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AGIPD

Status Report:

Radiation Damage and Sensors

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Outline

- Summary on radiation damage

- Short summary on sensor optimization and design
  - optimization of gap, overhang, junction depth, curvature and surface protection
  - design of test structures and sensors

- Overall summary + following work

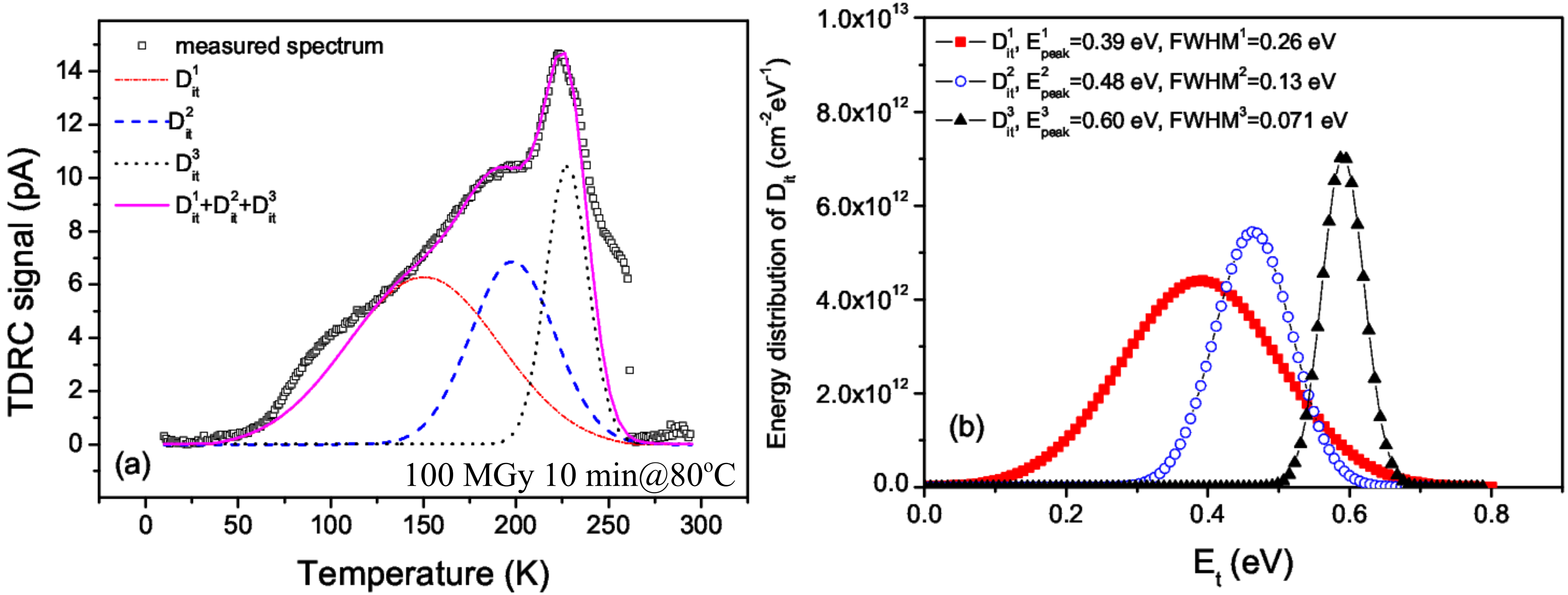
Summary on radiation damage

MOS capacitor

- Properties of MOS capacitor under study
  - fabricated by CiS
  - orientation: <1 0 0>
  - thickness: 285 ± 10 µm
  - resistivity: 5 - 6 kΩ•cm
  - substrate: n-doped silicon
  - insulator: 350 nm SiO_2 + 50 nm Si_3N_4
  - gate area: $1.767 \cdot 10^{-2}$ cm^2
  - doping: $0.7 \cdot 10^{12}$ cm^{-3} boron
- Procedure to extract microscopic parameters
  - TDRC measurement → distribution of interface states density D_{it}
  - C/G-V measurement + model calculation → oxide charge density N_{ox}

