Sensor Development for the European XFEL

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Introduction

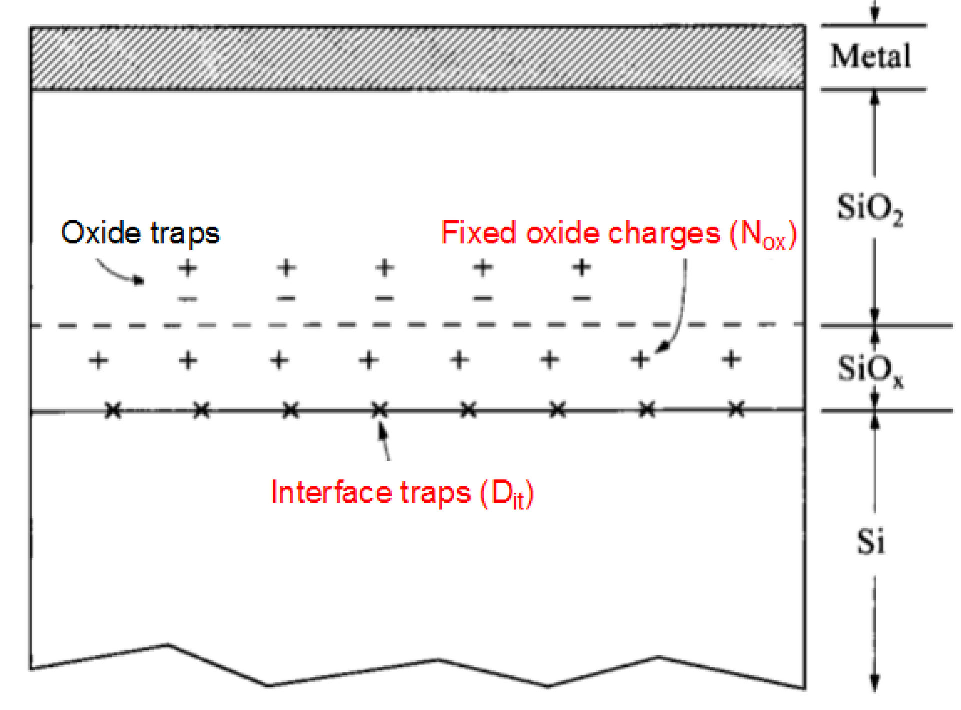
At DESY, Hamburg, the **European X-ray Free Electron Laser (XFEL)** is under construction. Starting in 2015, the XFEL will open up completely new research opportunities for science as well as for industrial applications. Examples are the structural analysis of single complex organic molecules, the investigation 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 aim of this work is to understand the X-ray induced radiation damage, 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 defects

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



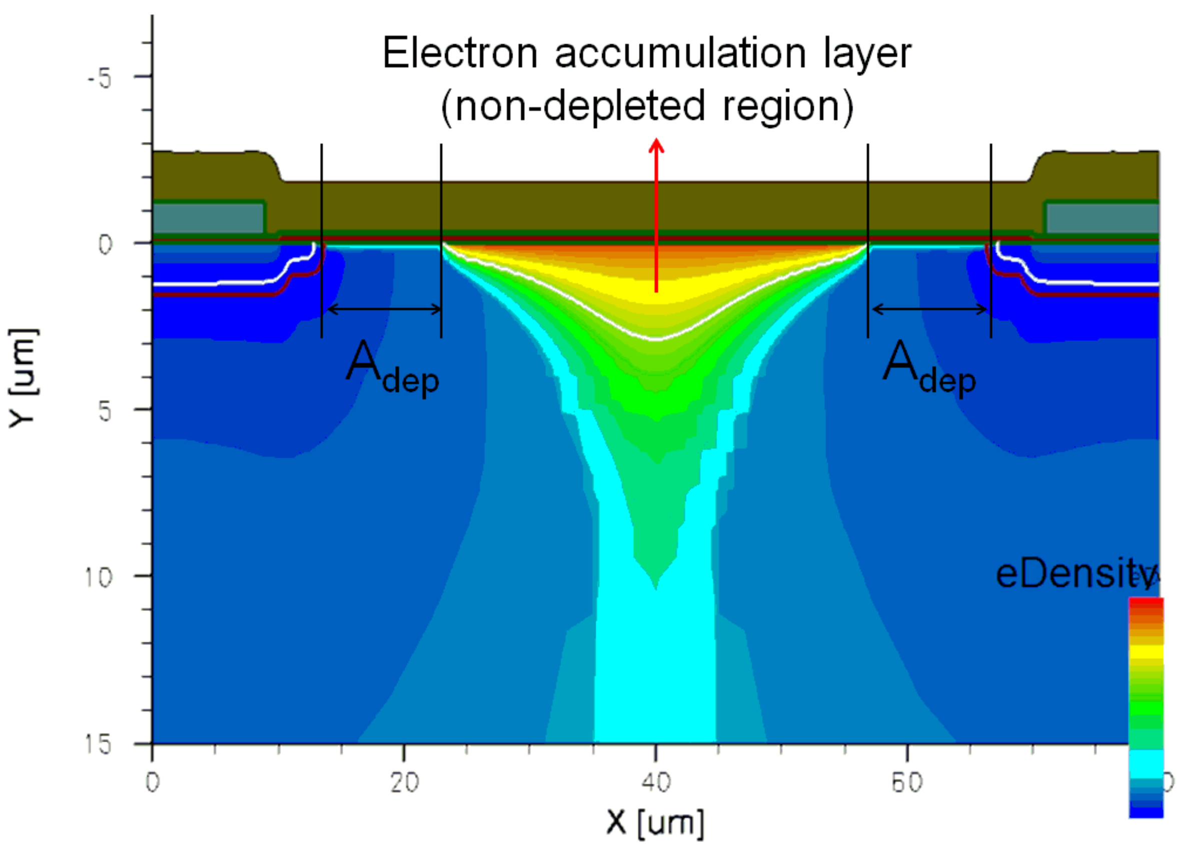
Influence of X-ray radiation damage on the electrical properties of segmented p^+n sensors

