N_{eff} tuning in MCz-Si detectors by isothermal annealing

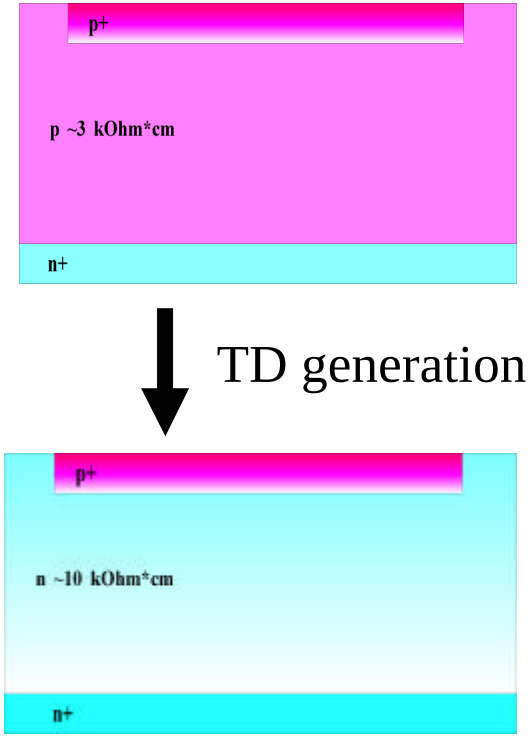
Mara Bruzzi, Zheng Li, Jaakko Harkonen,
E. Tuovinen, P.Luukka, D. Menichelli

INFN Florence, University of Florence
Brookhaven National Lab., Upton, NY
Helsinki Insitute of Physics, Finland

- ✓ **Motivations**
- ✓ **Experimental Procedure**
- ✓ **Results**
- ✓ **Conclusions**

Aim of the work

Starting from the talk presented by J. Harkonen at 4th RD50 Workshop, May, CERN, systematically perform N_{eff} tuning to produce p^+nn^+ detectors on high resistivity Cz Si



1. **Process $p^+/p/n^+$ diodes from p-type MCz-Si few kWcm (Okmetic)**
2. **Activate shallow thermal donors via an isothermal annealing cycle**
3. **Measure at each annealing step the full depletion voltage and N_{eff} sign by Transient Charge Technique (TCT)**
4. **Evaluate TDs activation**
5. **Aim is modulation of N_{eff} by isothermal annealing to achieve easily high resistivity p^+ n/p n^+**

Experimental

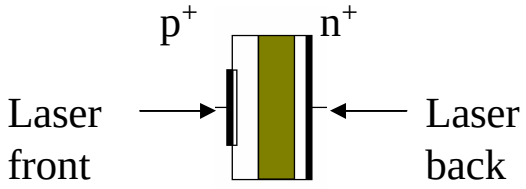
- Six $p^+/p/n^+$ diodes (active area 0.25cm^2, thickness 300μm) manufactured on p-type Cz Si Okmetic wafers (nominal resistivity 5kΩcm) at the Helsinki University of Technology, Finland .

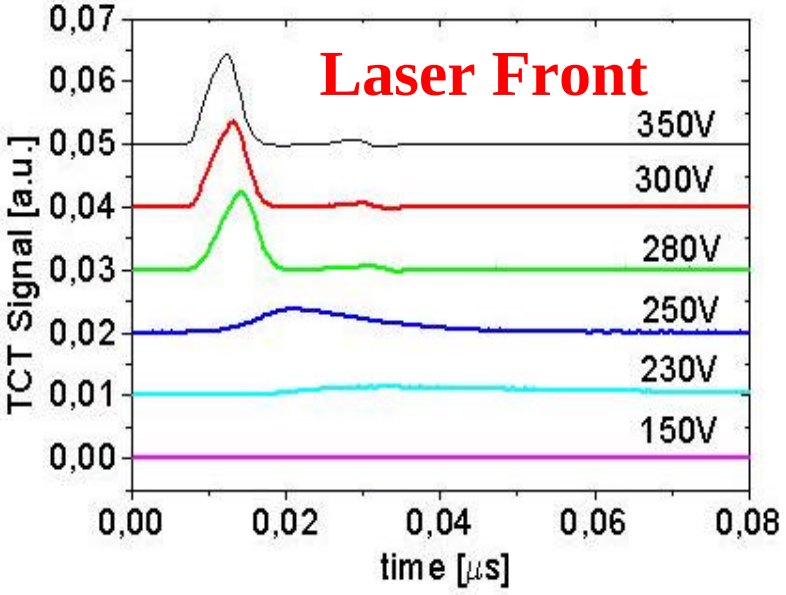
- Devices studied at BNL by Transient Current Technique using a pulsed infrared laser (660nm) beam placed close either front or back electrodes. Collected charge measured in the range 0-400V, to determine full depletion voltage and sign of the effective space charge concentration N_{eff}.

