Electrical tests of the first n-on-p devices fabricated at ITC-irst

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for the SMART collaboration

History

SMART collaboration

End 2003 finalized the layout

May 2004 first batch of p-on-n devices on different substrates (FZ, MCz, Cz, EPI)
Various samples sent for irradiation.

August 2004 first batch of n-on-p devices with same layout
Some samples sent for irradiation.

Layout

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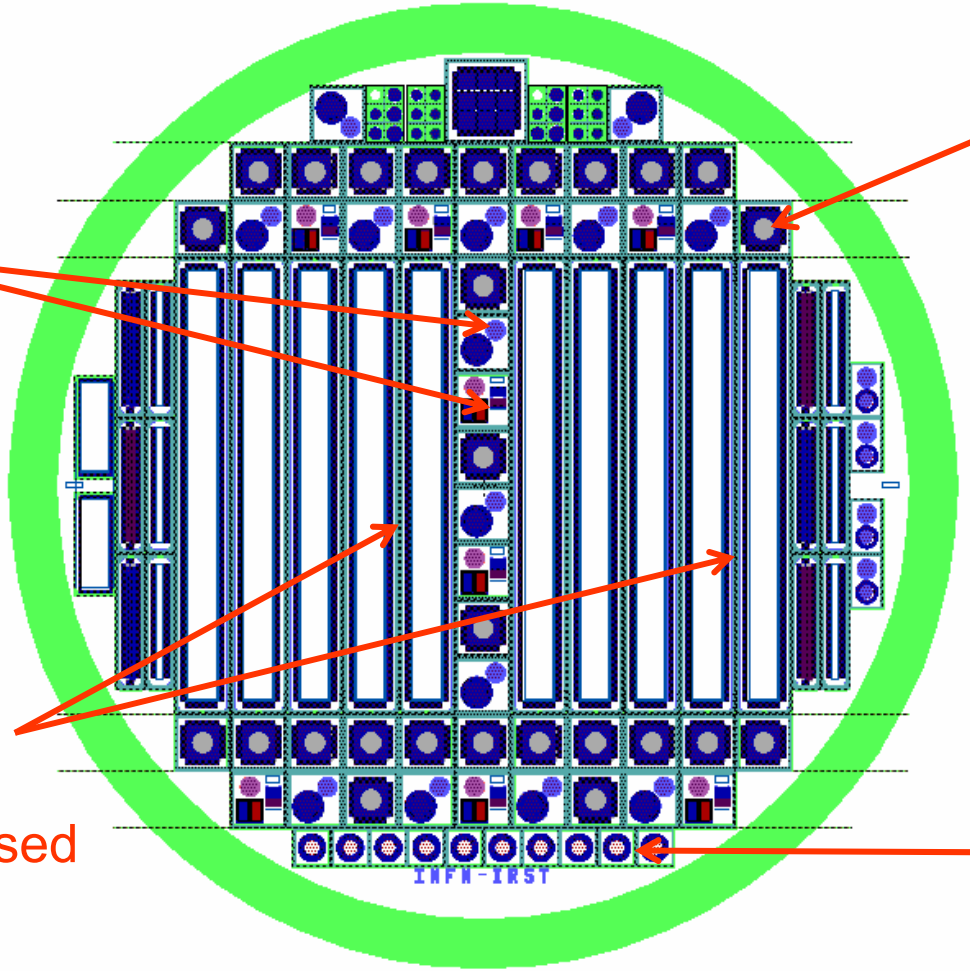
13 Test pads including diode, MOS, gated diodes, resistor, etc.



27 MG diodes

Area 13.6 mm²
die 6x6mm²

5 (pitch 50µm)
+ **5** (pitch 100µm)
Microstrip detectors AC coupled, poly-resistor biased

die 6x47mm²

10 Small MG Diodes
Area 4 mm²
die 4x4mm²

1st batch - p-on-n

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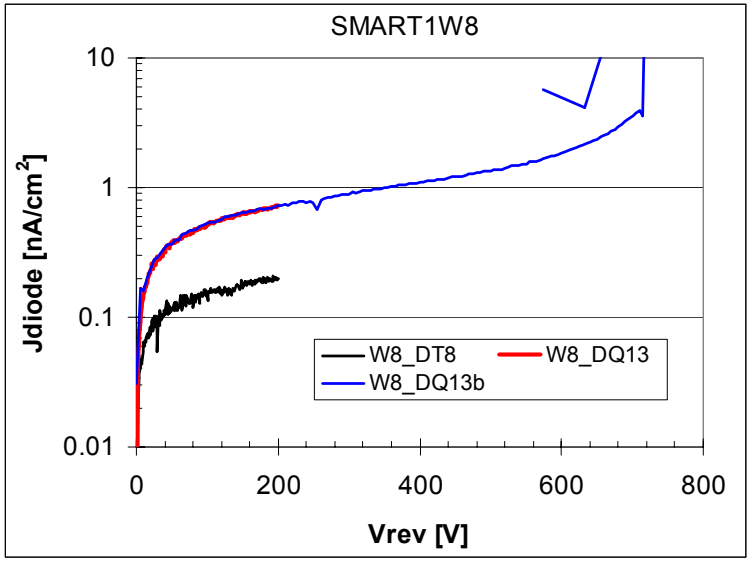
Silicon substrates

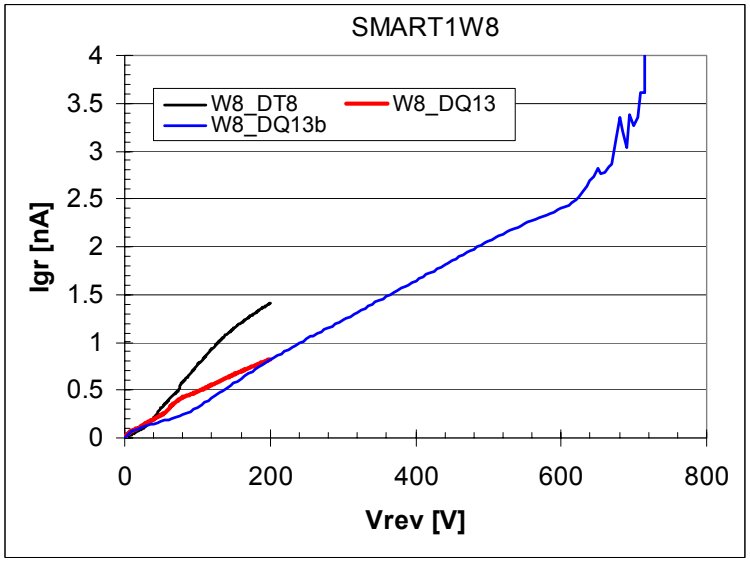
- **Fz** n-type 6 kΩ-cm <111>
- **MCz** n-type >500Ω-cm <100>
- **Cz** n-type >900Ω-cm <100>
- **Epi** (ITME) n-type <100> (50 and 75 μm)

Process splittings

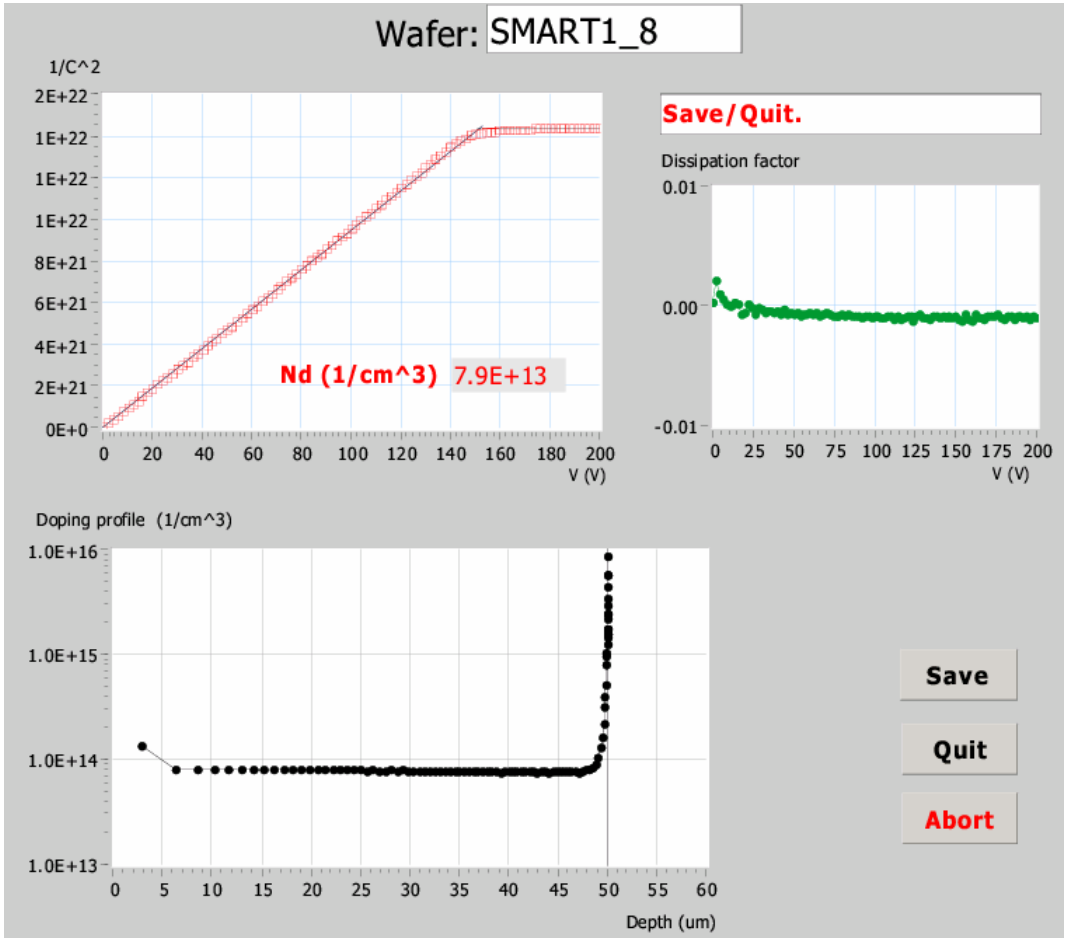
- STANDARD (LTO as passivation layer, sintering@420 °C)
- NO passivation, sintering @380°C or @350°C

