Surface damage characterization of FBK devices for High Luminosity LHC (HL-LHC) operations

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Motivations and aims

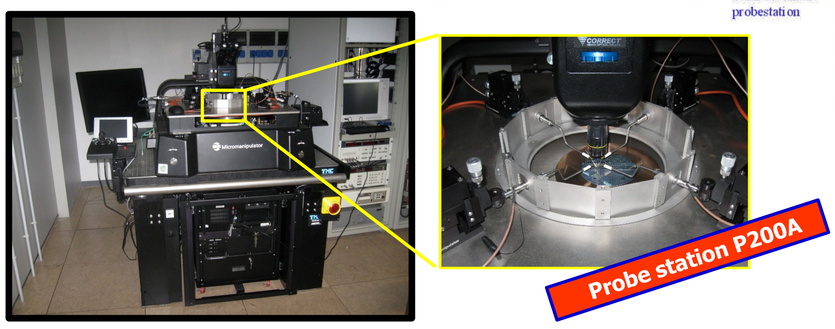
The very high fluences (> 2×10^{16} 1MeV n_{eq}/cm^2) and total ionising doses (≈ 1 Grad) expected at the High Luminosity LHC (HL-LHC) impose new challenges for the design of effective, radiation resistant silicon detectors.

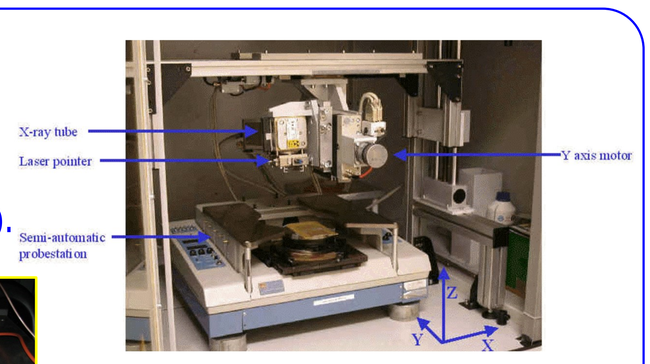
The surface damage by ionising energy loss strongly influences the devices performance in terms of breakdown voltage, the inter-electrode isolation and capacitance and might also impact the charge collection properties of silicon sensors.

The overall aim of this irradiation and measurement campaign was the extraction of the relevant parameters to be included within TCAD simulations for the modelling of surface damage effects.

Setting-up the measurements

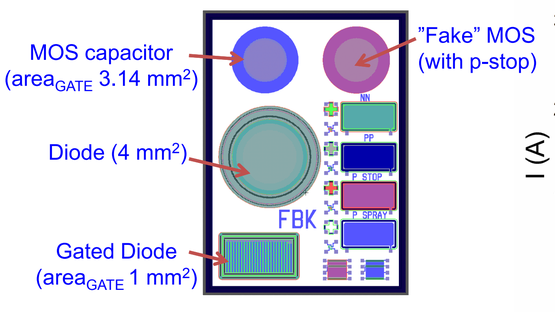
Irradiation campaign: X-ray irradiation
- ✓ carried out in Padova (IT),
- ✓ doses range: 50 krad(SiO_2) - 20 Mrad(SiO_2).



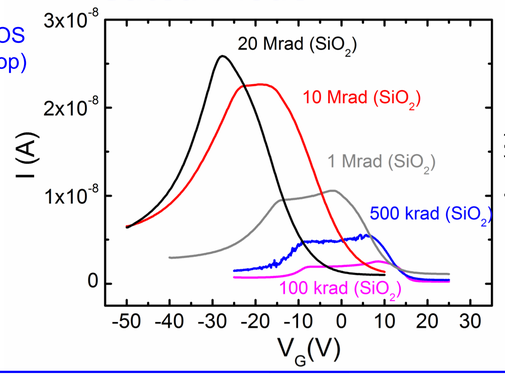


Measurements
- ✓ T = 20 °C,
- ✓ annealing 80 °C, 10 min,
- ✓ under a dry Nitrogen flux.

