DEPFET Irradiations

Status and plans

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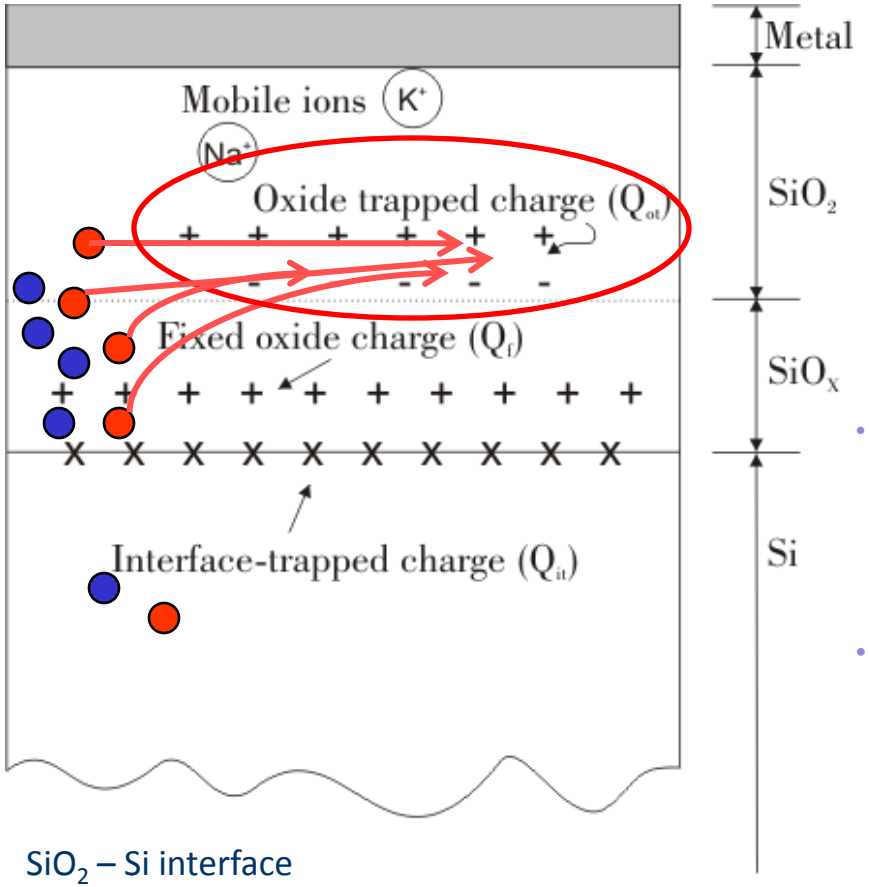
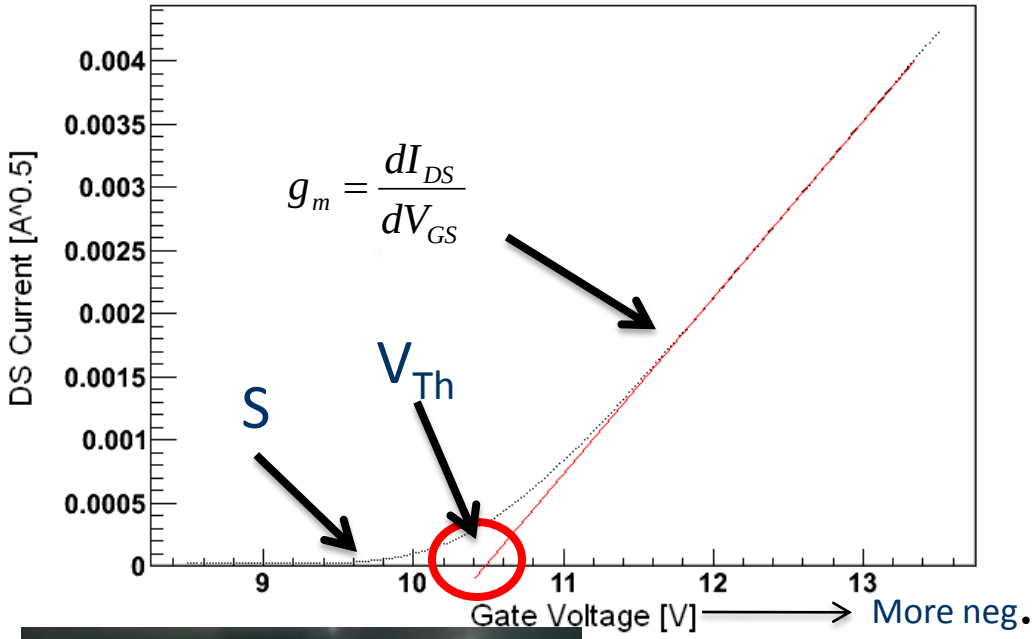
Why to irradiate?



