Sensor Development for the European XFEL

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Introduction

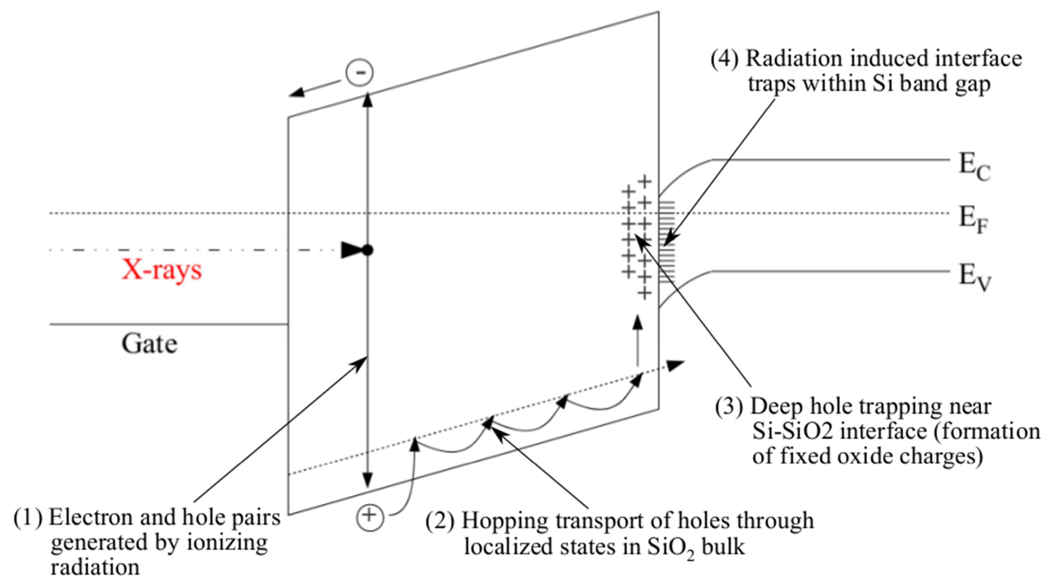
At DESY, Hamburg, the *European X-ray Free Electron Laser* (XFEL) is under construction. Starting in 2015, the XFEL will open up completely new research opportunities for science as well as for industrial applications. Examples are the structural analysis of single complex organic molecules, the investigation of chemical reactions at the femtosecond scale, and the study of processes which occur in the interior of planets.

Imaging experiments at the European XFEL require silicon pixel sensors with extraordinary performance specification: Doses of up to 1 GGy, up to 10^5 12 keV photons per pixel of 200 µm x 200 µm arriving within less than 100 fs, and a time interval between XFEL pulses of 220 ns. To address these challenges, radiation hard silicon sensors need to be developed.

The task is to characterize the radiation introduced surface charges for different X-ray doses, to study their influence on the electrical properties of segmented sensors, and to optimize the design of sensors for the XFEL applications.

X-ray induced damage

- No bulk damage due to 12 keV X-rays
- Damage at the Si-SiO_2 interface: fixed oxide charges and interface traps



