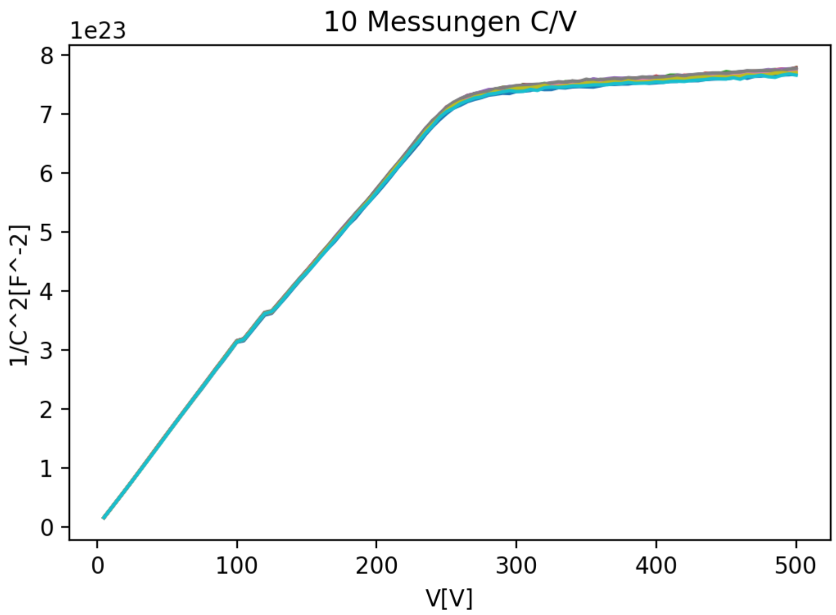
- Low variation between the different measurements
- Small current for 1000V, no breakthroughs