TDRC spectrum (and distribution of D_{it})

- From TDRC spectrum to properties of 3 dominant interface traps:



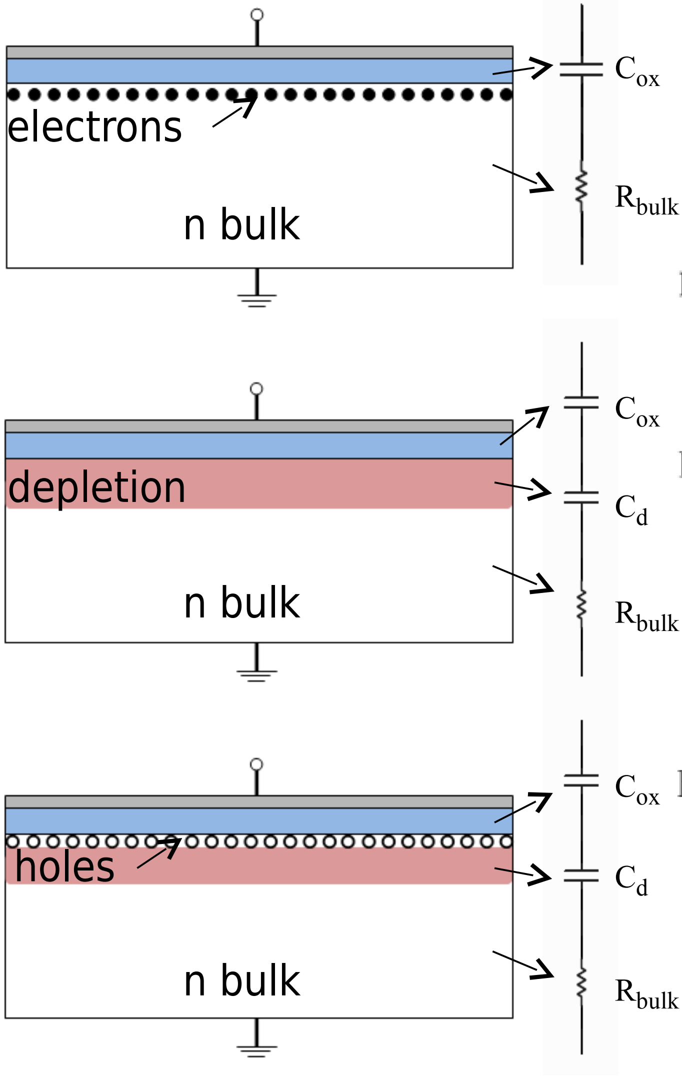
- Effective capture cross sections used for 3 interface traps:

	D_{it}^1	D_{it}^2	D_{it}^3
σ_{eff} * [cm^2]	$1.2\text{x}10^{-15}$	$5\text{x}10^{-17}$	$1.0\text{x}10^{-15}$