Epi50

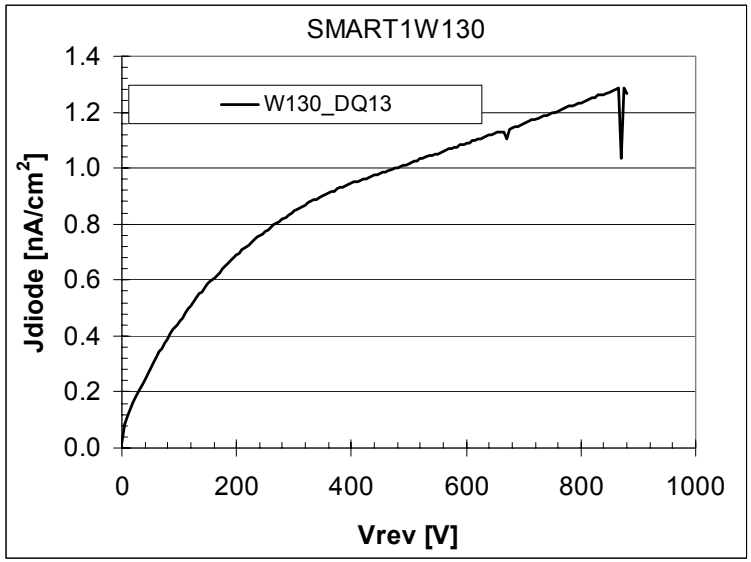


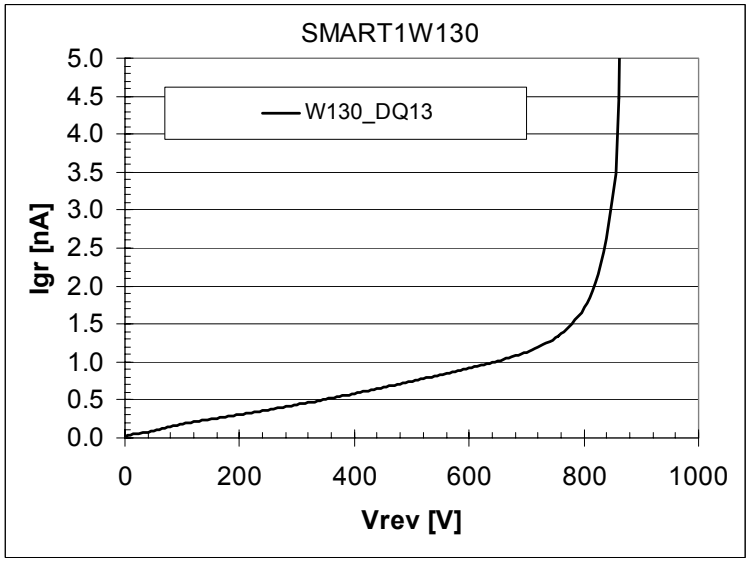


CV measurement

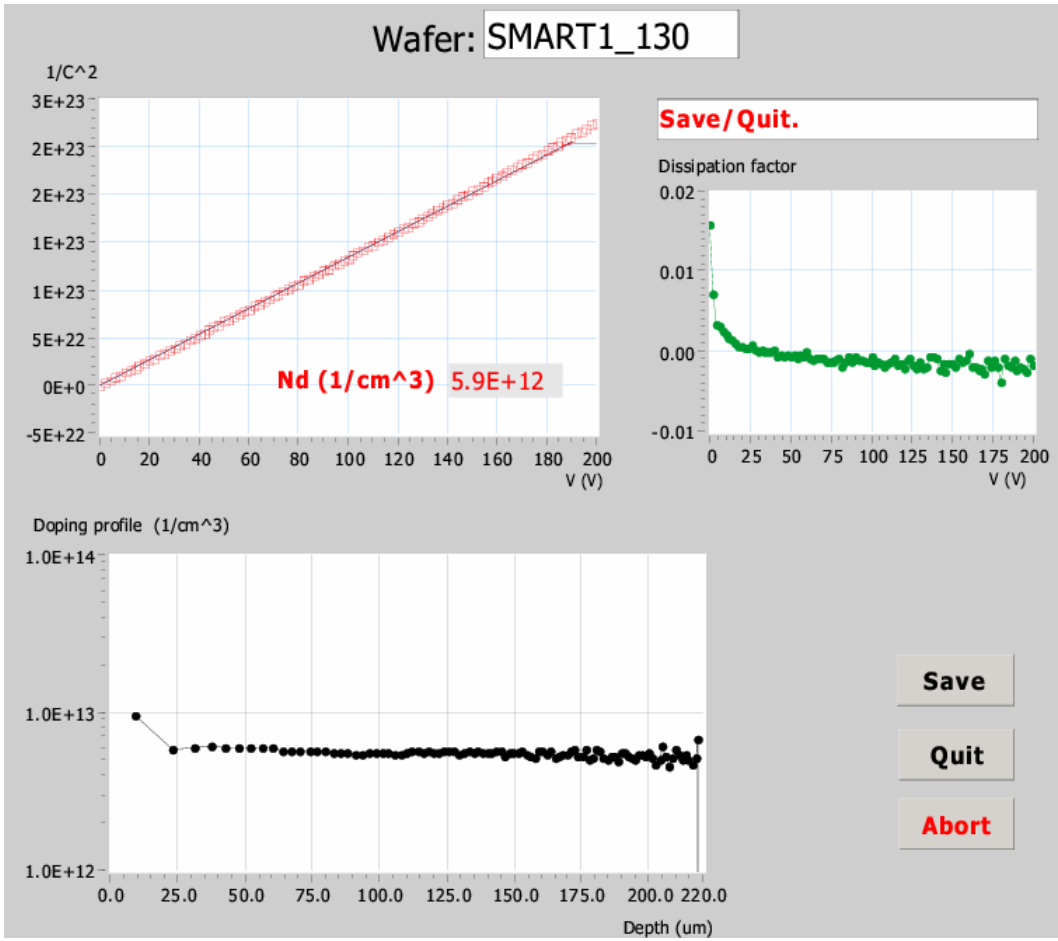


MCz - sintering@380

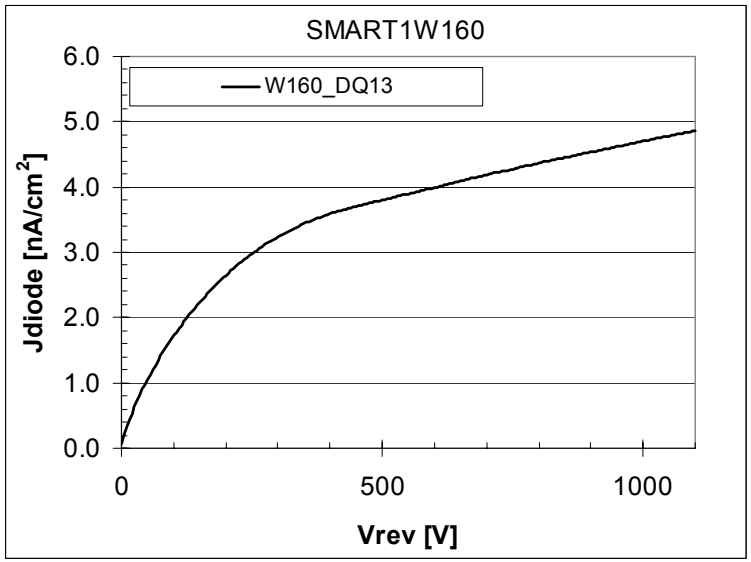