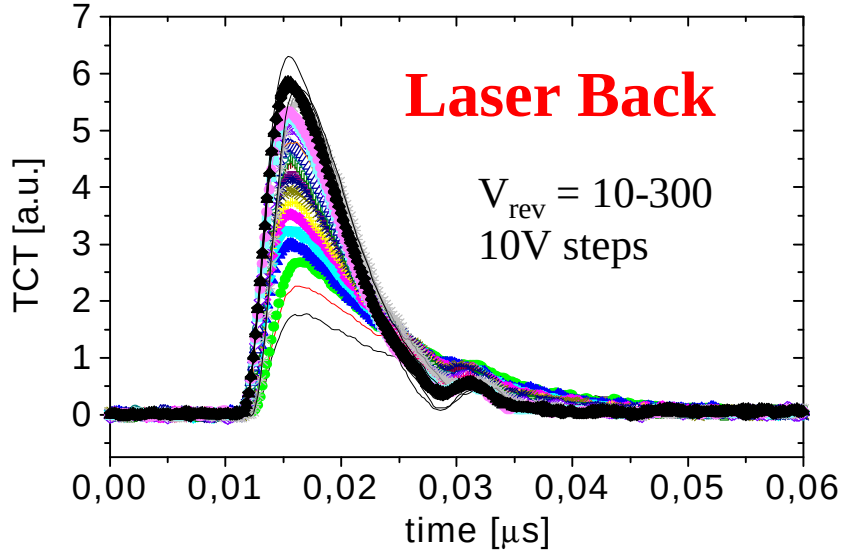
- An isothermal annealing cycle has been performed at 430°C with different time interval from 45min to 120min. TCT has been measured before and after each annealing step.

