

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

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for the SMART collaboration

History

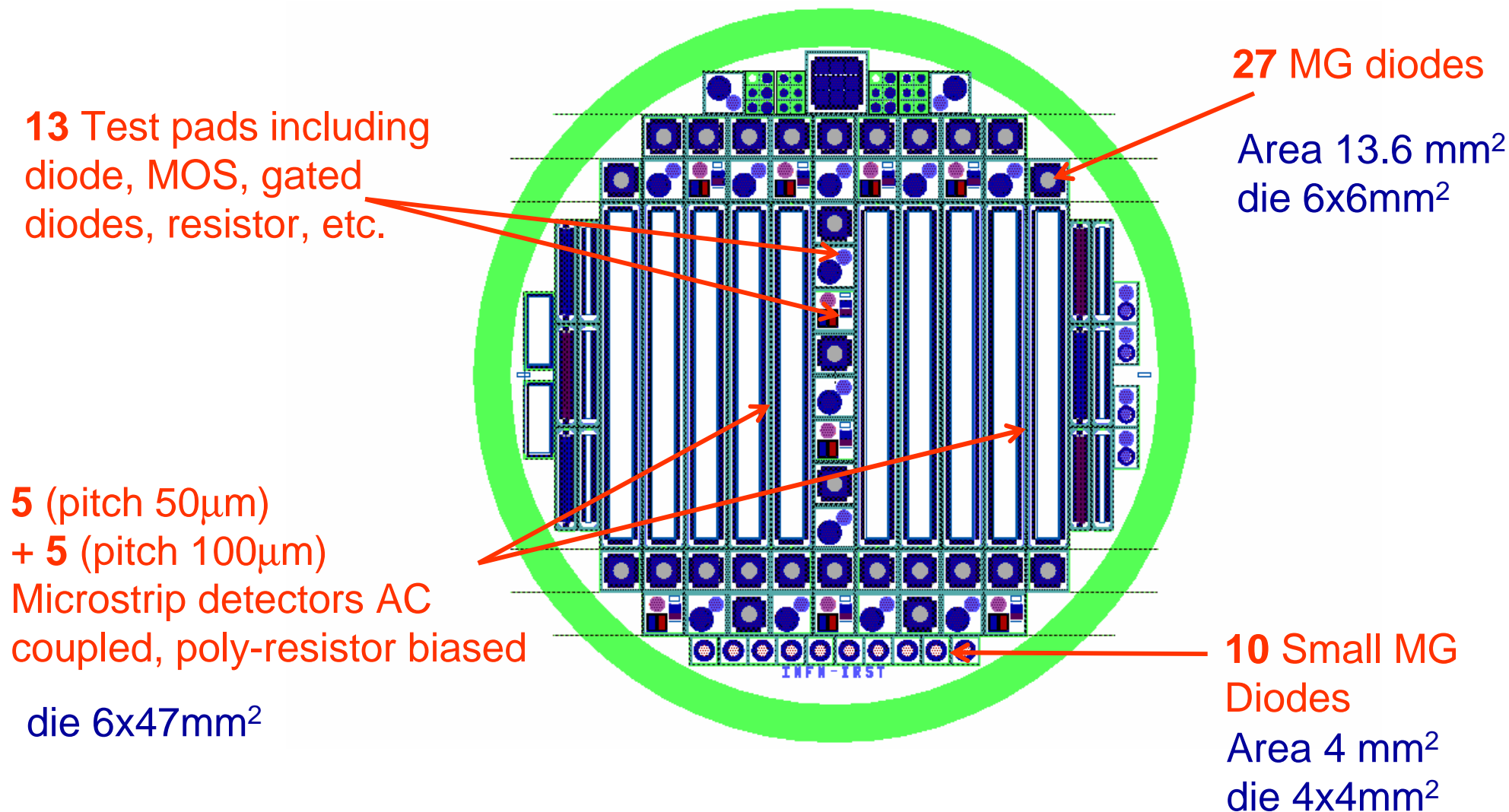
SMART collaboration

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



1st batch - p-on-n

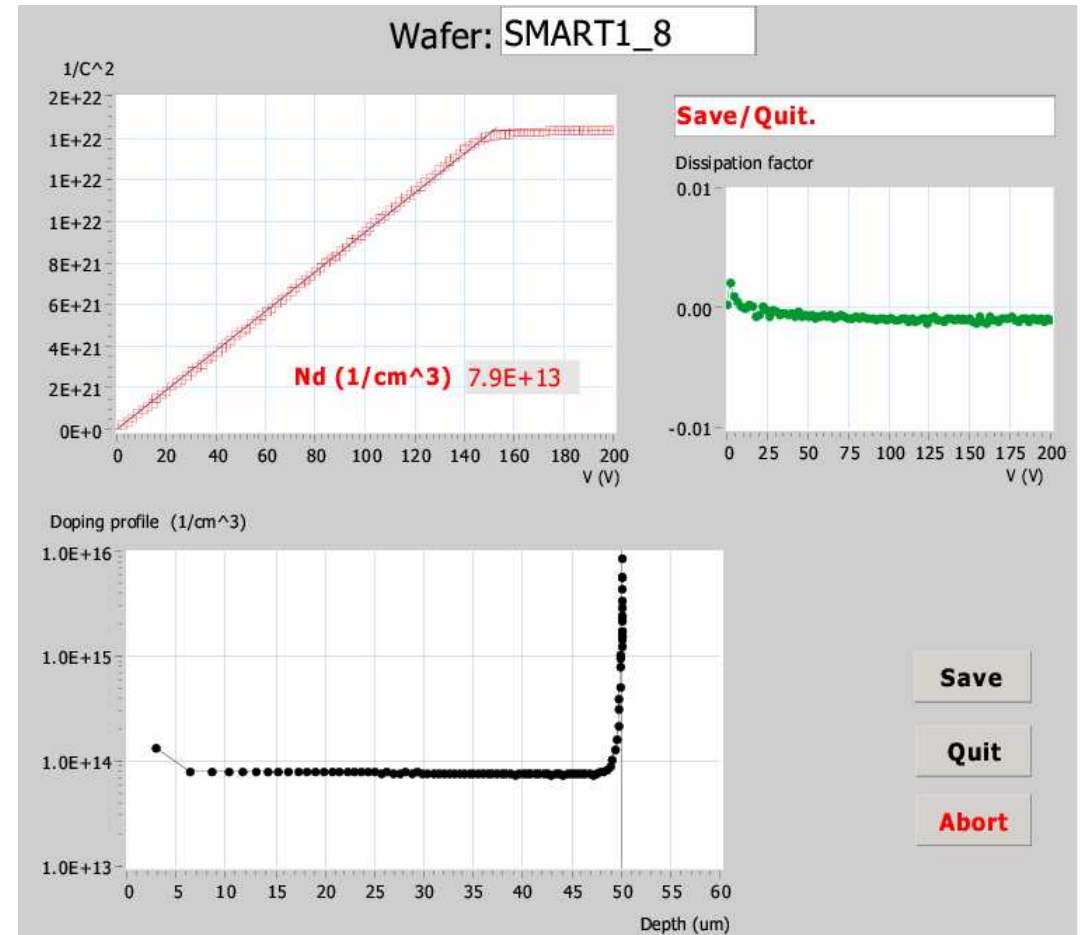
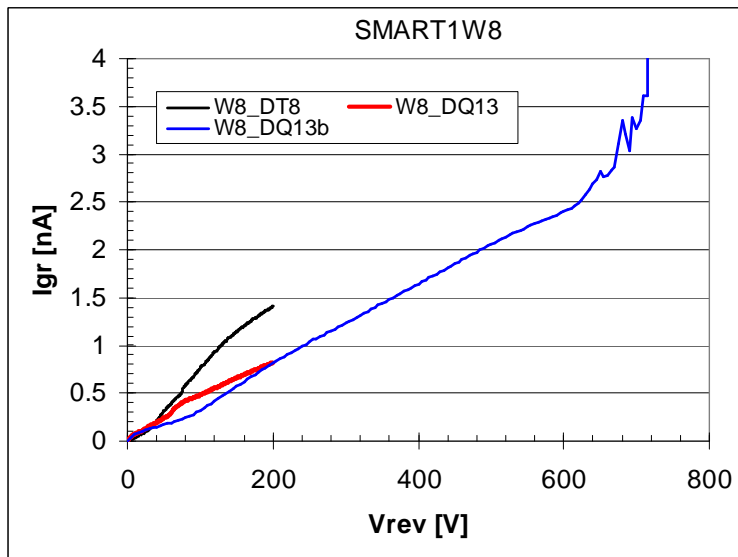
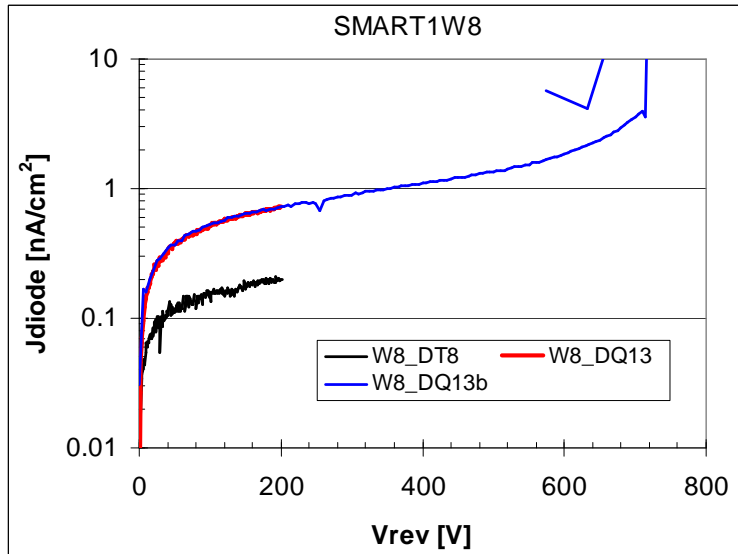
Silicon substrates

