Radiation Damage

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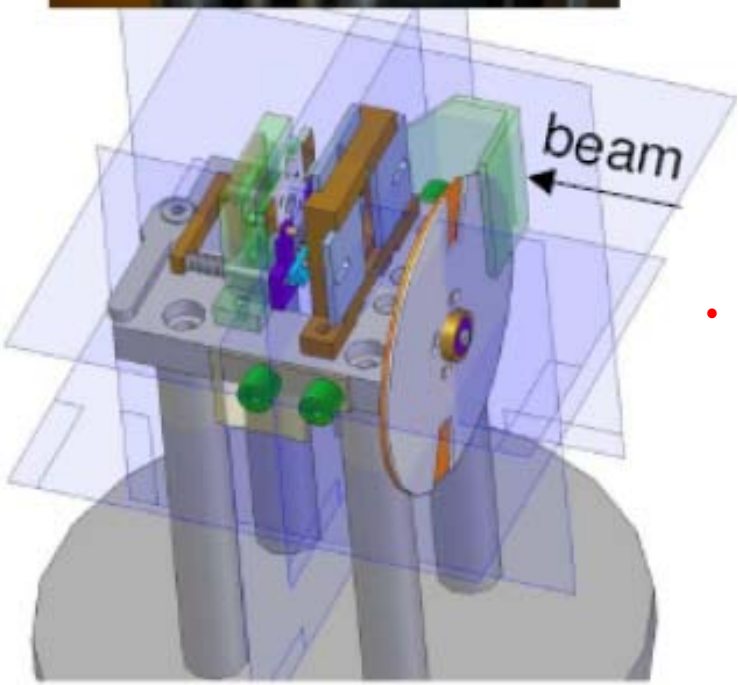
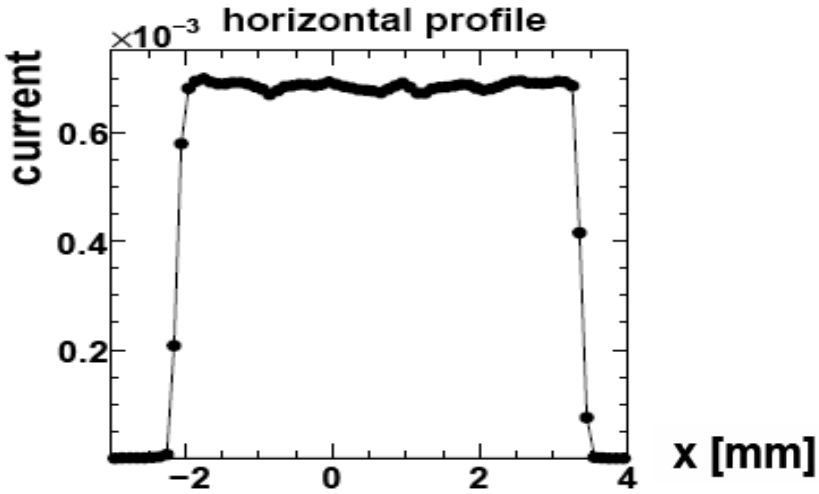
1. X-ray irradiation facility – new irradiations
2. Reminder: Status at last XDAC-meeting
3. X-ray radiation damage: new effects and first understanding
4. First results of annealing studies
5. Outlook – next steps

1. X-ray irradiation facility – new irradiations

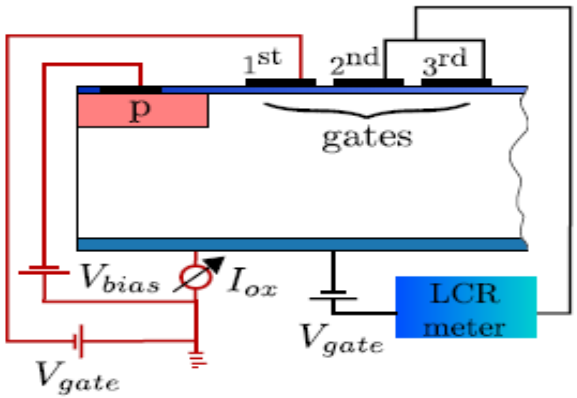


- Improved uniformity by vertical scanning
- Re-measurement of horizontal profile