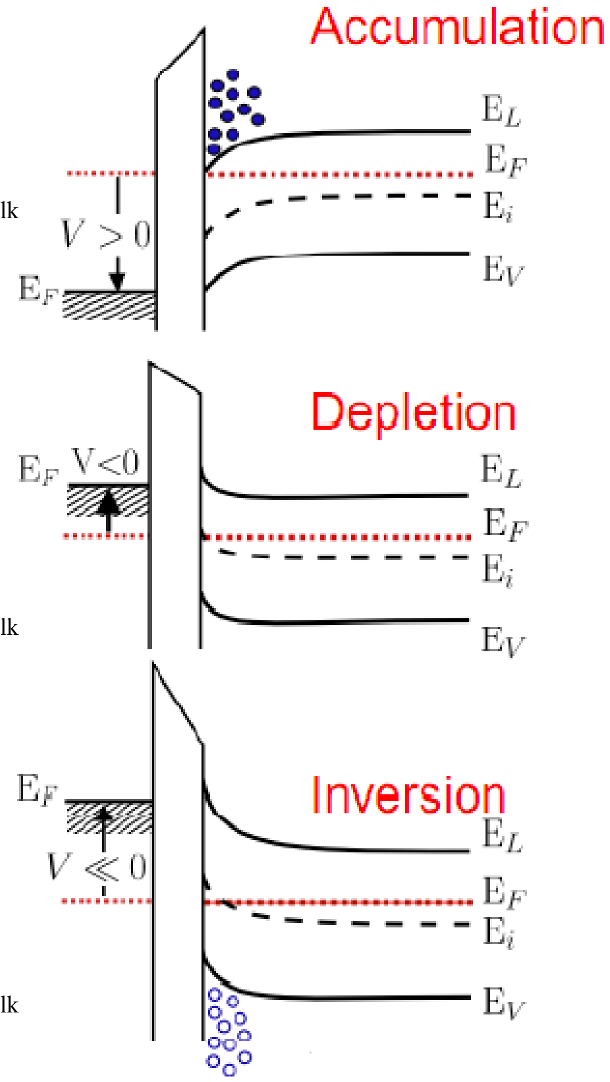
* Cross sections were obtained through comparison of C/G-V curves between measurements and model calculation, with large uncertainties.