Results before annealing

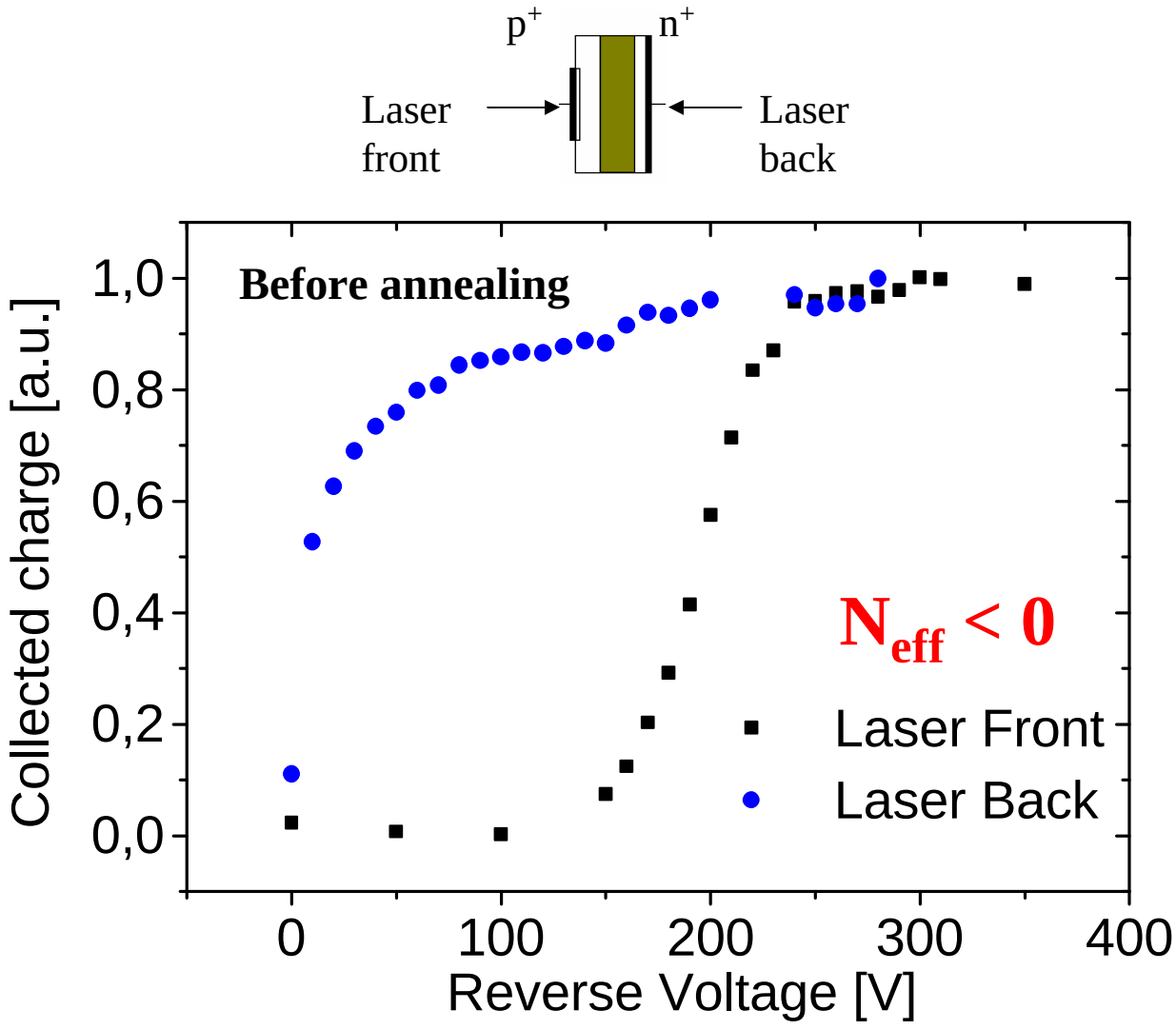
As the devices are $p^+/p/n^+$, when the reverse bias is increased the space charge region develops from the back electrode. The signal is measured with laser front only when $V_{rev} \geq V_{fd,}$ while it is always measured from back if $V_{rev} \neq 0$







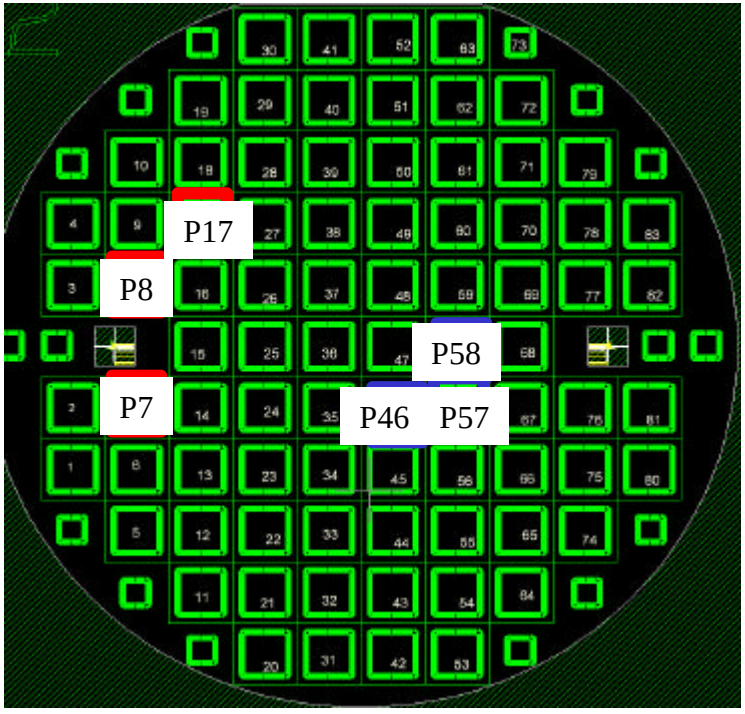
Signal integrated in time, plotted against Vrev to determine the N_{eff} sign



