Studying microscopic defects as origin of macroscopic effects in irradiated silicon detectors

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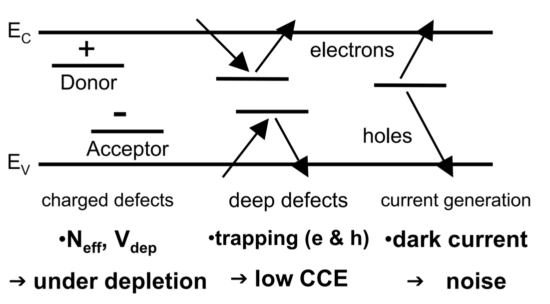
Radiation hard silicon for sLHC

Today's most awaited high energy physics experiment is the large hadron collider (LHC) at CERN. In the tracking area of the LHC experiments up to 200 m^2 of silicon sensors are used. The aimed luminosity for the LHC upgrade is L=10^{35} cm^{-2}s^{-1}.
The radiation induced bulk damage in silicon crystal will lead to a severe decrease of the signal to noise ratio during the operational time. In particular, the pixel detectors in the innermost layers will be exposed to fluences of some 10^{16}cm^{-2}. An improved radiation hardness of the silicon sensors is needed.

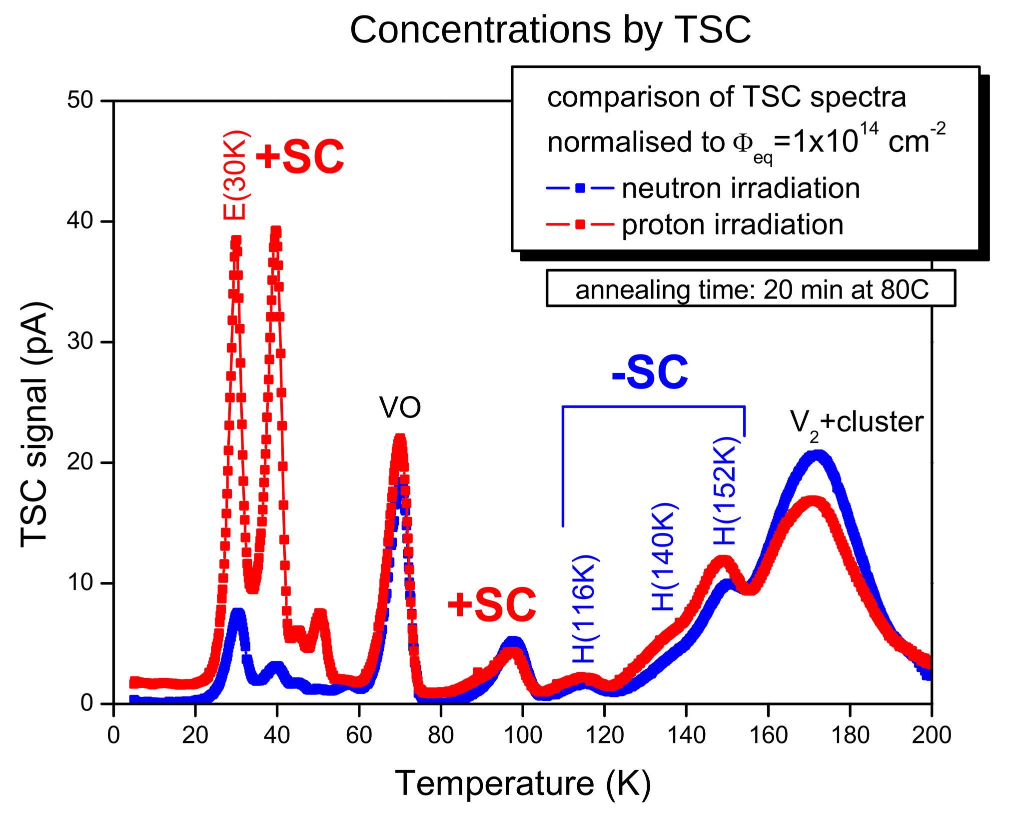
Effects due to radiation damage



Bulk damage results in changes of the sensor properies such as

- field distribution
  ⇒ depletion voltage
- dark current
- trapping

Impact of microscopic defects on the effective doping concentration



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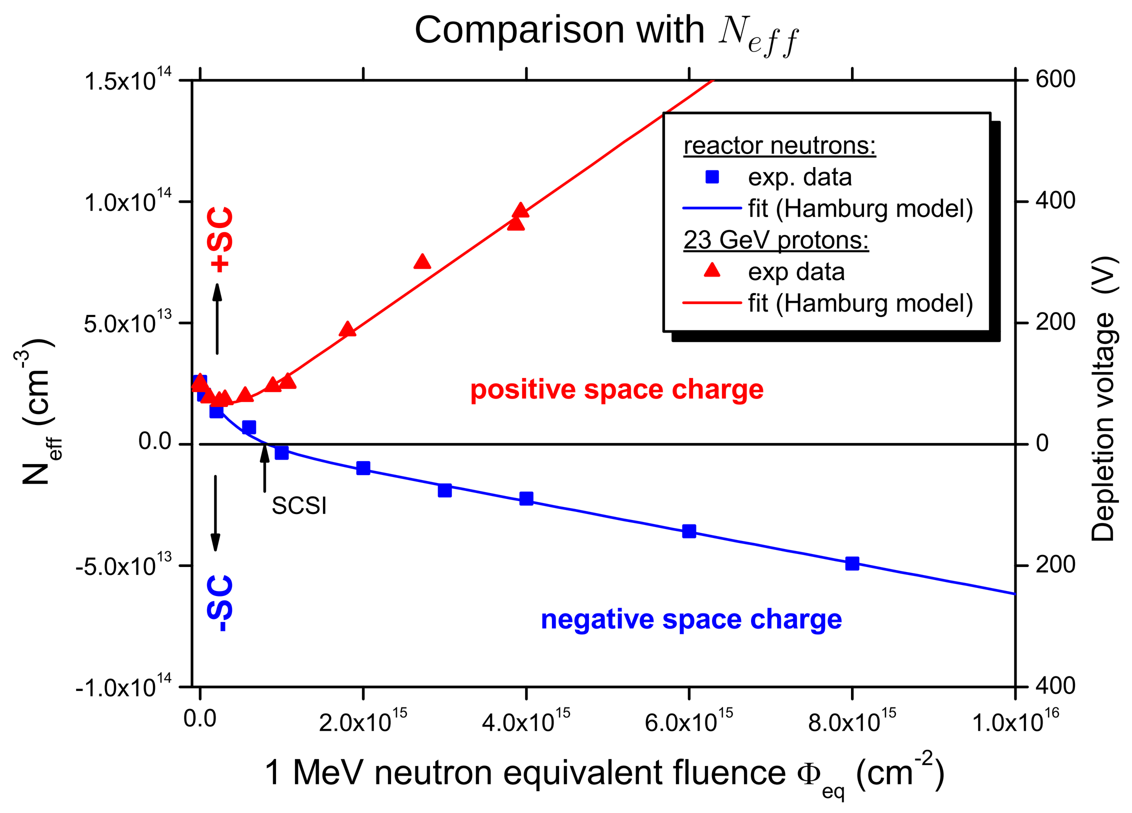


Measurements of epitaxial material (EPI) demonstrate a dominant acceptor generation after neutron irradiation being the source for type inversion. This is not seen after proton irradiation due to a pronounced donor generation. The defects influence the space charge (SC), either donors with positive or acceptors with negative contribution [1]. Annealing experiments were performed to identify these defects.

Approach: defect engineering

Aims:

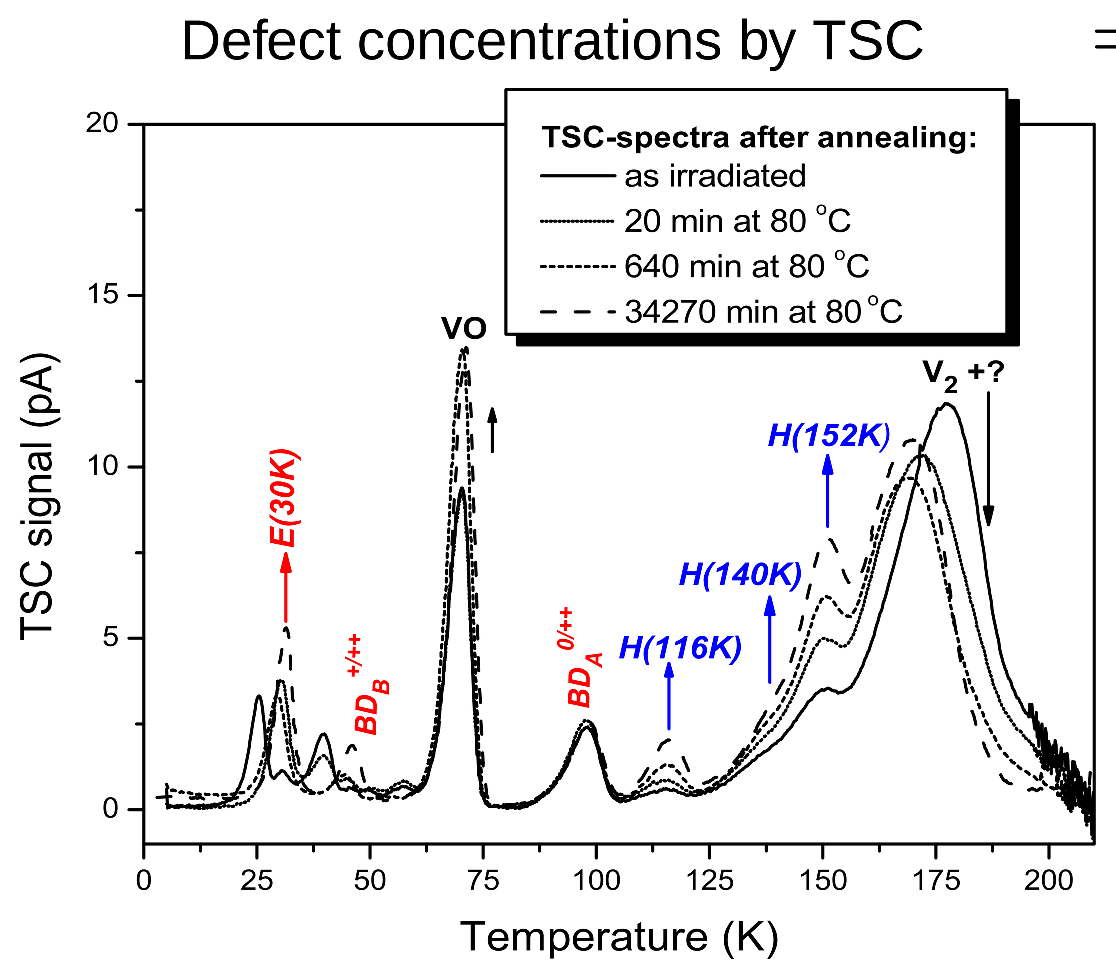
- identification of damage induced defects
- understand defect kinetics
- passivate defects by introducing impurities
- find best silicon material
- combine defect engineering with other approaches

Methods:

- combined microscopic and macroscopic measurements
- defect concentrations by Deep Level Transient Spectroscopy (DLTS) and Thermally Stimulated Current technique (TSC)
- determine macroscopic sensor properties by CV/IV
- annealing experiments