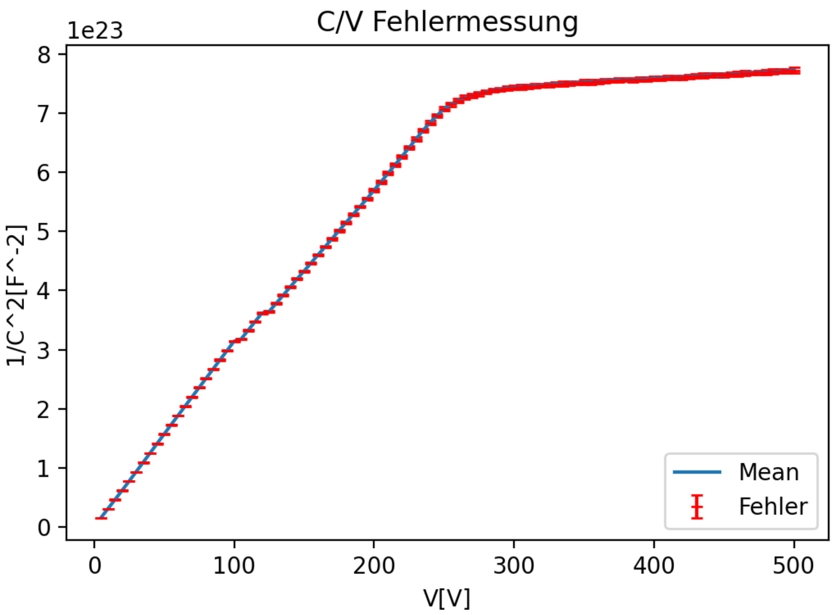




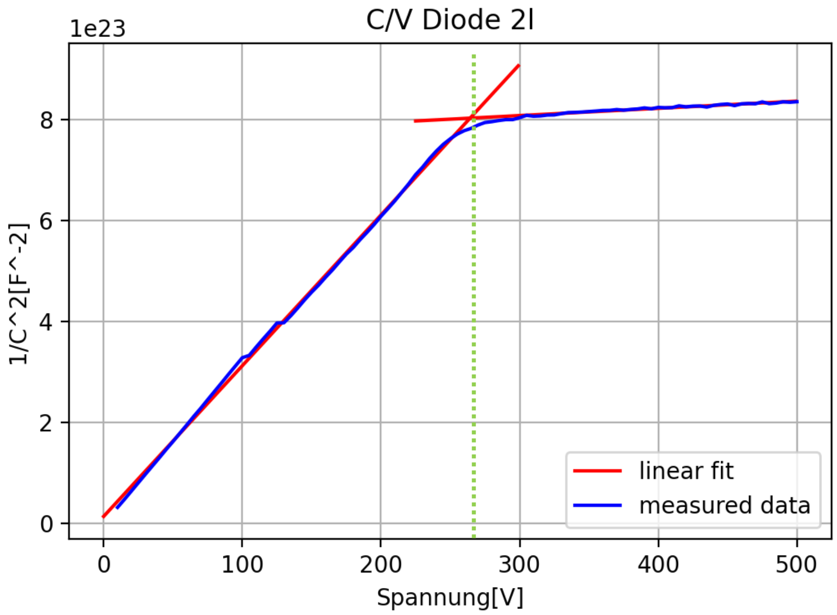
Error measurement C/V-curve

- Low varianz between measurements for the same diode





Determination of the depletion voltage

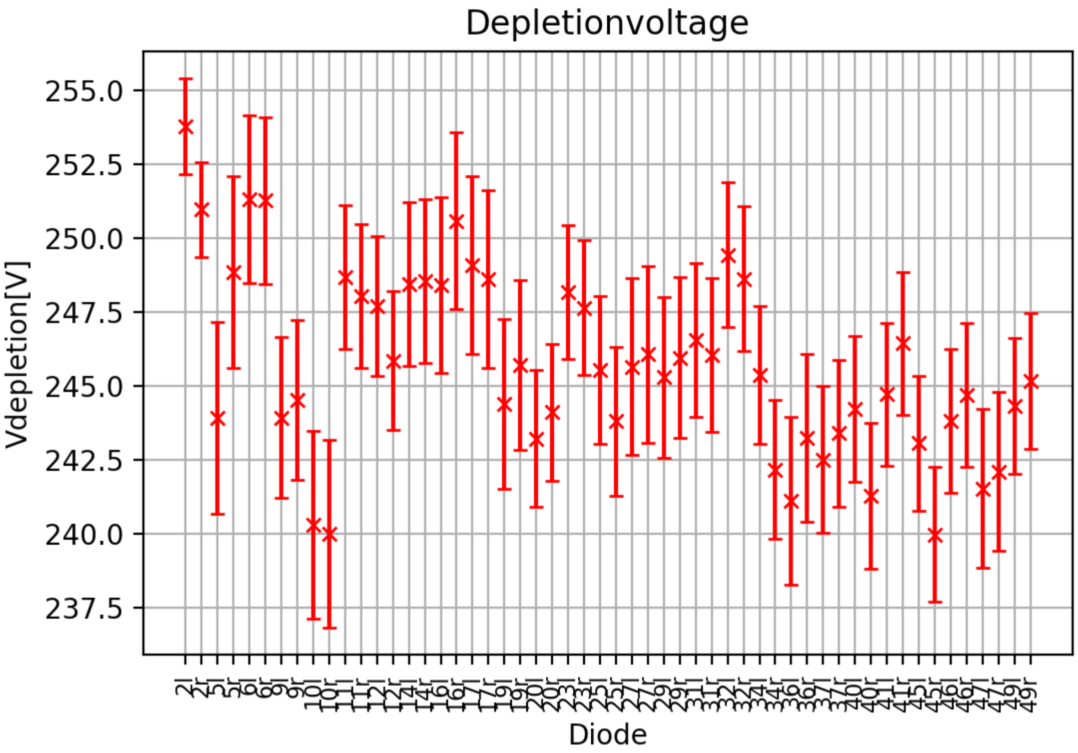


Width of depleted area: $w \propto \sqrt{V}$

➔ V ∝ $^1/_{C^2}$ for $V < V_{dep}$

V_{dep} corresponds to the intersection of the two linear fits

V_{dep} for different diodes



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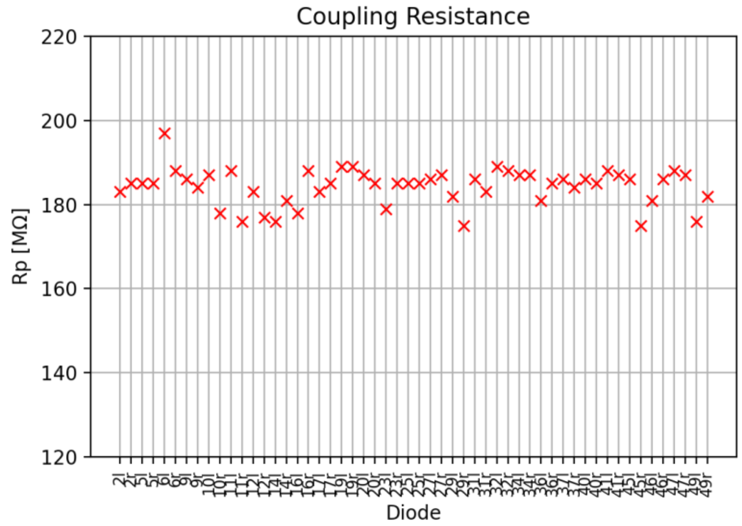
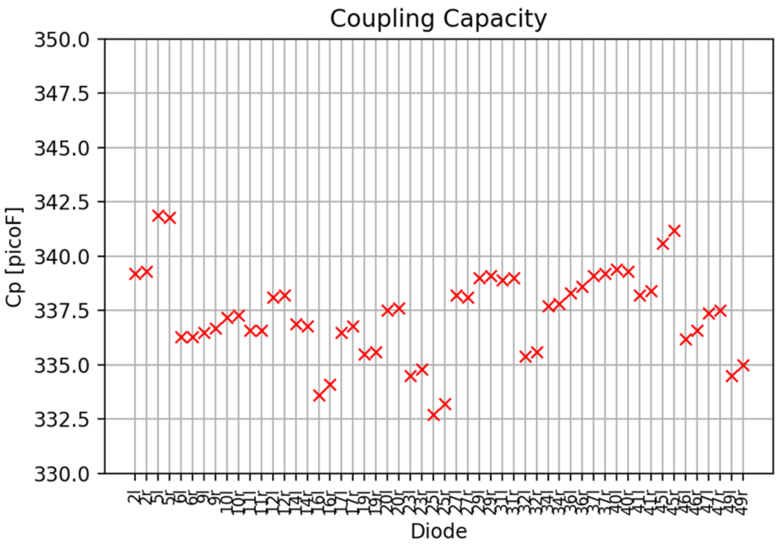
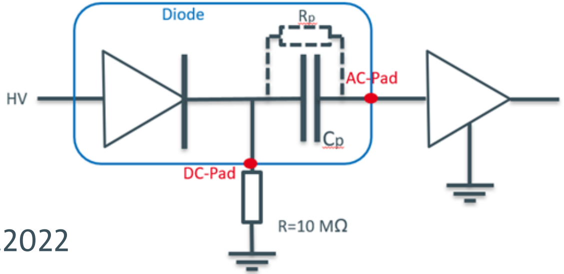
Coupling Capacity and Resistance



- $R_c \gg R_{external}$ = 10 MΩ

→ most of the leakage current drains to the ground via the DC-pad





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Measurement results

- 27/30 A-grade Si-diodes
- $V_{dep} \sim 246$ V
- $C \sim 1{,}6$ pF
- $R_p \sim 184$ MΩ
- $C_p \sim 337$ pF