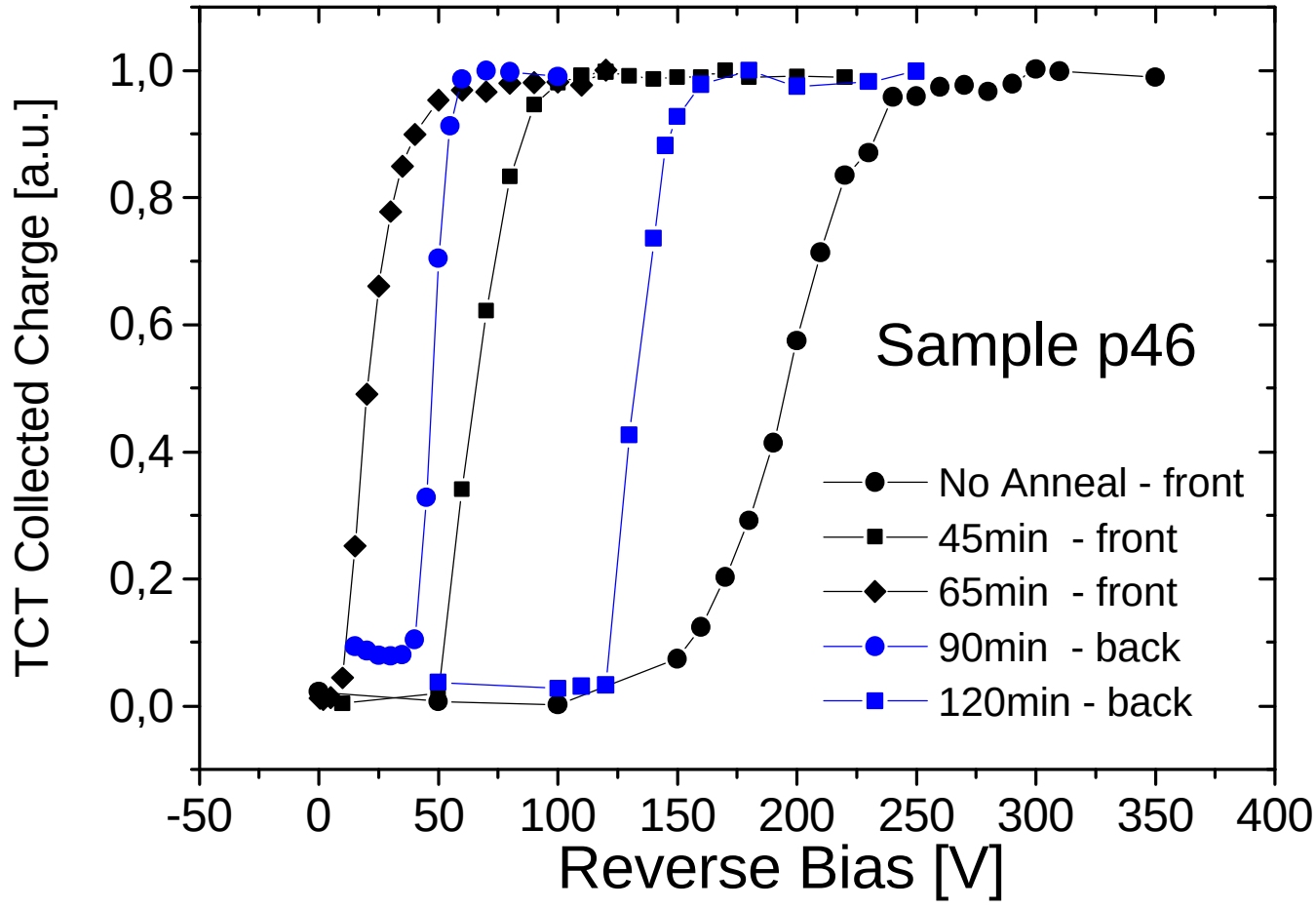
Full depletion voltage (V_{fd}) and effective concentration (N_{eff}) as determined by TCT before annealing

Sample	V_{fd} [V]	N_{eff} [$10^{12}cm^{-3}$]
P7	262,00	- 3.86
P8	226,65	- 3.34
P17	229,05	- 3.37
P46	232,95	- 3.43
P57	237,15	- 3.49
P58	214,75	- 3.16

No correlation between N_{eff} and position in wafer



The TCT measurements are repeated for each diode after 5 different annealing steps (0-45-65-90-120min) at 430°C. Samples invert from p to n-type in between the two last annealing steps.