SiO_2 – Si interface

- Radiation dosage for DEPFET pixel detector in Belle II consists of:
  - Synchrotron radiation
  - Beam gas interaction (vacuum in the interaction region could be worse than in present KEKB)
  - Intra beam scattering (Touchek Effect)
  - Luminosity-related QED processes (!)
- Exact Dose parameters and radiation profiles aren't available at present
  - First Simulations and "Back on the envelope" calculations are scary (!)
- Impact on DEPFET:
  - Threshold voltages in gate and clear-gate

December 09: X-Ray Irradiations in Karlsruhe



Up: Typical extraction of threshold voltage from $I_{DS} - V_{GS}$ data.

Bottom: X-ray tube at the Karlsruhe Irradiation center (from [http://www-ekp.physik.uni-karlsruhe.de/index.php?option=com_content&view=article&id=93&Itemid=12&lang=de])

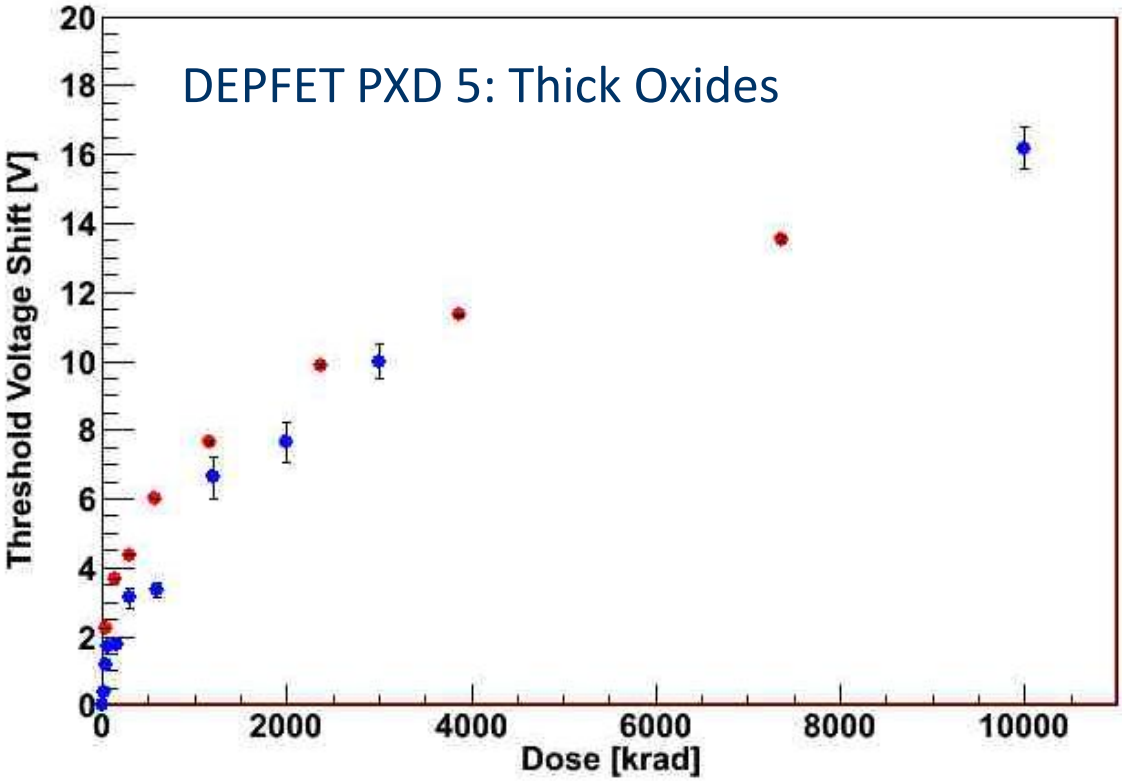
DEPFET

- 2 Devices under Test