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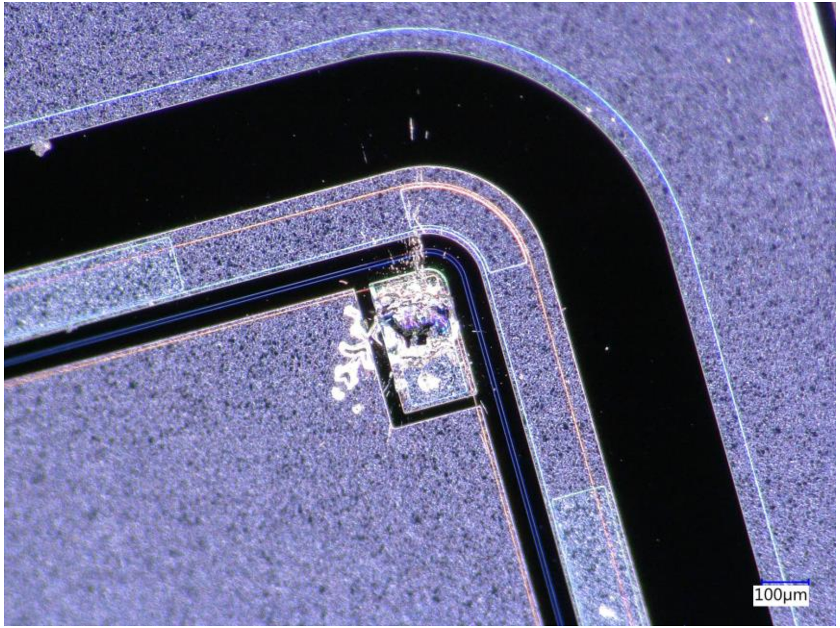
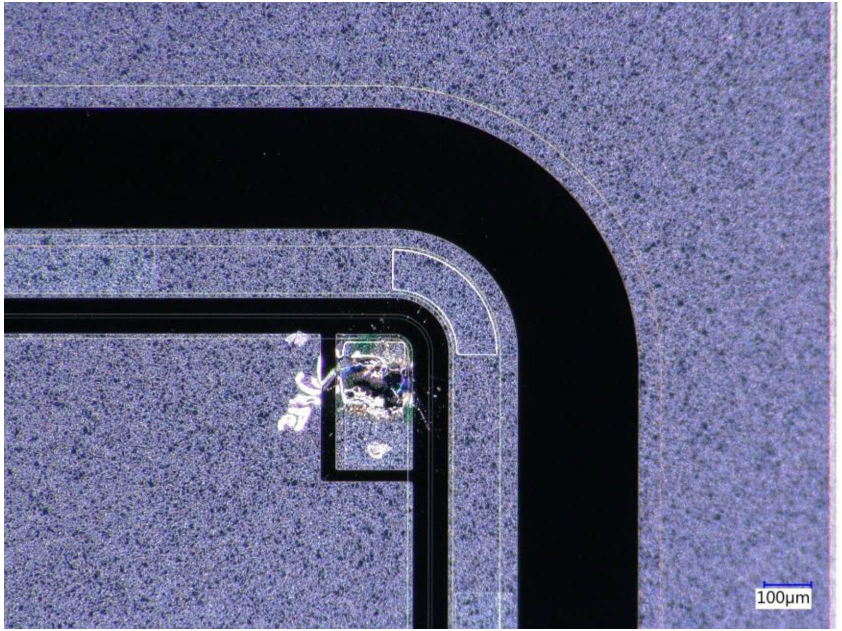
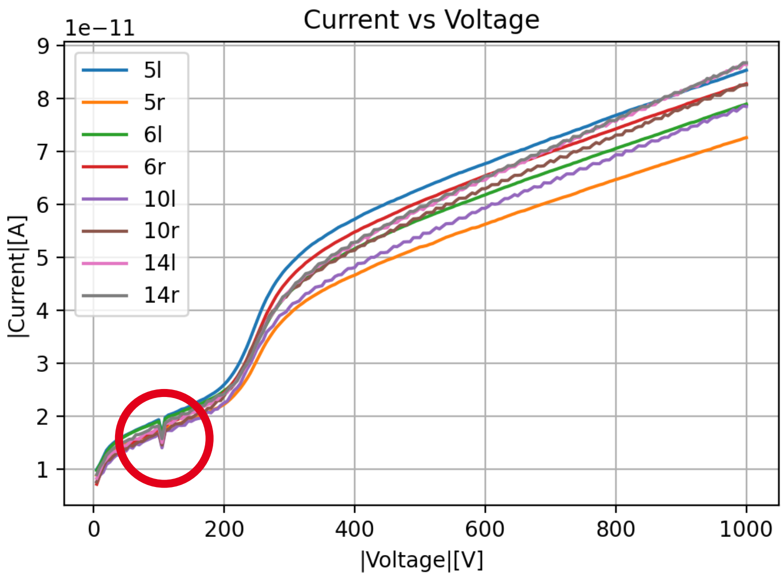
Problem "Explosion" of the DC-Pad

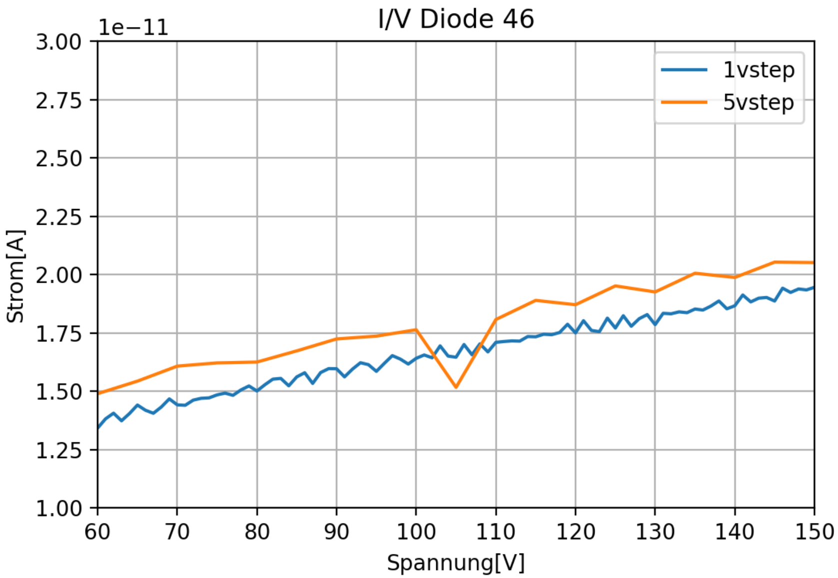




- "Explosion" of the DC-pad after a successful IV-measurement on two different diodes
- possibly due to too fast ramp-down voltage

