Marie Curie Initial Training Networks

Radiation Damage in Silicon Particle Detectors

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ESR at University of Hamburg Sept. 2009

Outline

- Project Overview
- Results in the first year
- Outlook
- Benefits from MC-PAD

Overview of the project

Project goal:

- LHC upgrade: silicon sensors need improvement to resist in the harsh radiation environment
- Correlation of microscopic defects parameters with macroscopic sensor properties

Overview of the short-term objectives:

- Learn and earn experience in experimental techniques: Deep Level Transient Spectroscopy (DLTS), Thermally Stimulated Current (TSC), measurements of semiconductor parameters (C/V, I/V)
- Characteristics of radiation induced defects and their annealing behaviour
- Correlation of parameters defects with sensor performances

Radiation damage effects in Si

➢ Non Ionizing Energy Loss produces ➡ point defects and clusters

Change in the properties:

➢ Change of effective doping concentration Neff (Electric field, full depletion voltage)

➢ Increase of leakage current (increase of shot noise, thermal runaway)

➢ Increase of charge carrier trapping (reduced charge collection efficiency (CCE))

Development radiation hard Si detectors:

➢ Correlation of microscopic with macroscopic properties of the detector

➢Knowledge of defect kinetics

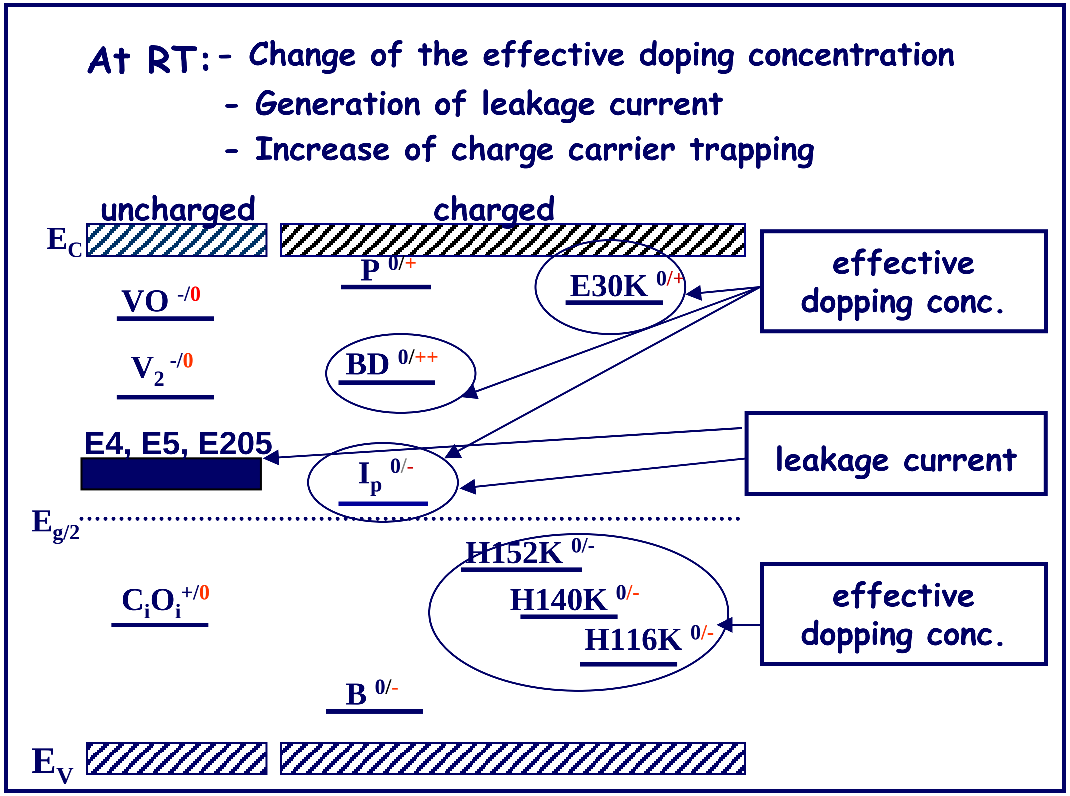
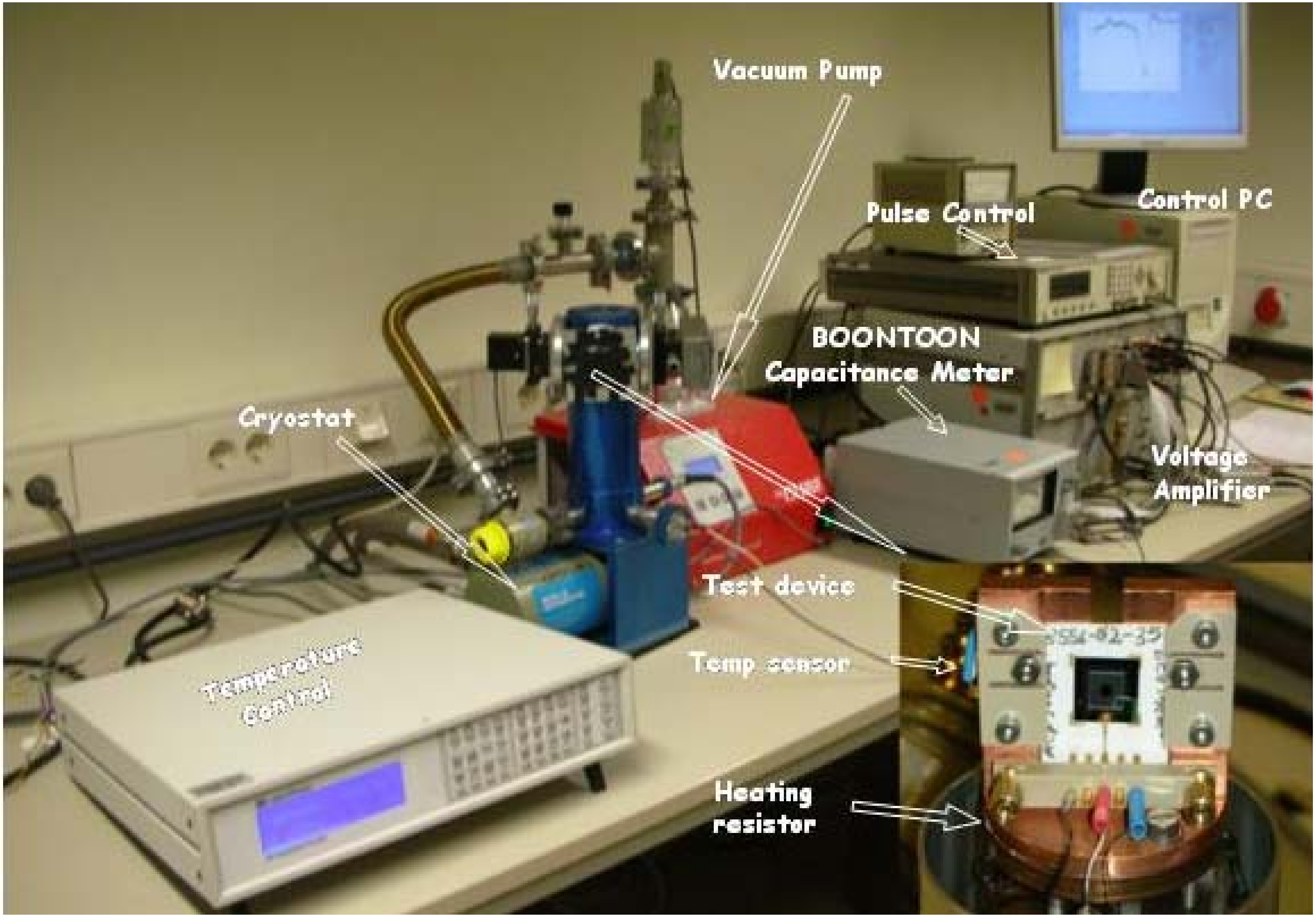