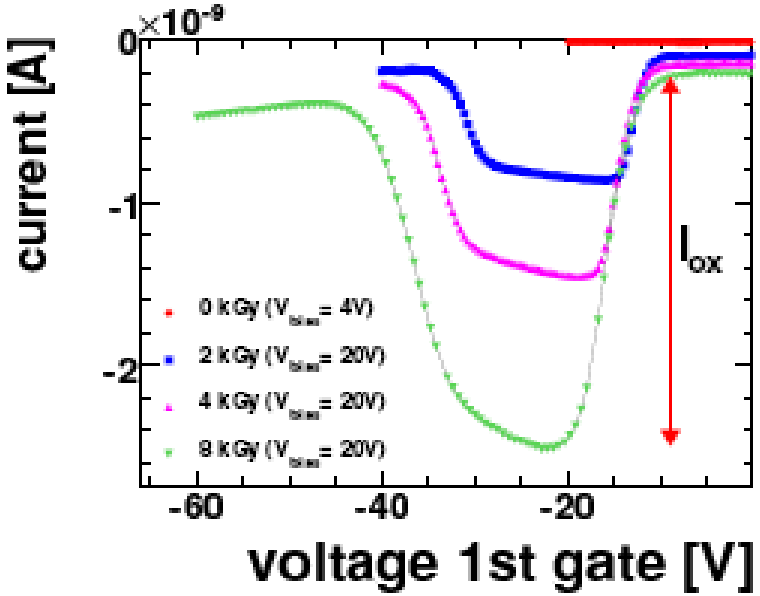
- Irradiation of test structures repeated
  - verify previous results
  - check effect of vertical non-uniformity
  - assure better defined "annealing-status" (put samples in freezer to avoid room temperature annealing)

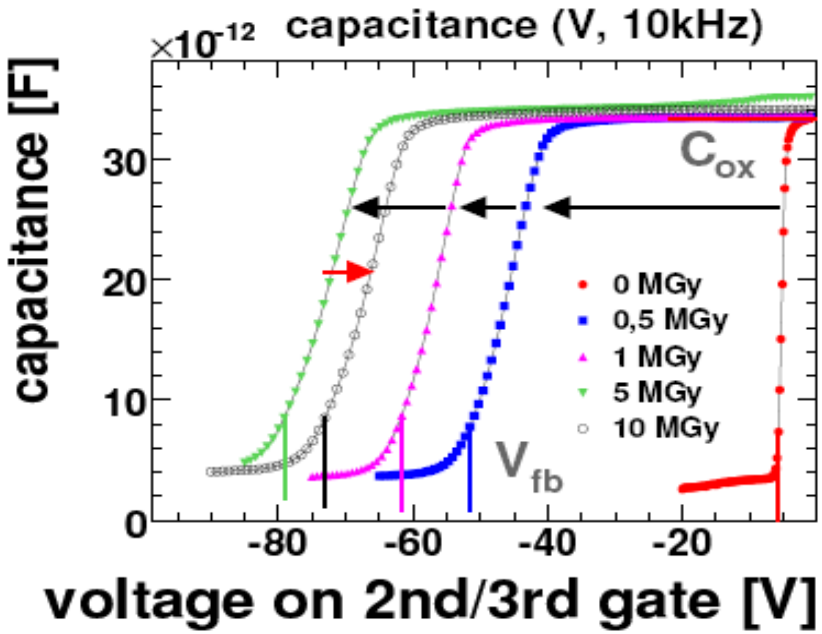
2. Status at last XDAC-meeting – measurement techniques



N_{it}+N_{Ox}(interface trap- + oxide charge-density) from V-shift of C/V curve
N_{it} also → frequency dependence of C/V

I_{Ox} (oxide current): from I/V when Si below gate in depletion



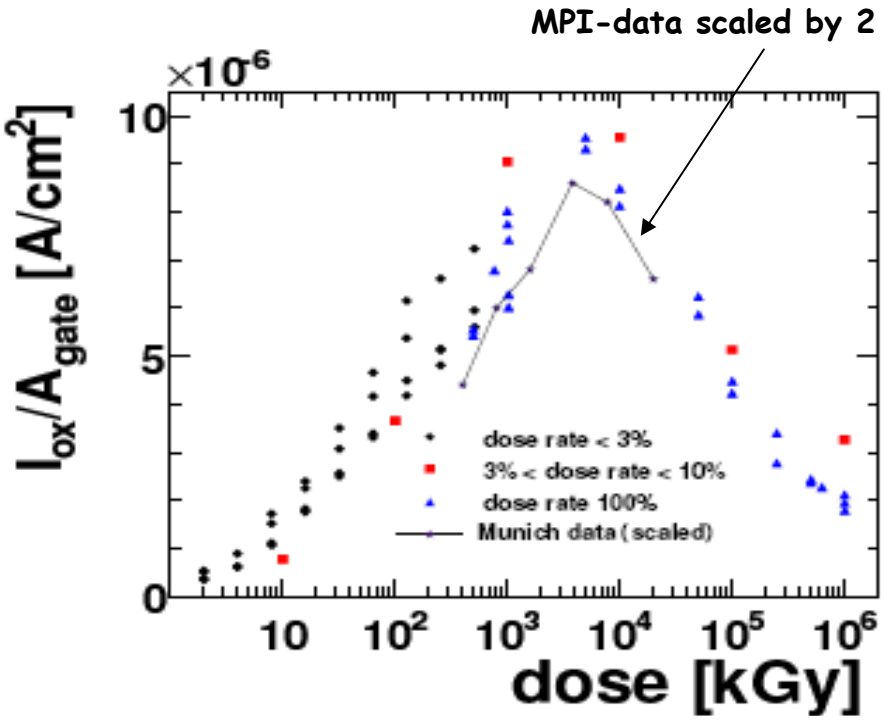


D_{it} (distribution of interface traps in band gap [$cm^{-2}eV^{-1}$] from TSC (Thermally Stimulated Current technique)