Bumps I/V



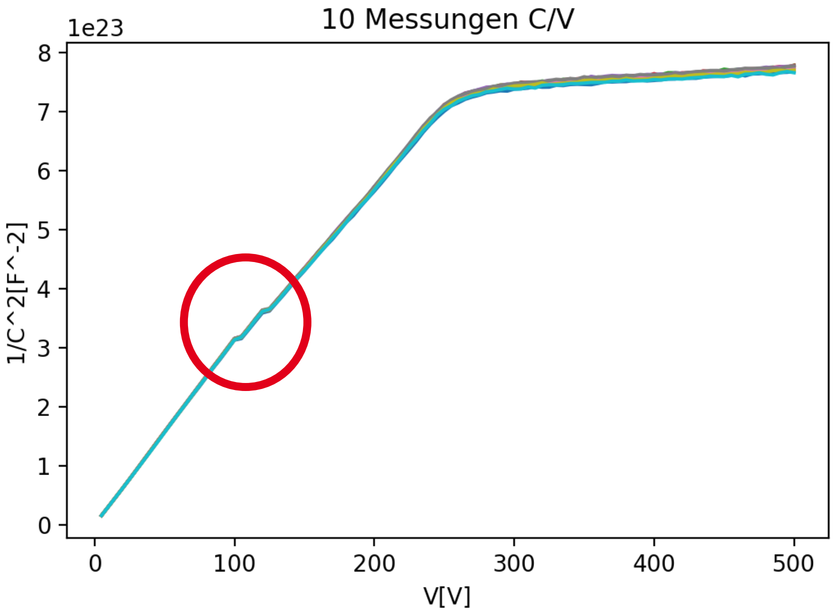


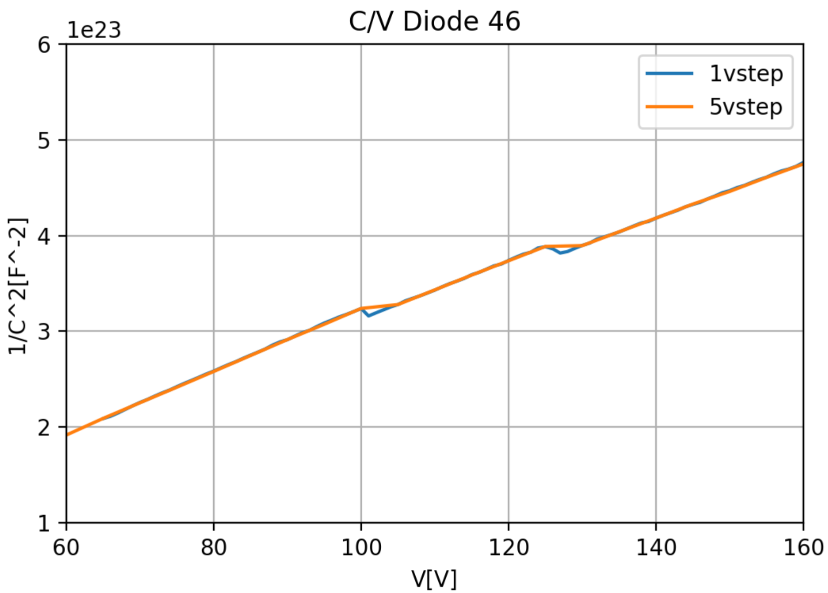
$\Delta t = 5s$, $\Delta t = 1s$

- Bump disappears for smaller volt steps and larger time intervals between measurements

→ probably caused by the voltage source, when switching between different voltage ranges

Bumps C/V

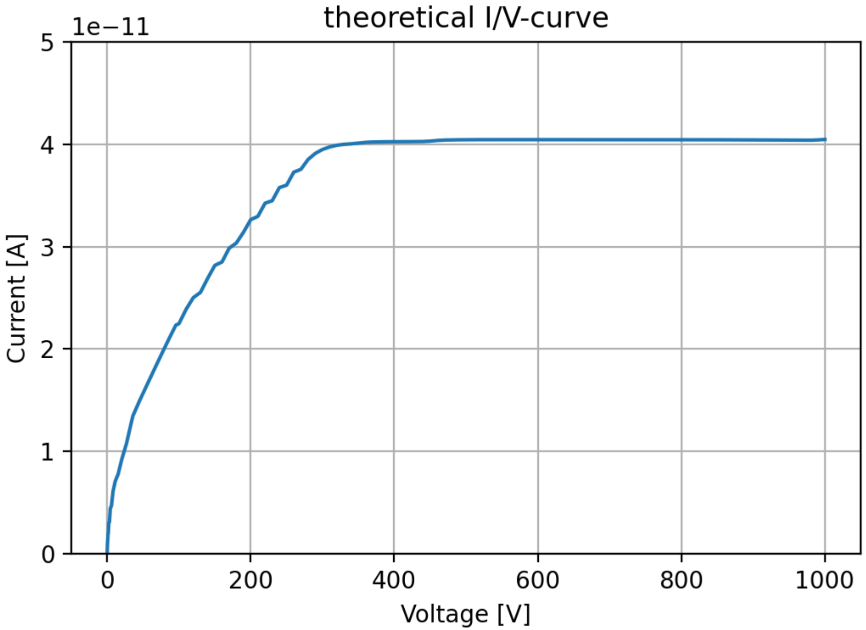




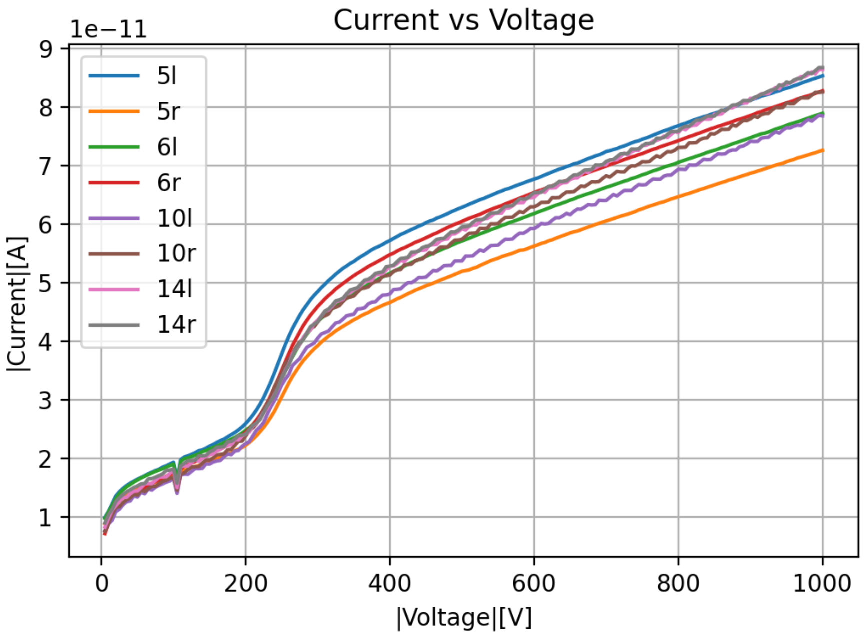
$\Delta t = 5s$, $\Delta t = 1s$

Ongoing Work: Theory vs Measurement

Expectation (Simulation of ideal sensor)