- **Fz** n-type 6 k Ω -cm $\langle 111 \rangle$
- **MCz** n-type $>500\Omega$ -cm $\langle 100 \rangle$
- **Cz** n-type $>900\Omega$ -cm $\langle 100 \rangle$
- **Epi (ITME)** n-type $\langle 100 \rangle$ (50 and 75 μm)

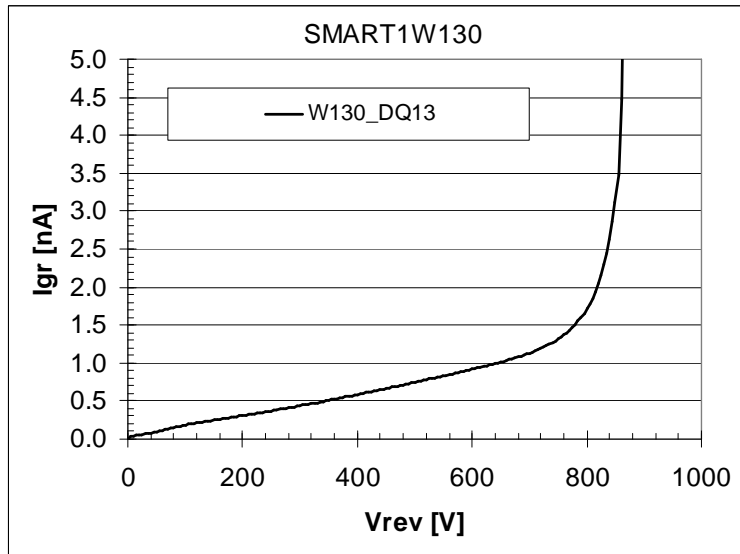
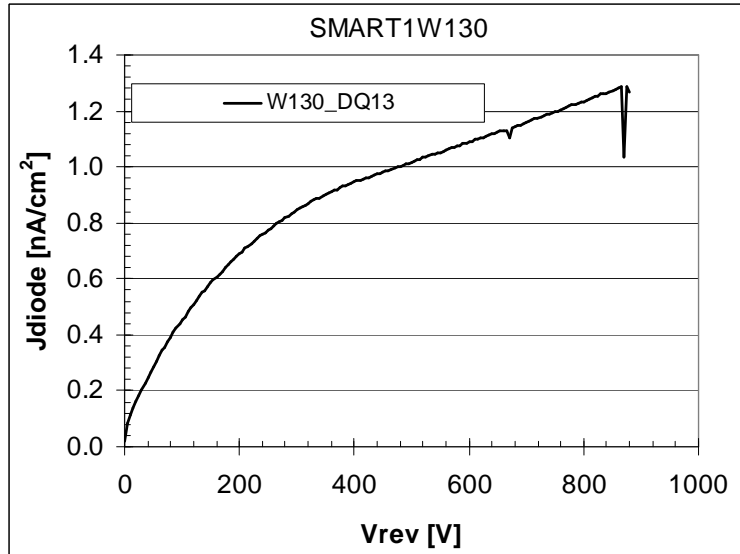
Process splittings

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

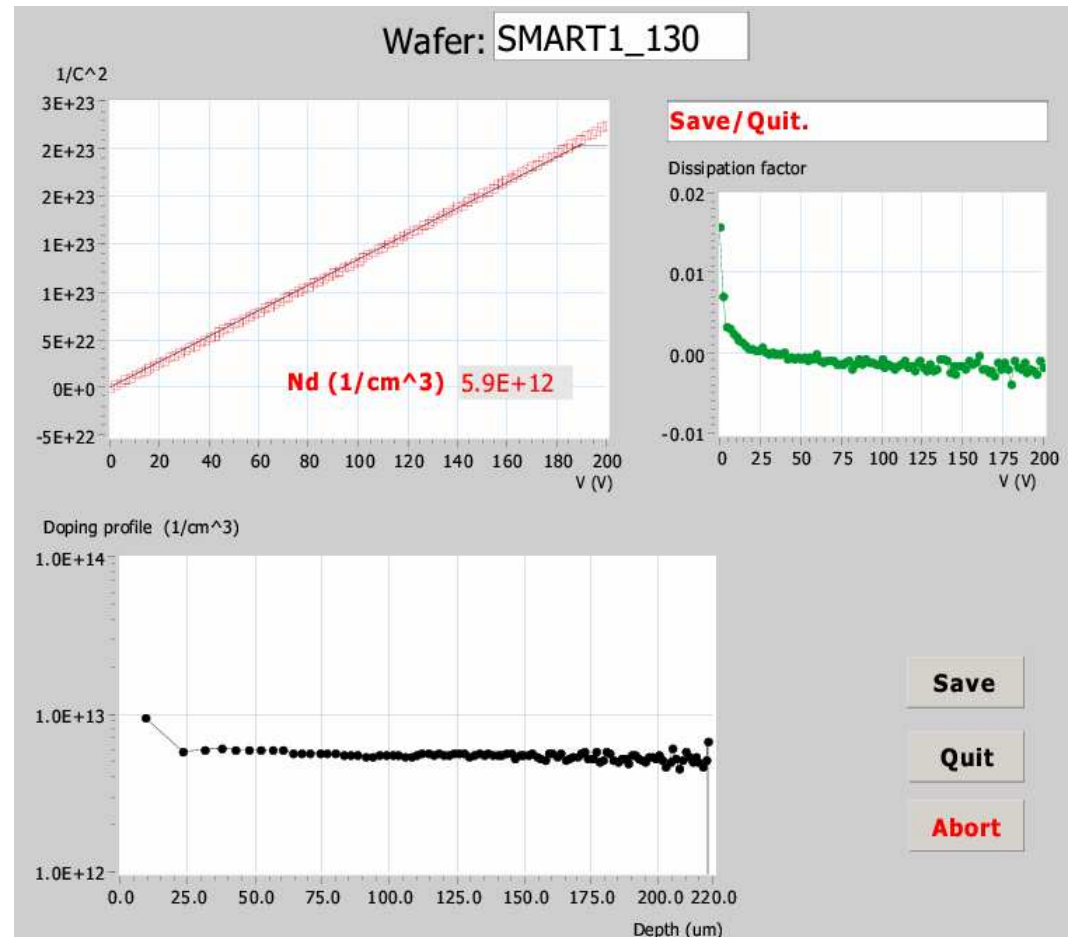
CV measurement



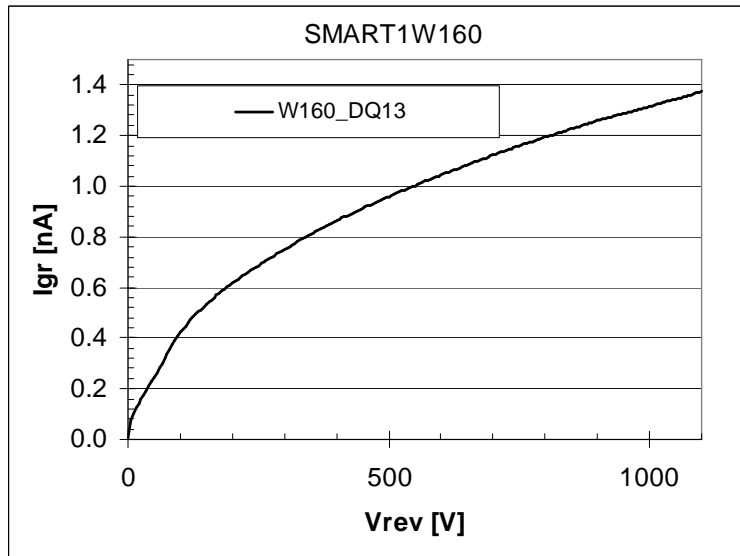
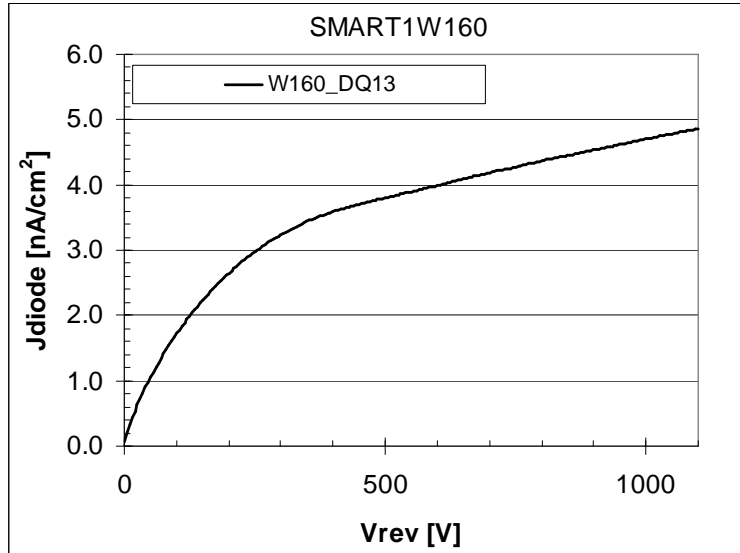
MCz - sintering@380