Simple model and ideal C/G-V curves

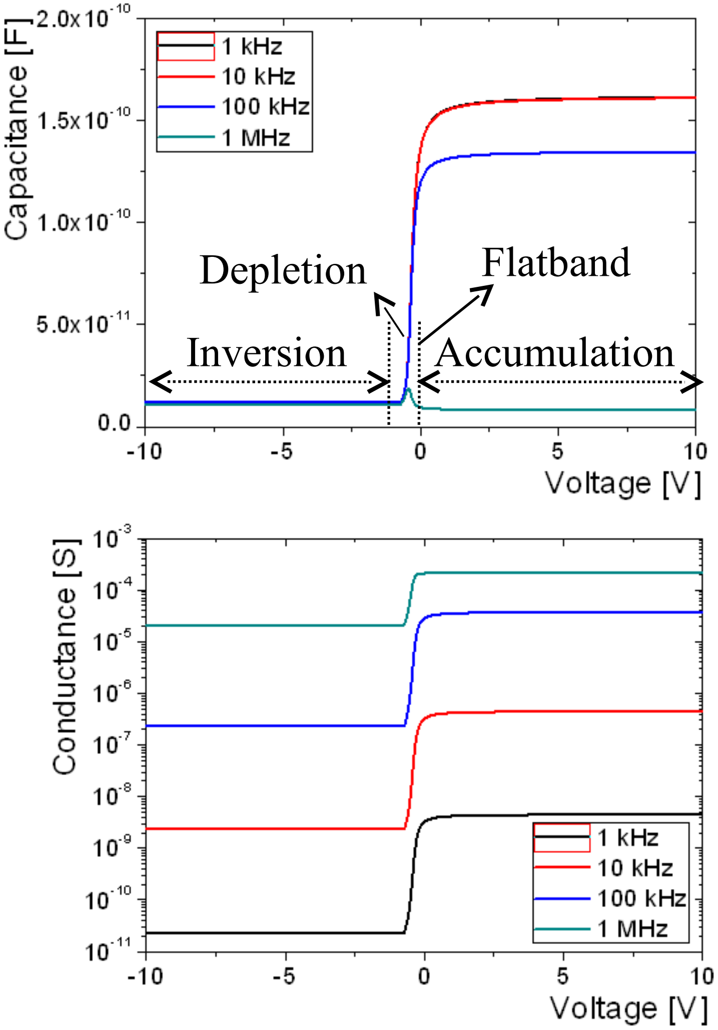
MOS capacitor



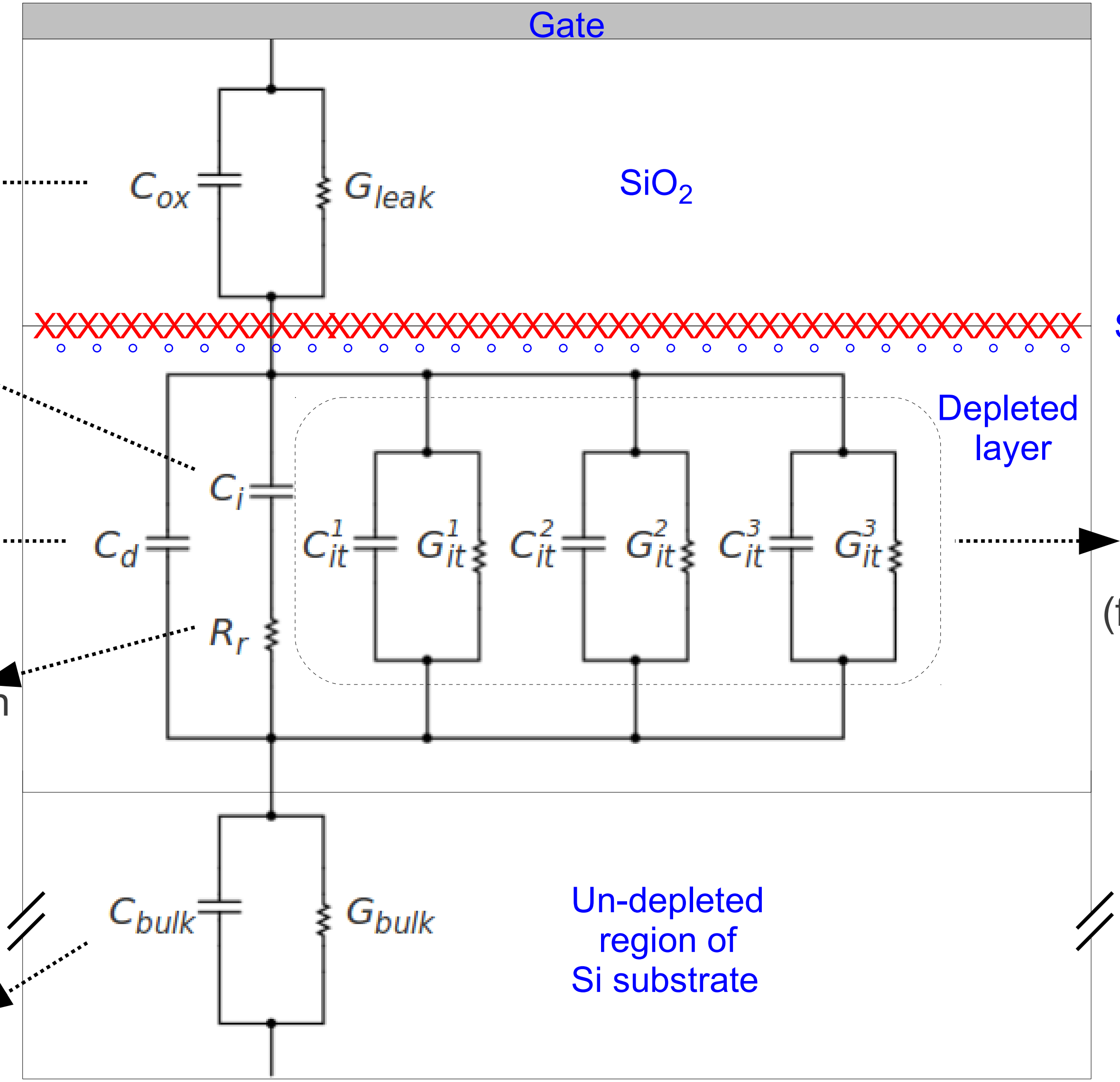
Energy band diagram



Ideal curves of Capacitance/ Conductance-Voltage



Model of MOS including interface traps



Capacitance and conductance of isolation layer