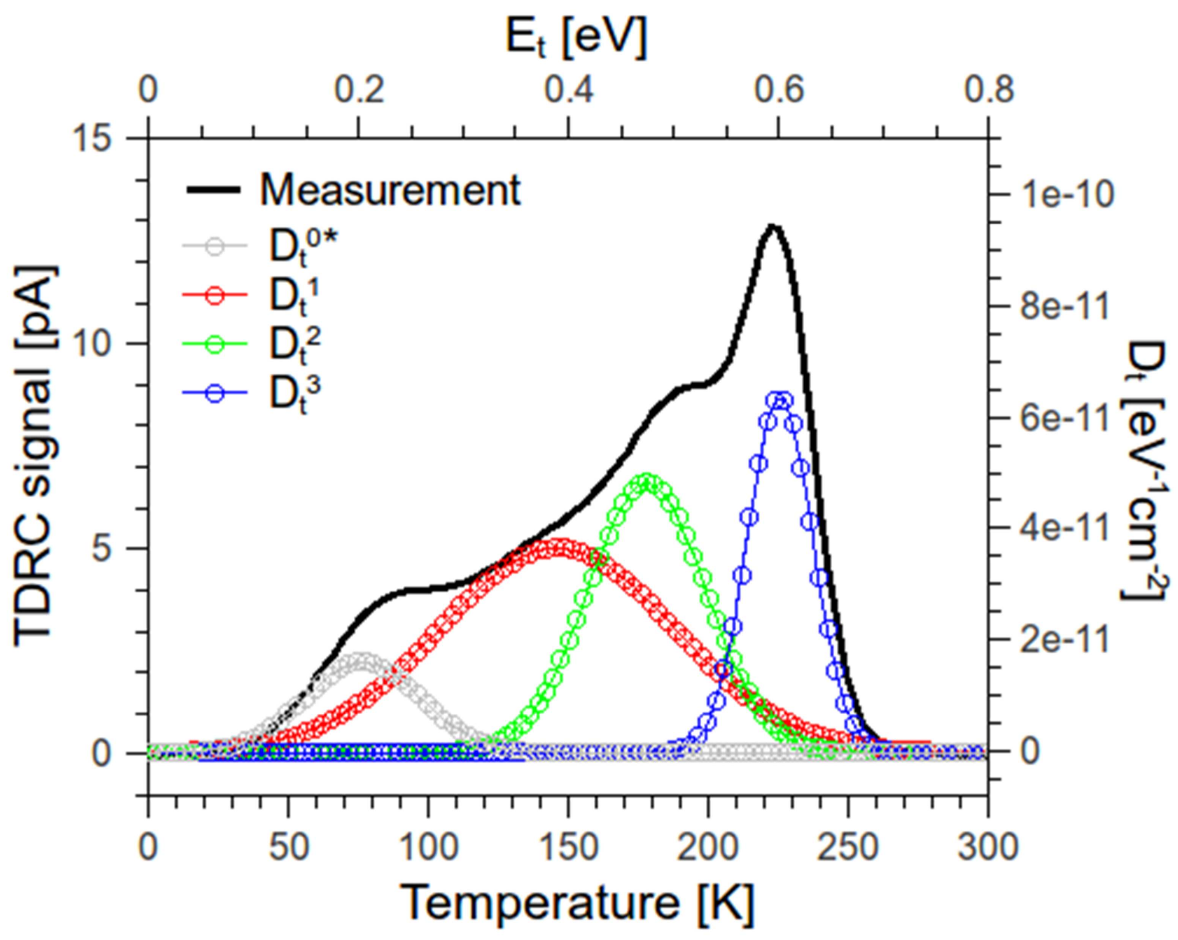
Extraction of the microscopic damage parameters from <100> MOS capacitors