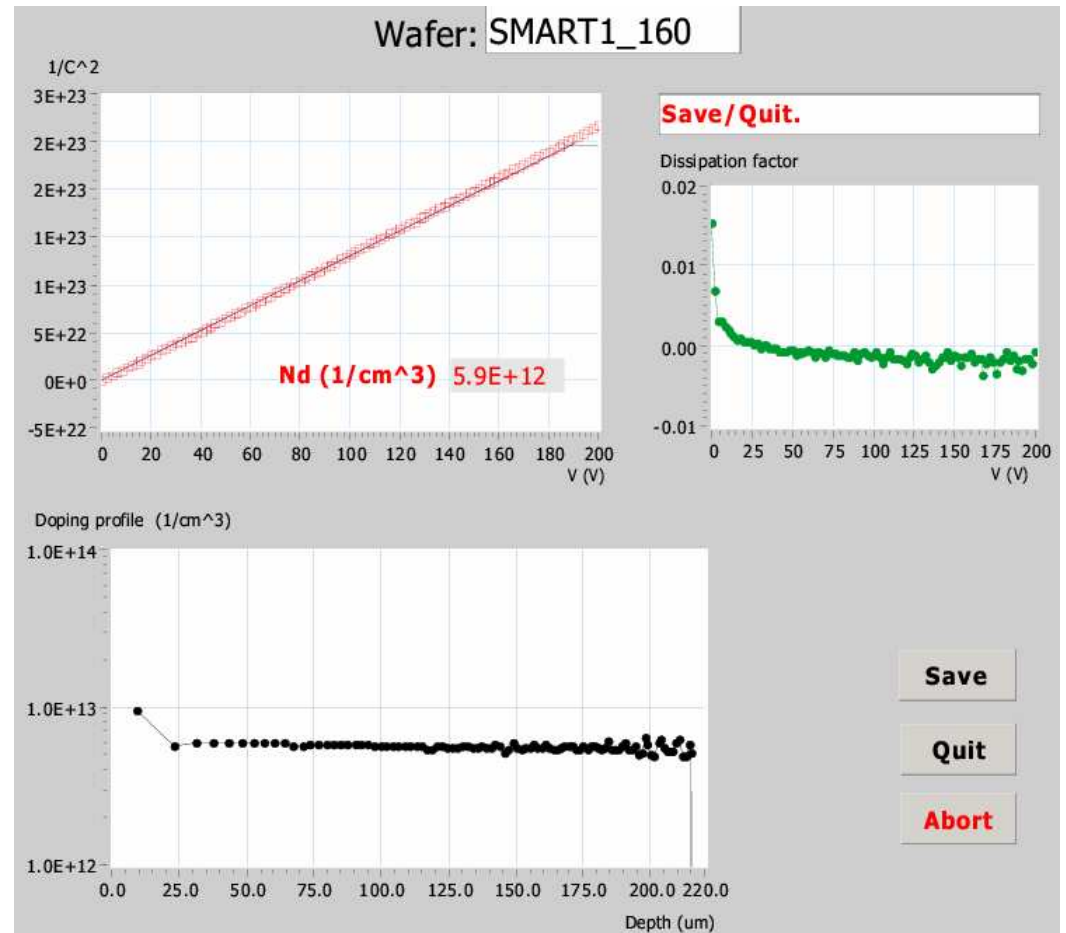
CV measurement (Vfd=400V)

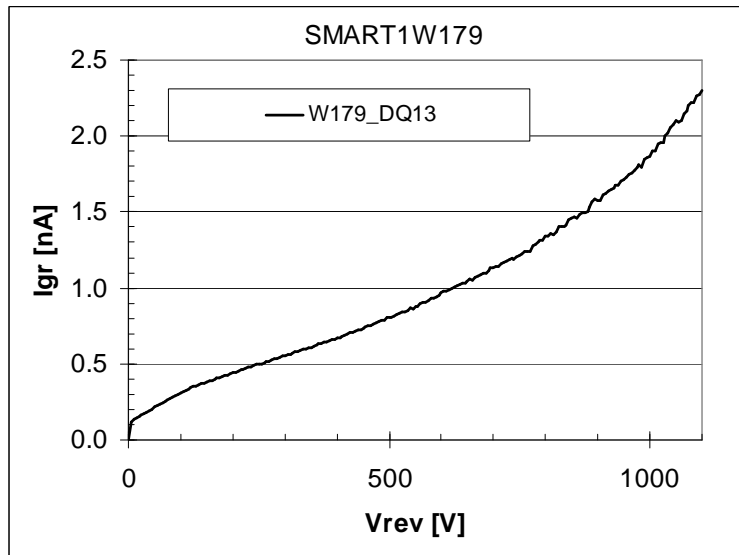
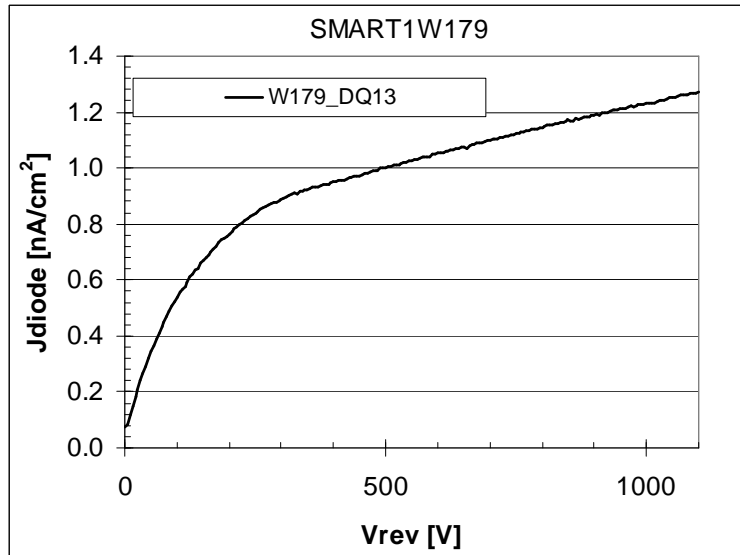