Inversion capacitance

Depletion capacitance depends on thickness of depletion layer

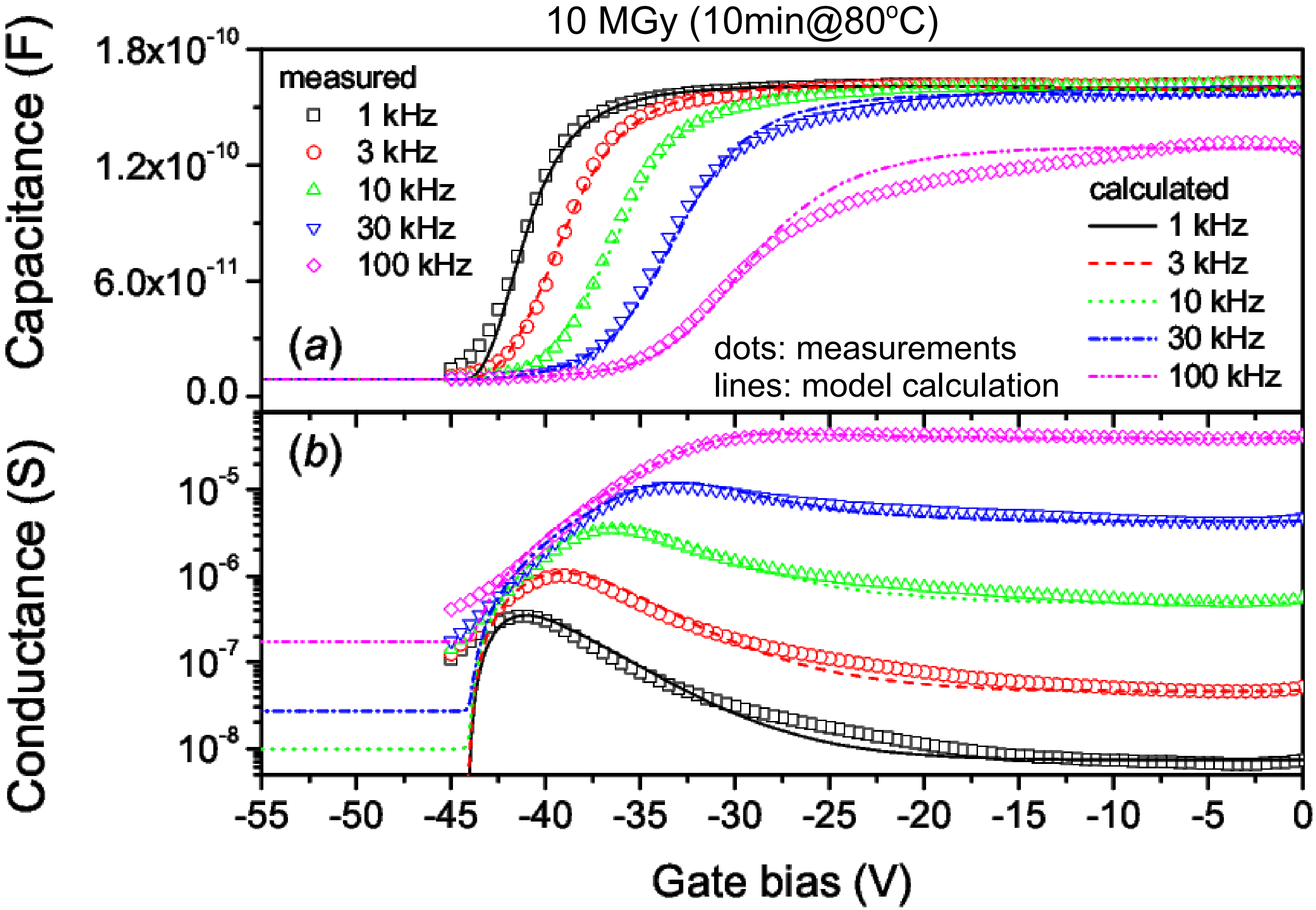
Recombination/generation resistance

Capacitance and conductance of un-depleted region

Capacitance and conductance due to interface traps (frequency dependent)