- Irradiation scheme:
  - DUT 1: Zero Voltage at all contacts
  - DUT 2: Adaptive biasing from Off voltage (5V) to zero voltage at Gate contact (other contacts 0V)
- Interest in input characteristics of devices
  - Threshold voltage V_{Th}
  - Transconductance g_m
  - Subthreshold Swing S
- Mini matrices from PXD 5

DEPFET: Results of threshold voltage shift

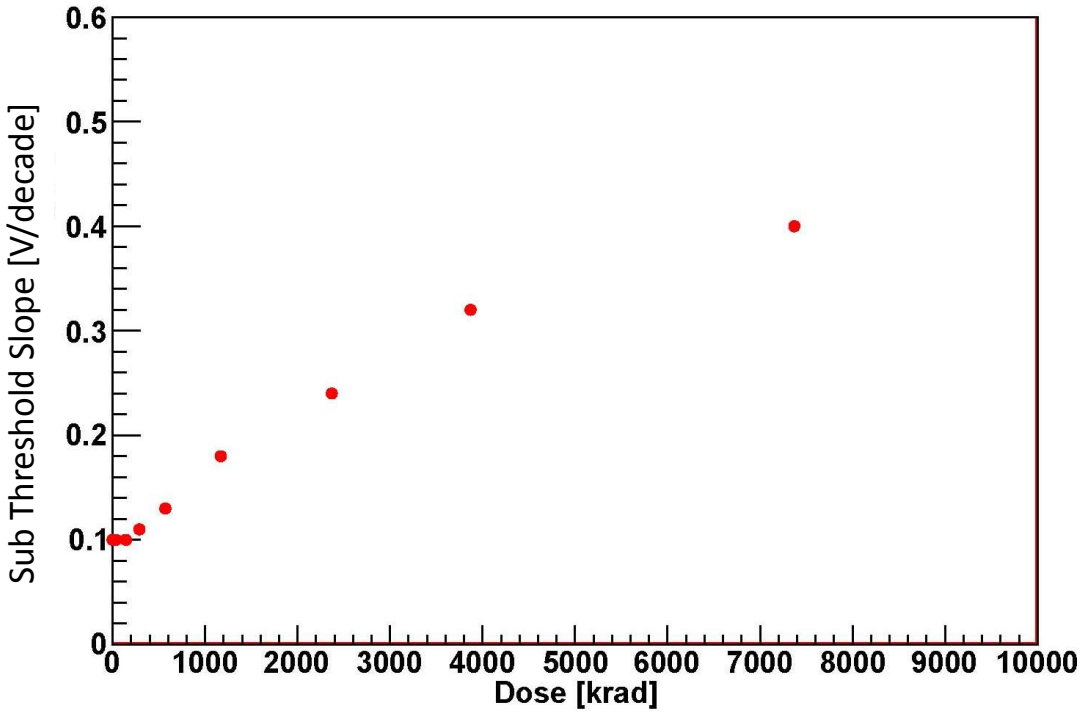
Observation and conclusions:

- Breakdowns:
  - Short circuit current between layers Poly 1 and Poly 2 with DUT 1 prevented further measurements at higher doses (>7.5 Mrad)
  - 2nd DUT still lived after 10Mrad
- Voltage shift of about 16.5 V at 10 Mrad
- Annealing of threshold voltage shift after approx. 500 h is around 4 V → V_{Th} ~12.5V
- Threshold voltage spread over several pixels is under investigation, especially of DUT2



Red: DUT 1
Blue: DUT 2
Measurement done by P. Müller.