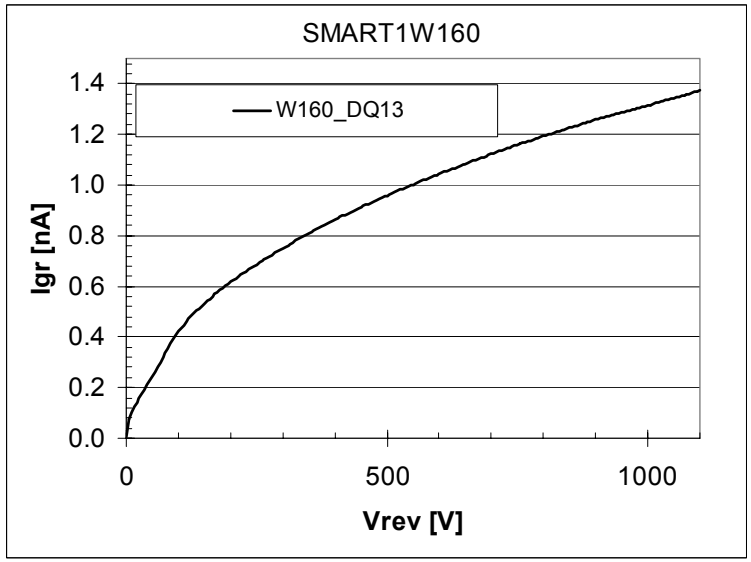


CV measurement (Vfd=400V)

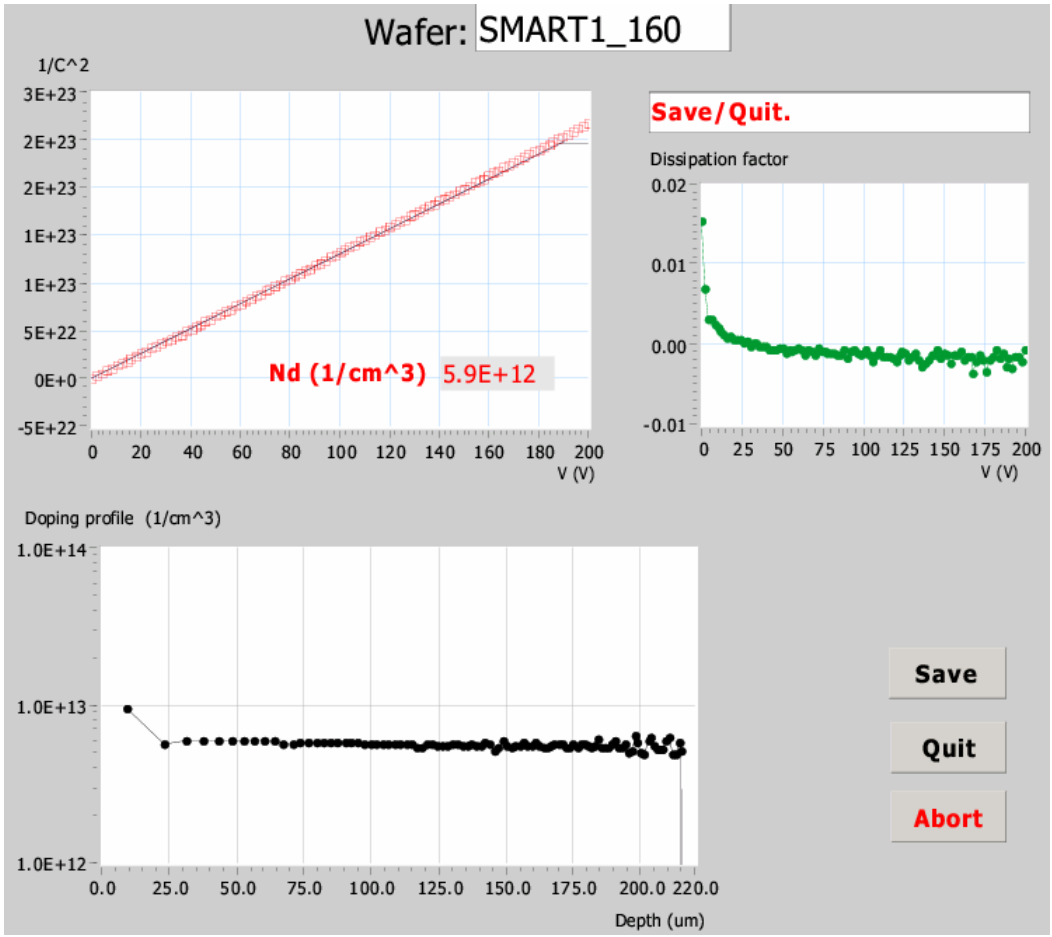


MCz 380 & TDK

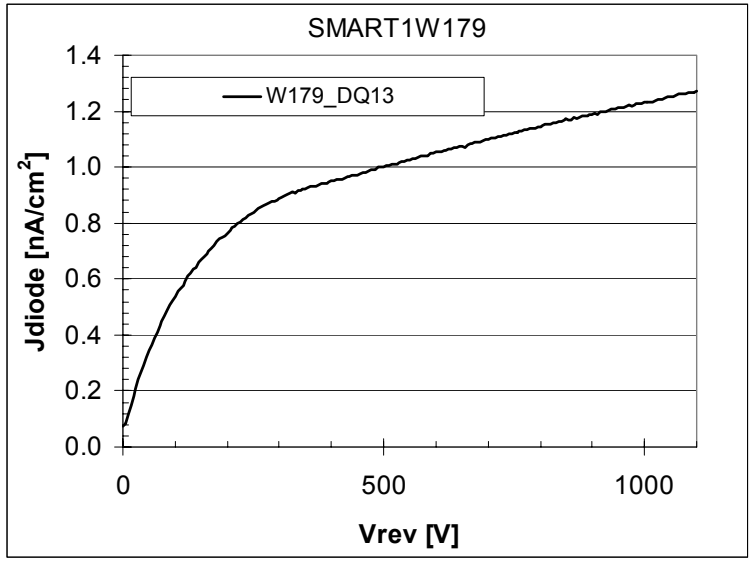


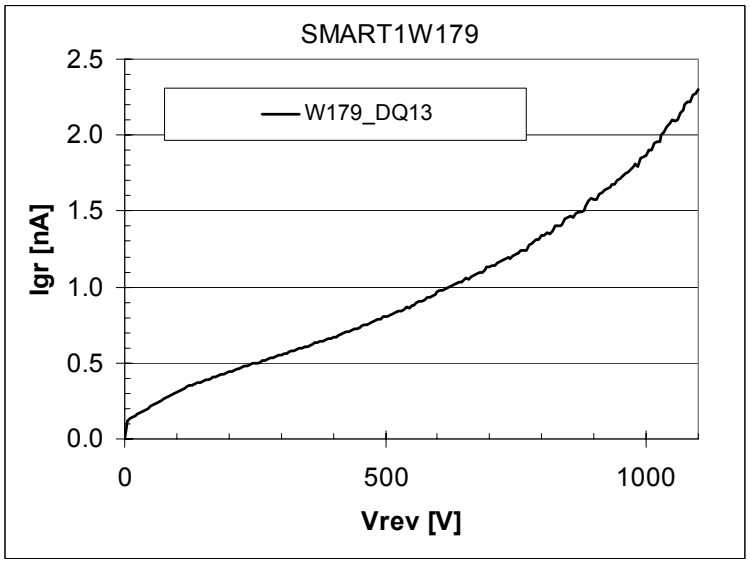


CV measurement (Vfd=400V)