MCz 380 & TDK

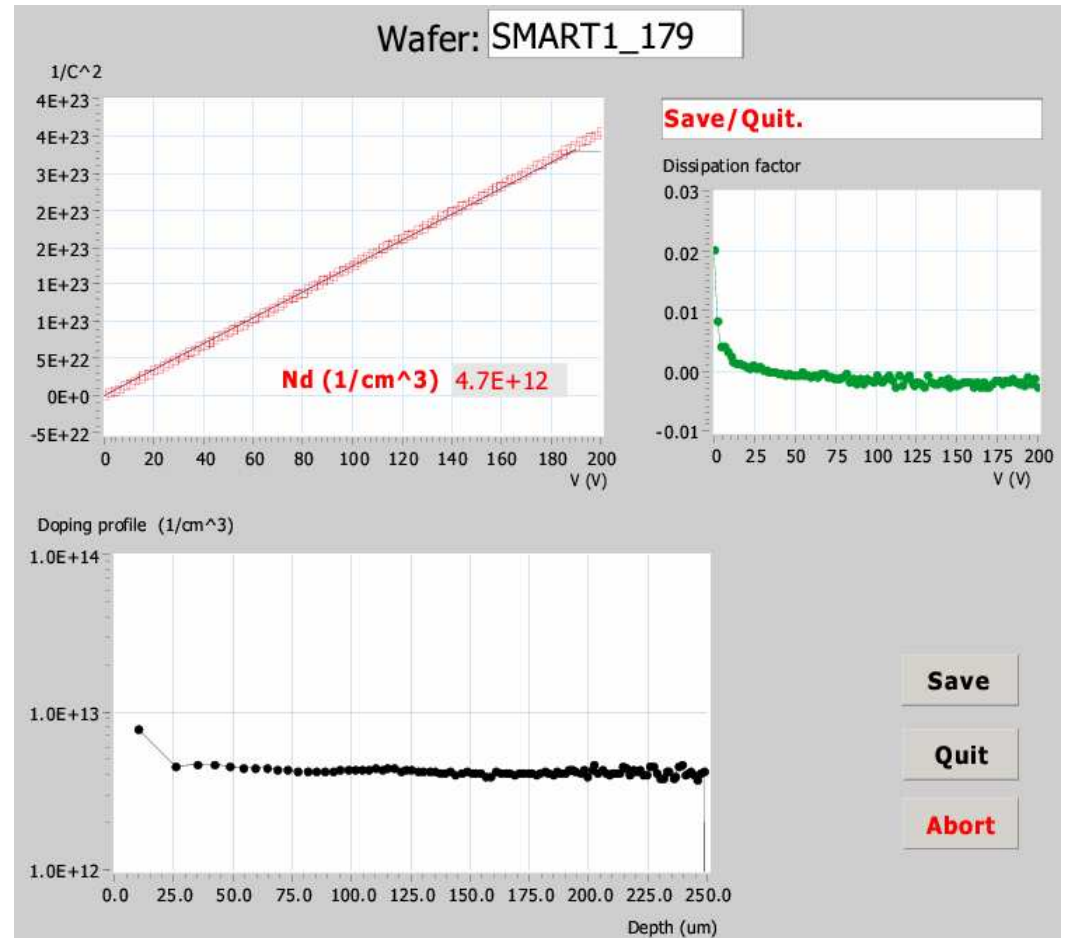


CV measurement (Vfd=400V)





CV measurement (Vfd=350V)

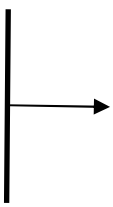


2nd batch - n-on-p

sub-type comments

3 FZ 200 p-spray 3E12


3 FZ 200 p-spray 5E12



FZ <100>
p-type
>5000Ωcm
200μm

6 MCz no OG; p-spray 3E12

5 MCz no OG; p-spray 5E12

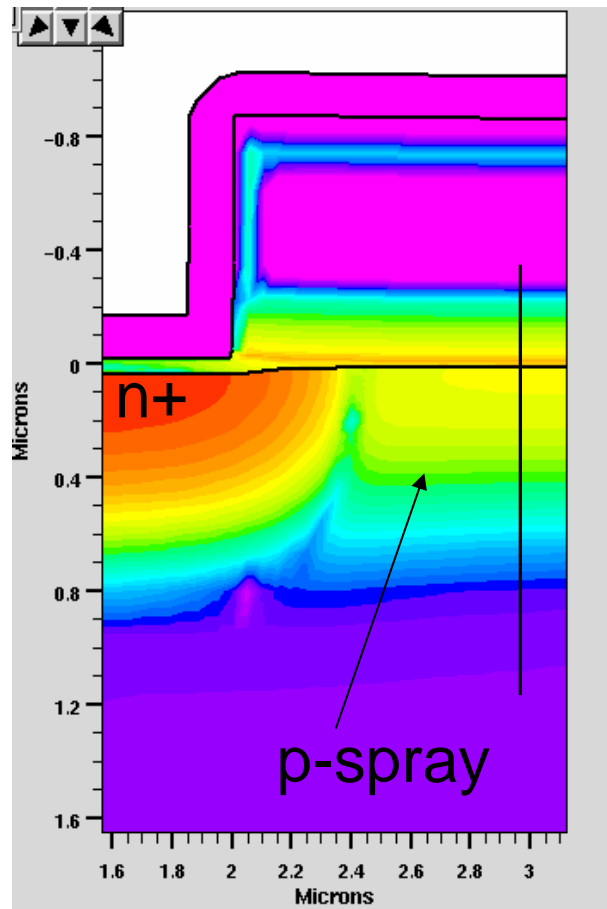


MCz <100>
p-type
>1.8kΩcm
300μm

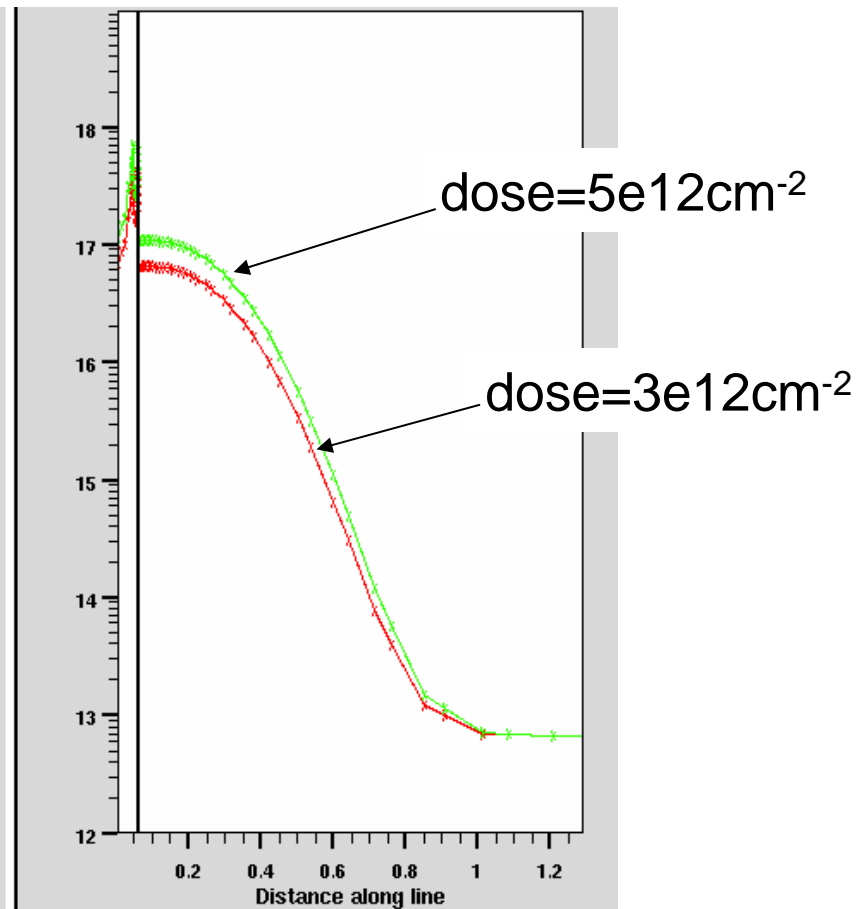
n-on-p – p-spray

Process simulations to determine dose & energy

Net-doping conc.



p-spray profile along cut-line

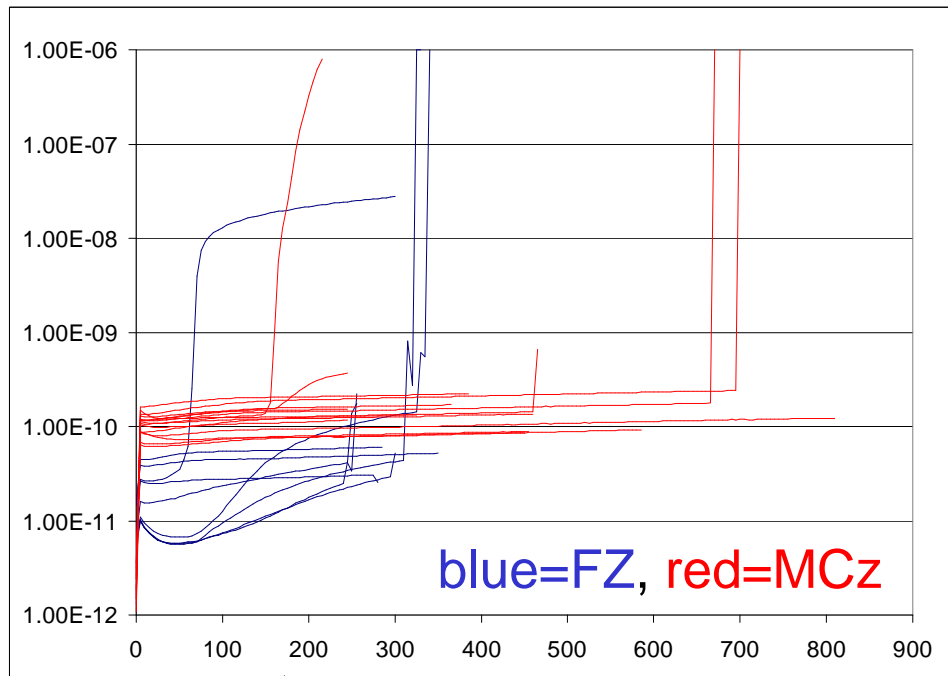


n-on-p – IV on MG diodes (1)