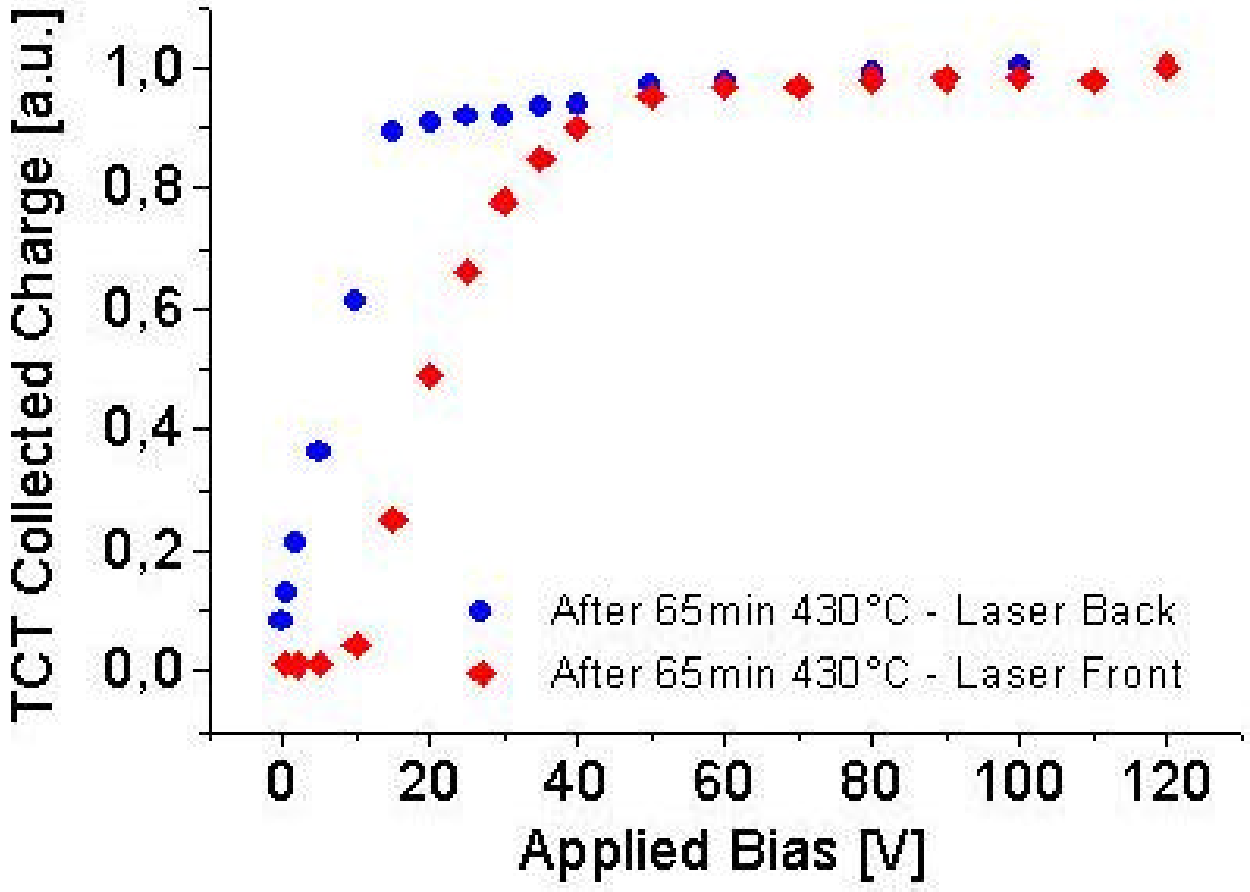


BULK:

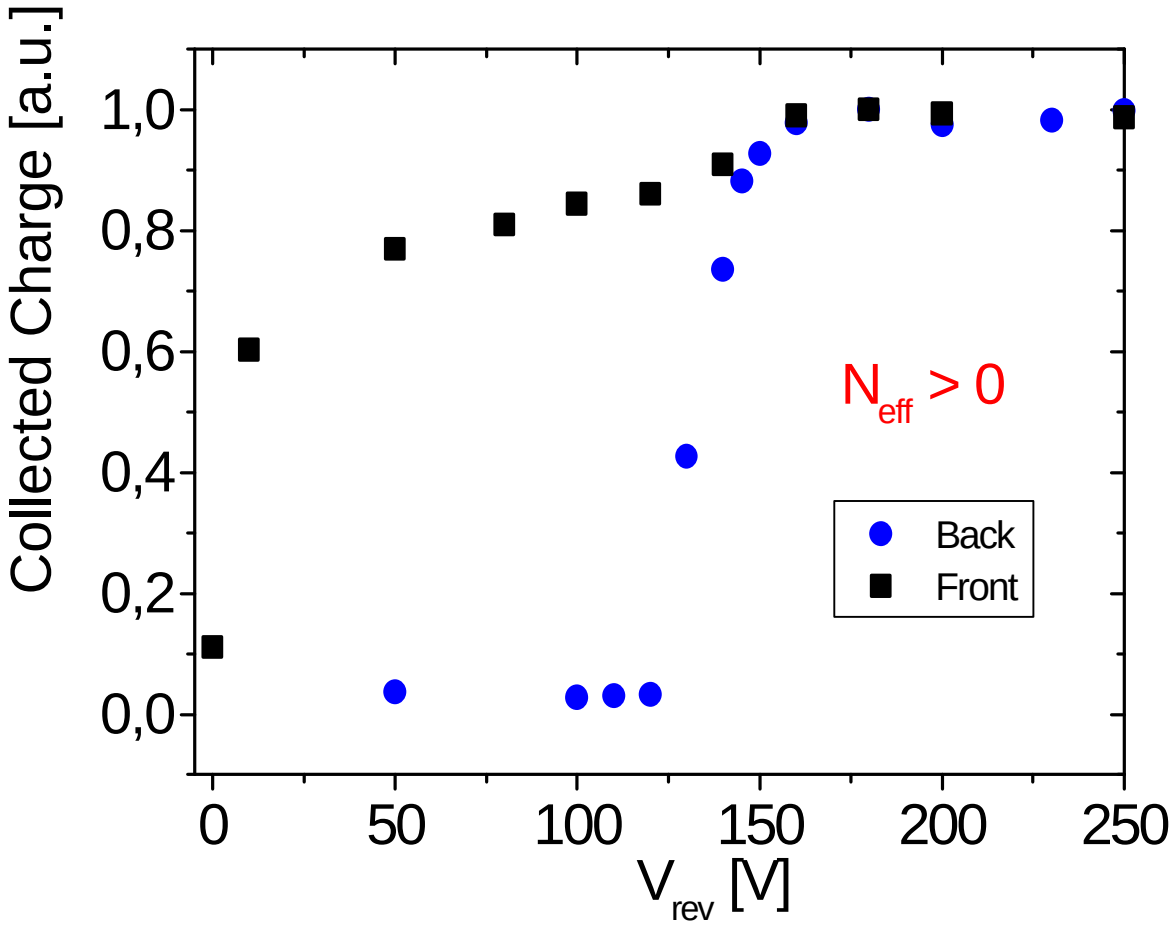
P-type

N-type

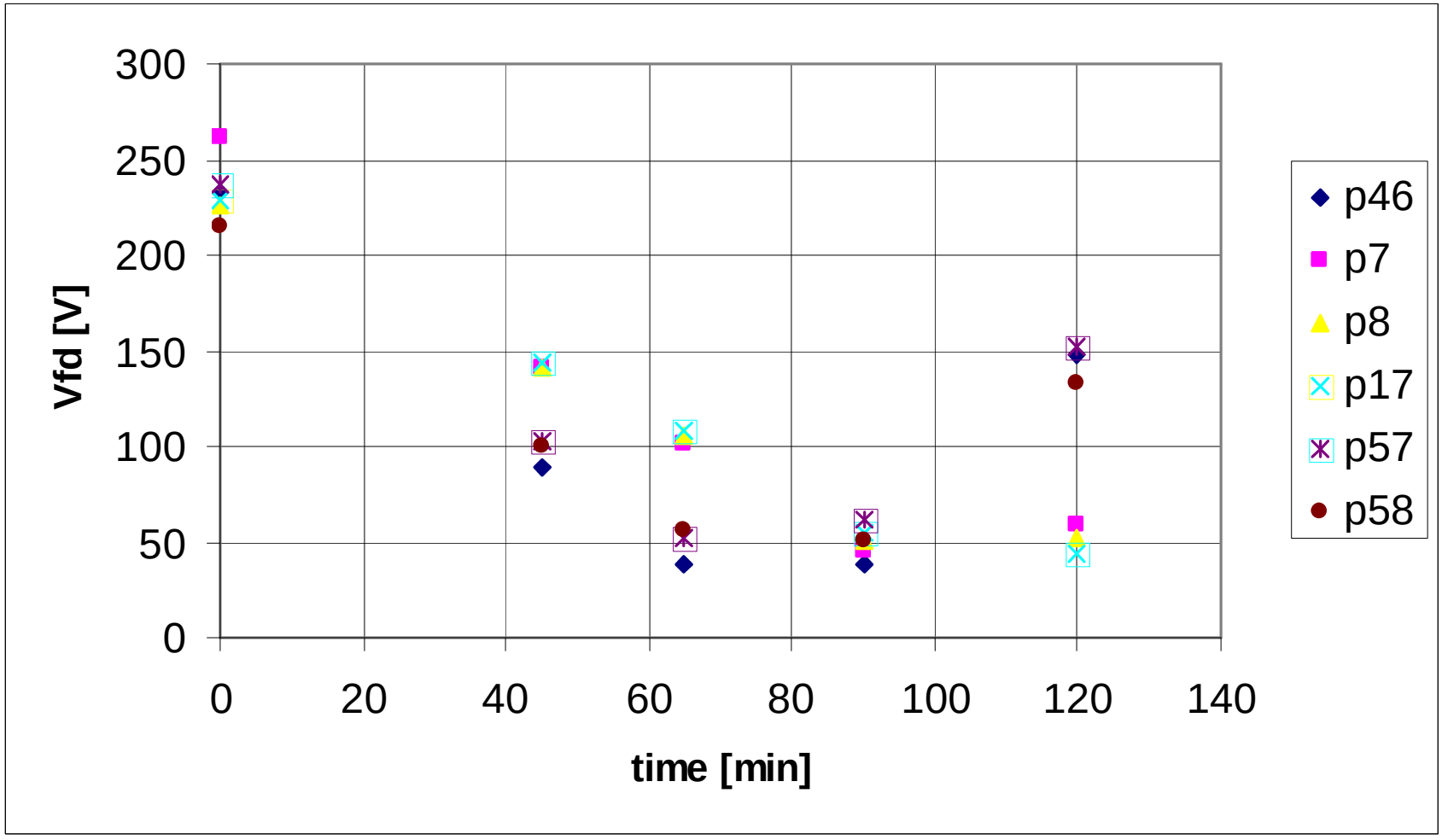
Annealing activates TDs which compensate the shallow Boron present in the starting material: very high resistivity, up to r ~10-30kWcm, are achieved.