Fig1: Schematic representation of additional levels introduced by different defects in the band gap

Capacitance Deep Level Transient Spectroscopy



Microscopic investigation of Epi-DO and Epi-ST

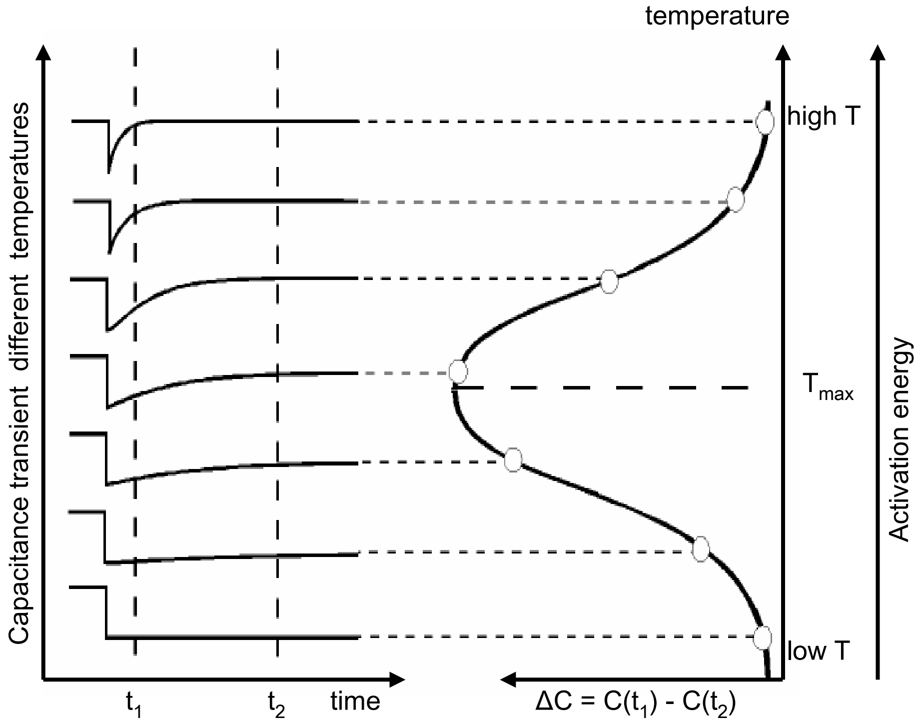


Fig2: Obtaining DLTS Spectrum

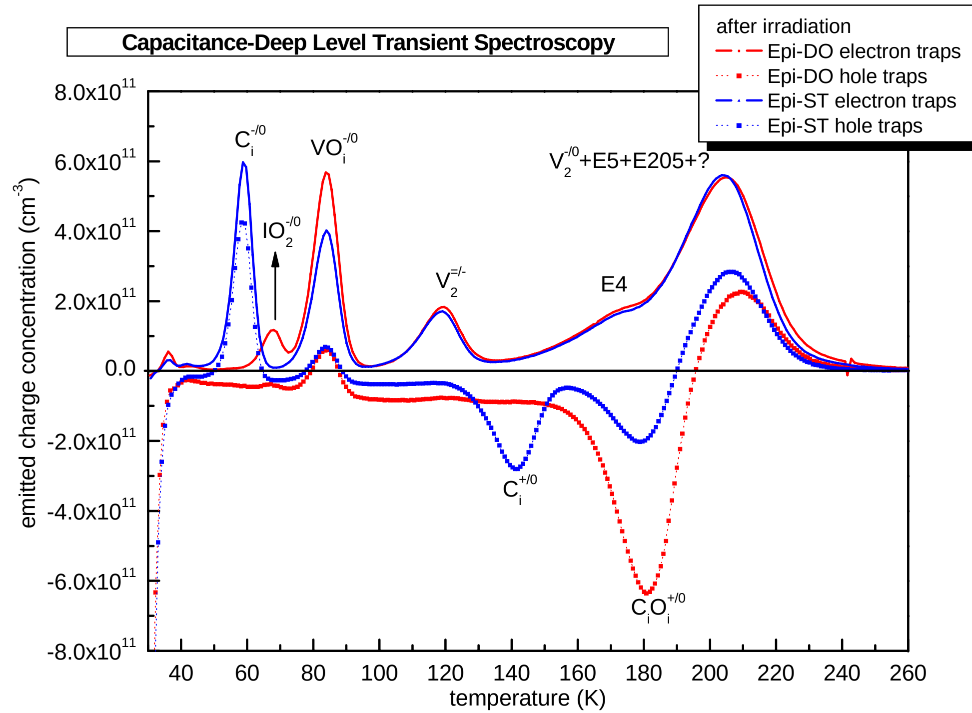
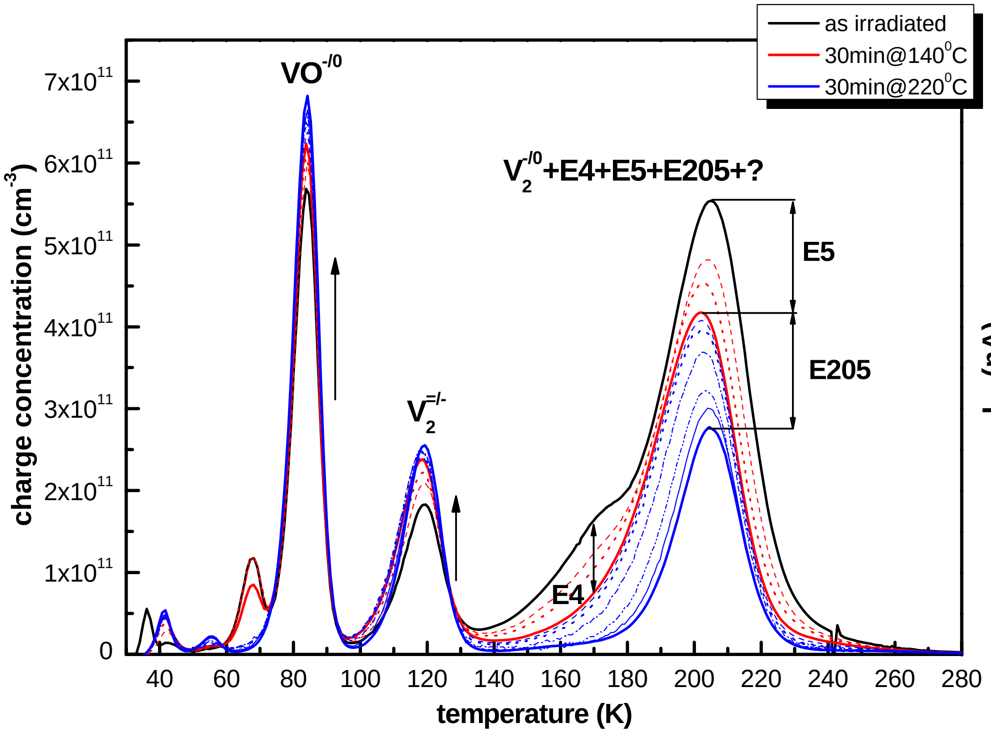