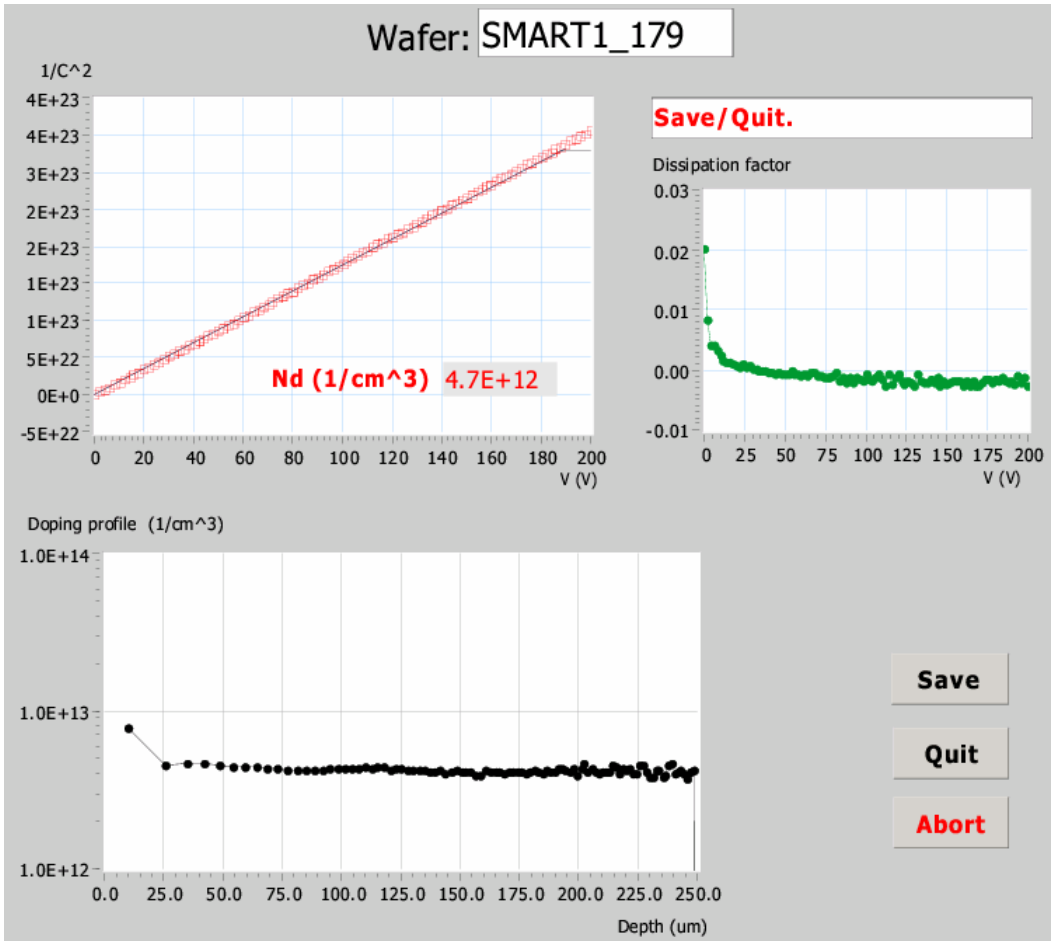


MCz 350



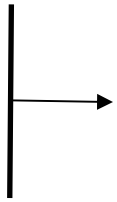


CV measurement (Vfd=350V)



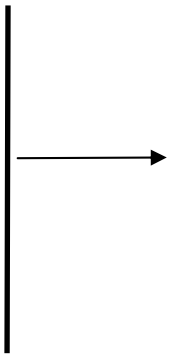
2nd batch - n-on-p

#	sub-type	comments
3	FZ 200	p-spray 3E12
3	FZ 200	p-spray 5E12



FZ <100>
p-type
>5000Ωcm
200µm

#	sub-type	comments
6	MCz	no OG; p-spray 3E12
5	MCz	no OG; p-spray 5E12

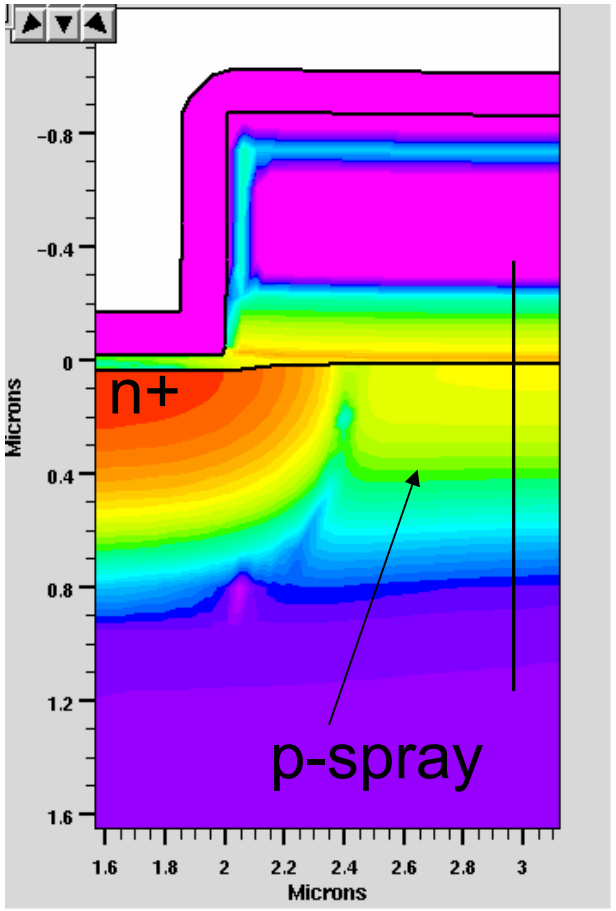


MCz <100>
p-type
>1.8kΩcm
300µm

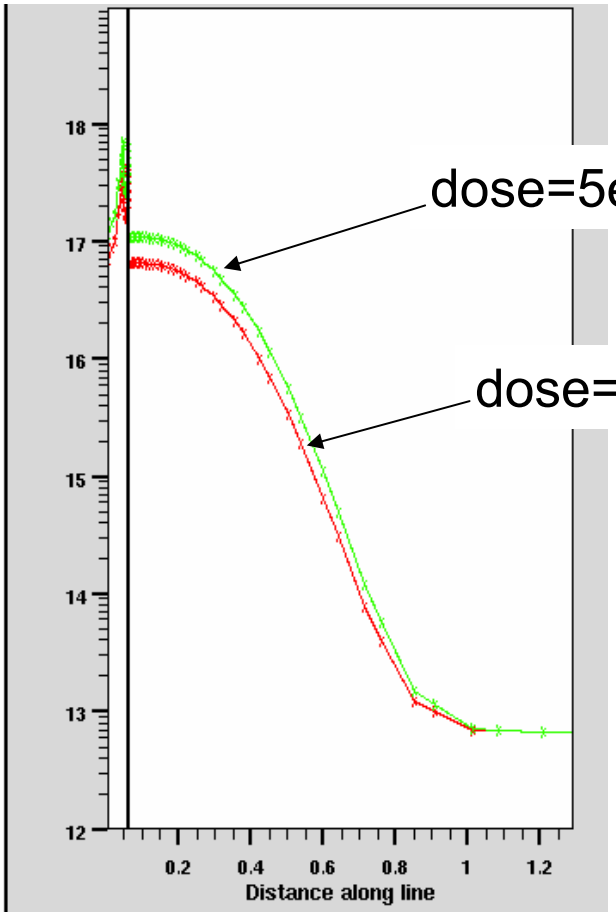
n-on-p – p-spray

Process simulations to determine dose & energy

Net-doping conc.



p-spray profile along cut-line

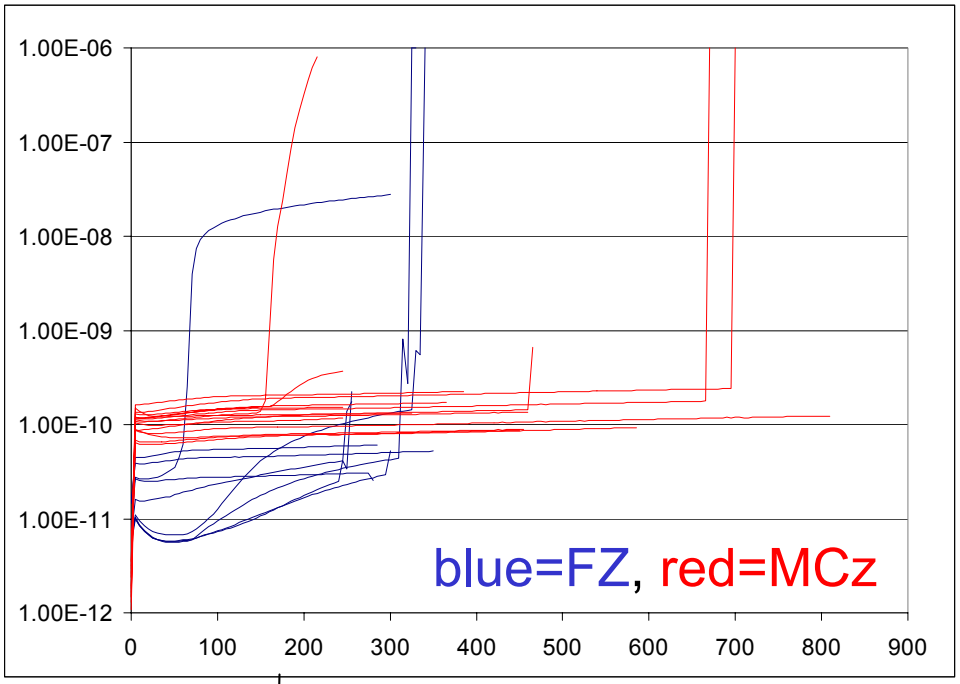


n-on-p – IV on MG diodes (1)