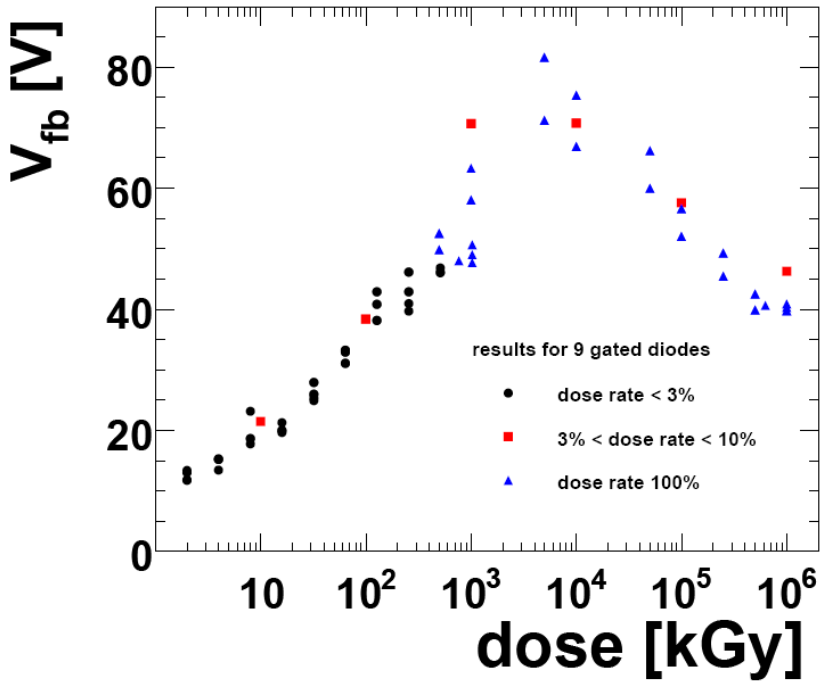
Reminder last XDAC-meeting (Oct.14.08)

Status at last XDAC-meeting – main results:

Surface generation current vs dose



"Flat-band voltage" vs dose

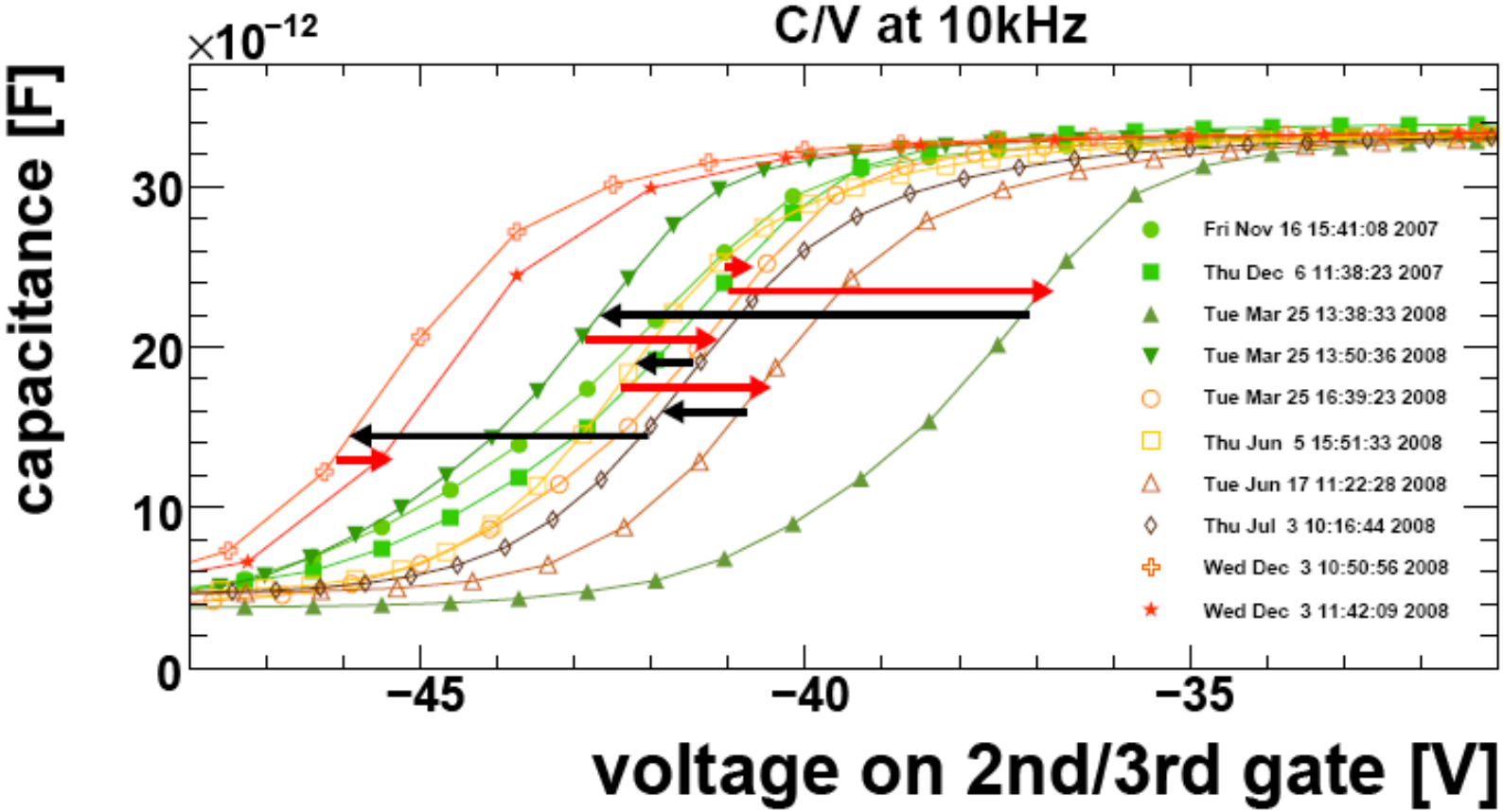


→ V_{fb} [N_{Ox}+N_{it}] and I_{Ox} [N_{it}] reach maximum at few MGy – then decrease

(tentative conclusion: decrease due to N_{it} at high doses – reason not clear)

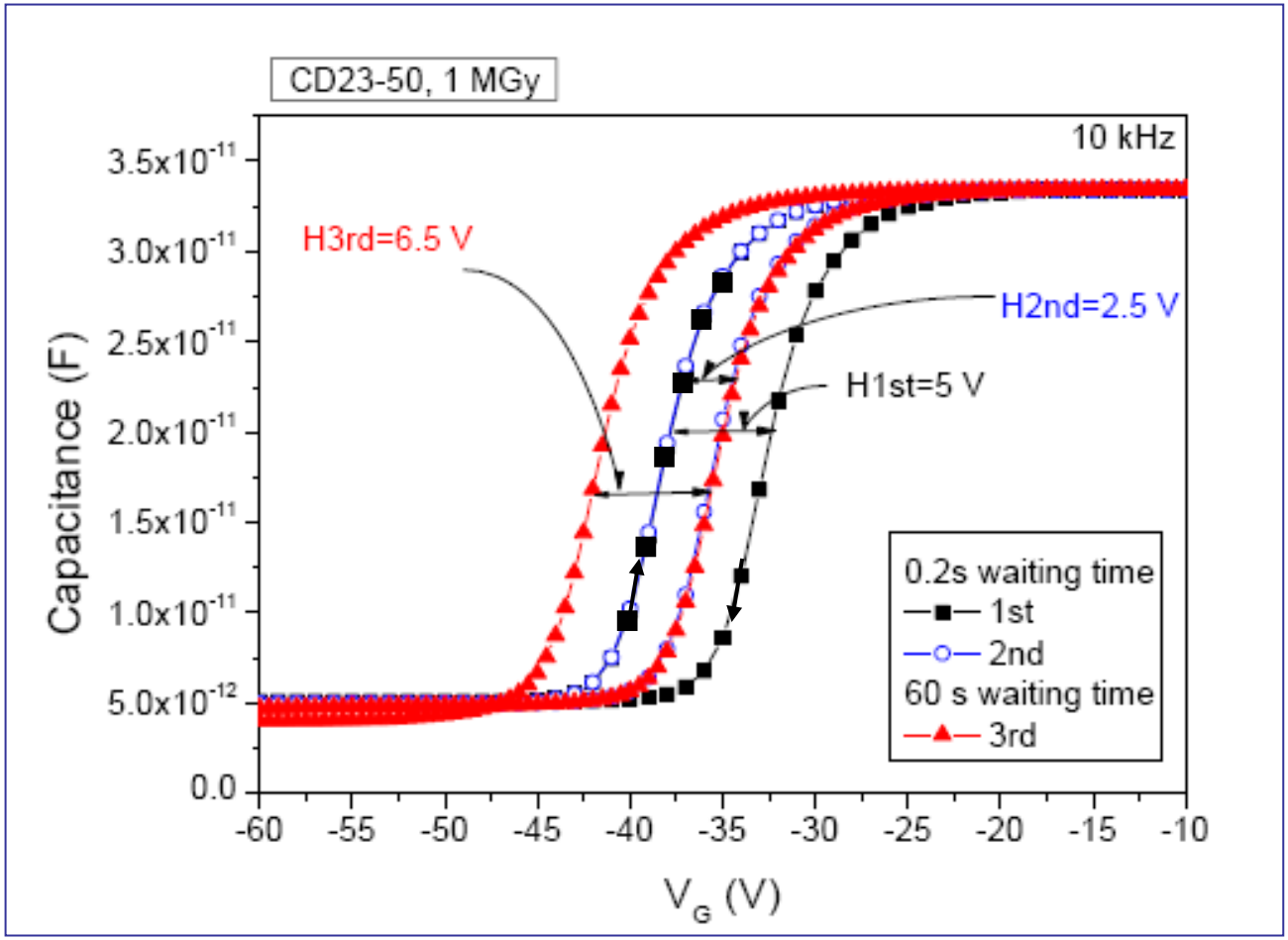
3. New effects and (attempt of a) first "understanding":