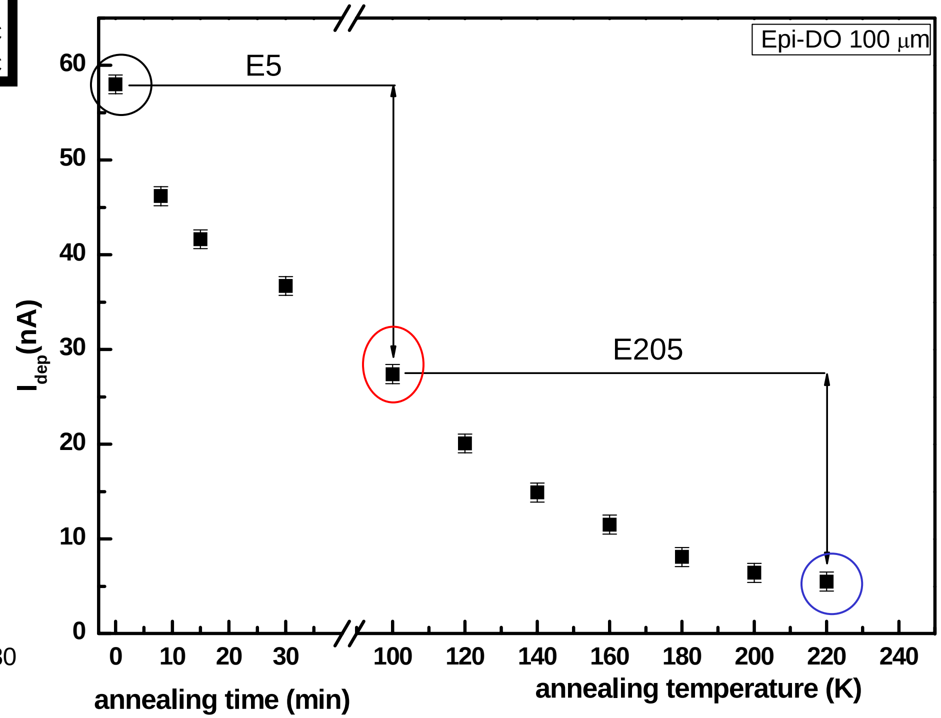
Fig3: DLTS spectrum after irradiation

- **Defect concentration → from amplitude of the capacitance transient ΔC**
- **Activation energy → from the slope of an Arrhenius plot**
- **Cross section → from the intercept of Arrhenius plot**