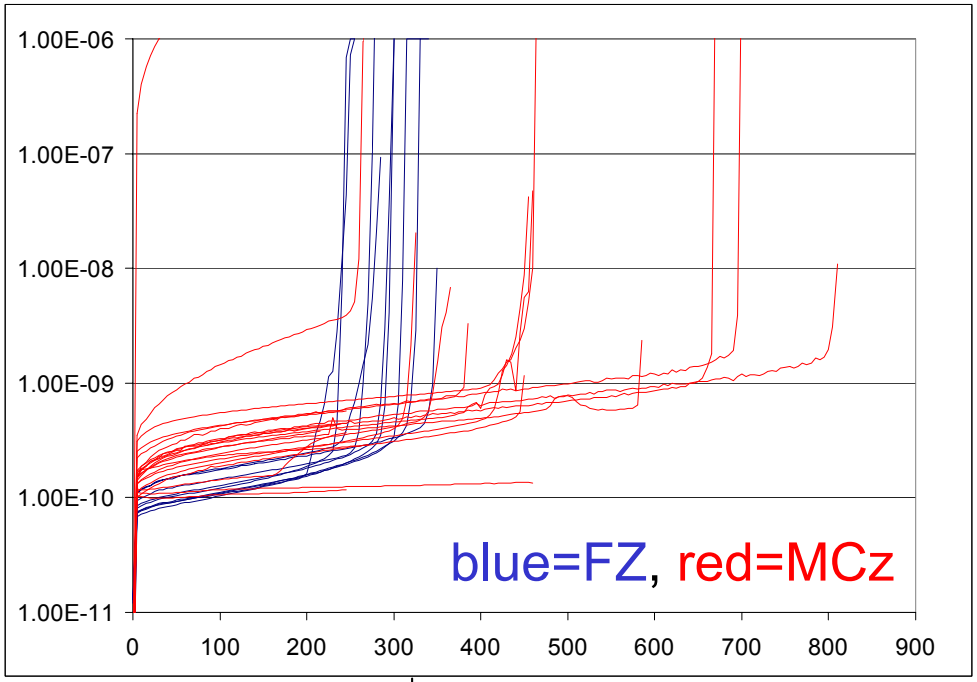
High dose p-spray

Measurements on 3 diodes per 8 wafers

Diode current (A) vs Voltage (V)



GR current (A) vs Voltage (V)



Leakage current ~ **10nA/cm²**

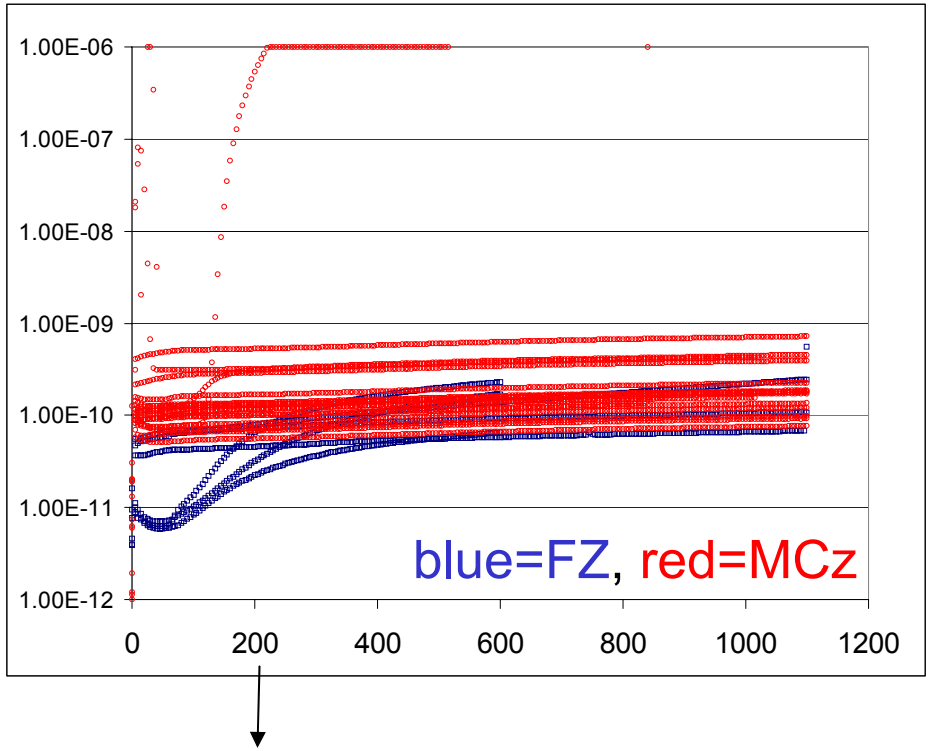
Breakdown voltage **~200-300V**

n-on-p – IV on MG diodes (2)

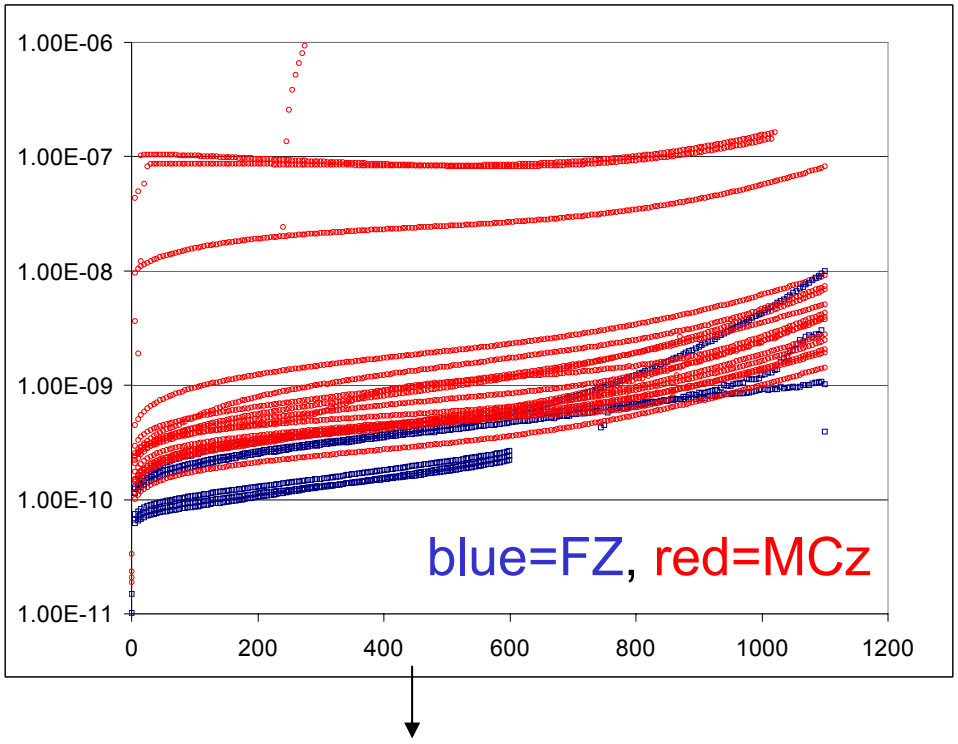
Low dose p-spray

Measurements on 3 diodes per 9 wafers

Diode current (A) vs Voltage (V)



GR current (A) vs Voltage (V)