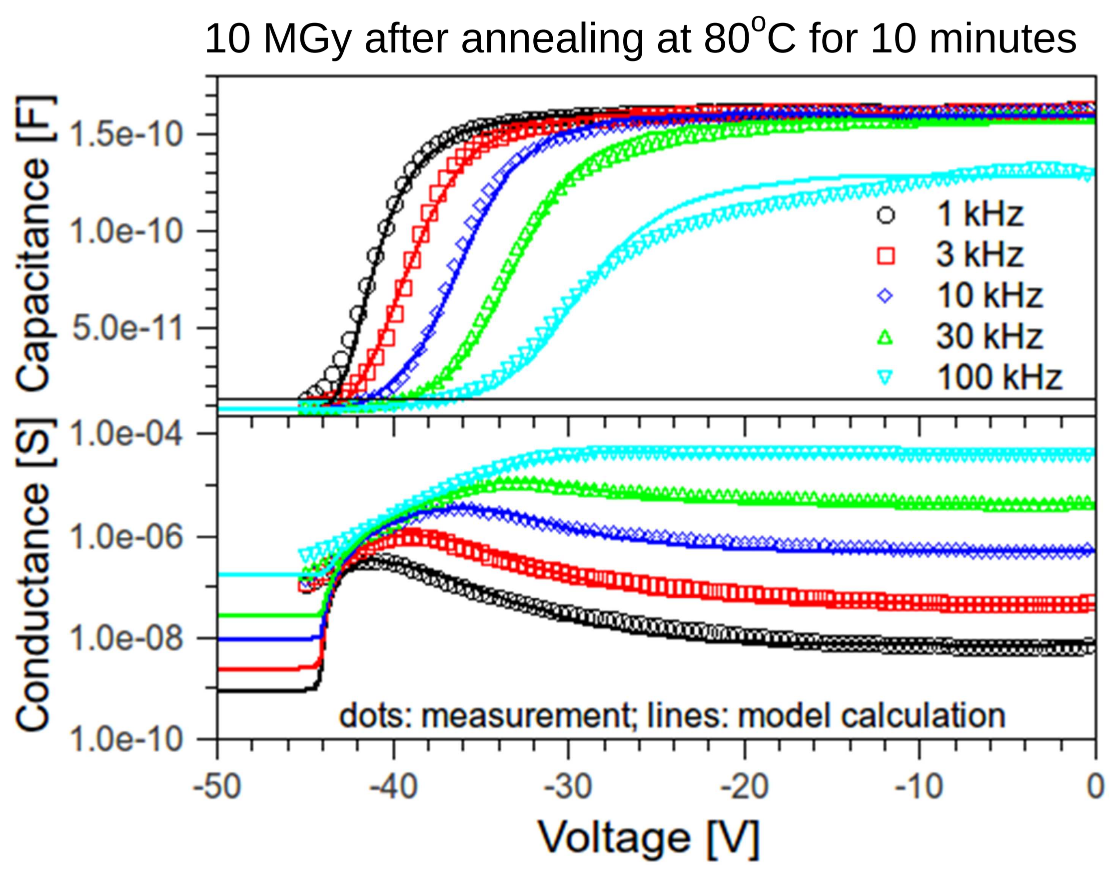
Method to determine the densities of fixed oxide charges and interface traps:

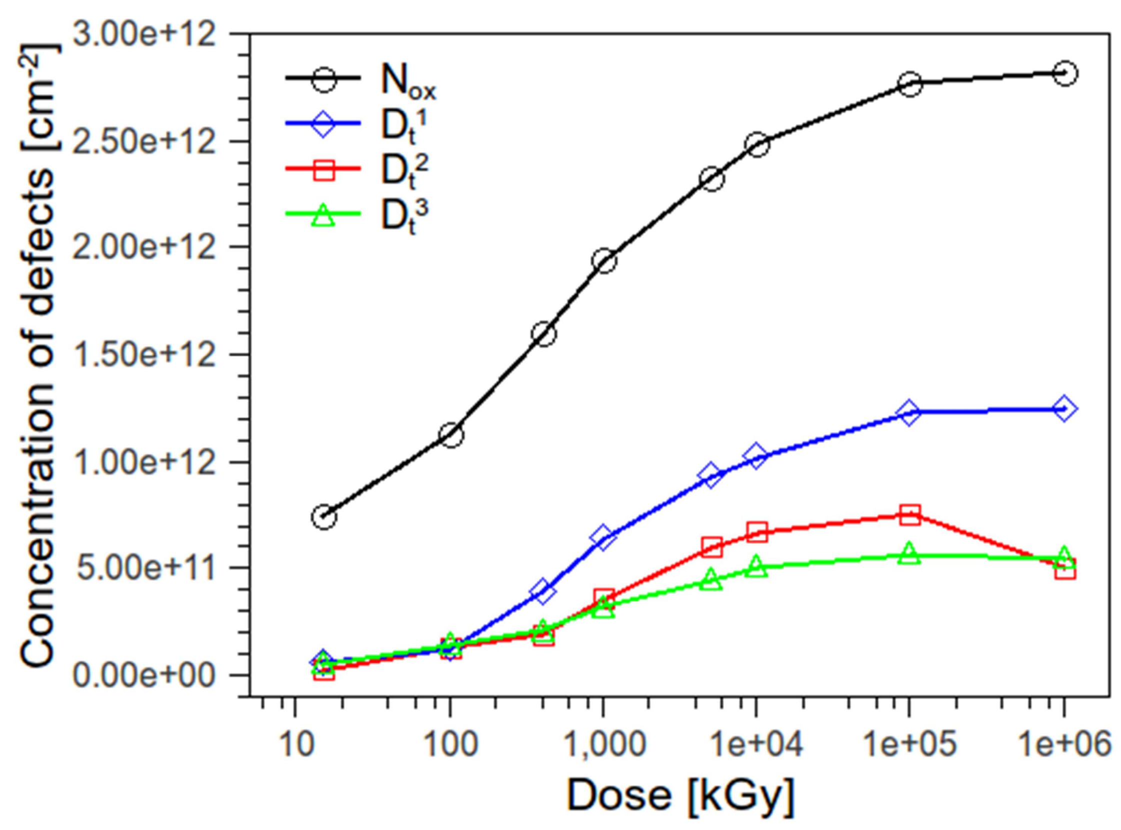
- Thermally Dielectric Relaxation Current (TDRC) technique → densities of interface traps D_{it}
- Capacitance/Conductance-Voltage (C/G-V) + Model calculation → fixed oxide charge density N_{ox}