Prediction of the reverse annealing for n-EPI material

1 MeV neutrons



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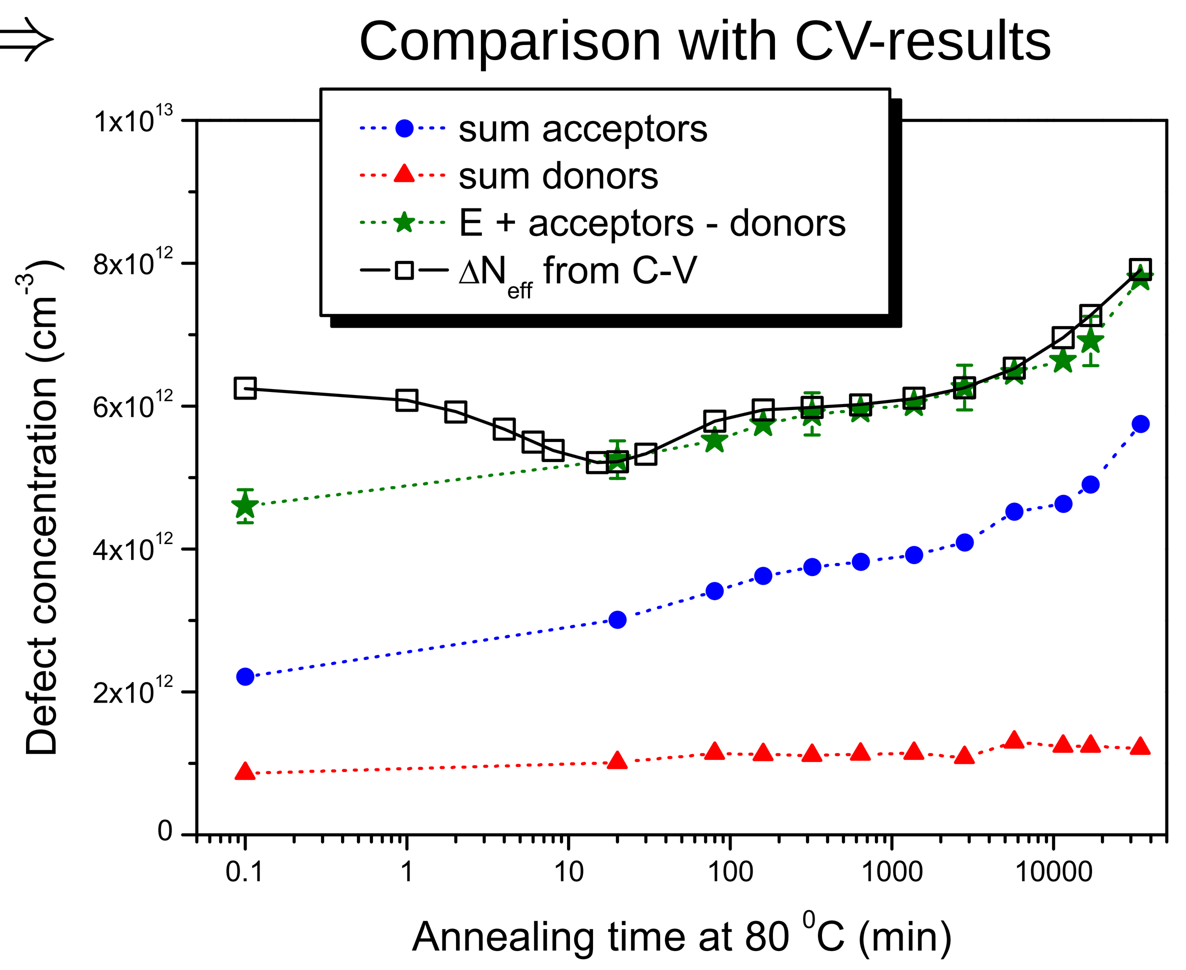
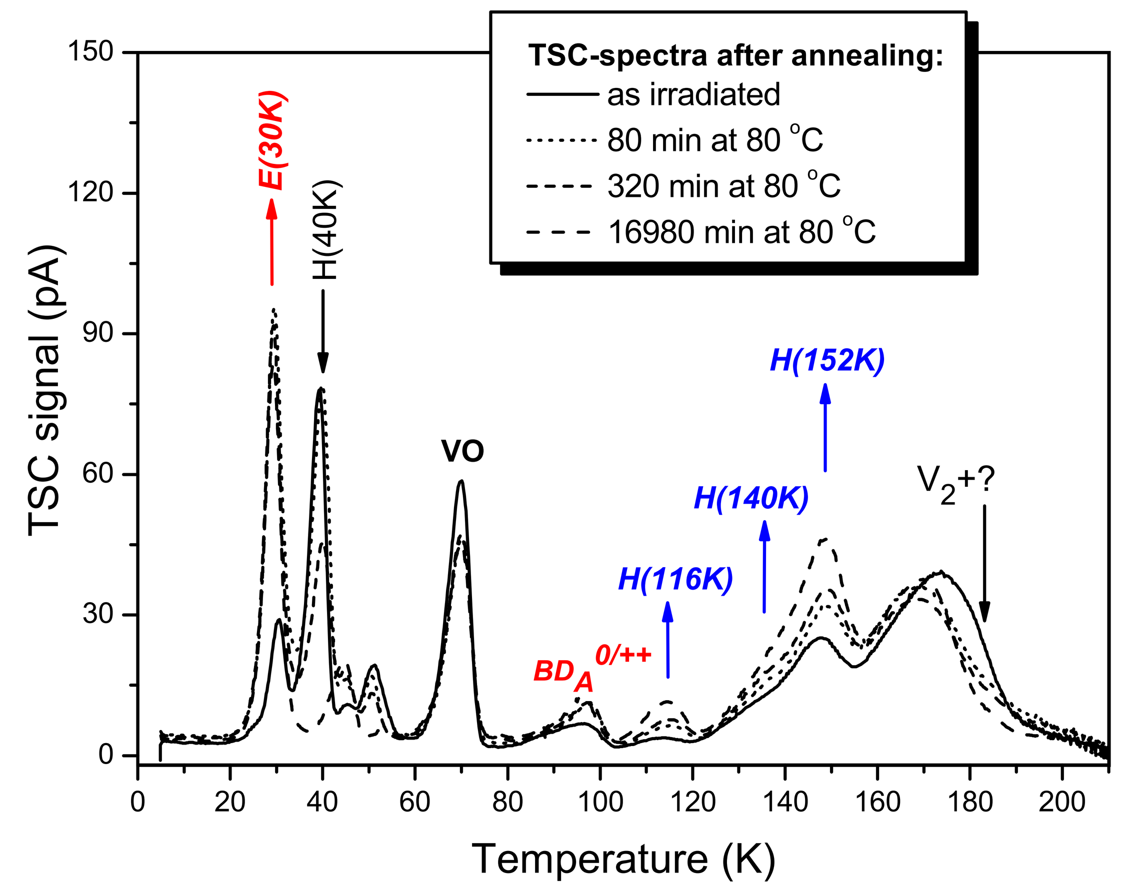
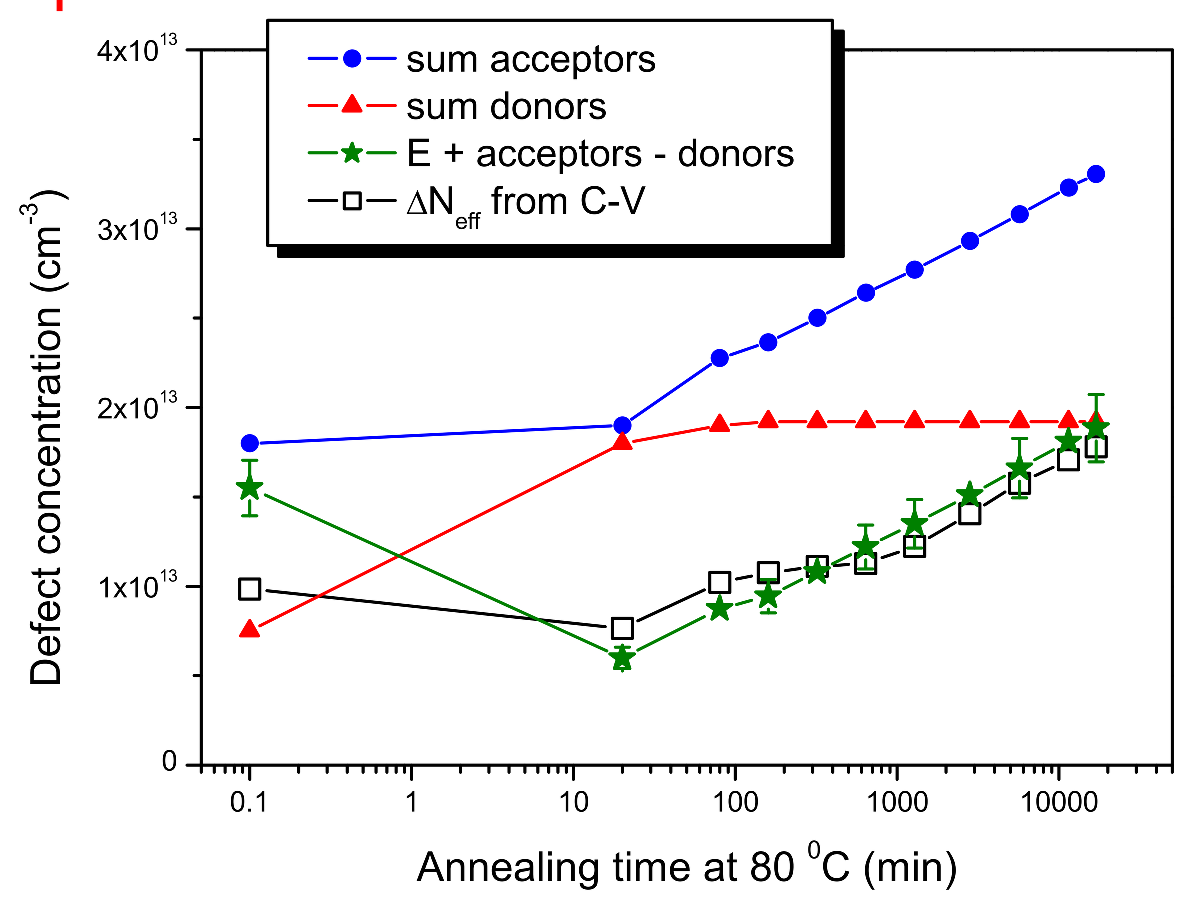