DEPFET: Sub threshold Slope



What is this Slope?

Slope S: Measured in sub threshold region, how much voltage is needed to change I_{DS} by one decade

Why evaluate this Slope?

The Slope is affected by interface traps – Information about oxide quality and radiation induced traps → Compare with MOS diodes irradiations

Increase of traps from 0 krad to 10Mrad by factor 4

MOS Diodes with thin oxides

Irradiation of MOS diodes with thin oxides

MOS diodes consists of:

- Gate (Metal) contact
- Bulk contact

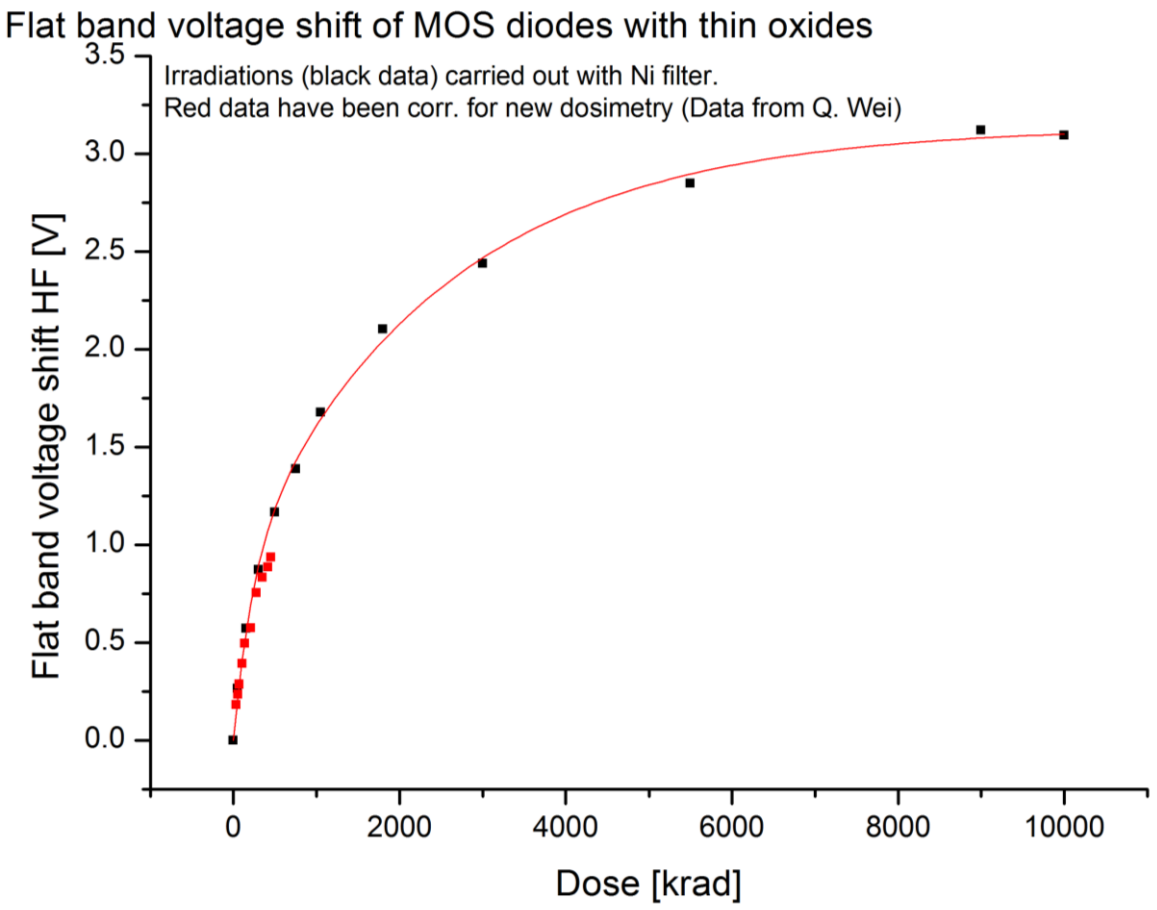
With DC bias, different charge states possible (accumulation, depletion, inversion)