C/V measurements exhibit a random component (hidden parameter)



→ quasi random shifts at the level of O(10 Volts) !

Observation of strong hysteresis and temperature effects:
(→ C/V curve depends (eg) on stepping speed and direction of V)



→ N_{Ox} component with long (>> $1/f_{AC}$) time constant → dependence on biasing history

New effects and first understanding

→assume 3 components of irradiation effects:

1. N_{Ox}^{fix} **fixed** oxide charges → shift of ideal CMOS-C/V-curve (no bending C/V, no f-dependence C/V, no I_{Ox})

2. N_{Ox}^{mob} **mobile** oxide charges (close to interface) → shift C/V-curve, no f-dependence C/V, responsible for hysteresis effects, no I_{Ox})

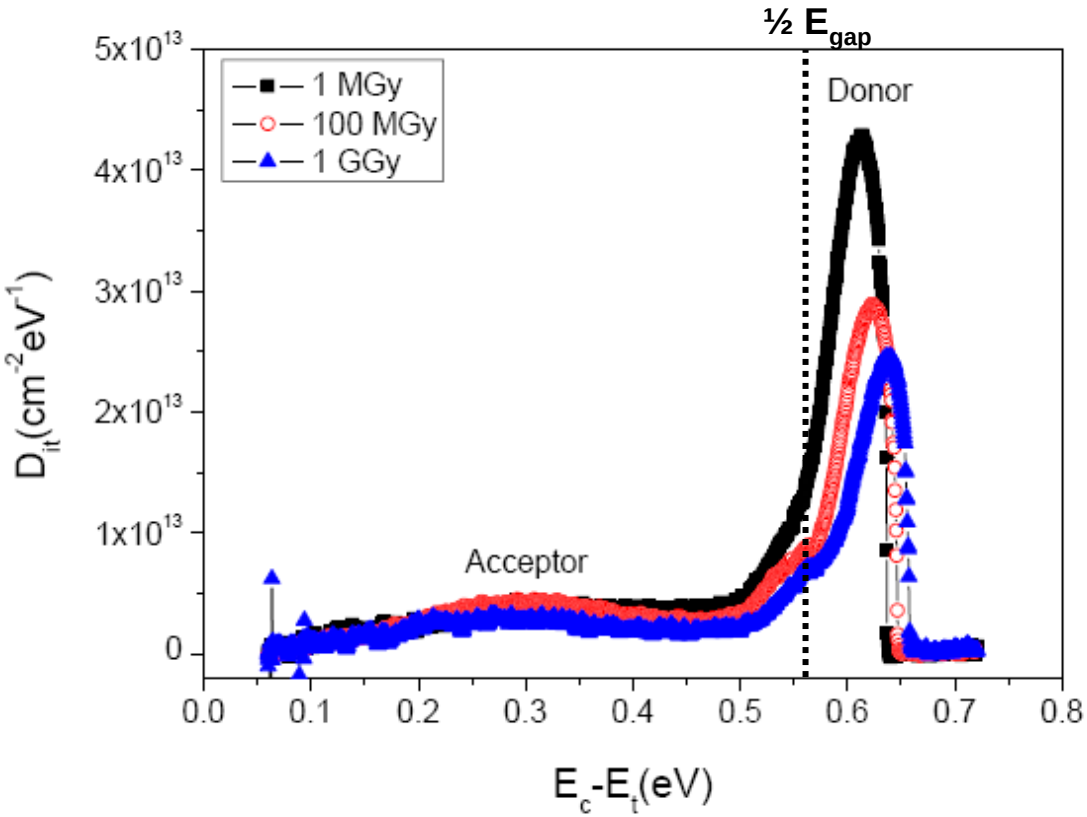
3. D_{it} **interface traps** (integral N_{it}) → oxide charges (close to interface) → shift C/V-curve (N_{it}), f-dependence C/V, I_{Ox} (D_{it} close to mid-band)

attempt to use disentangle the 3 components:

- obtain D_{it} and N_{it} from TSC-measurements
- simulate C/V curve and compare the shape
- "erase" mobile charges (eg anneal 30' at 80°C) → 1st "fast" C/V curve is determined only by N_{Ox}^{fix} and N_{it}
- obtain N_{Ox}^{mob} from "C/V" hysteresis for fast (0.2 sec waiting time) C/V-curve (0 → -80 → 0Volts) [result depends on waiting time at -80Volts)
- verify that simulation describes data
- check that results are consistent with I_{Ox} results