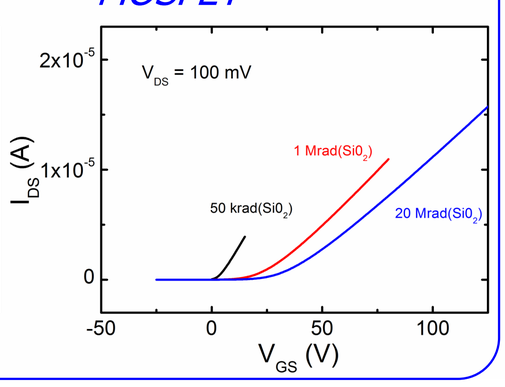
FBK Test Structures: n-on-p



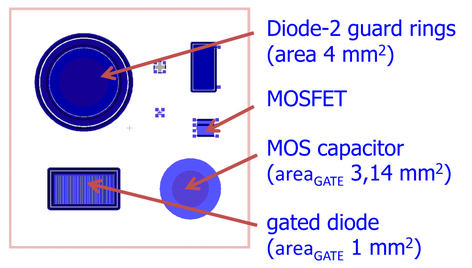
Gated Diode

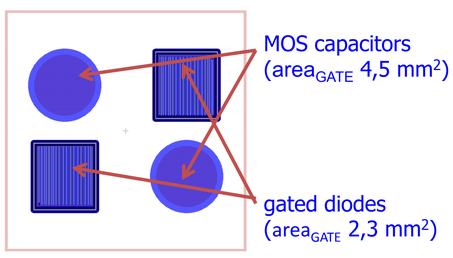


MOSFET



FBK Test Structures: p-on-n





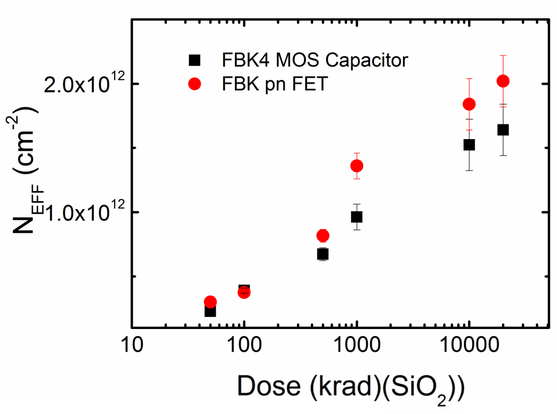
- HF measurements at 100 kHz with a small signal amplitude of 15 mV.
- QS measurements with delay times of 0.7 s, voltage step of 100 mV.

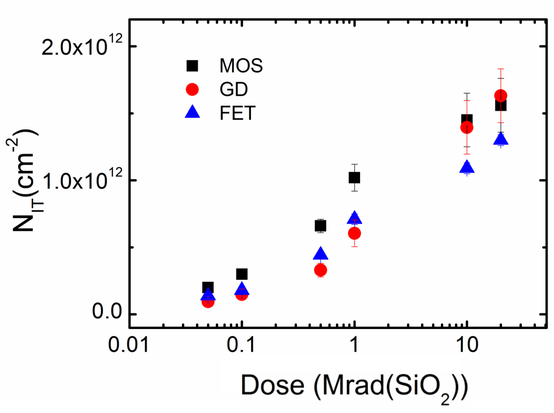
Extrapolation of the surface radiation damage parameters

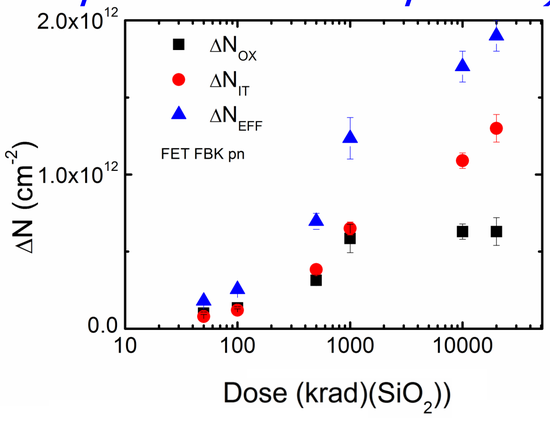
From C–V and I-V measurements, the oxide-charge density **N_{ox}**, the surface generation velocity **s_0** and the integrated interface-trap density **N_{IT}** have been determined before and after X-rays irradiation as a function of the dose, for MOS capacitors and Gated Diode (GD).

From the I_D-V_G curve of MOSFETs in saturation, it is possible to evaluate the threshold-voltage shift which can be separated in a contribution due to the **N_{IT}** and due to **N_{ox}**.

*Characteristics of **Donor** trap states (from MOS, GD n-on-p and MOSFET p-on-n)*

