Studies on radiation hardness of DEPFET-like test structures

DPG Frühjahrstagung 2011

Karlsruhe

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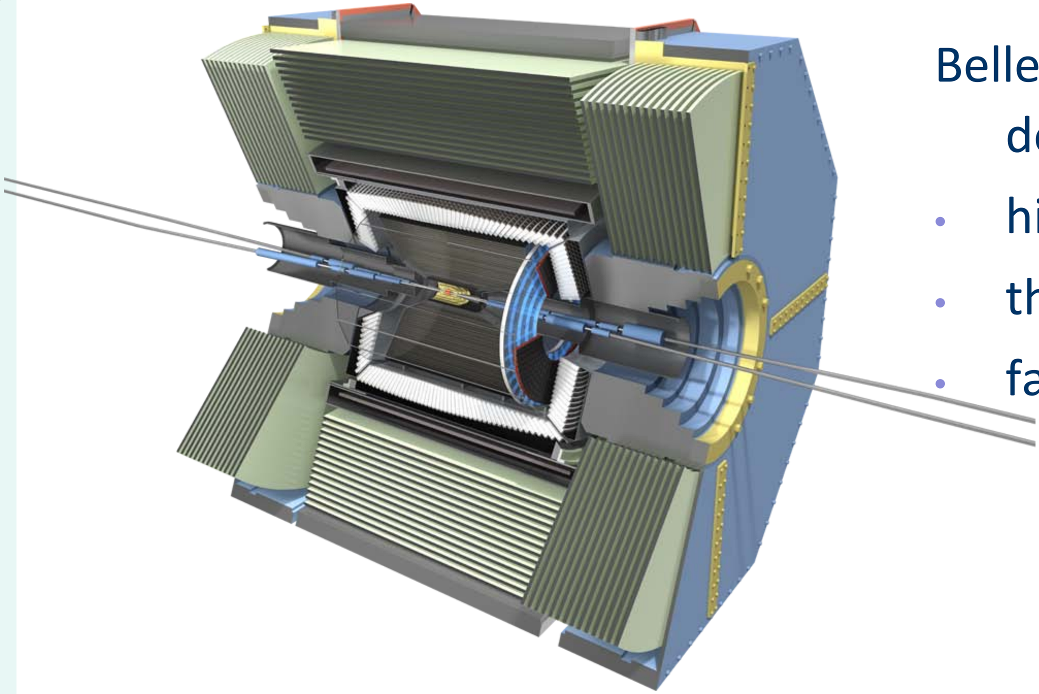
Motivation – Pixel Detector at Belle II



Belle II requirements for Vertex detector:

- high vertex resolution
- thin detector material
- fast readout and DAQ

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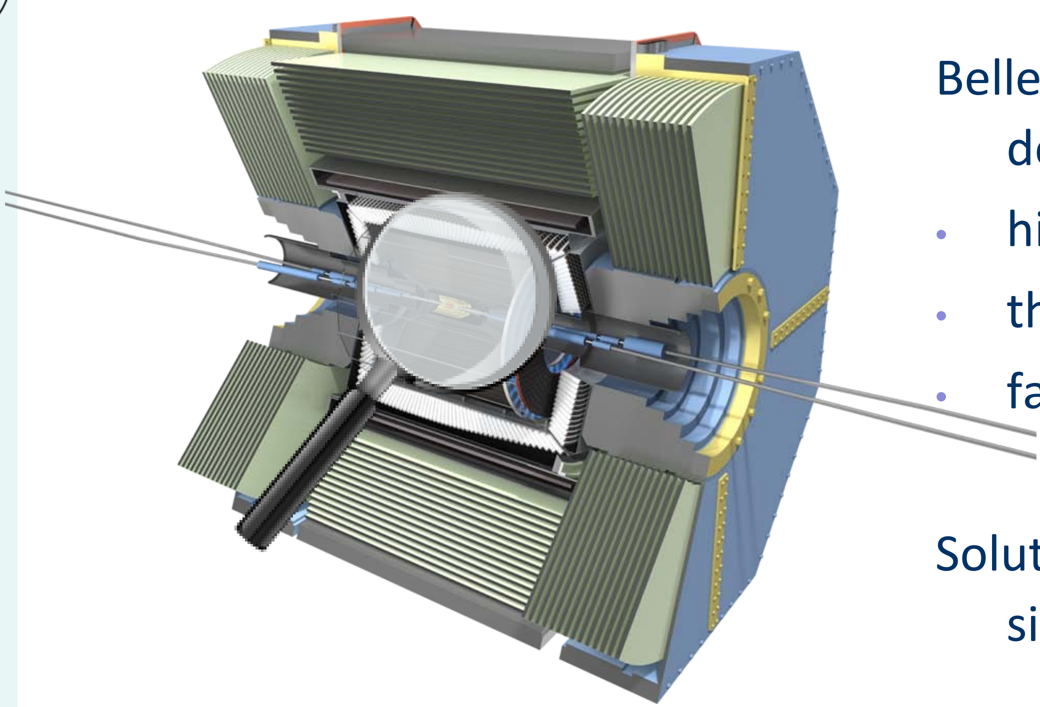