C/G-V curves after X-ray irradiation

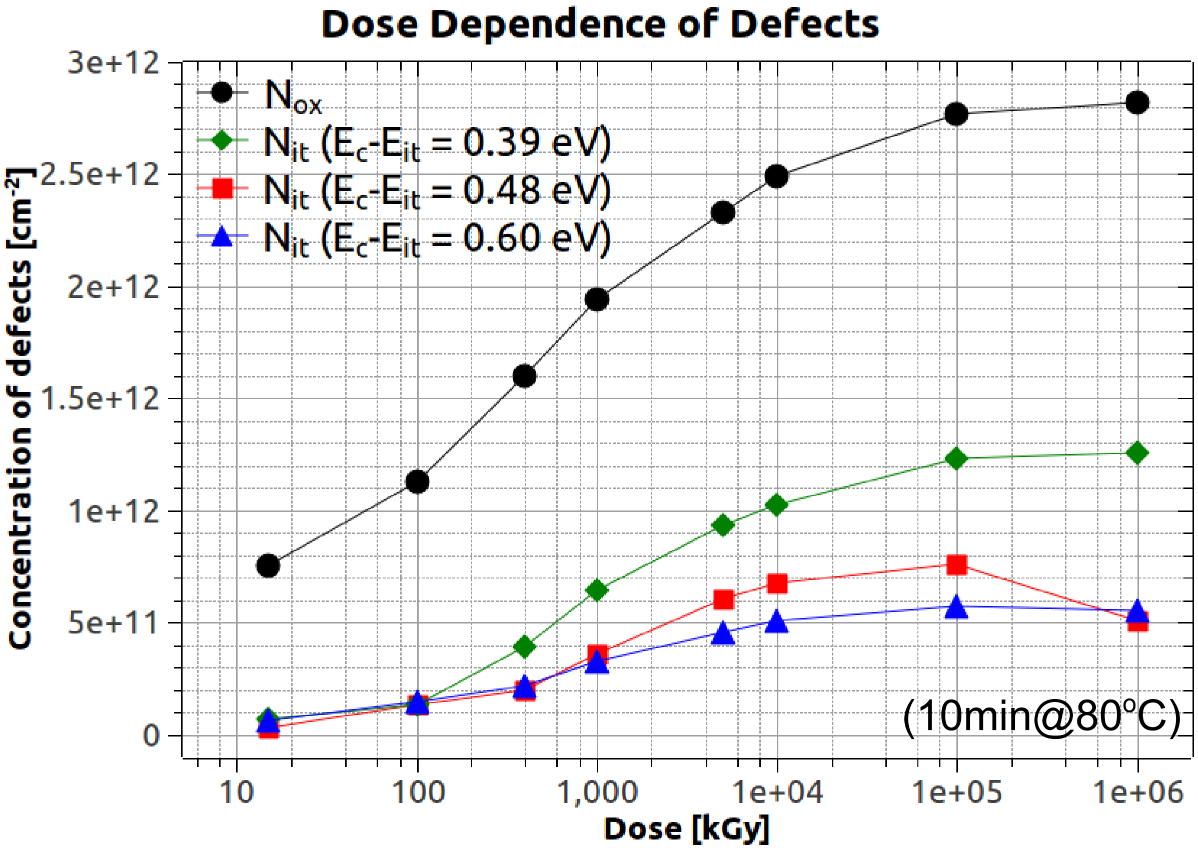
- C/G-V curves from both measurements and model calculation:



- N_{ox} extracted when model calculation describe measurements.