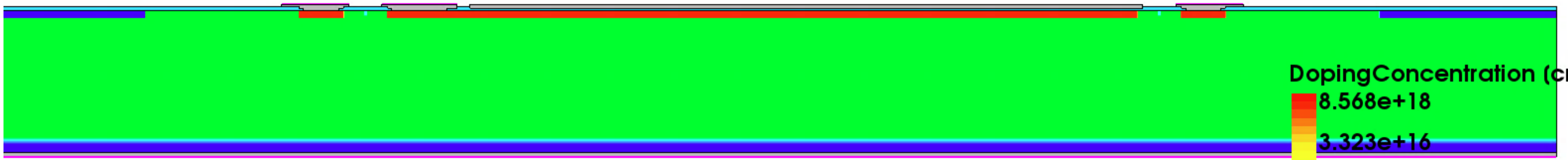


Measurement

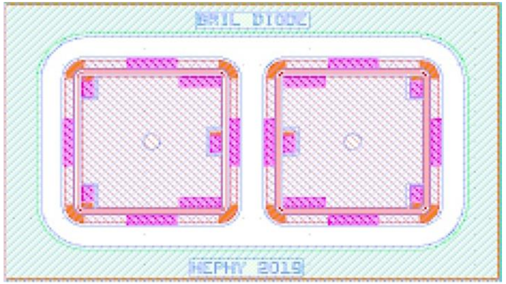


TCAD Simulation

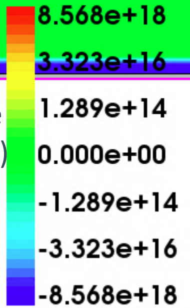
- finite element simulation of the electrical behaviour of the diode
- Goal: reconstruction and understanding of the IV curves



- 2D-doping profile (Data needs to be rescaled to 3d)

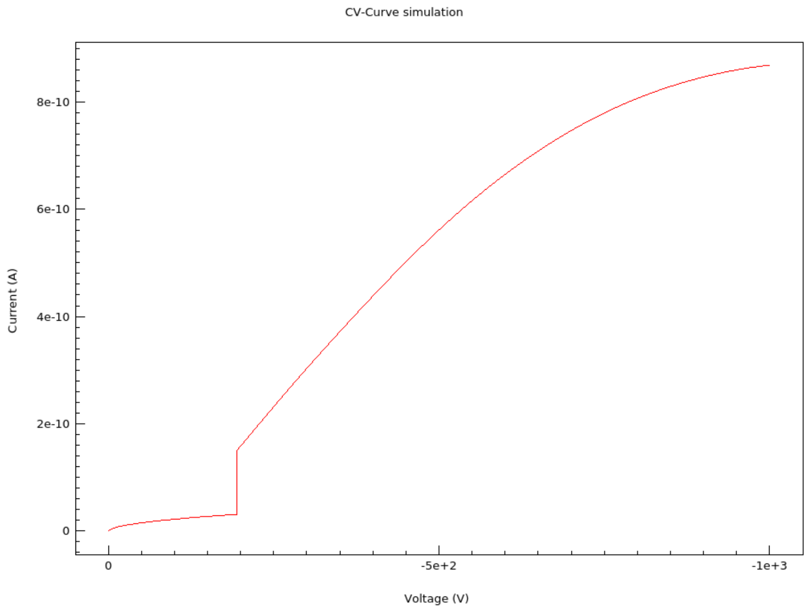


(doping profile sizes are NOT accurat in this plot)