Sensors under investigation:

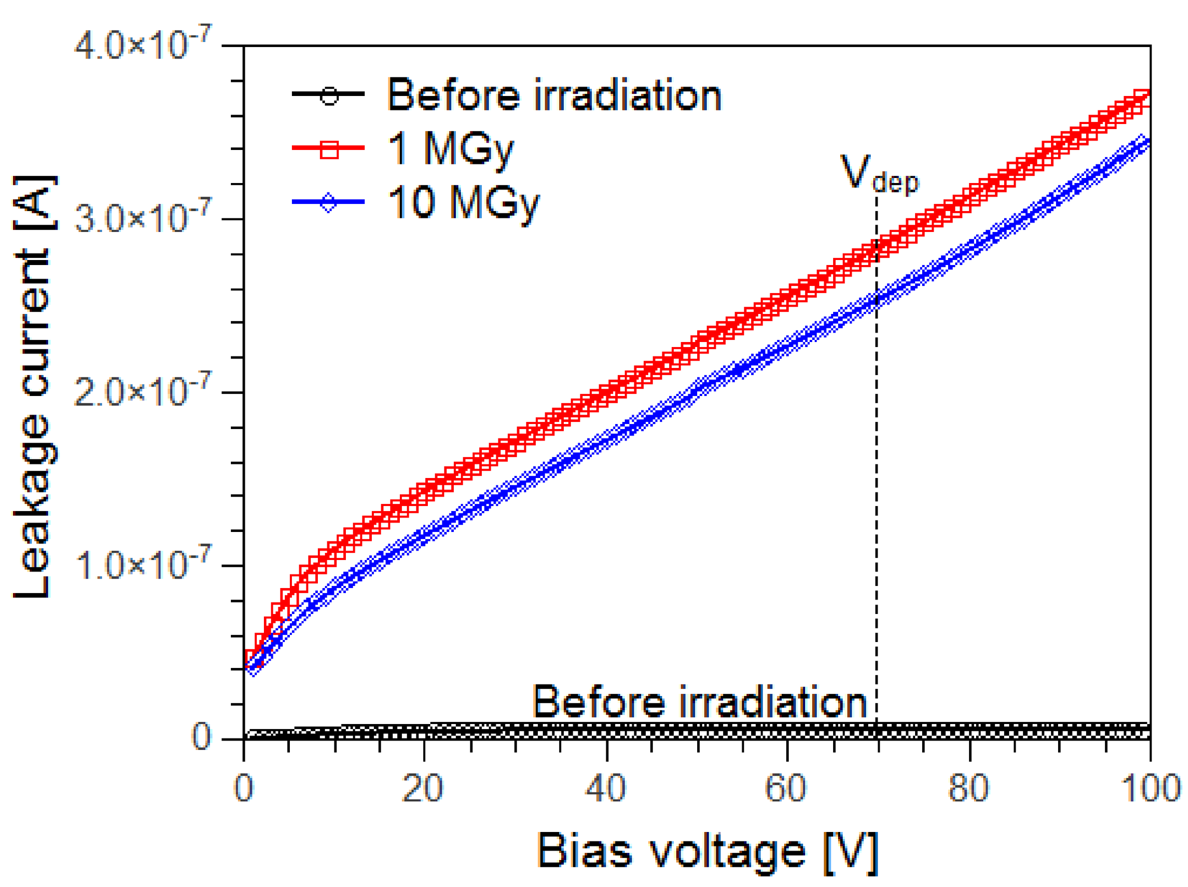
- Coupling: AC
- Type: p^+n microstrip
- Insulator: 200 / 300 nm SiO_2 + 50 nm Si_3N_4
- Pitch: 80 μm
- Gap: 62 μm
- Orientation: <100>
- Doping: 8×10^{11} cm^{-2}