Dose dependence of N_{it} and N_{ox}

- Dose dependence of concentration of defects for orientation <1 0 0>:



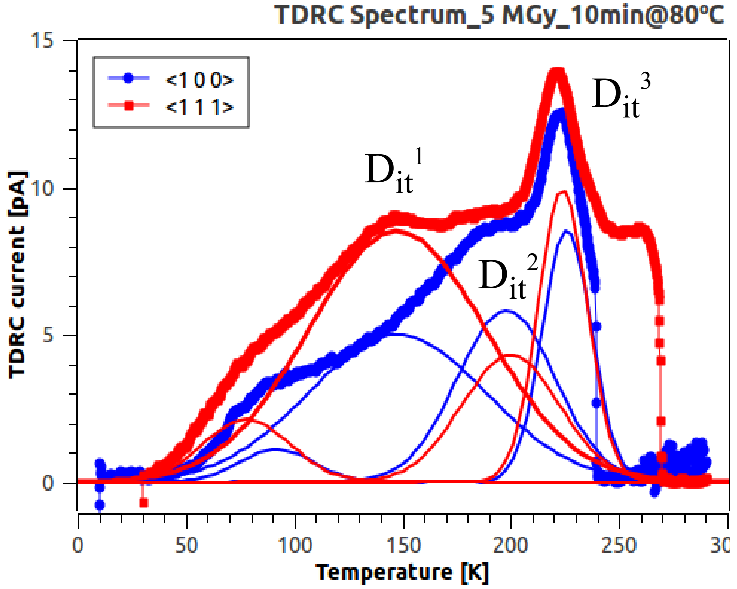
- N_{ox} and N_{it} saturate at a dose value in between 10 MGy and 100 MGy

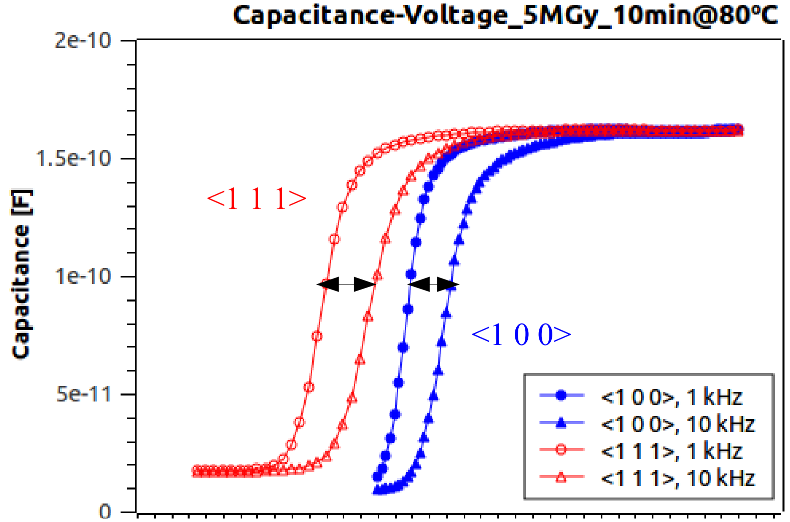
- Saturation value of N_{ox} is 2.8×10^{12} cm^{-2}