High dose p-spray

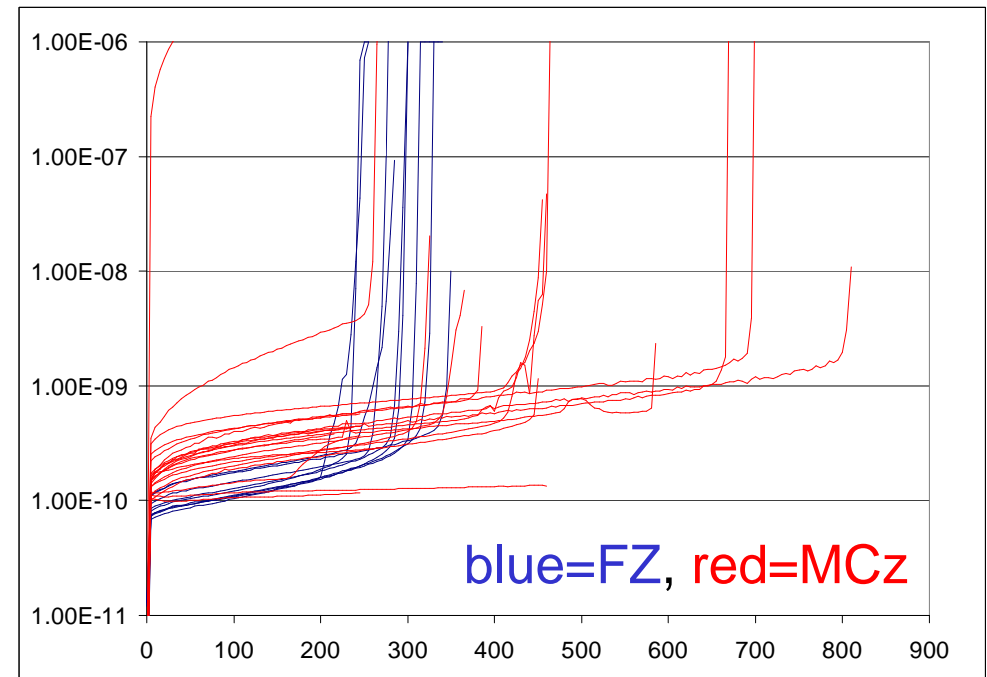
Measurements on 3 diodes per 8 wafers

Diode current (A) vs Voltage (V)



Leakage current ~ **10nA/cm²**

GR current (A) vs Voltage (V)



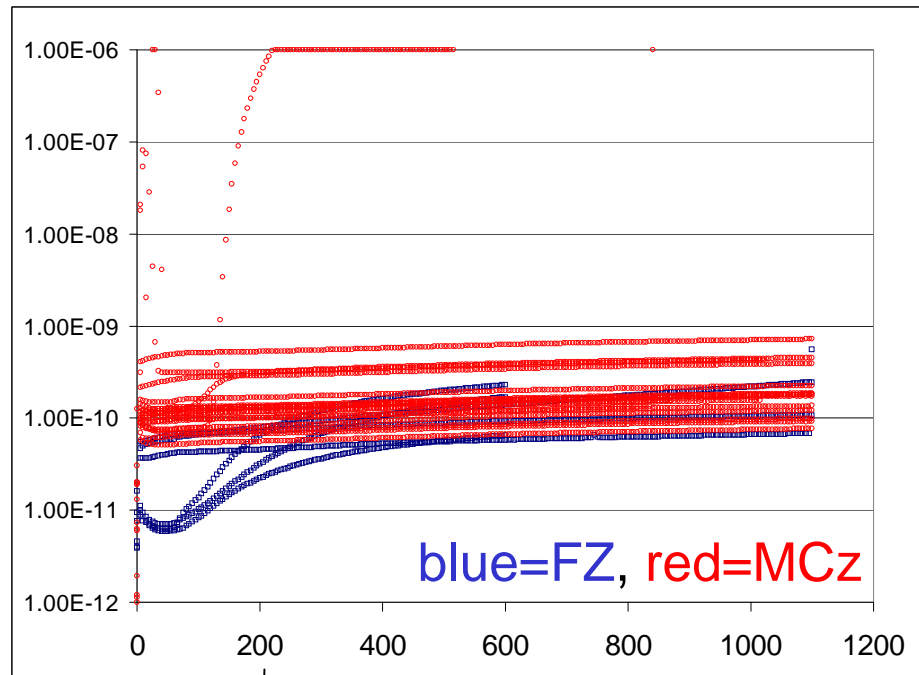
Breakdown voltage ~ **200-300V**

n-on-p – IV on MG diodes (2)

Low dose p-spray

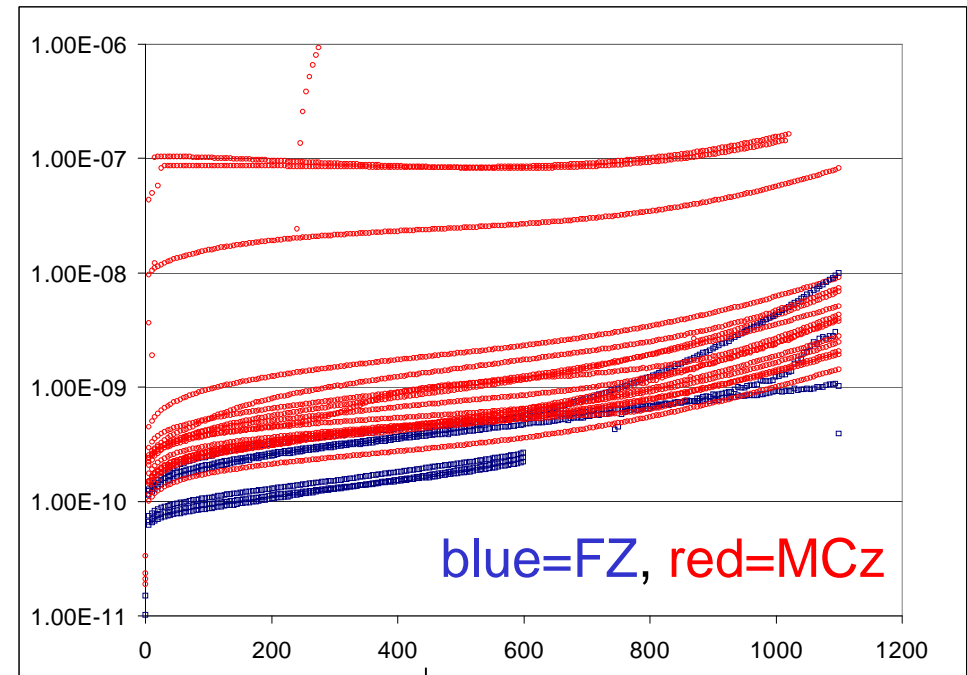
Measurements on 3 diodes per 9 wafers

Diode current (A) vs Voltage (V)



Leakage current ~ **10nA/cm²**

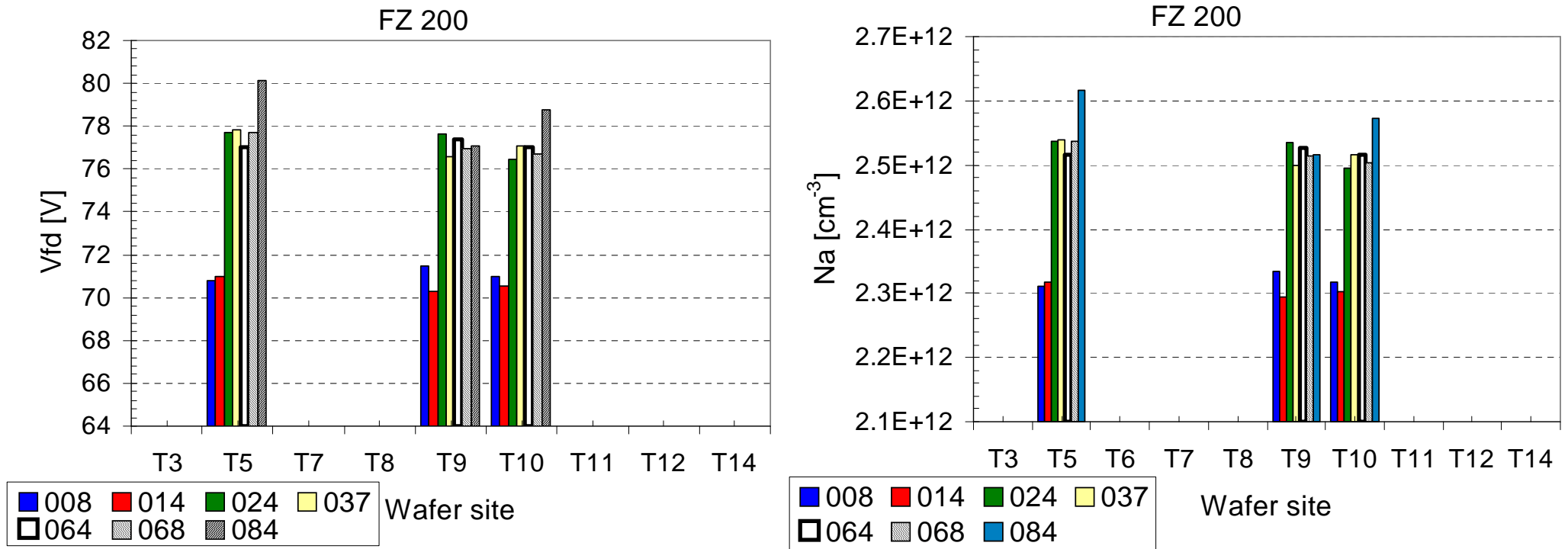
GR current (A) vs Voltage (V)