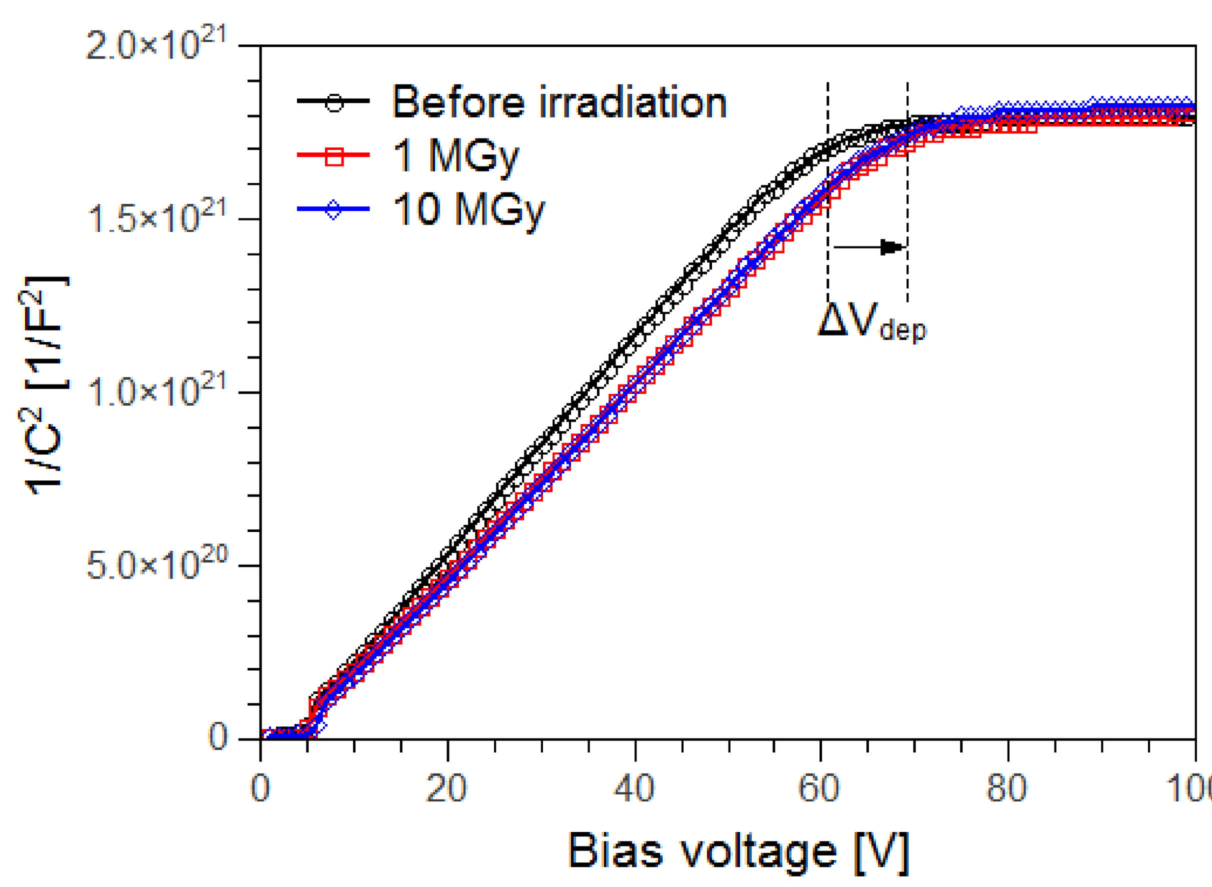
Conclusions:

- $I_{leakage}$: dominant by surface current ∝ $D_{it} * A_{dep}$
- V_{dep} increases ~ 10 V after irradiations (compensate for radiation induced charges)
- Accumulation layer at the interface
- The electron accumulation layer related to most changes of electrical properties: V_{dep}, $I_{leakage}$, charge collection and interstrip capacitance



Picture from J. Schwandt

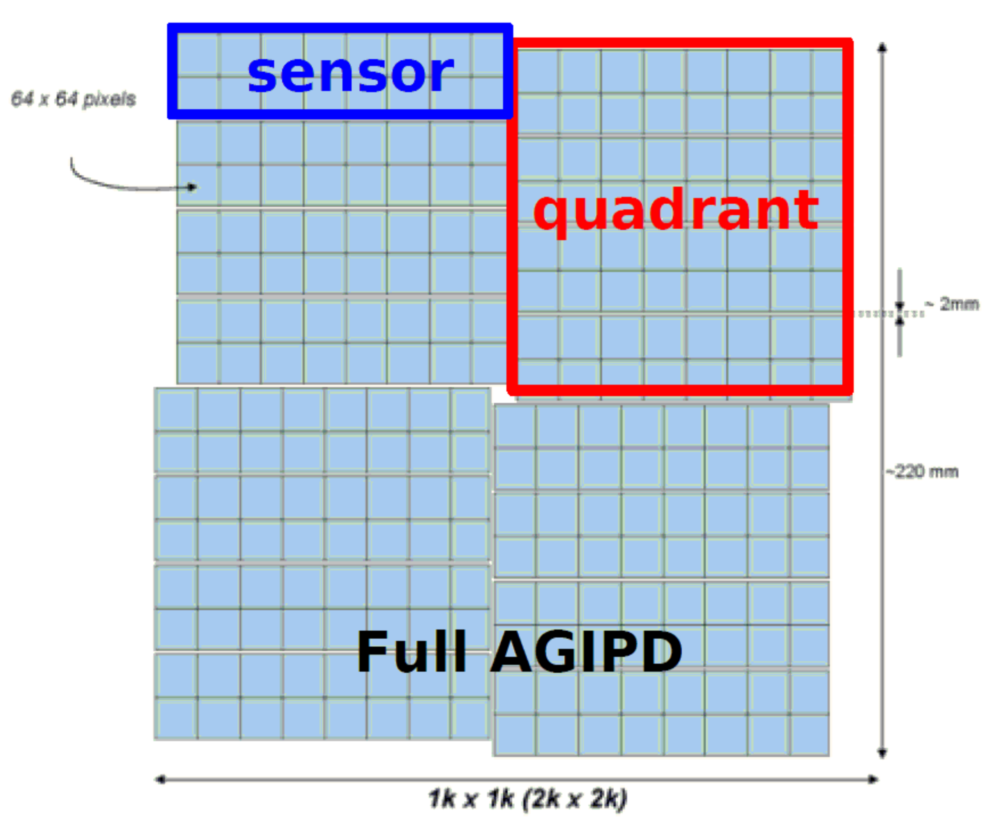




The sensor of Adaptive Gain Integrating Pixel Detector (AGIPD) for the European XFEL

The sensor of AGIPD for the European XFEL:

- Coupling: DC
- Type: p^+n pixel sensor
- Pitch: 200 μm
- Gap: 20 μm
- Thickness: 500 μm
- Resistivity: 3-8 kΩ·cm
- Overhang: 5 μm
- Pieces of sensor: 16
- Number of chips covered by sensor: 16
- Number of pixels/chip: 64 x 64
- Total number of pixels/sensor: 512 x 128



Requirements of the AGIPD detector:

- Operation voltage: 500 V (reduce plasma effect)
- Breakdown voltage: > 1000 V
- Photon sensitivity: 0, 1, … ,10^5 photons/pixel
- Sensitive energy: 3 keV – 25 keV
- Frame rate: 4.5 MHz

Acknowledgements

I would like to thank Marie Curie FP7 multi-site initial training network "MC-PAD" for the financial support for my PhD study and funding from the XFEL GmbH and the Helmholtz Alliance "Physics at the Terascale".

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ESOF2012 DUBLIN

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