D_{it} [$cm^{-2}eV^{-1}$] Interface density vs Irradiation dose

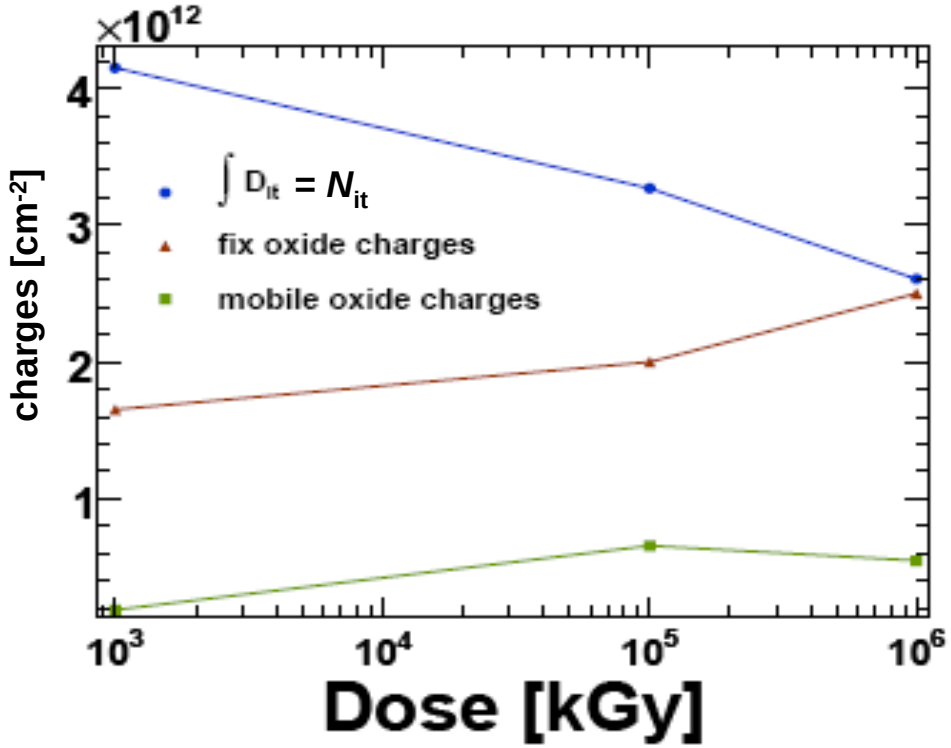
(from TSC thermally Stimulated Current- measurements):



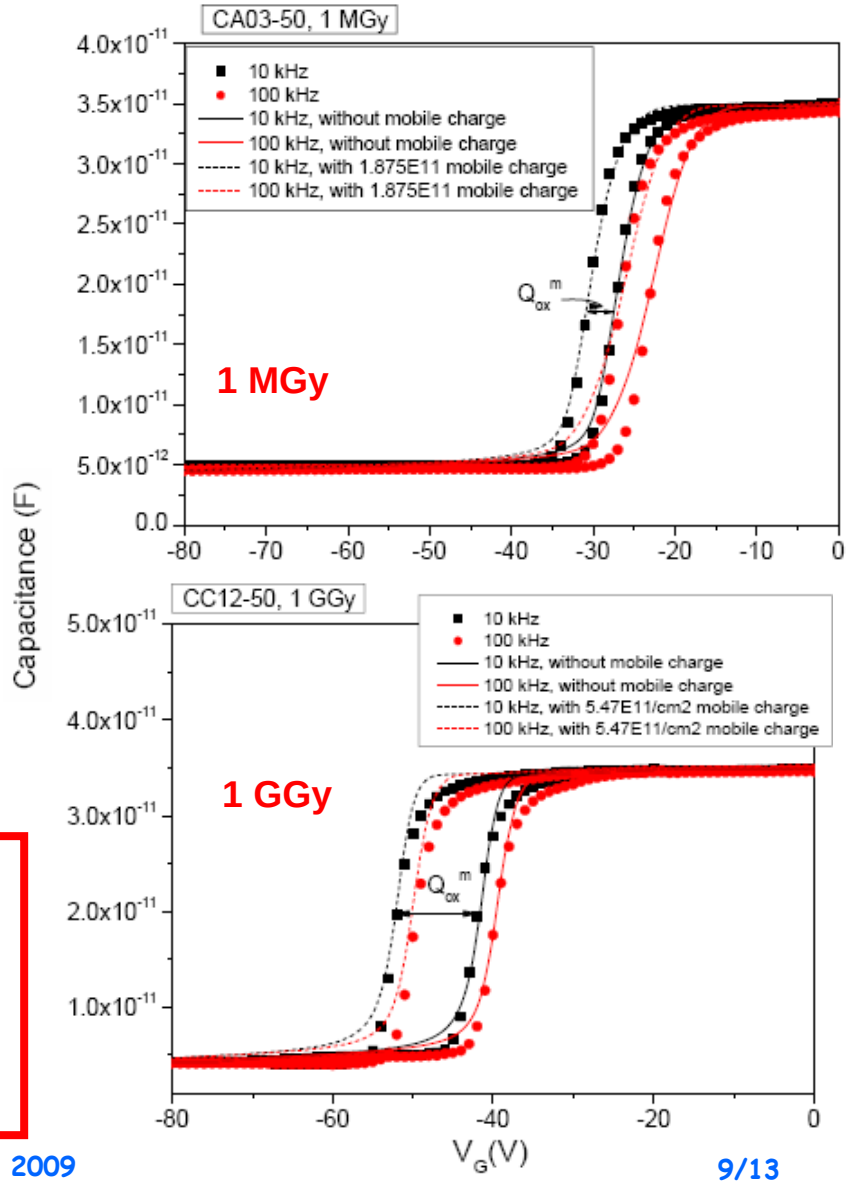
→ **significant decrease (1 MGy → 1 GGy) of D_{it}**
in particular close to the middle of the band gap, where sensitivity to I_{Ox} highest