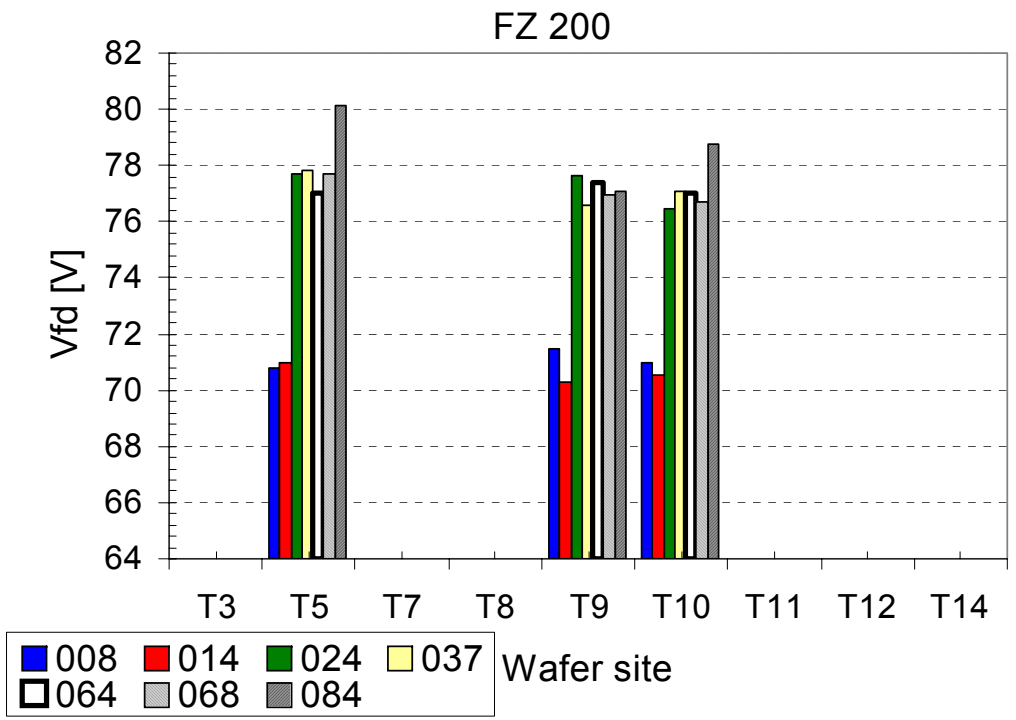


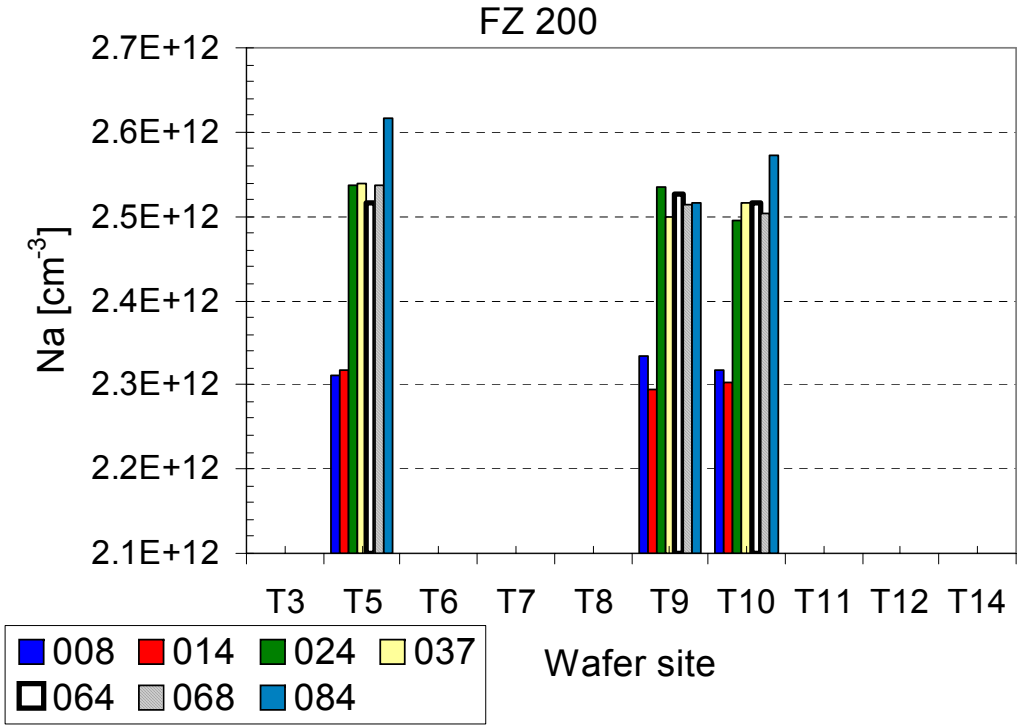
Leakage current ~ **10nA/cm²**

Breakdown voltage **>1000V**

n-on-p – CV on diodes (1)

Measurements on **FZ wafers**





Depletion voltage very uniform at the wafer level.

n-on-p – CV on diodes (2)

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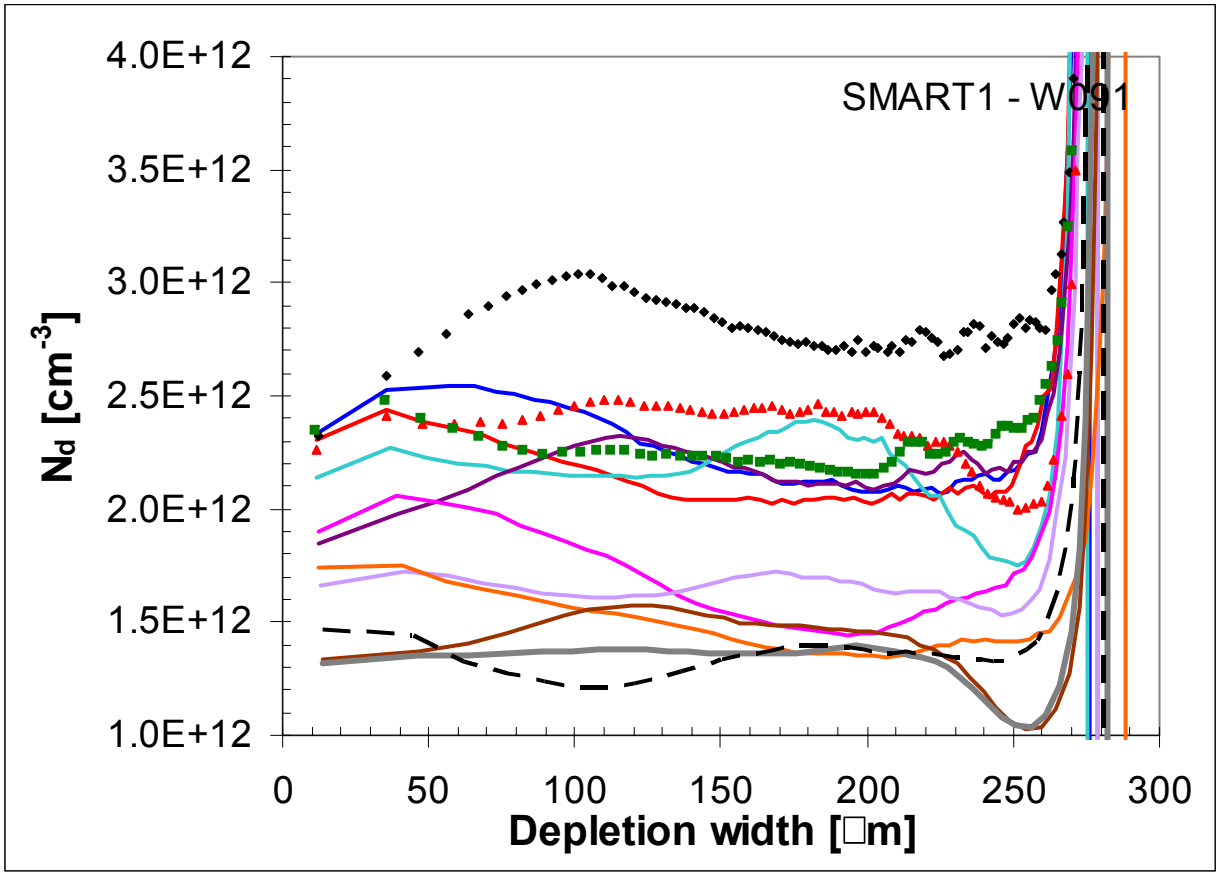
Measurements on **MCz wafers**

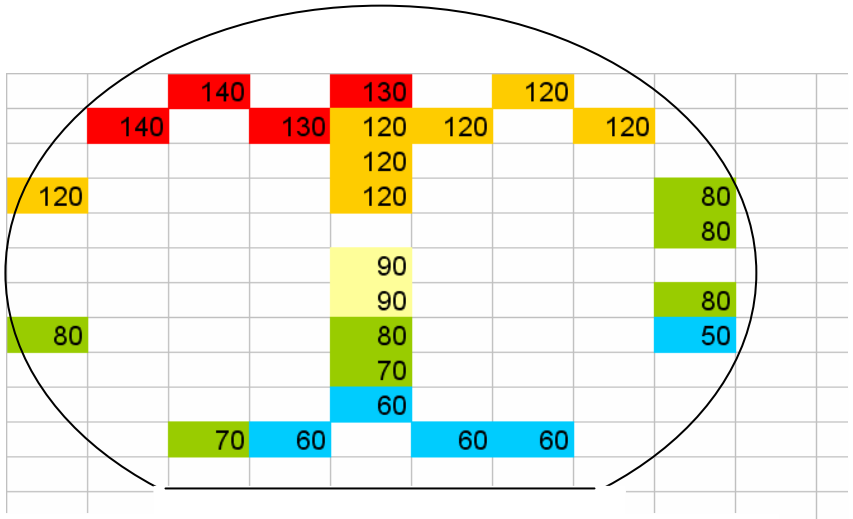
Example of Doping profile from CV measurement



Doping concentration lower than n-type MCz (~2e12 against 7e12) but fluctuations of the same order