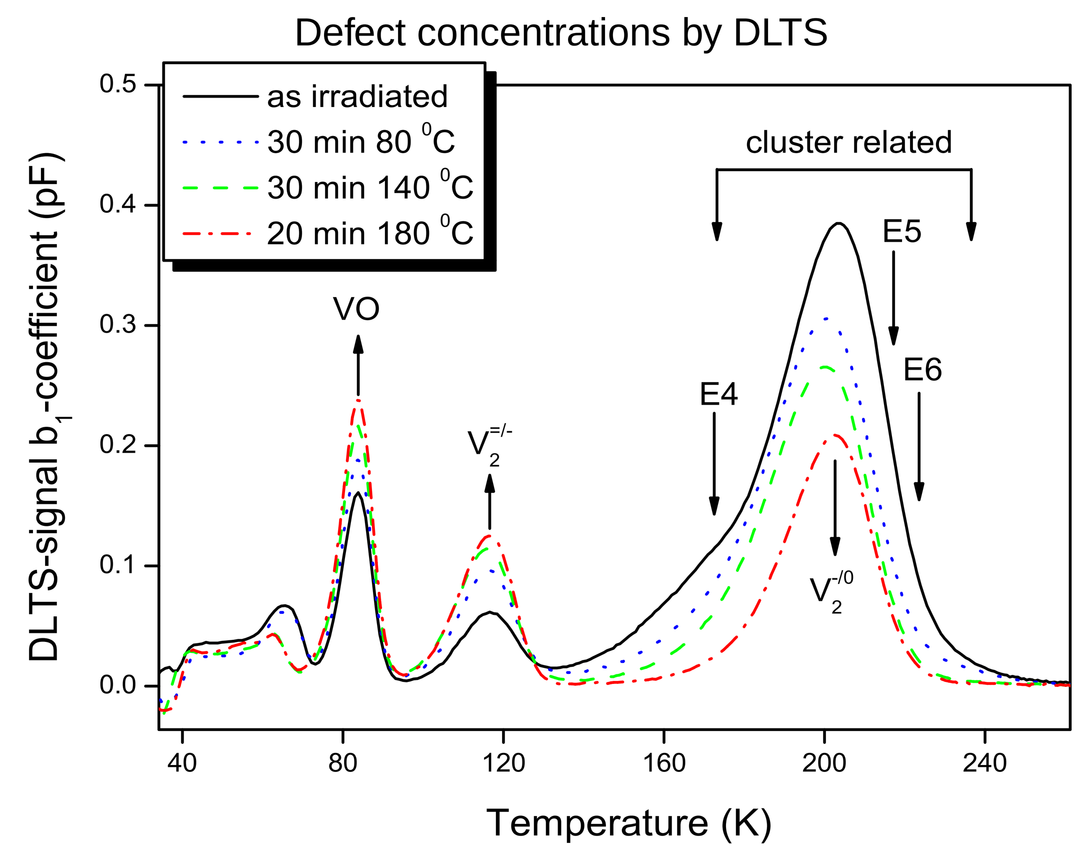
23 GeV protons

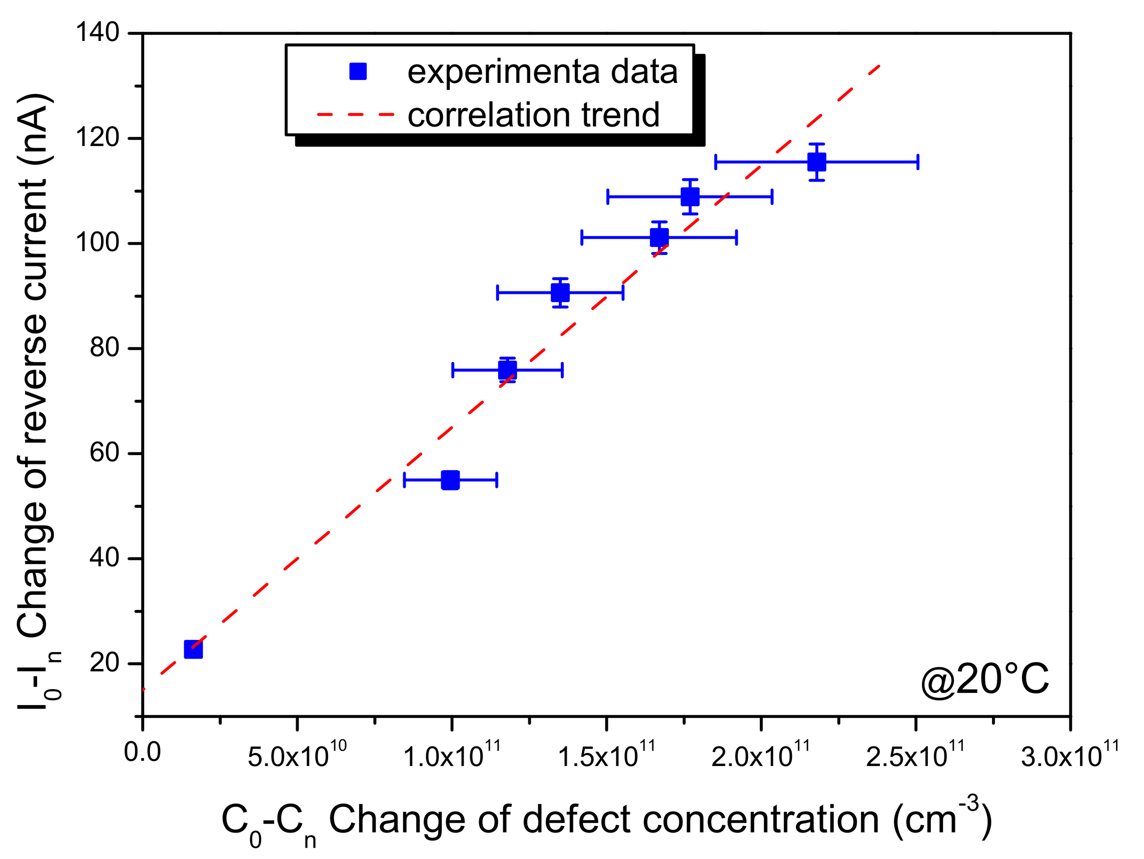




Defect kinetics fully understood [3]!
Breakthrough in understanding radiation damage!

Defect cluster: source for dark current





A correlation between the generation of the dark current and vacancy like defect clusters [2] is found. This DLTS study was performed on $\Phi_{eq} = 3 \times 10^{11}$ cm^{-2} neutron irradiated MCz material.

Major progress

- breakthrough in understanding radiation damage
- complete understanding of defect kinetics
- prediction of reverse annealing
- correlation between cluster defects and dark current

next:

- find ways to passivate cluster defects

Acknowledgements

This study was performed in the frame of the CERN-RD50 collaboration and funded by CiS, the BMBF and the Helmholtz Alliance. The authors would like to thank G. Kramberger for the neutron irradiation at the TRIGA reactor at JSI Ljubljana and M. Glaser who provided the proton irradiation at the Proton Synchrotron at CERN.

References

[1] I. Pintilie, E. Fretwurst, G .Lindström, Appl. Phys. Lett. 92, 024101 (2008); DOI:10.1063/1.2832646

[2] A. Junkes, 2008th RADECS conference proceedings, Jyväskylä, Finland

[3] I. Pintilie, G. Lindström, E. Fretwurst, A. Junkes, to be published

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