New effects and first understanding

Results:



Comparison to measurements:



→ results preliminary – have to be checked
- data can be described by microscopic model, which can be put into simulations
- reason for decrease of N_{it} not understood

"understanding" more complex than expected

4. First results from annealing studies:

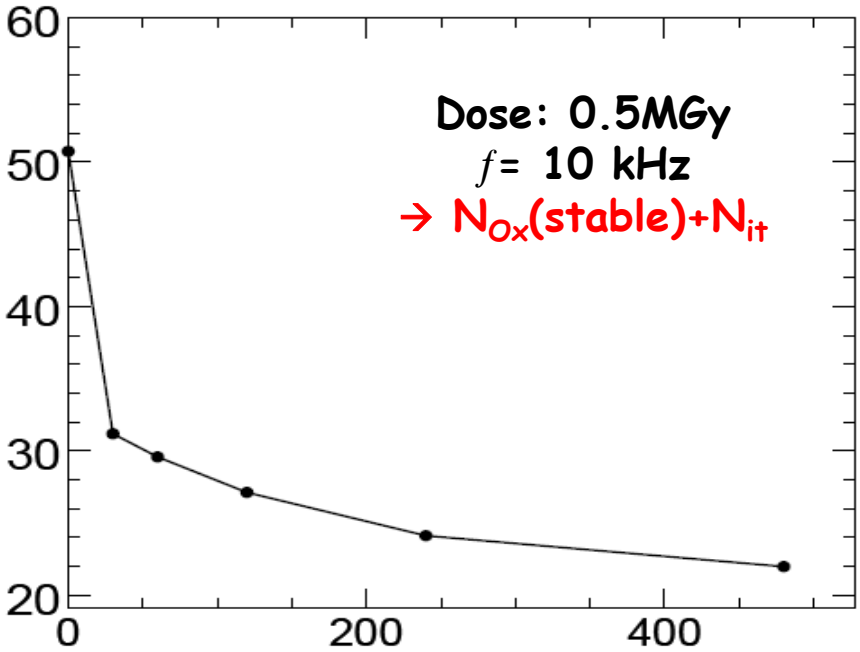
We have learned only recently to obtain reproducible results

→ delays in annealing studies

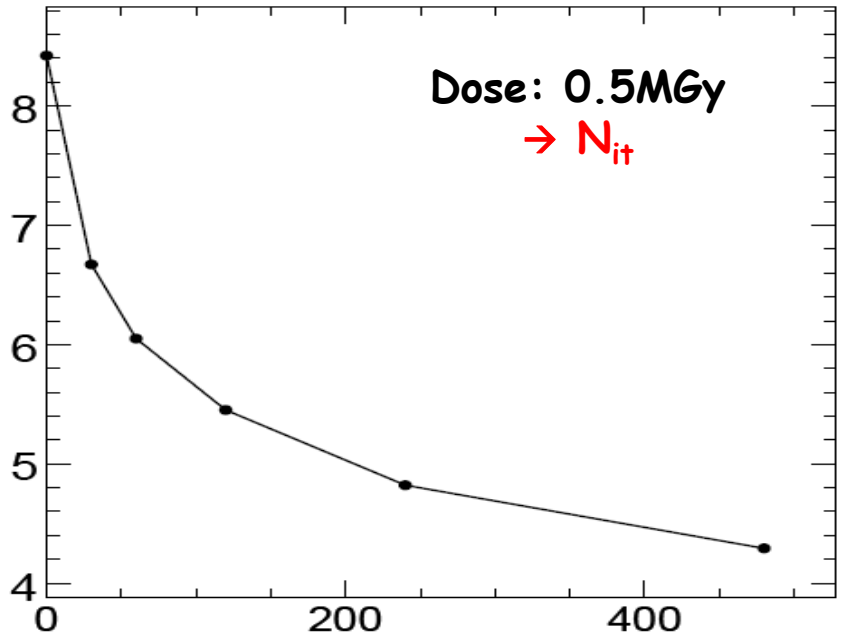
Start: measure CV, IV and TSC-spectra vs annealing time at 80°C:

→ first results

Voltage($C=\frac{1}{2}C_{accum.}$)[V] vs annealing time



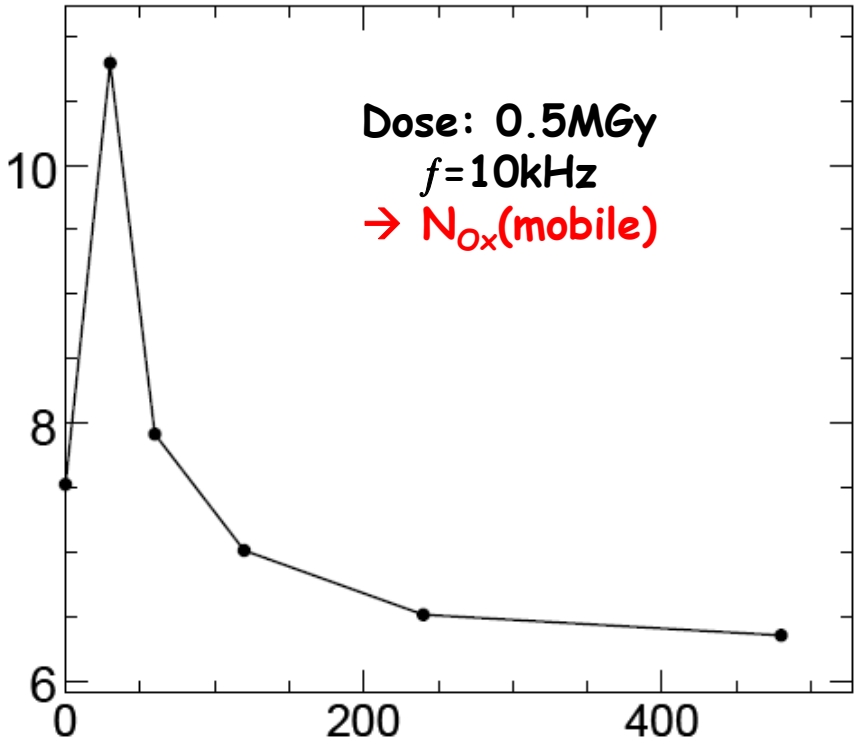
Δ Voltage(100kHz-10kHz) [V] vs $t_{annealing}$



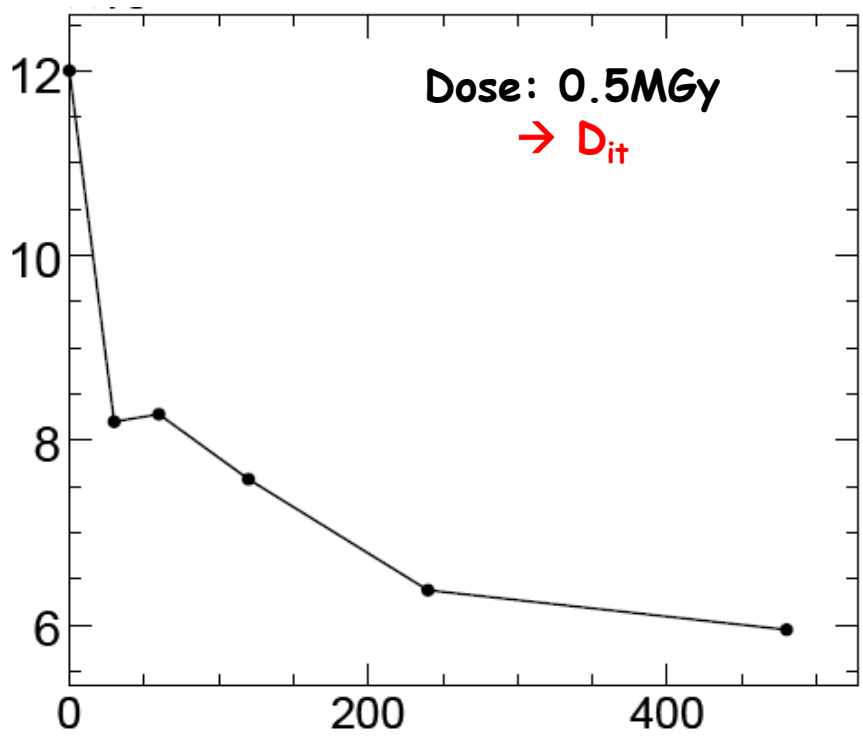
time (minutes)

First annealing studies

ΔV(hysteresis)[V]@10 kHz vs $t_{annealing}$



I_{Ox} (nA) vs $t_{annealing}$



annealing time [minutes]

→ strong annealing effects observed