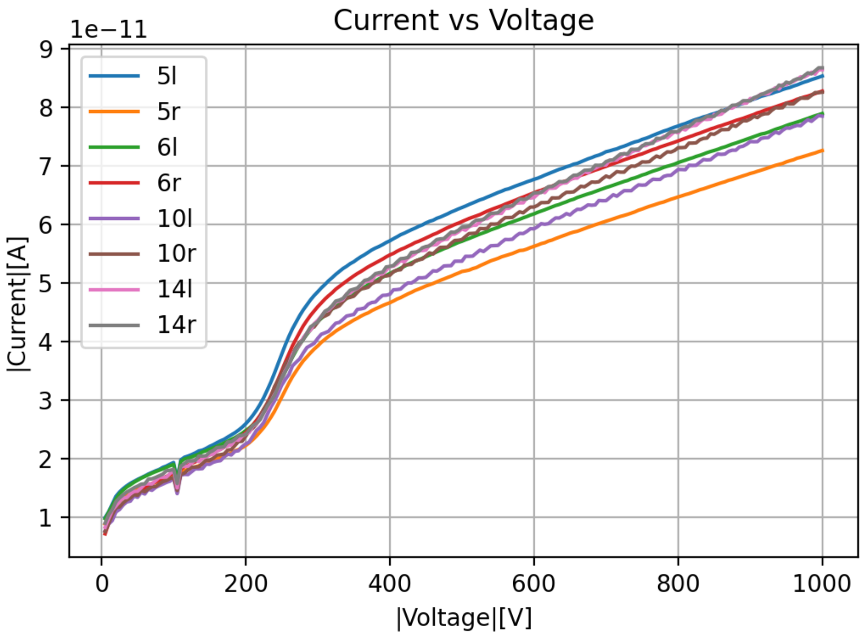


Simulation vs Measurement

Simulation



Measurement



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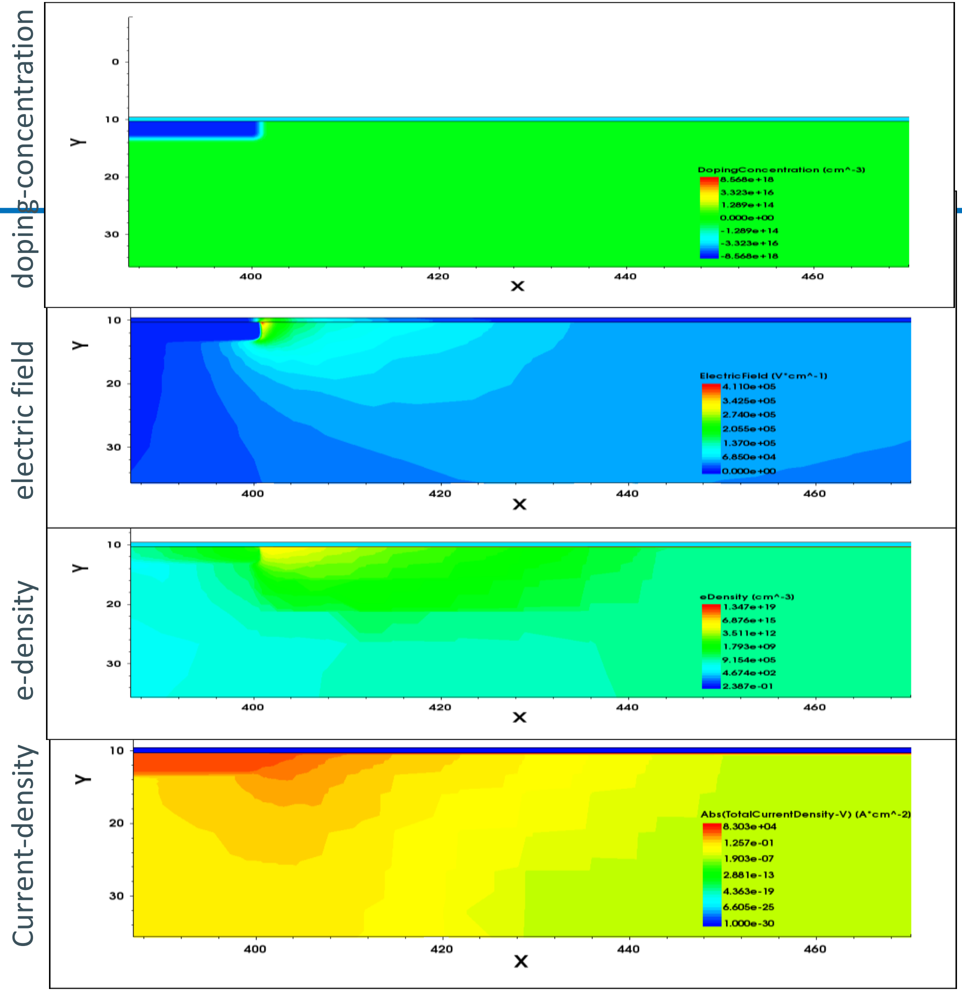
Hypothesis

- High E-field on the Edge-implant edge

→ Charge generation

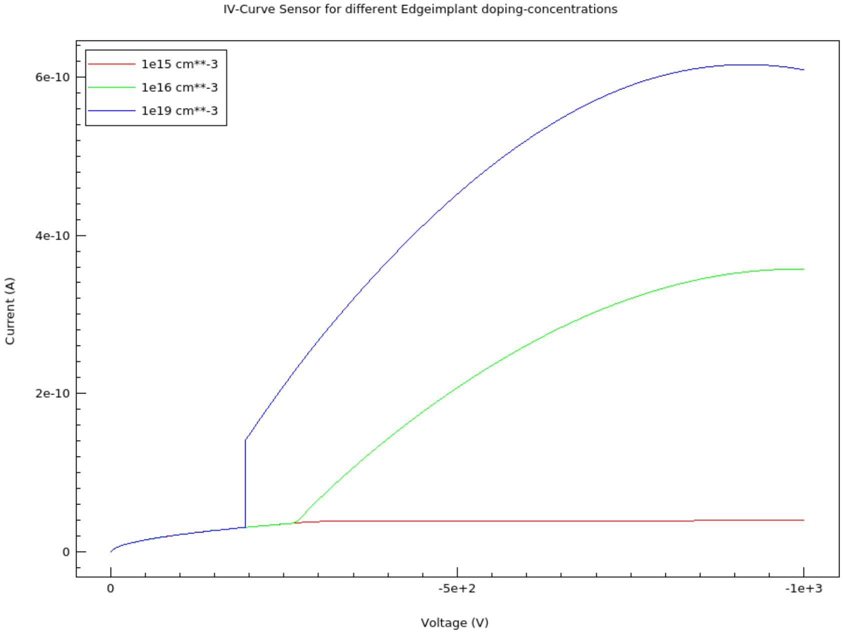
→ High current density underneath the positiv charged SiO

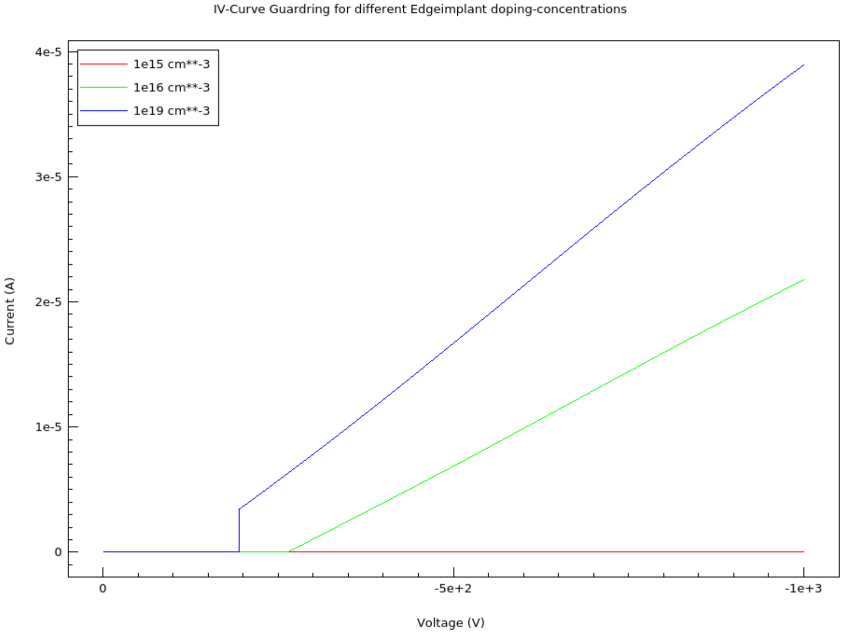
- Most of it is absorbed by the guardring but some current reach the DC-Pad