Cluster annealing



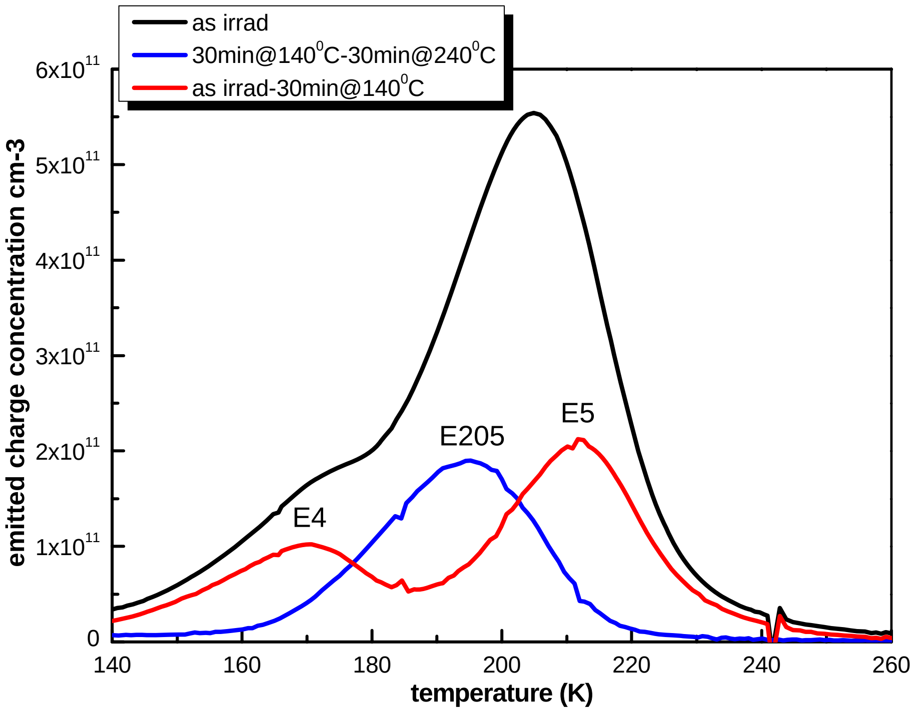
Leakage current annealing

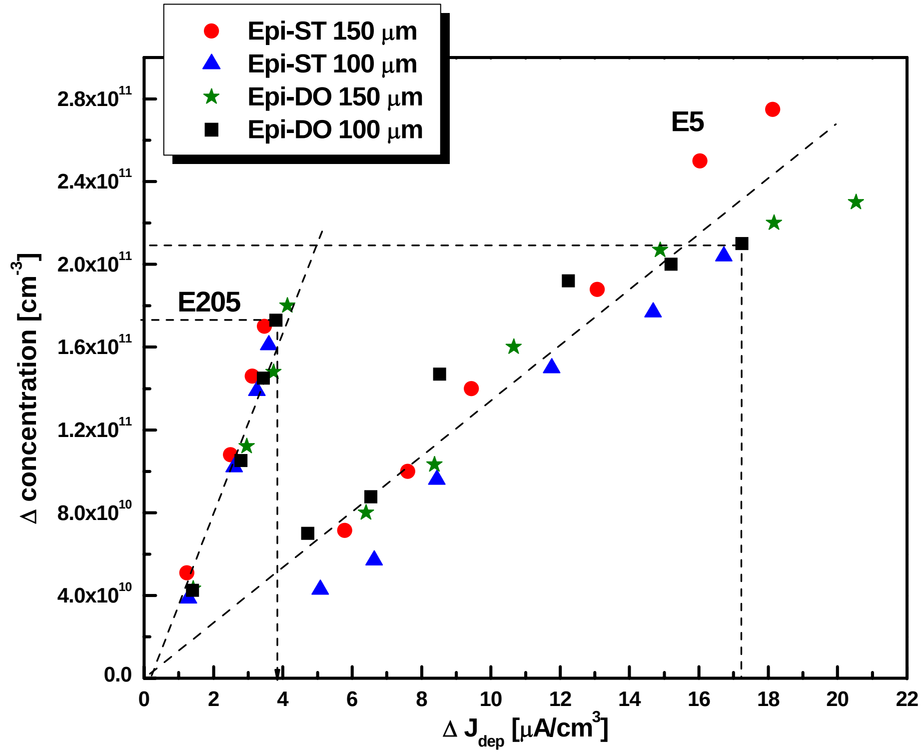


Annealing of E5 and E205 defect correlated with decrease of leakage current → dedicated study of correlation

Correlation between leakage current and concentration

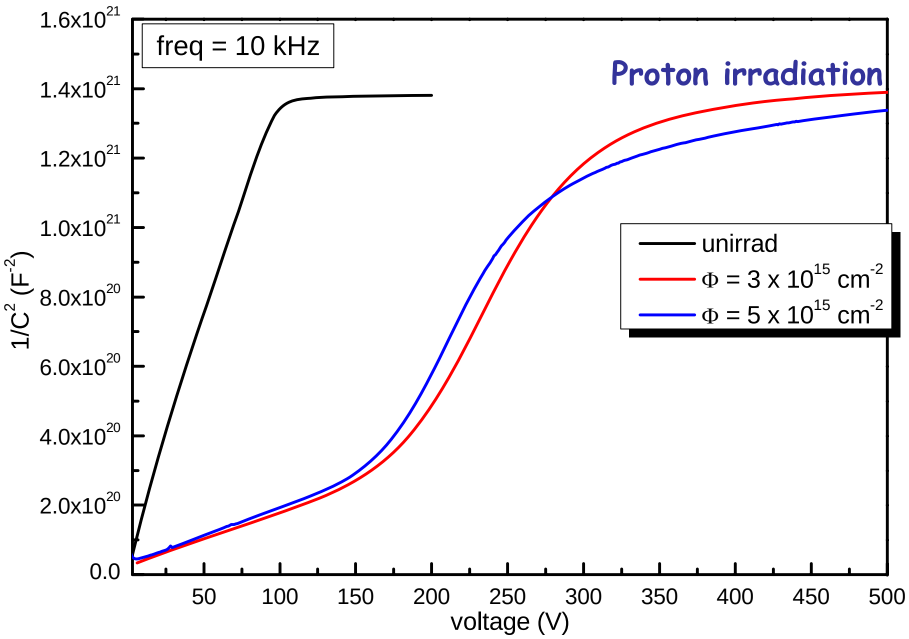
➢ **Break through in understanding the origins of leakage current**