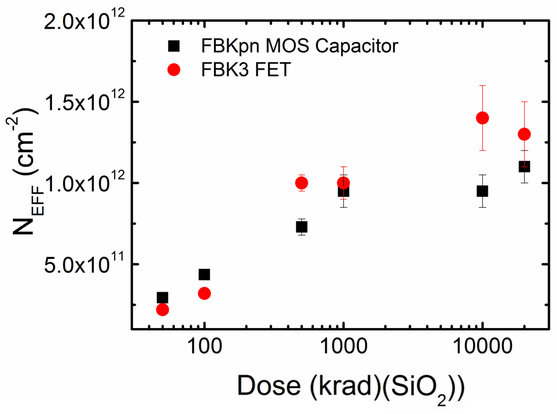


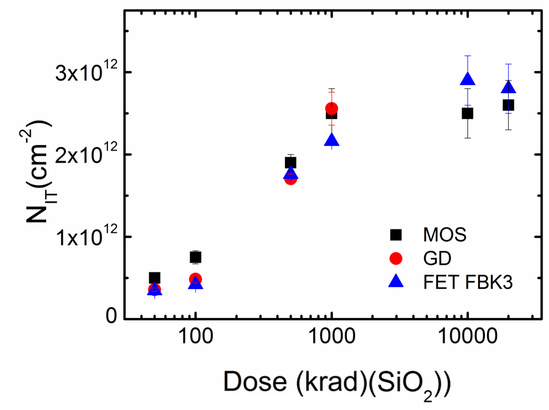


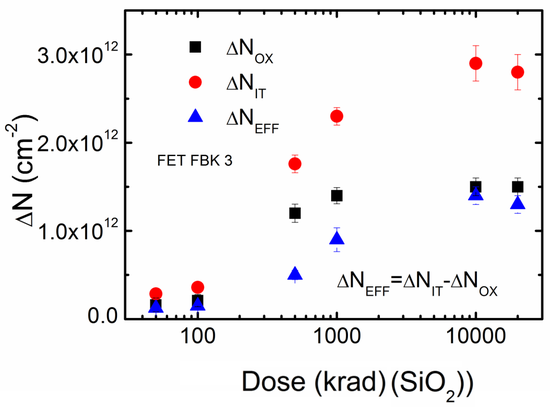


NO BIAS during irradiation steps

*Characteristics of **Acceptor** trap states (from MOS, GD p-on-n and MOSFET n-on-p)*

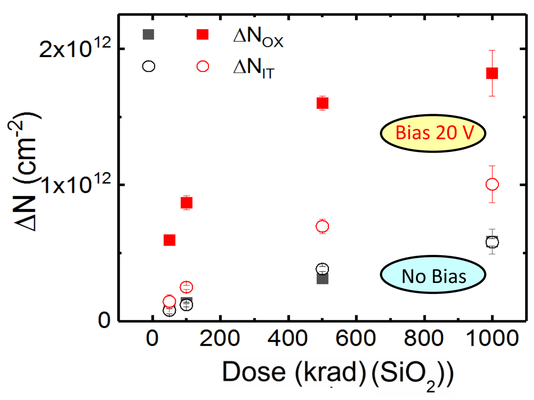




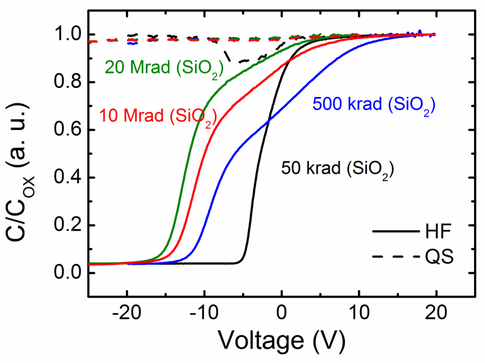


NO BIAS during irradiation steps

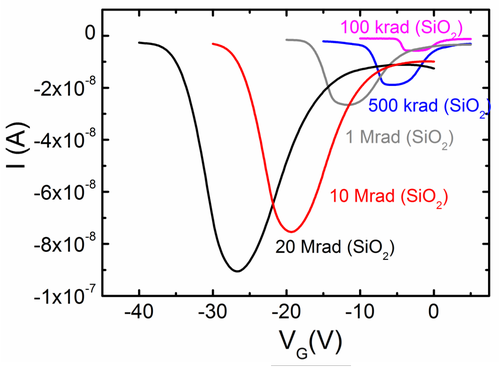
Two different irradiation conditions: without/with biasing the devices.



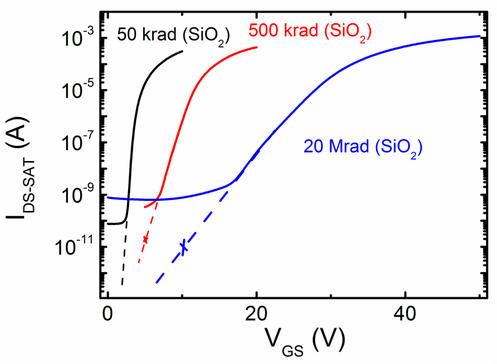
MOS capacitor



Gated Diode



MOSFET



Conclusions

- ✓ A wide set of measurements has been carried out on dedicated FBK p-on-n and n-on-p test structures before and after irradiation with X-rays.
- ✓ Surface radiation damage effects have been deeply investigated aiming at the extraction of the most relevant parameters: N_{OX}, N_{IT}, …
- ✓ These results foster the development of an enhanced TCAD modelling scheme of surface damage effects for the design and optimization of the new generation of silicon detectors to be used in the future HEP experiments.

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This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement no. 654168.