Breakdown voltage >**1000V**

n-on-p – CV on diodes (1)

Measurements on FZ wafers

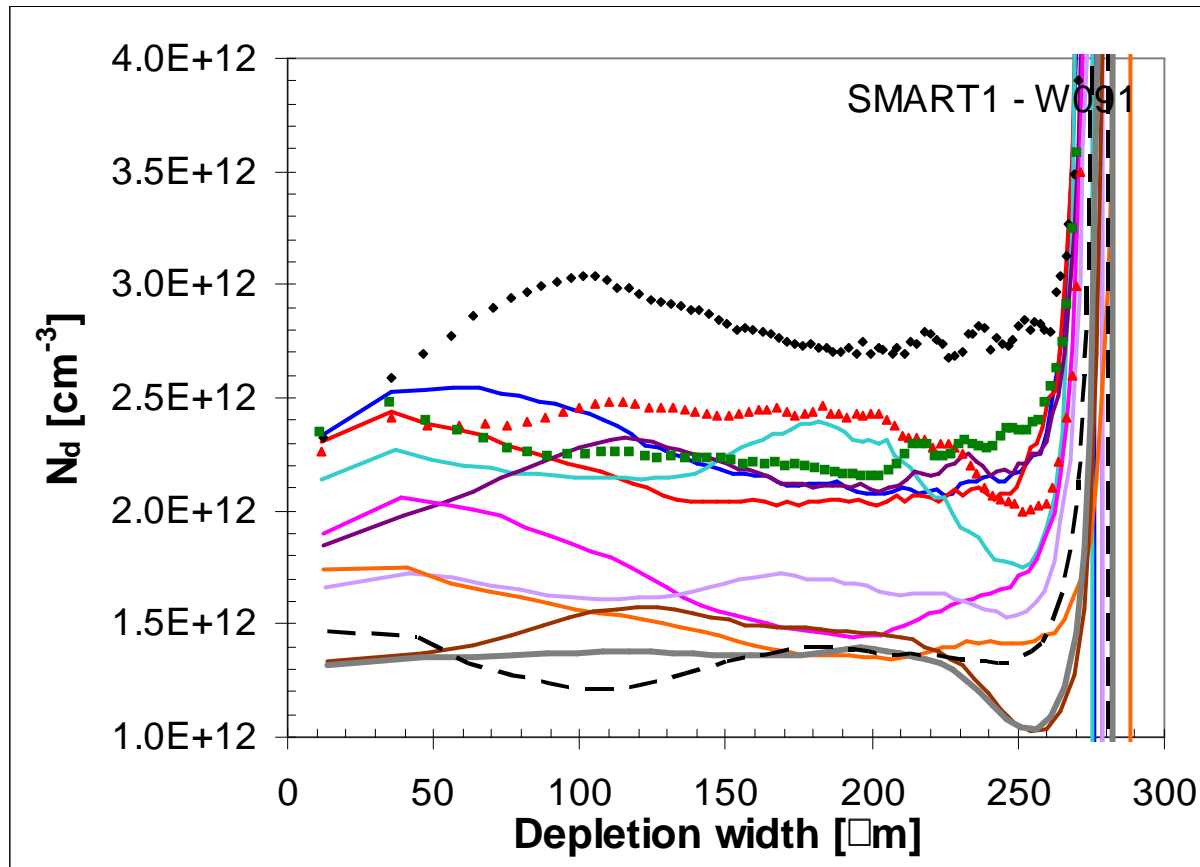


Depletion voltage very uniform at the wafer level.

n-on-p – CV on diodes (2)

Measurements on **MCz wafers**

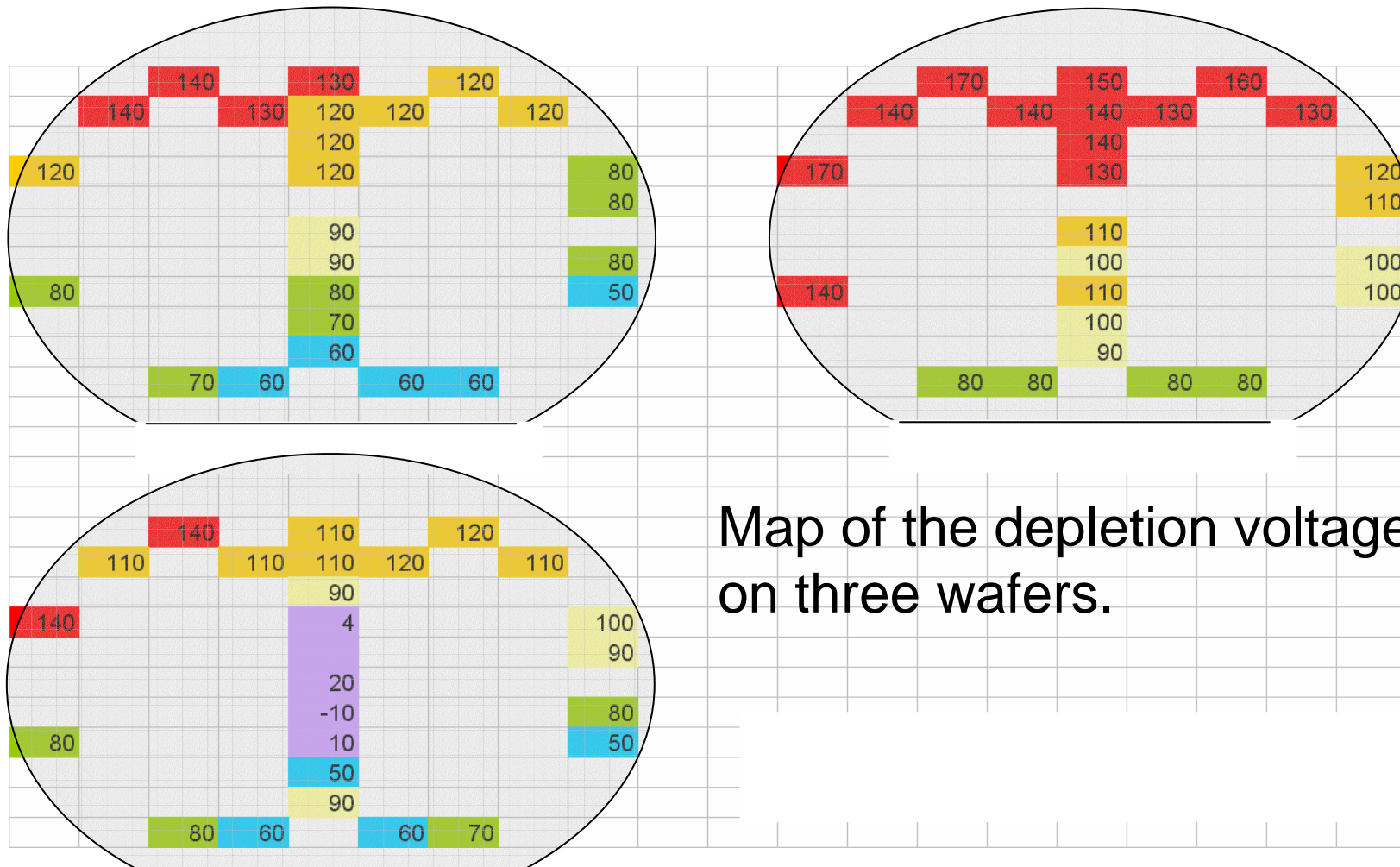
Example of Doping profile from CV measurement