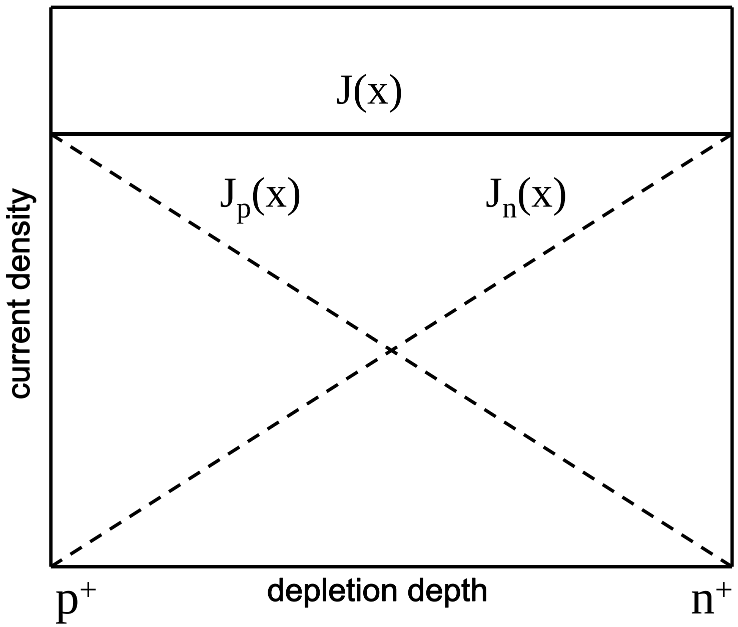




➢ **Density of individual defects correlate with the leakage current with different efficiencies (E5 > E205)**

Outlook: Understand electric field in irradiated detectors





- **Non-irradiated sensors → uniform doping $1/C^2 \sim V$**
- **Damaged sensors → non-uniform doping**
- **Method: - C/V and I/V measurements versus frequency**
  - model calculation using microscopic defect properties from Thermally Stimulated Current (TSC) measurements

Benefits from MC-PAD

Trainings:

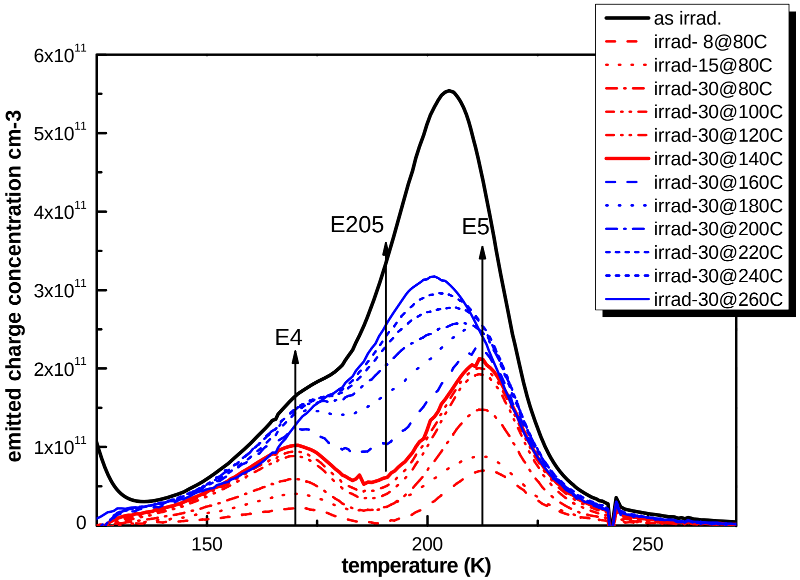
- MC-PAD training event on "Readout electronics" in Krakow (Sep.'09)
- MC-PAD training event on "Detector Simulation and Data Analysis" (Geant4 and Root) in Hamburg (Jan.'10)
- MC-PAD training event on "Radiation Hardness of Semiconductor Detectors and Detector Processing" in Ljubljana (Sep.'10)
- Deep Level Transient Spectroscopy technique (local training)