Via Capacitance – Voltage measurement with High (10 kHz) and Low Frequencies (20 Hz) one can get Information about:

- Flat band voltage
- Interface traps

Flat band voltage shift vs. Dose in MOS Diodes is equivalent to threshold voltage shift in MOSFETs

MOS diodes: Flat band voltage shift



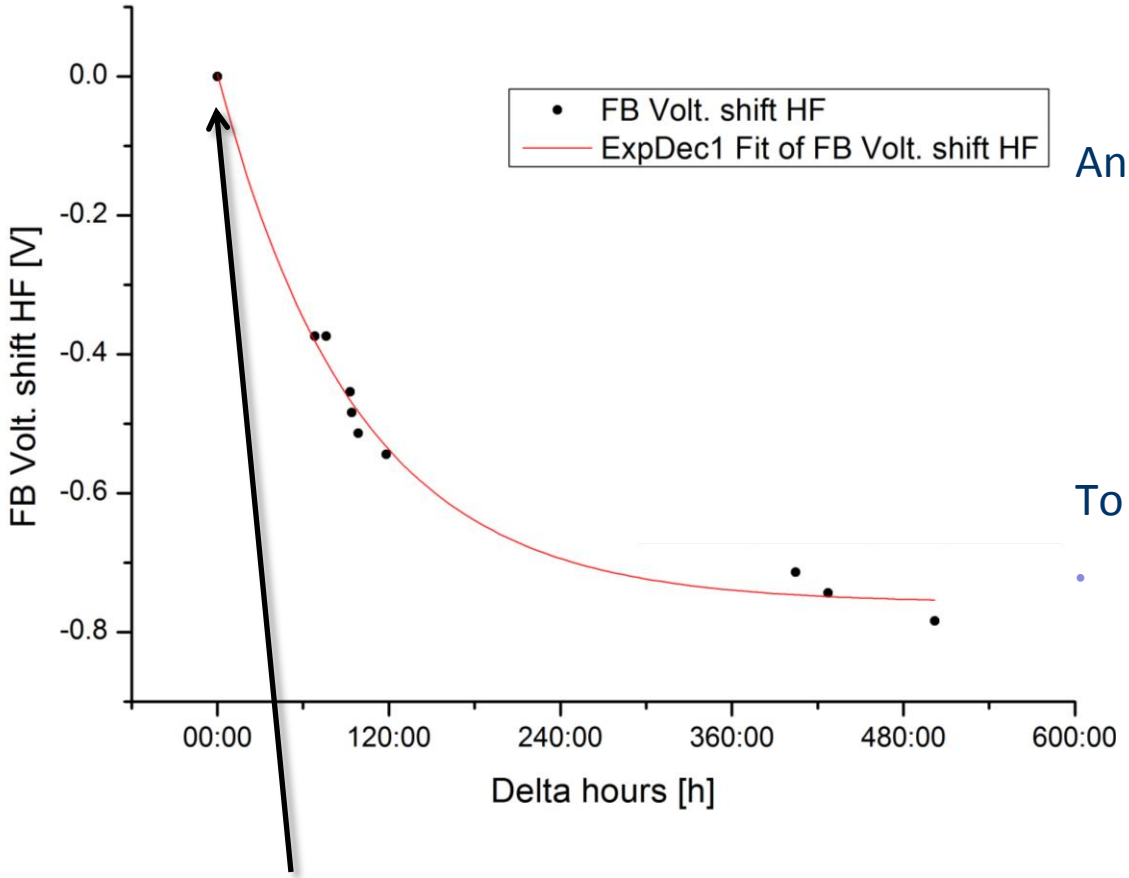
Tasks:

- Irradiate MOS diode up to 10 Mrad
- Evaluate flat band voltage shift and interface traps
- Compare results with data of Q. Wei

Conclusions:

- Corrected data from Q. Wei corresponds well with new dosimetry
- Fit model seems to agree fine

MOS diodes: Annealing of flat band voltage shift



Flat band voltage value at 10 Mrad is set to „0“

Annealing is still under investigation, but so far, the threshold voltage shift is in good shape

To be done:

- Evaluate interface traps and annealing of them

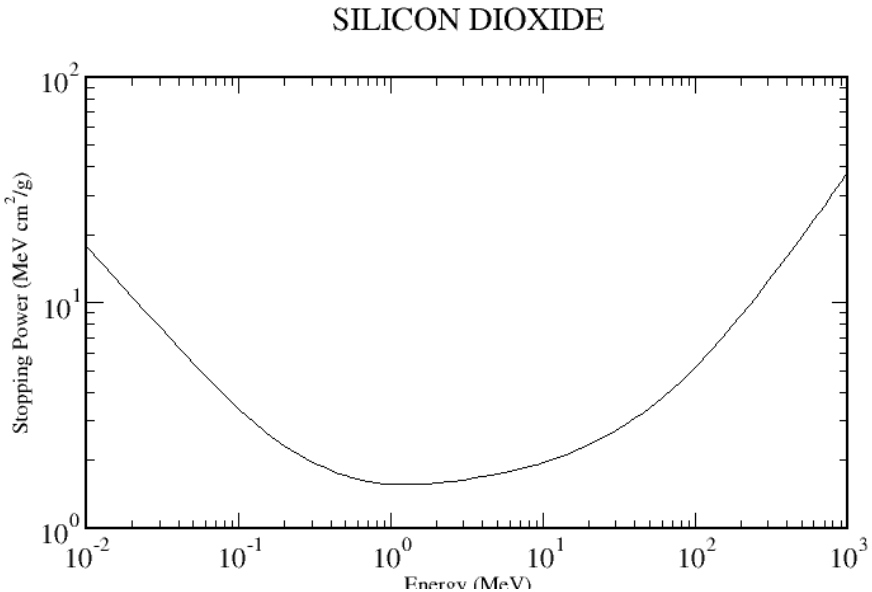
"Back on the envelope" calculation
-From Occupancy to Radiation Damage-

"Scary" Version

- Stopping power for 6 MeV electron in SiO_2: 1.65 MeV cm²/g (from NIST, http://physics.nist.gov/cgi-bin/Star/e_table.pl)
- Density of SiO_2: 2.66 g/cm³
- Pixel size: 50*50*0.13 µm³
- Deposited energy in 130 nm SiO_2: 57eV
- Mass of oxide layer⁺: $8.65*10^{-13}$ kg
- Dose MIP= E/m= $1.05 * 10^{-5}$ Gy/pixel
- Occupancy: **0.5%** in 10µs → 100% in 2ms
- Assumed duty cycle: 4 months≈10^7 s
- Cumulated dose: $0.525 * 10^{-5}$ Gy/ms $*10^3 * 10^7$s = 52.5 kGy/a

  = **<u>5.25Mrad/a</u>**

⁺In fact, gate oxide layer is much smaller, but anyway, the area cancels out



Preliminary:
*Estimated Occupancy from Belle SVD2, Layer 1 transferred to PXD Layer 1: 0.05 % → "**Normal**" Version*

→ Electron irradiations needed – Investigate Ionizing and NIEL damage

Backup Slides

Backup slides