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

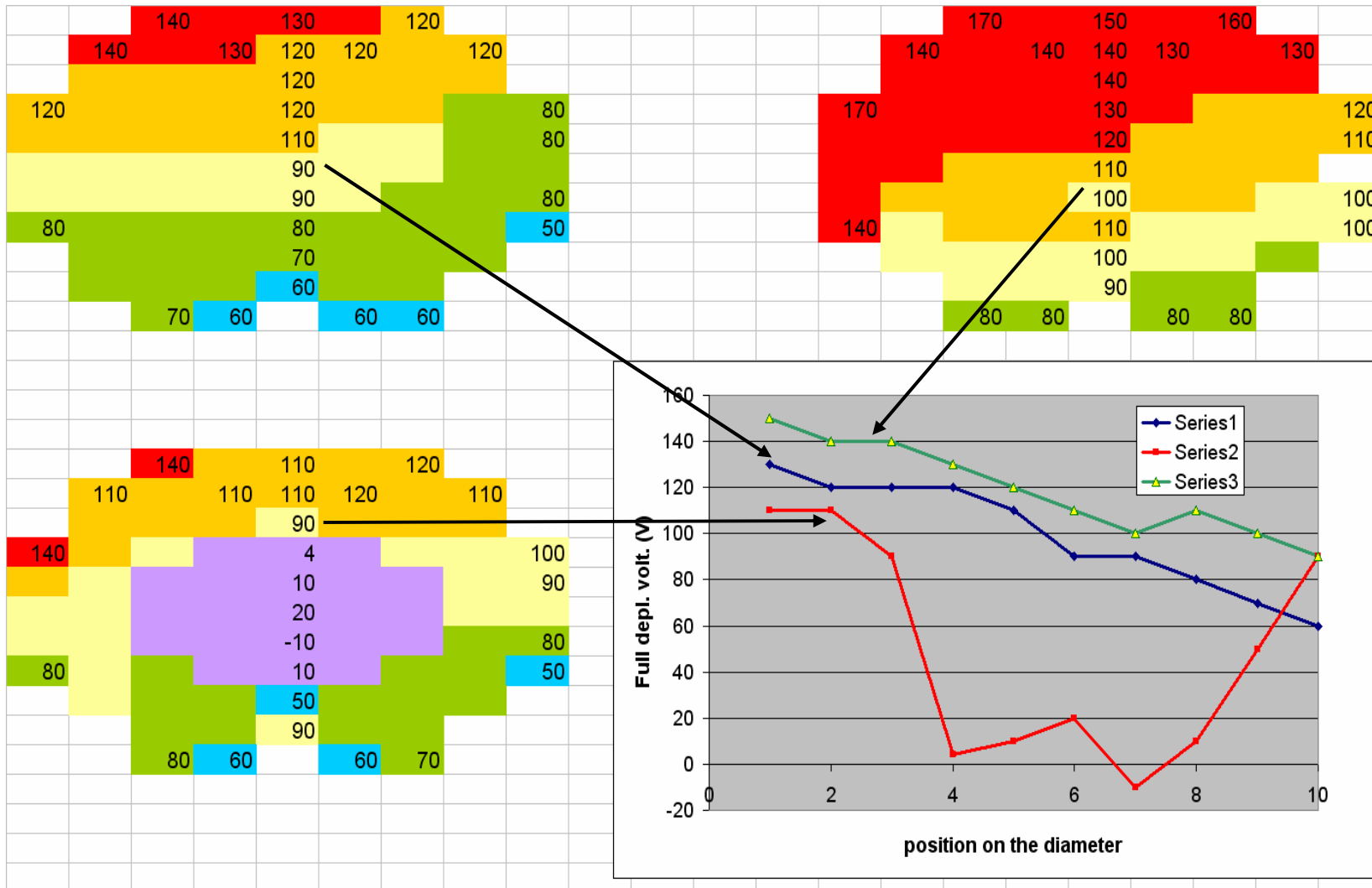
n-on-p – CV on diodes (3)

More measurements on **MCz wafers**



Map of the depletion voltages on three wafers.

n-on-p – CV on diodes (3)

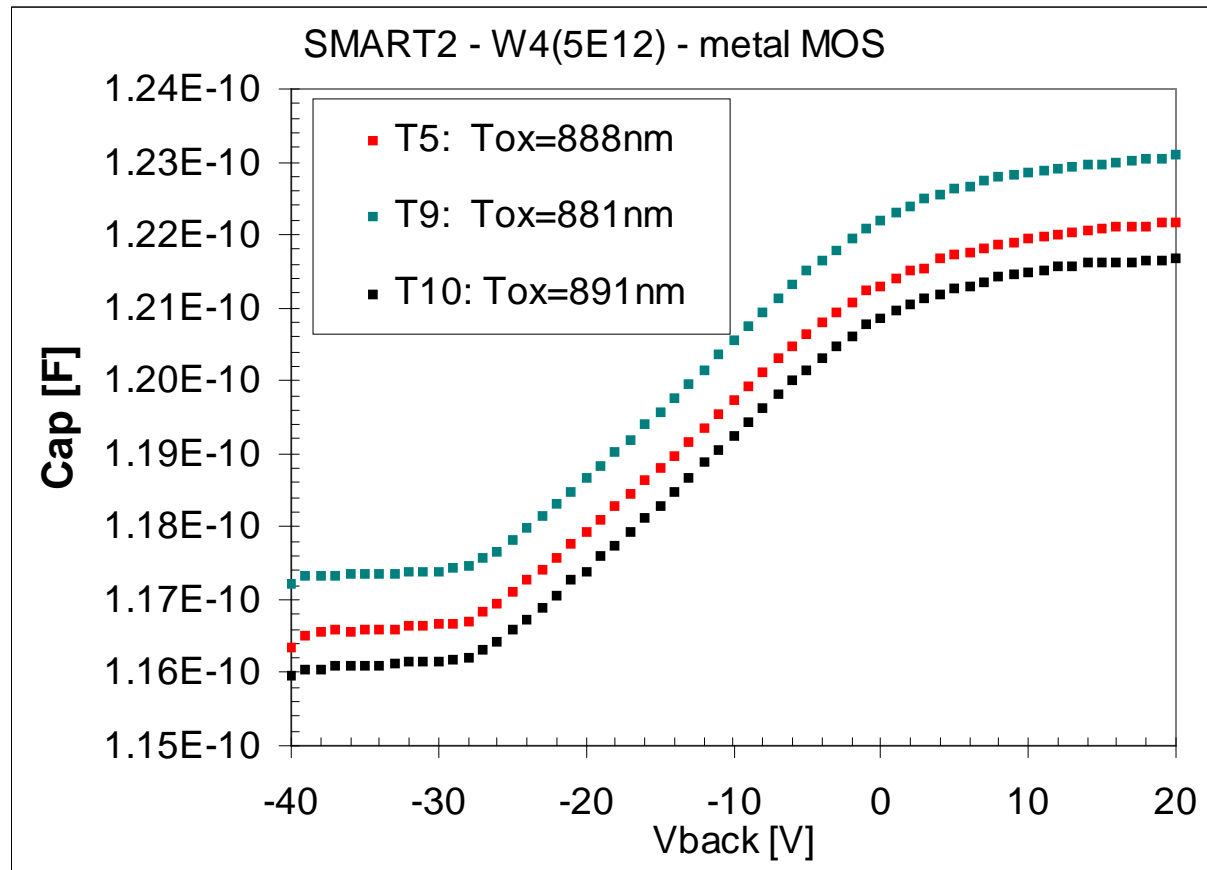


Probably due to fluctuations of the oxygen concentration.