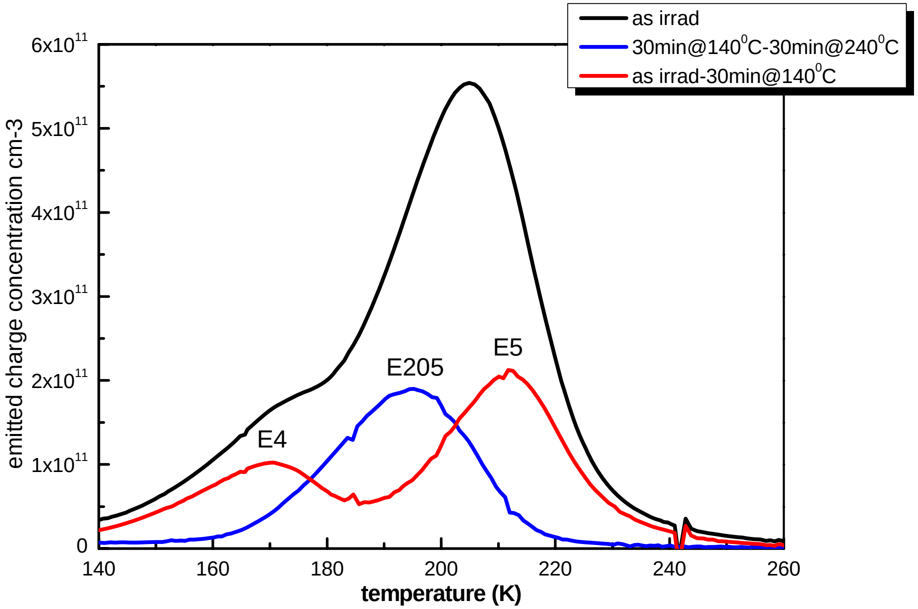
Other activities:

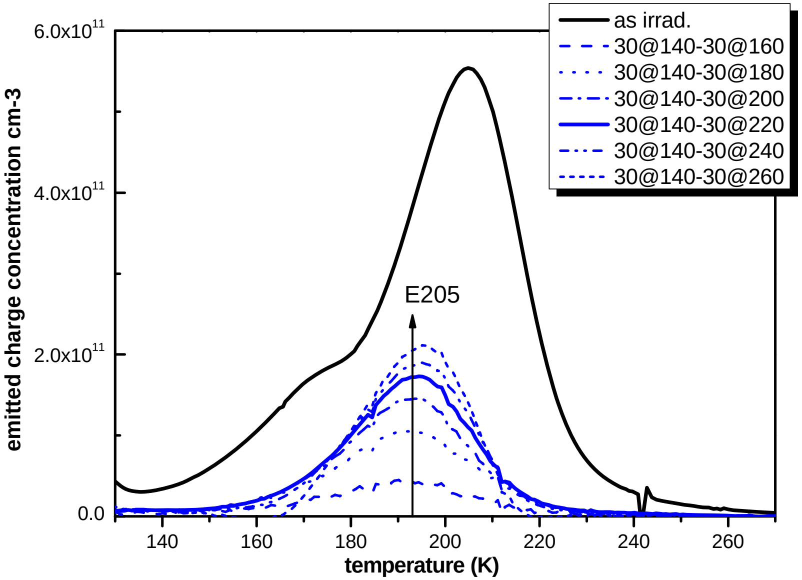
- German language courses at Desy
- Joint Instrumentation Seminar organized by Desy and UHH
- Presentation in Spring Meeting of Deutsche Physikalische Gesellschaft –Annealing studies on 23GeV proton irradiated epitaxial diodes (Mar '10)
- Participation in Workshop on Defect Analysis in Silicon Detectors in Bucharest (May '10)
- PSI Zuoz summer school on high energy physics - Gearing up for LHC physics (Aug '10)

Thank you for your attention!