Results:

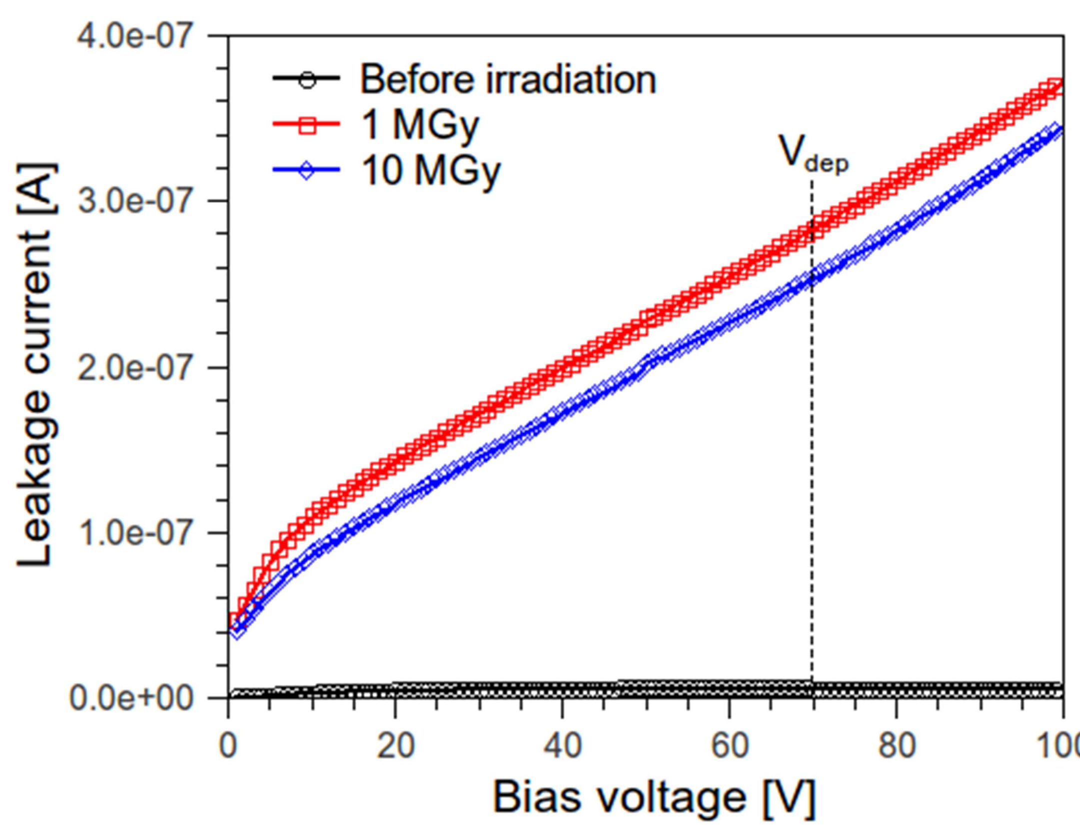
- Three dominant interface traps found
- N_{ox} and $D_{it}^{1,2,3}$ saturate at doses 10 ~ 100 MGy