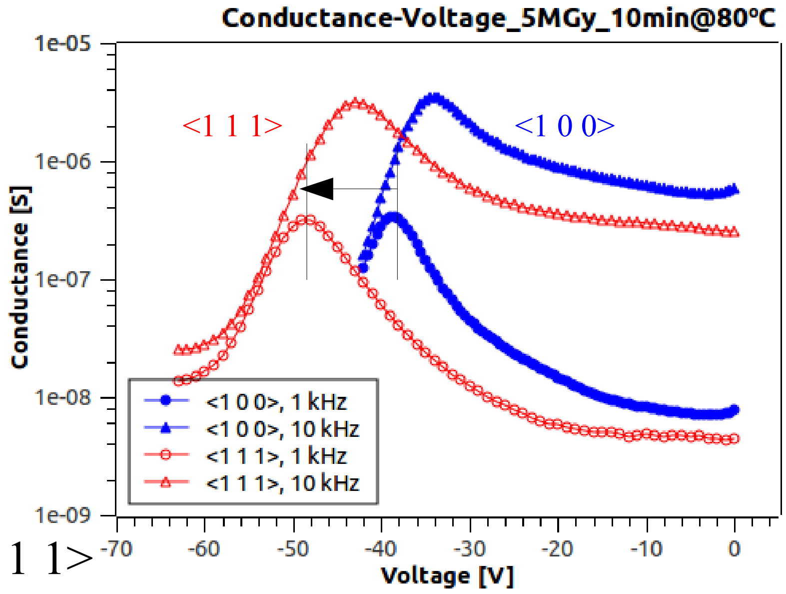
- Similar results for orientation <1 1 1>

Orientation dependence: <1 0 0> vs. <1 1 1 >

- TDRC spectrums, C/G-V curves for different orientations:







- Difference between D_{it}^{1} :

  D_{it}^{1} ↑ ⇒ frequency shift ↑

- Difference between C/G-V curves

  $V_{flatband}$ ↑ ⇒ N_{ox} ↑

- D_{it}^{1} and N_{ox} of <1 0 0>: ~ 25%-30% less than <1 1 1>

Short summary on sensor optimization and design

Sensor optimization with TCAD

- Results of simulation (from J. Schwandt @ 8th AGIPD meeting):

Optimized parameter	Main influence on	Conclusion
gap	W_{acc} ($I_{leakage}$, C_{int})	smaller gap preferred
metal overhang	W_{acc} ($I_{leakage}$, C_{int}), V_{bd}	≥ 2 µm
junction depth	V_{bd}	as deep as possible [Canberra: 0.5-0.8 µm; CiS: 1.0-1.5 µm]
curvature	V_{bd}	smooth
insulator	radiation induced charges at interfaces [Si-SiO_2; SiO_2-Si_3N_4]	SiO_2? [Canberra: 100 / 180 nm SiO_2; CiS: 200 / 350 nm SiO_2 + 50 nm Si_3N_4]
surface protection	W_{acc}, Charge losses	higher conductivity? [Canberra: 500 nm SiO_2; CiS: ~1 µm SiON]

Sensor design and test structures

- Sensors:
  - 64 x 64 single chip sensors
  - 16 x 16 test sensors
- Test structures:
  - DC coupled strip sensors
  - "AC" coupled strip sensors
  - test alumina strips
  - pad diodes
  - MOS capacitors
  - gated diodes
  - PMOSFETs
- Status of sensor fabrication:
  - submitted to Canberra and VTT
  - long delay of fabrication from Canberra due to existing wafer problem (production of wafer can not be finalized before the beginning of March, 2012)
- Go to and discuss with other vendors: Hamamatsu? CiS? ...

Overall summary
+
following work

Overall summary

Radiation damage

- 3 dominant interface traps D_{it}^{n} after irradiation → parameters extracted
- C/G-V measurements can be described by D_{it}^{n} and N_{ox}

  interface trap density + fixed oxide charge density as function of dose

  saturation with dose

  similar dose dependence of for <1 0 0> and <1 1 1>

  but <1 0 0> seems to be more radiation hard compared to <1 1 1> (tentatively)

Sensor optimization and design

- optimized parameters proposed
- designed sensors and test structures submitted to Canberra and VTT

Following work

Develop more dedicate algorithm and well define capture cross sections for traps

Extend measurements to sensors/test structures with different materials (Epi & DOFZ) and from different vendors (Hamamatsu & Canberra)

Implement parameters into TCAD and compare simulation results to the measurements of segmented sensors

Discuss with other vendor for sensor fabrication

Thanks for your attention!