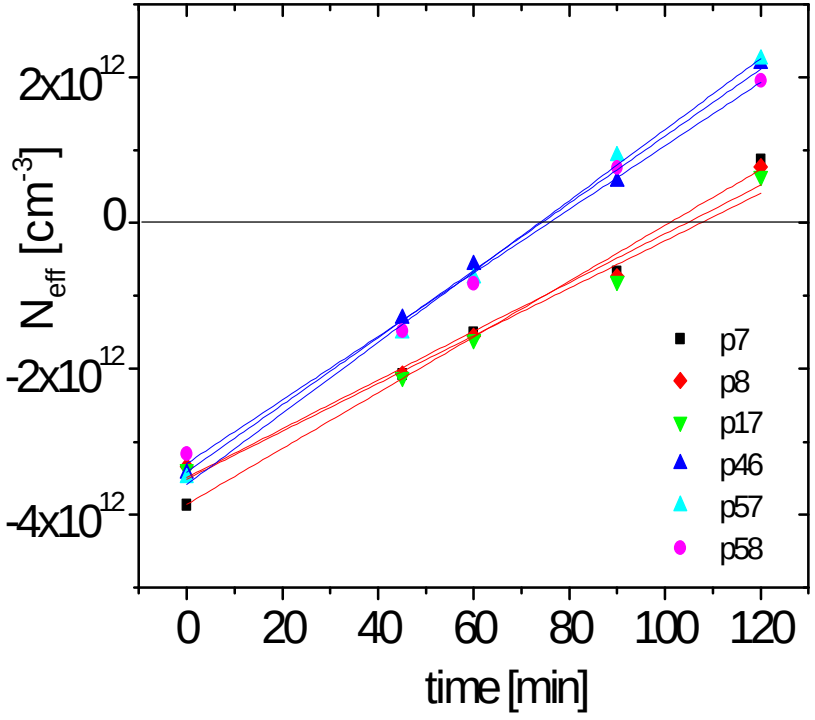
At the last annealing step a N_{eff} with positive sign is measured for the 6 diodes. The depletion region moved to front electrode.

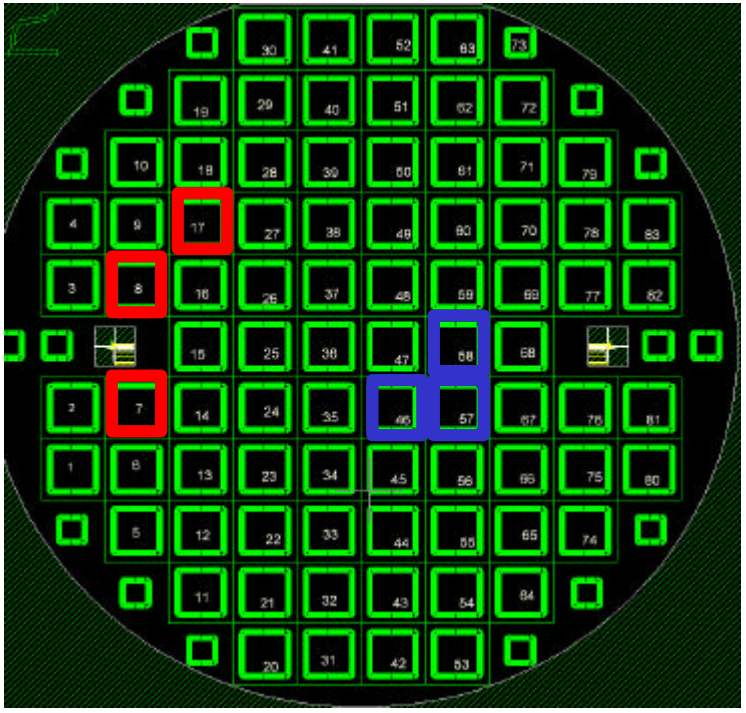


Full depletion voltage as measured with TCT



The generation rate for N_{eff} is not correlated to the initial N_{eff} value, but depend on the position of the diode inside the wafer → O_i concentration or other impurity involved





Initial N_{eff} (▭)/N_{eff} (▭) = 1.05

Final N_{eff} (▭)/N_{eff} (▭) = 2.8

In the simple hypothesis:

$$N_{eff} = N_{eff}(0) + b(T)* t$$

b = (3.48 ± 0.30) x 10^{10} cm^{-3}/min

b = (4.61± 0.25) x 10^{10} cm^{-3}/min

Conclusions

Changes of N_{eff} have been studied after up to 120min isothermal annealing with T = 430C on detectors processed on p-type Cz Si.

The procedure allows a fine tuning of N_{eff} to obtain high resistivity n- and p-type material.

Uncertainties in the procedure are given by fluctuations on the concentration of native defects (O_i, H, ..) locally affecting the generation rates. Starting with V_{fd} = 220-260V, final full depletion voltage varied in the range 50-150V.

DLTS studies of shallow thermal donors are planned on the treated diodes to study activation processes and wafer disuniformities.