Pro Hypothesis

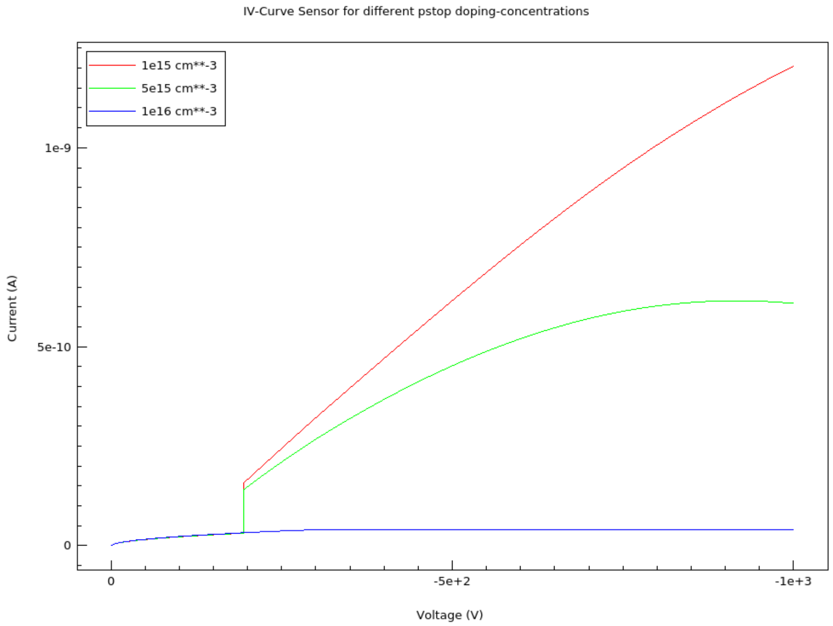
- Phenomenon becomes more exteme with higher edge-implant doping concentrations
- Disappears completely at lower doping concentrations

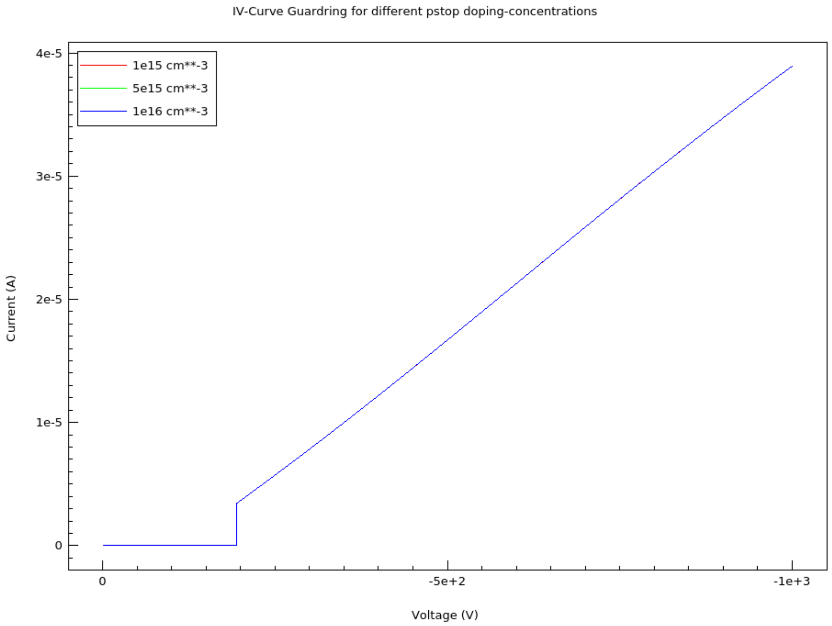




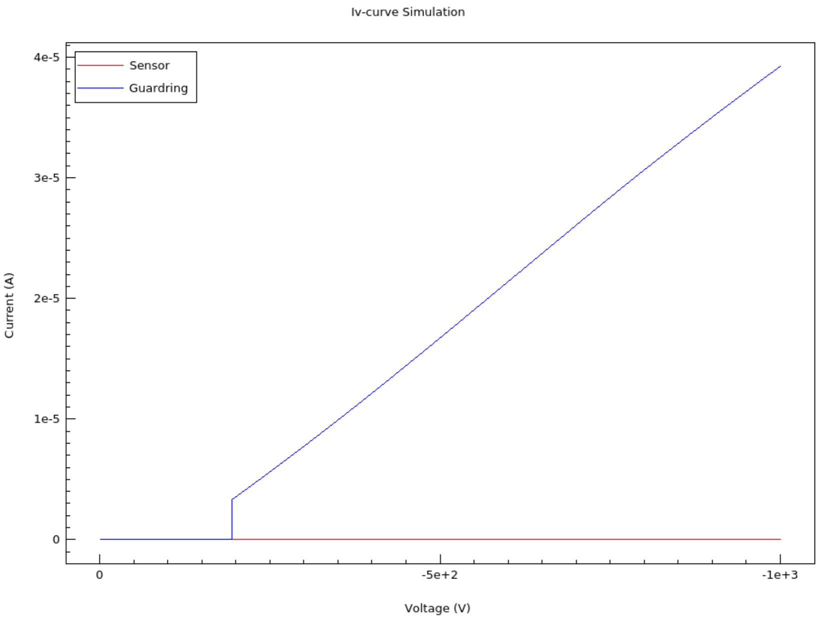
Pro Hypothesis

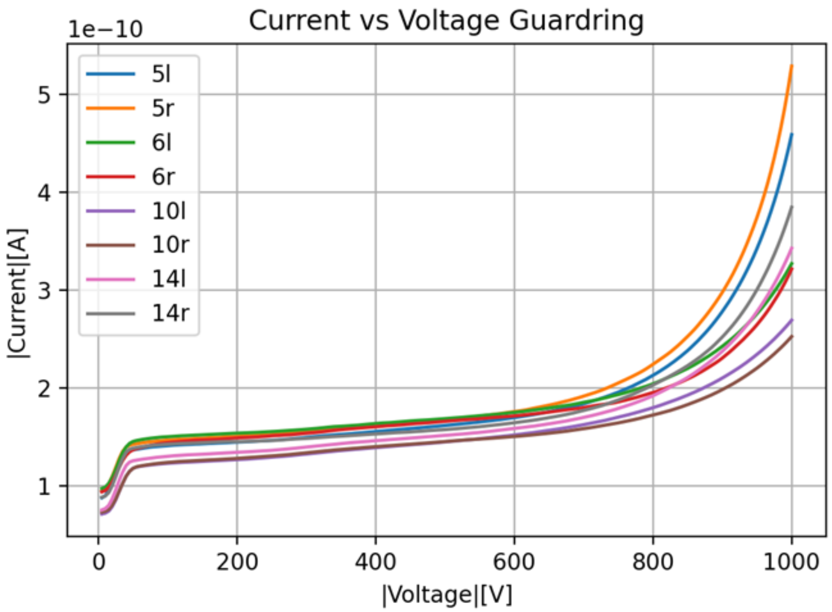
- Phenomenon becomes more exteme with lower pstop-implant doping concentrations
- Guardring Current is independent from the pstop doping concentrations