n-on-p – CV MOS

High dose p-spray

Measurement on 3 MOS capacitors of the same wafer



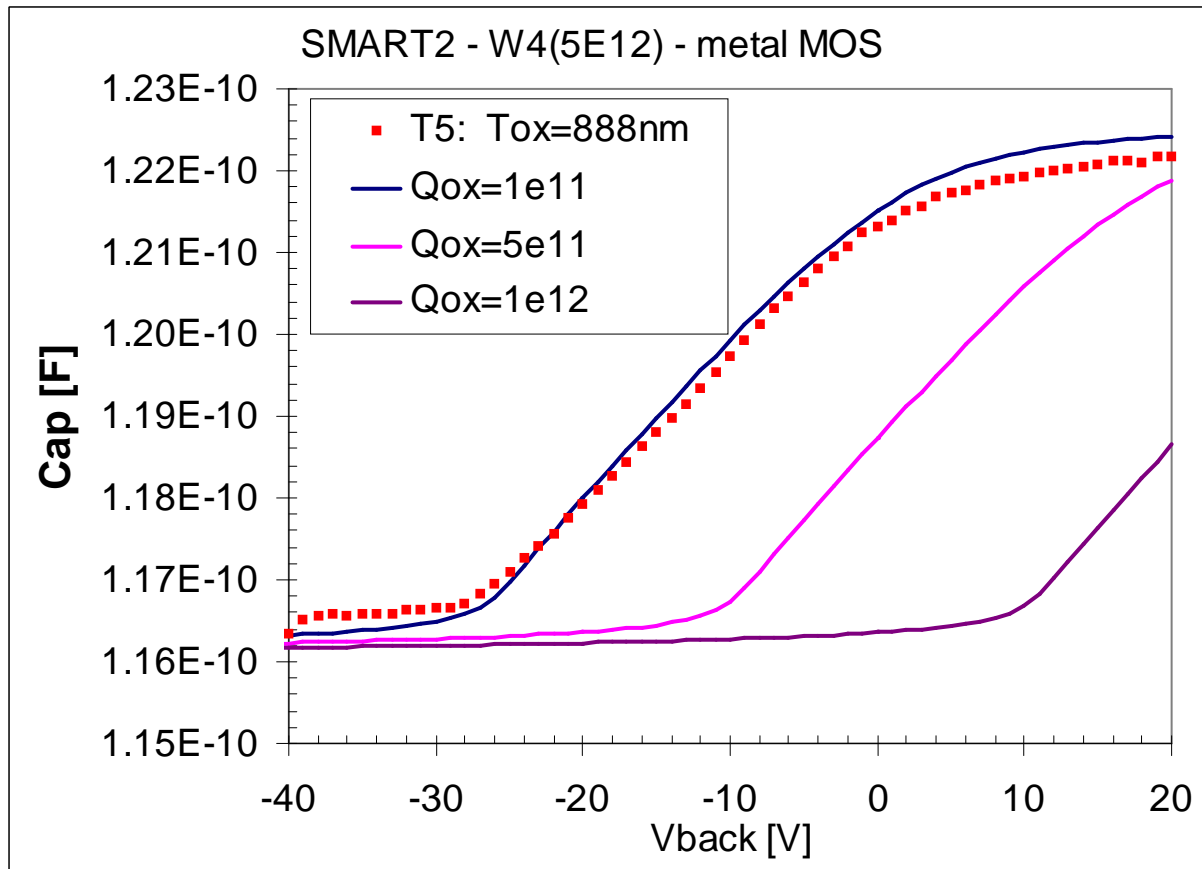
Using $C_{max}-C_{min}$ method



$N_{peak}=7e16\text{cm}^{-3}$ which is lower than what predicted by process simulation ($\sim 1e17\text{cm}^{-3}$).

n-on-p – CV MOS (2)

Simulation using measured parameters.

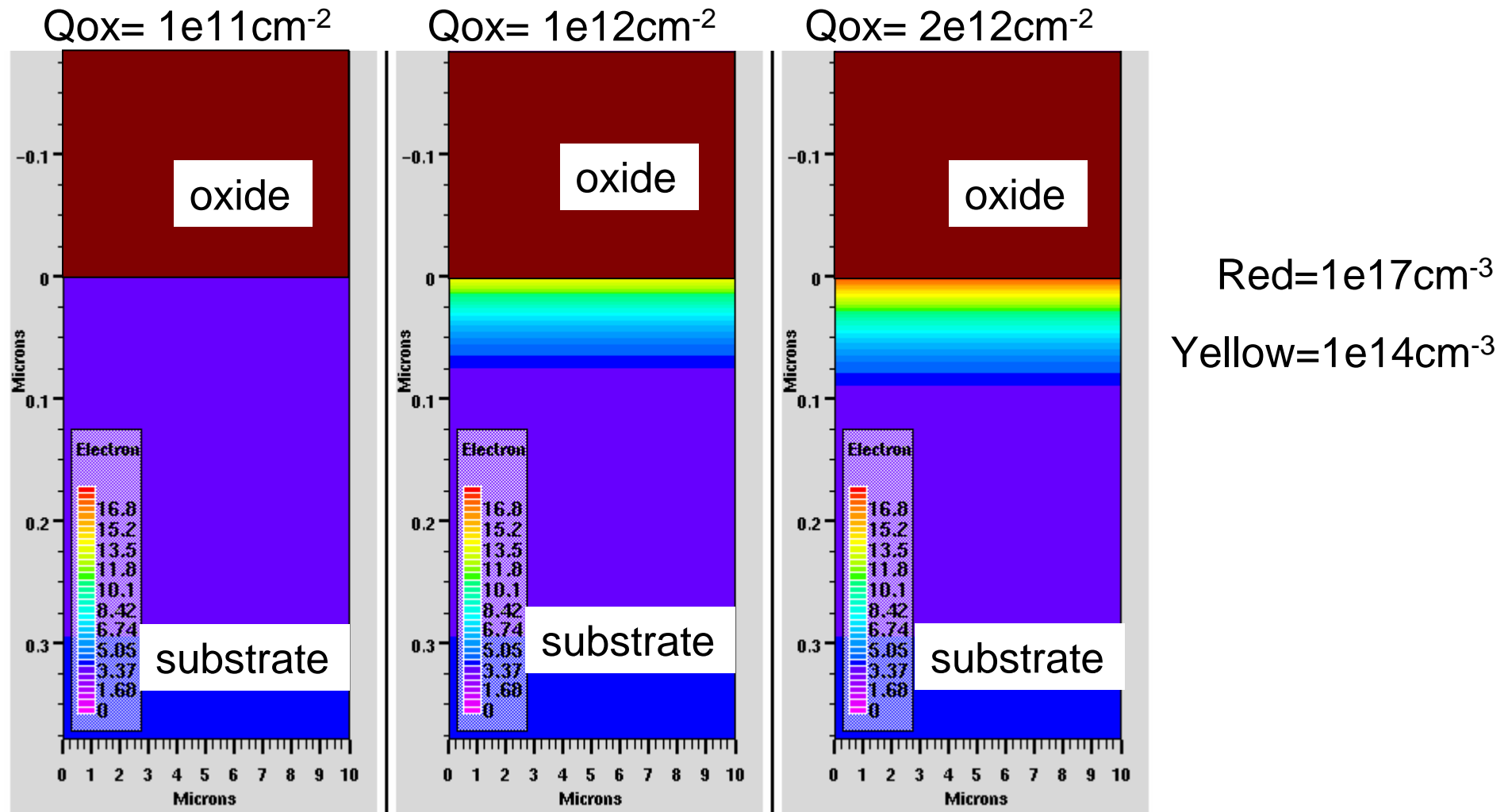


Perfect agreement with
an oxide charge density
of $1e11\text{cm}^{-2}$

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

n-on-p – CV MOS (3)

Electron concentration underneath the oxide.



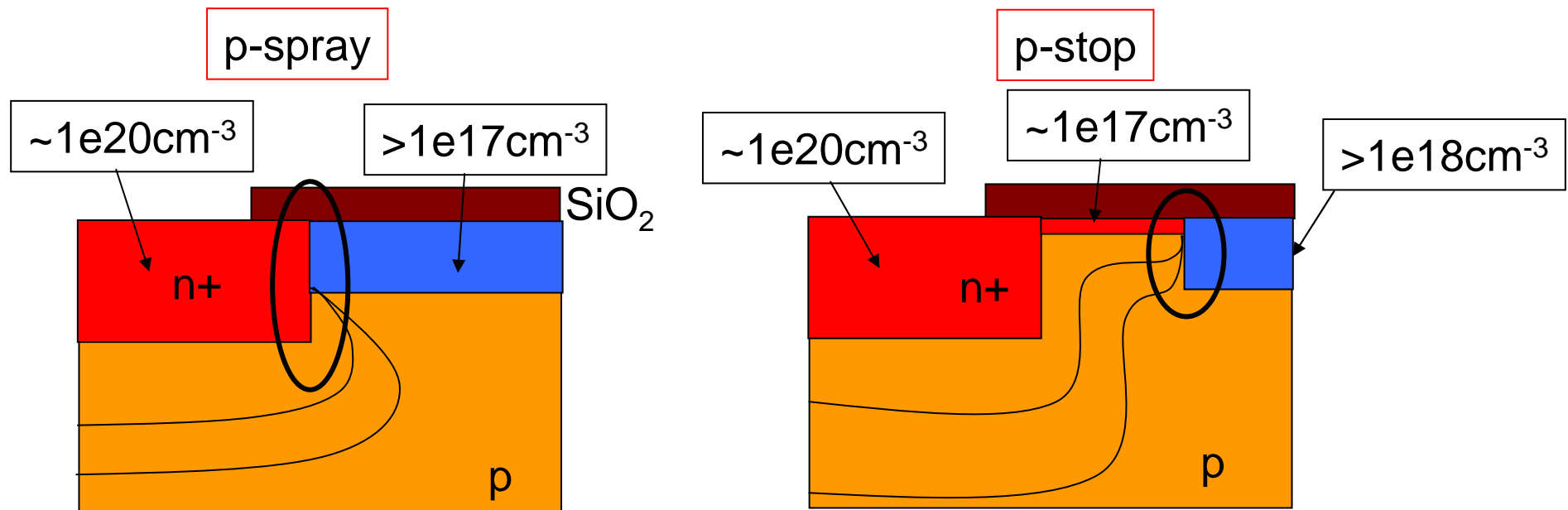
n-on-p – (p-spray) vs (p-stop)

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.