Influence of surface radiation damage on the electrical properties of segmented p⁺n sensors

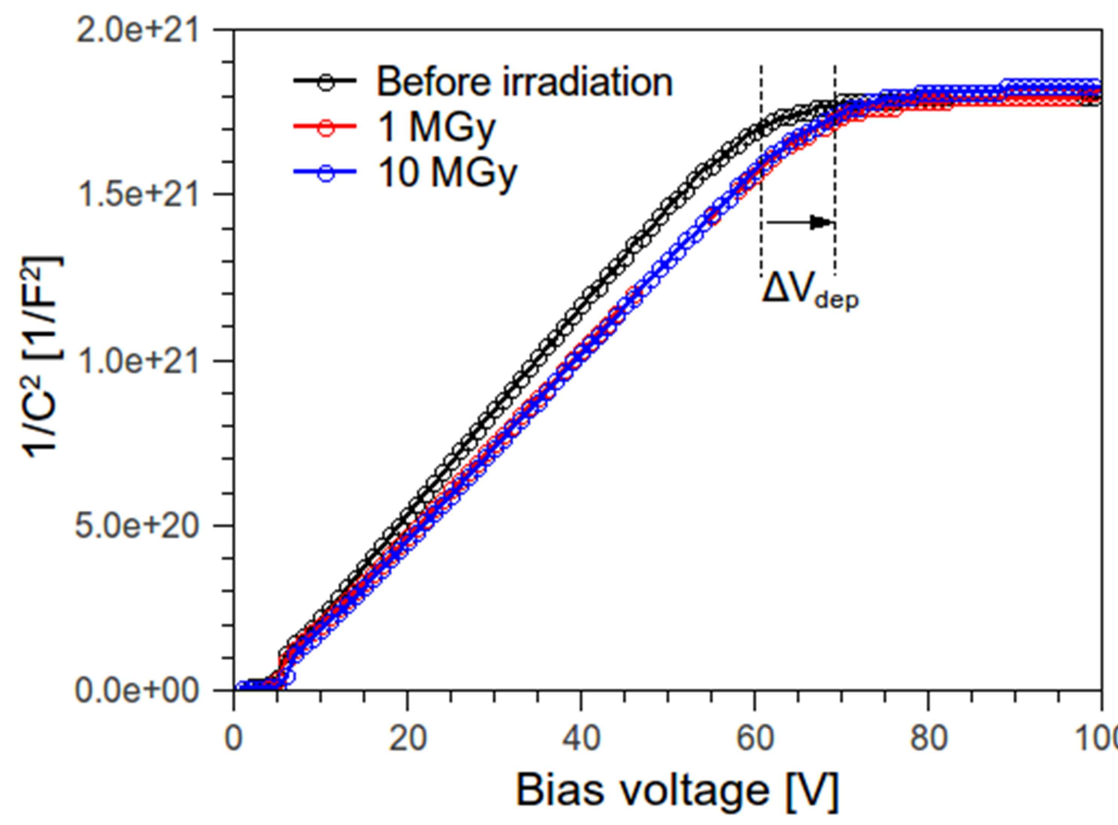


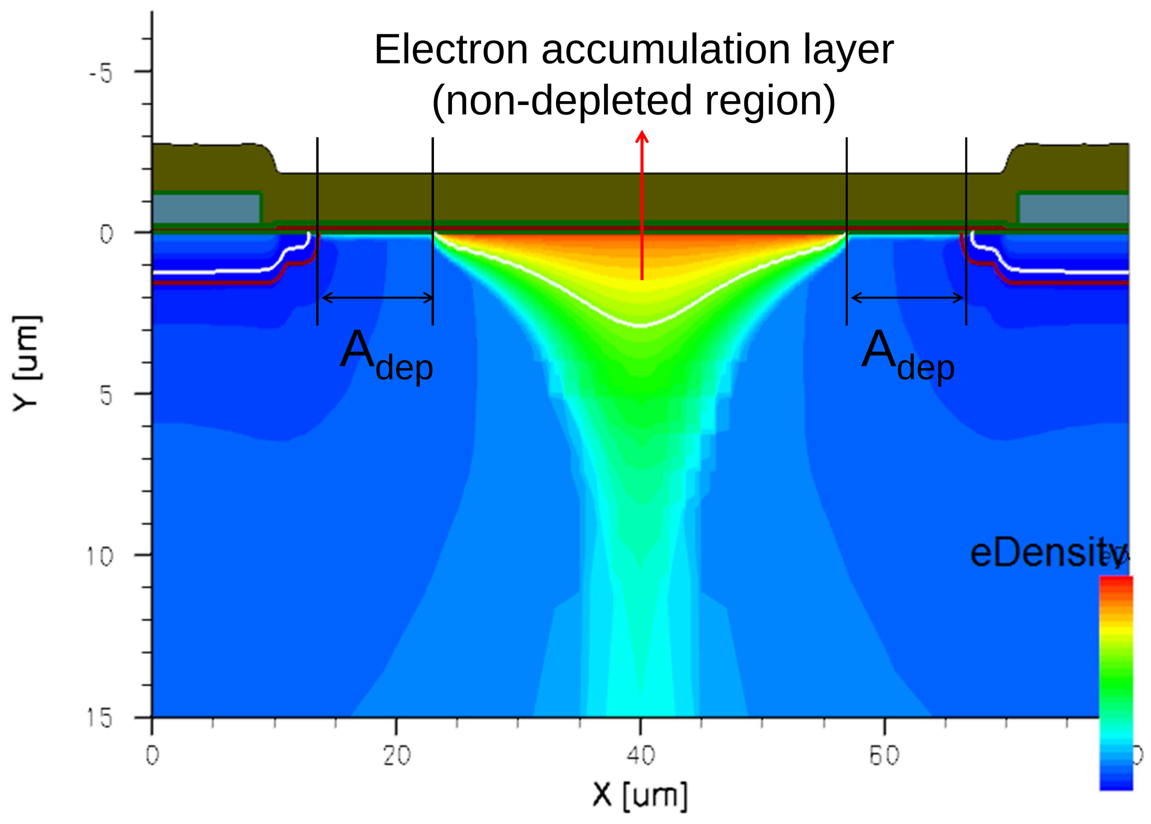
Sensors under investigation:

- Coupling: AC
- Type: p⁺n microstrip
- Insulator: 200 / 300 nm SiO_2 + 50 nm Si_3N_4
- Pitch: 80 µm
- Gap: 62 µm
- Orientation: <100>
- Doping: $8*10^{11}$ cm^{-2}

Conclusions:

- **$I_{leakage}$ ~ D_{it}*A_{dep} and no saturation observed**
- **V_{dep} increases ~ 10 V after irradiations**
- **An accumulation layer formed** at the interface
- The electron accumulation layer relates to most of the changes of the electrical properties of the sensor, e.g. V_{dep}, $I_{leakage}$, C_{int} and charge collection





Picture from J. Schwandt

Outlook

- Reproduce the results of segmented p⁺n sensors by Synopsys TCAD simulation
- Optimize the sensor design with the microscopic damage parameters for the XFEL applications
- Fabrication and test of sensors

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SEVENTH FRAMEWORK PROGRAMME

European XFEL

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