Contra Hypothesis





- simulation does not fit to the guardring IV-measurement
- the ratio of guardring current to sensor current is not correct

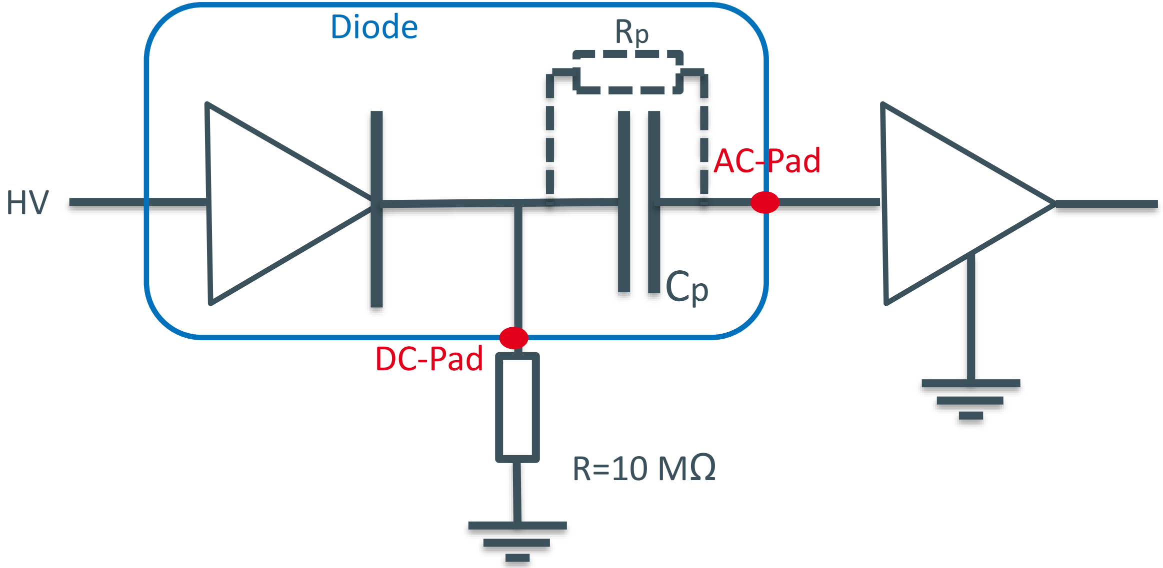
Ongoing Work

- IV-curve does not fit for the Guardring
- Simulated current is way to high

  → next step: increase carrier lifetime parameter (should reduce current)
- Rescale to 3D
- CV-curve simulation

Thank you for listening

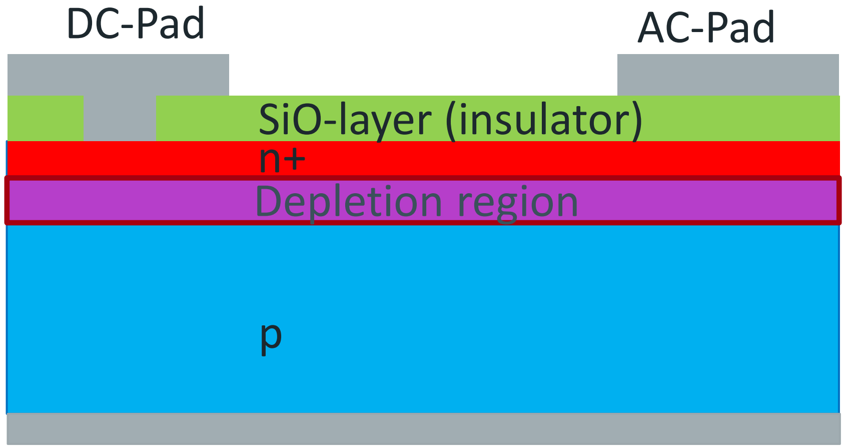
Si-Diode circuit



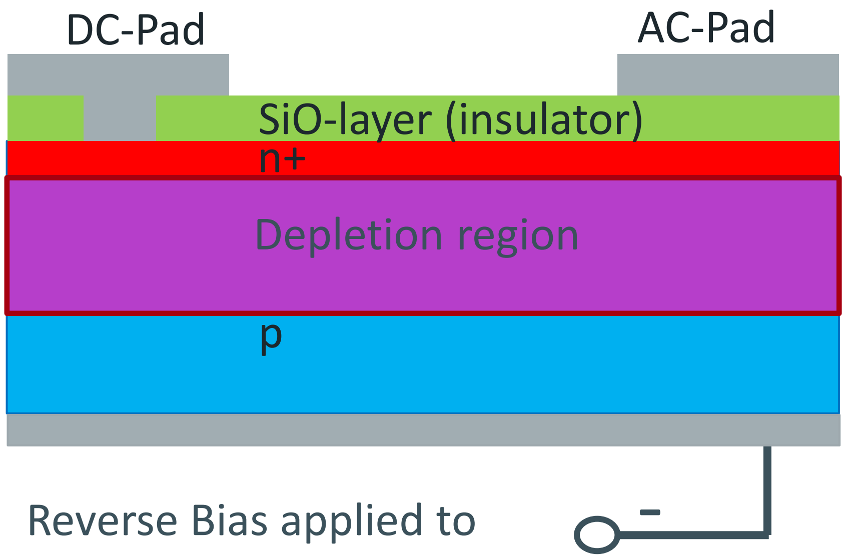
Doping Concentrations [cm^{-3}]

- Sensor /Guardring : 1e19
- Edgeimplant : 1e19
- P-Stop : 5e15
- Backplaneimplant : 1e19
- Pbulk : 45e11

Basic structure of Si-diode



No Voltage applied



Reverse Bias applied to backplane