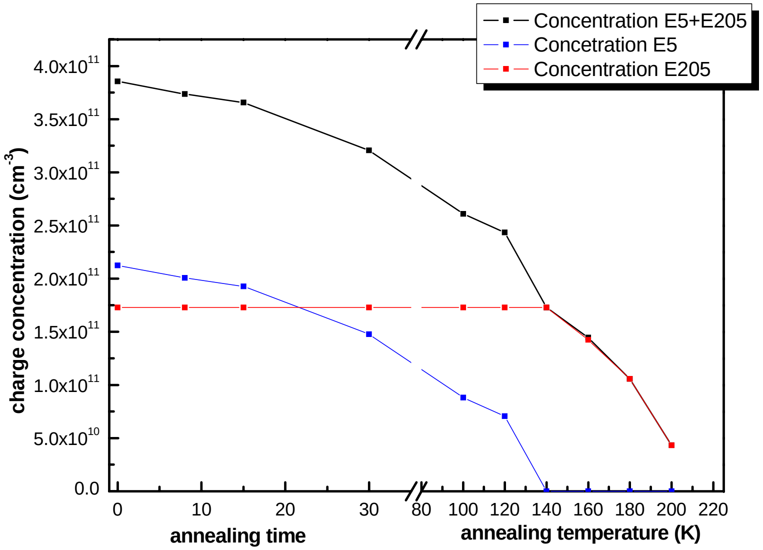
Backup slides

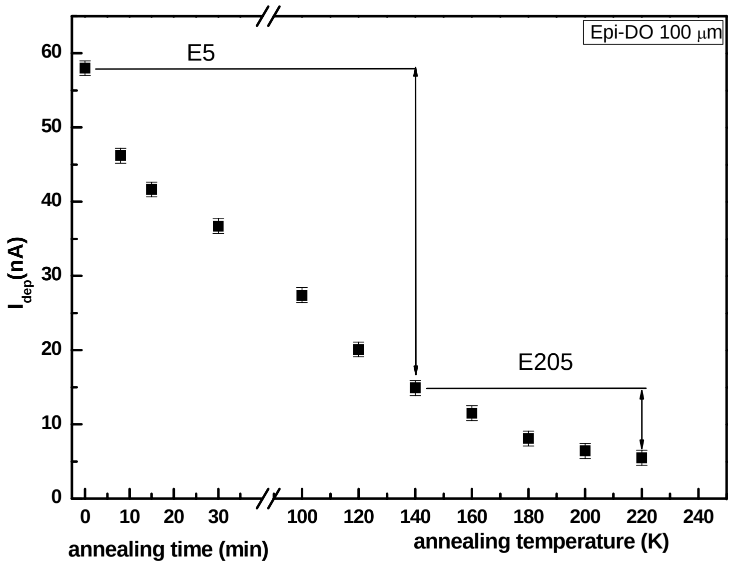


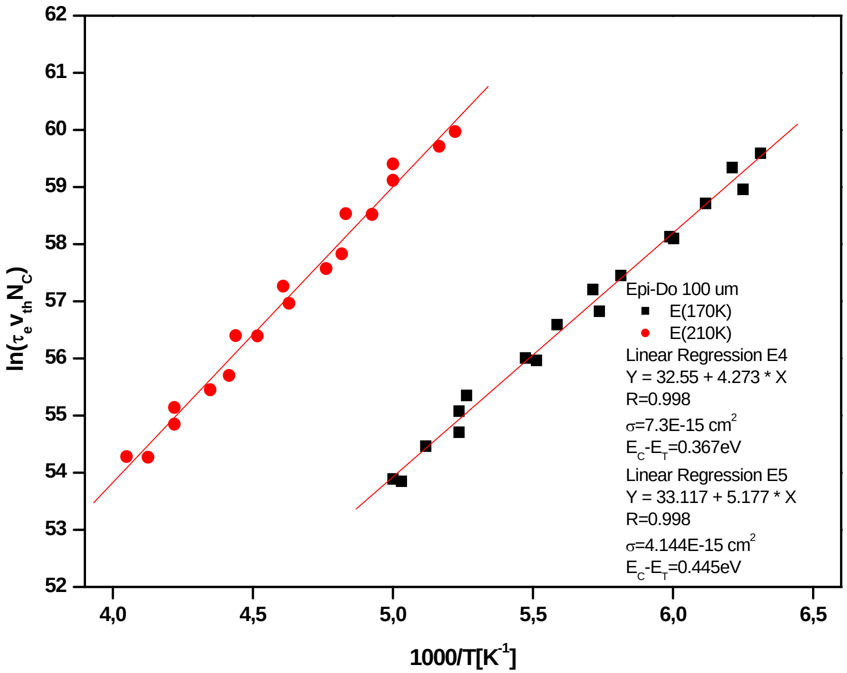




Reconstruction of the concentration of E5 and E205







Capacitance Deep Level Transient Spectroscopy (DLTS)

- Trap concentration << Doping concentration ⟶ Φ_{max} < 10^{12} cm^{-2}
- Principle of operation: capacitance transients measurements as function of temperature

$$C \approx \frac{1}{w_{depleted}}$$