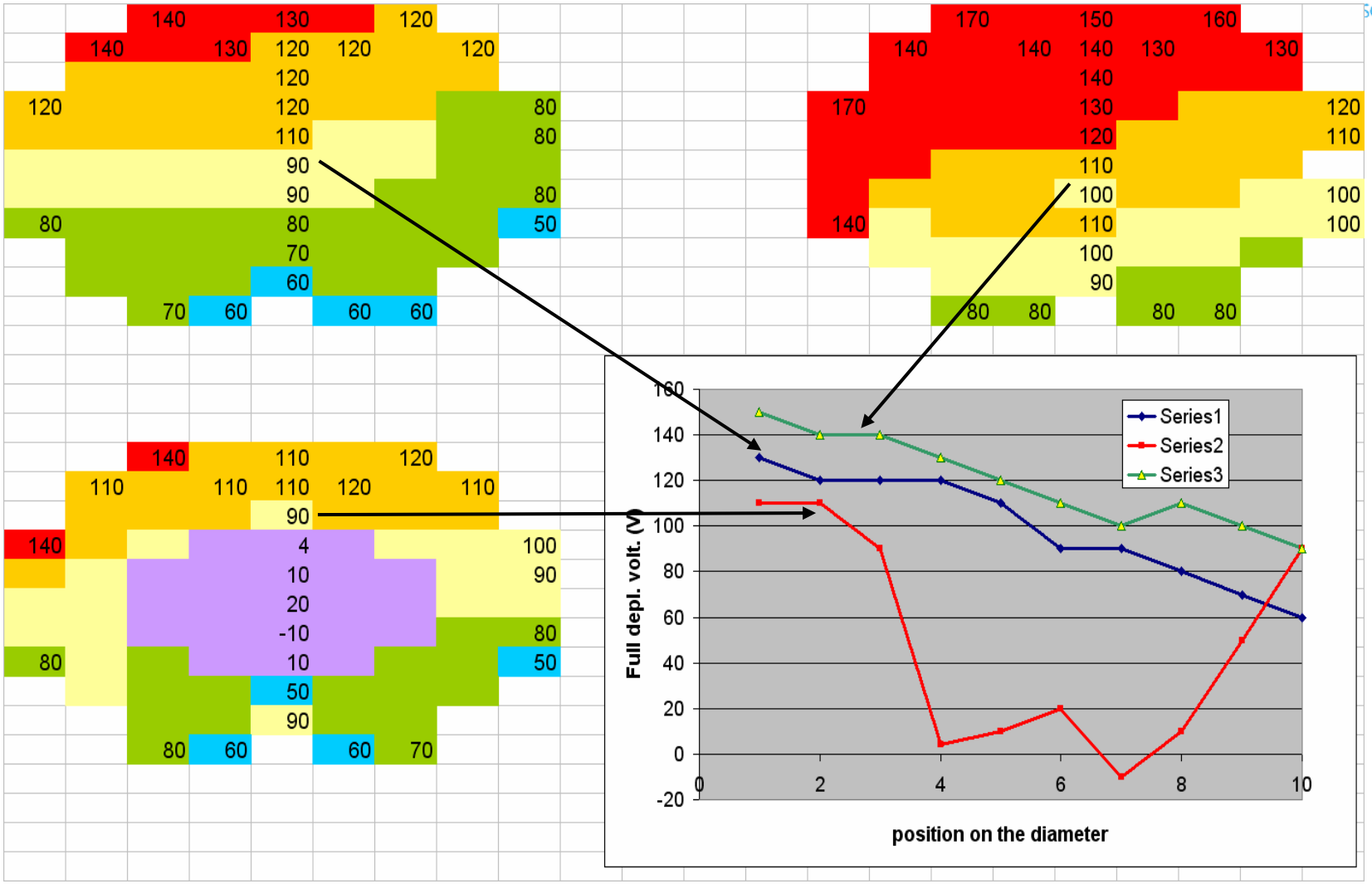
n-on-p – CV on diodes (3)

More measurements on **MCz wafers**



Map of the depletion voltages on three wafers.

n-on-p – CV on diodes (3)

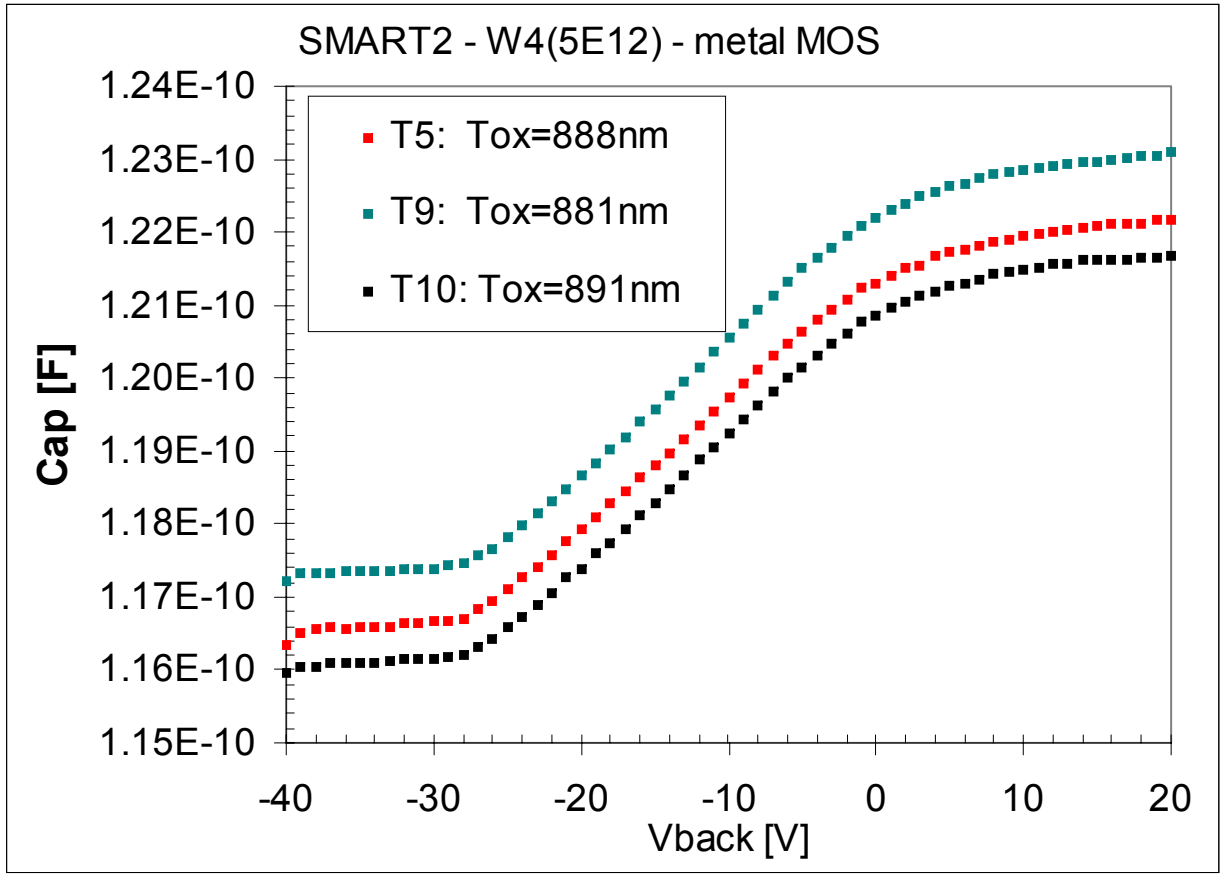


Probably due to fluctuations of the oxygen concentration.

n-on-p – CV MOS

High dose p-spray

Measurement on 3 MOS capacitors of the same wafer

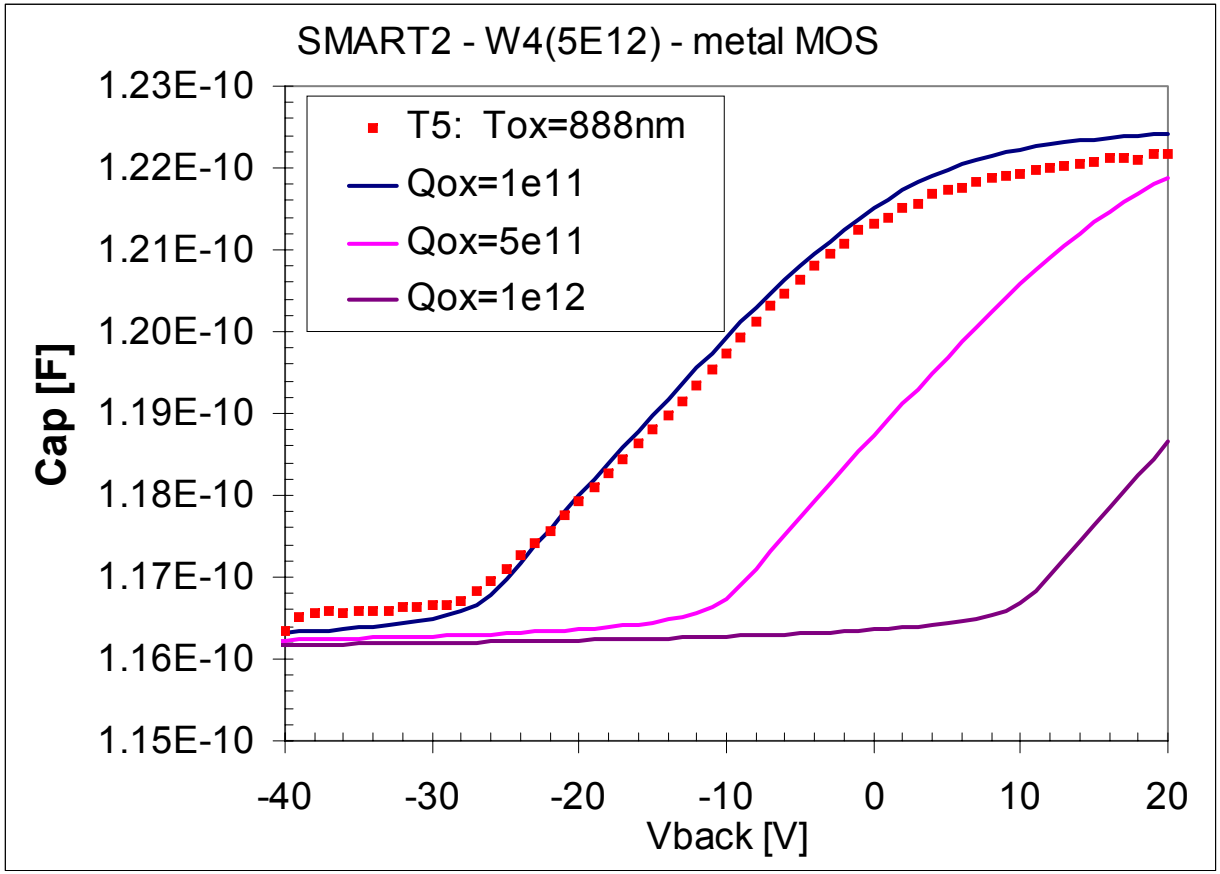


Using C_{max}-C_{min} method

N_{peak}=7e16cm^{-3} which is lower than what predicted by process simulation (~1e17cm^{-3}).

n-on-p – CV MOS (2)

Simulation using measured parameters.



Perfect agreement with an oxide charge density of **1e11cm^{-2}**

➡ Over-estimated N_{peak} with process simulator. Is it enough to balance oxide charge for high TID?

n-on-p – CV MOS (3)

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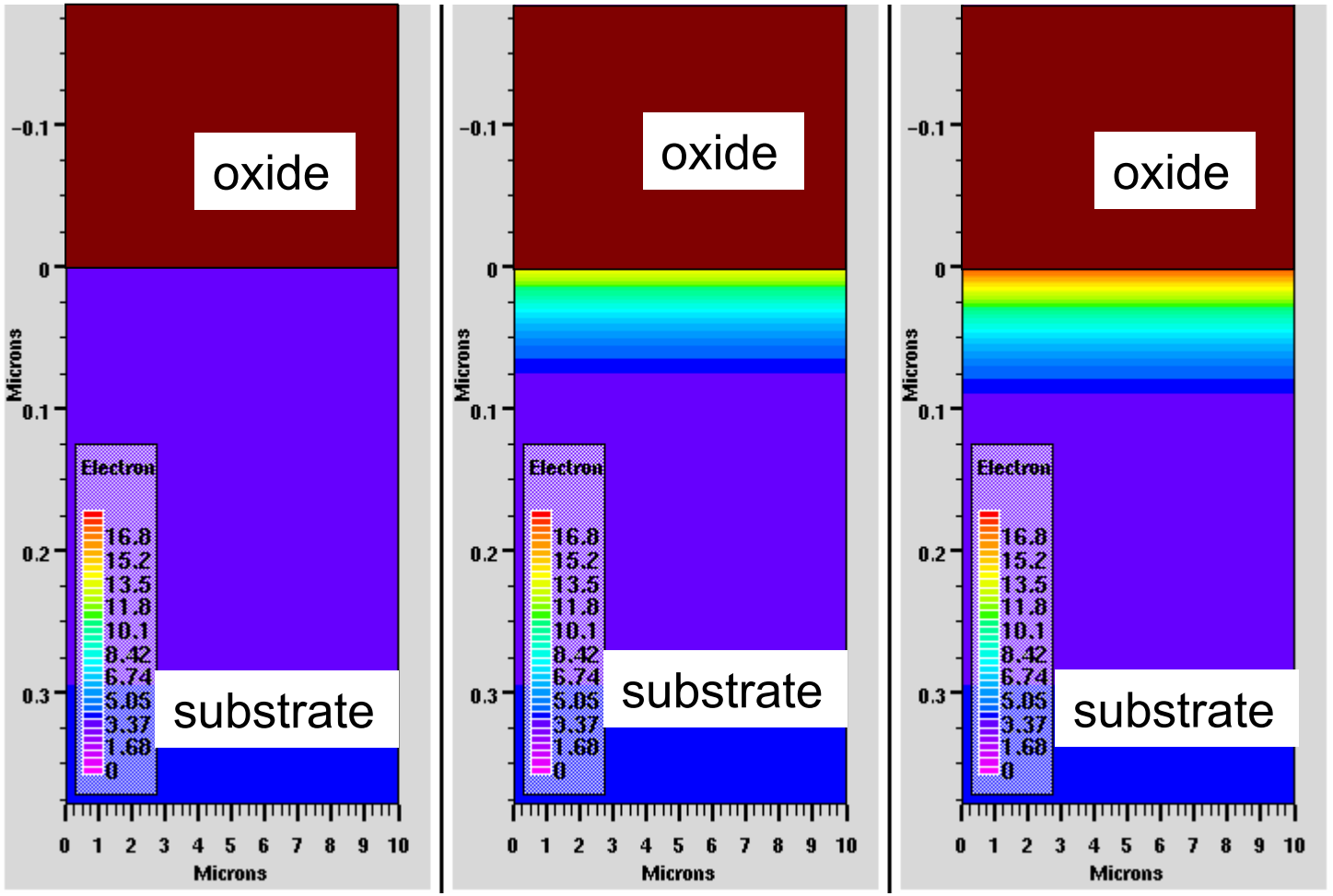
Electron concentration underneath the oxide.

Qox= 1e11cm^{-2} Qox= 1e12cm^{-2} Qox= 2e12cm^{-2}



Red=1e17cm^{-3}

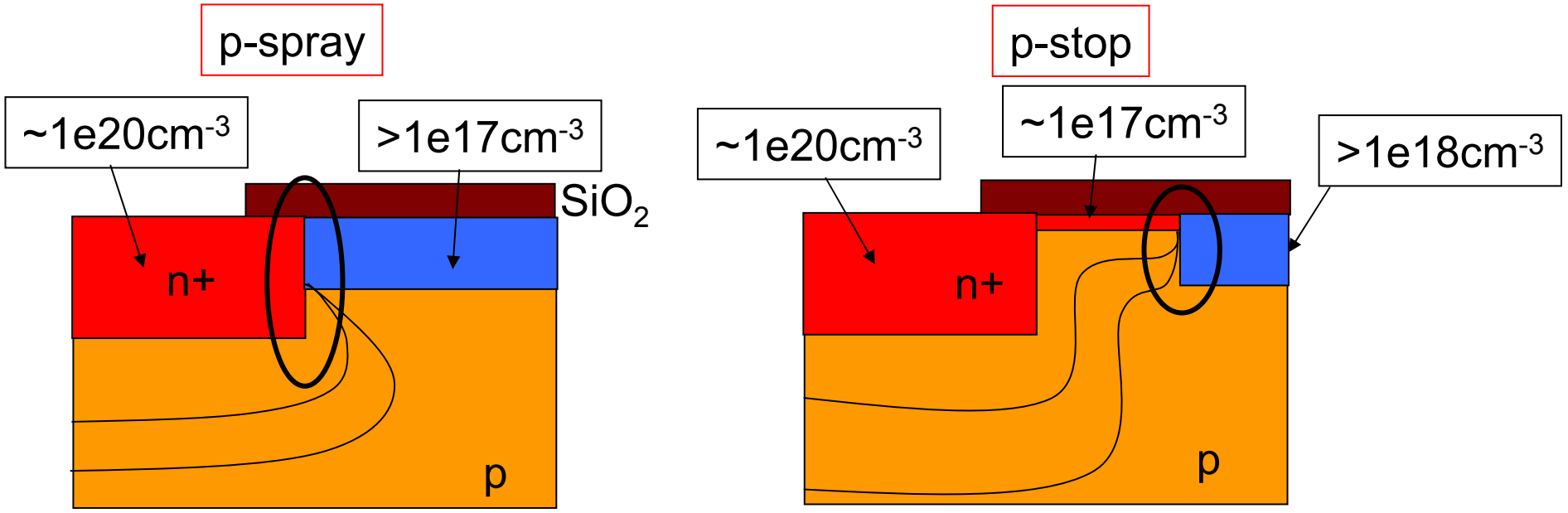
Yellow=1e14cm^{-3}

n-on-p – (p-spray) vs (p-stop)

p-spray should be implanted with a slightly higher dose

→ lower breakdown voltages!!! (<200-300V)
This could be not enough to fully deplete a MCz substrate.

What about a p-stop?



better after irradiation

better before irradiation

Conclusion

Problems on n-on-p production:

- non-uniformity of the depletion voltage

To be verified:

- effectiveness of actual p-spray

Samples available for the collaboration.