Belle II requirements for Vertex detector:

- high vertex resolution
- thin detector material
- fast readout and DAQ

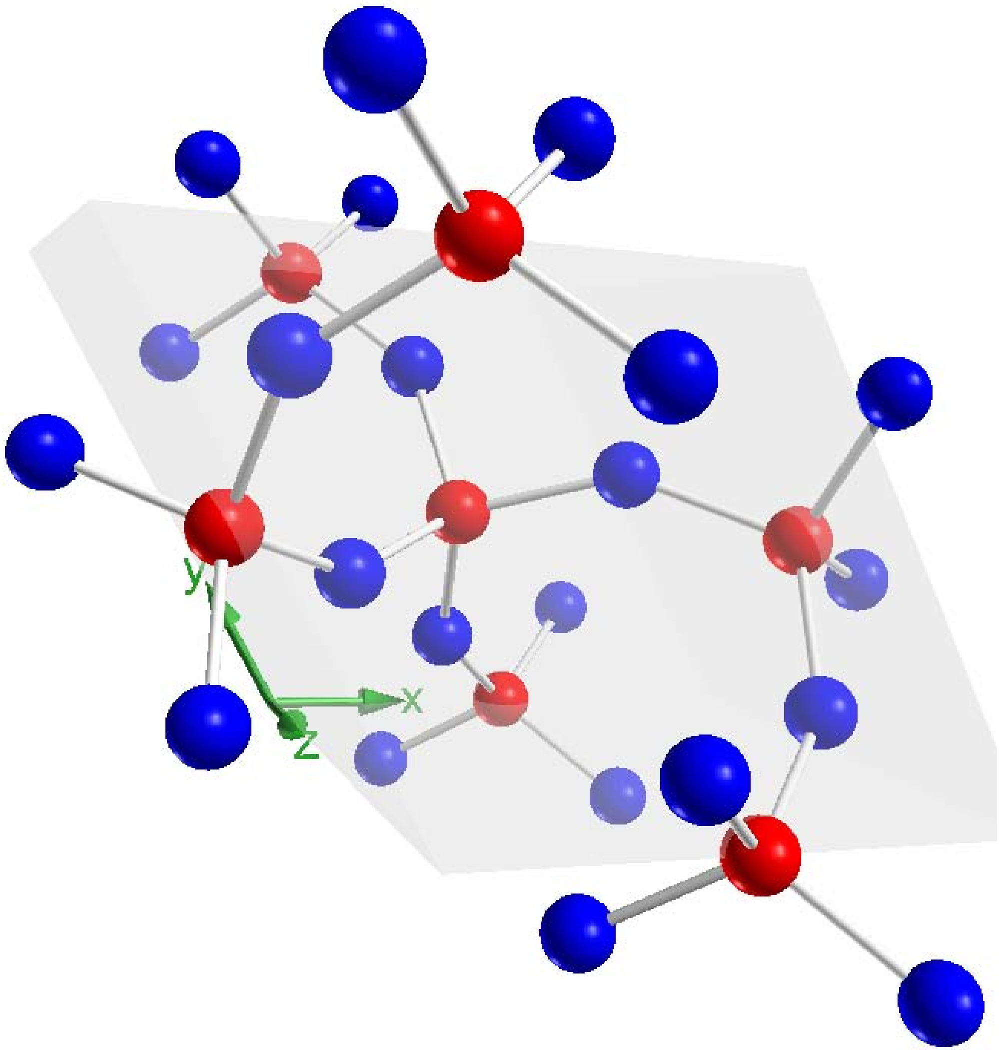
Solution: DEPFET pixels on thin silicon (75 µm)

One Issue: <u>Radiation Hardness in SiO_2</u>

Sources:

- Touschek effect
- synchrotron radiation
- beam gas interaction

Silicon dioxide - Formation of radiation induced E’ defect



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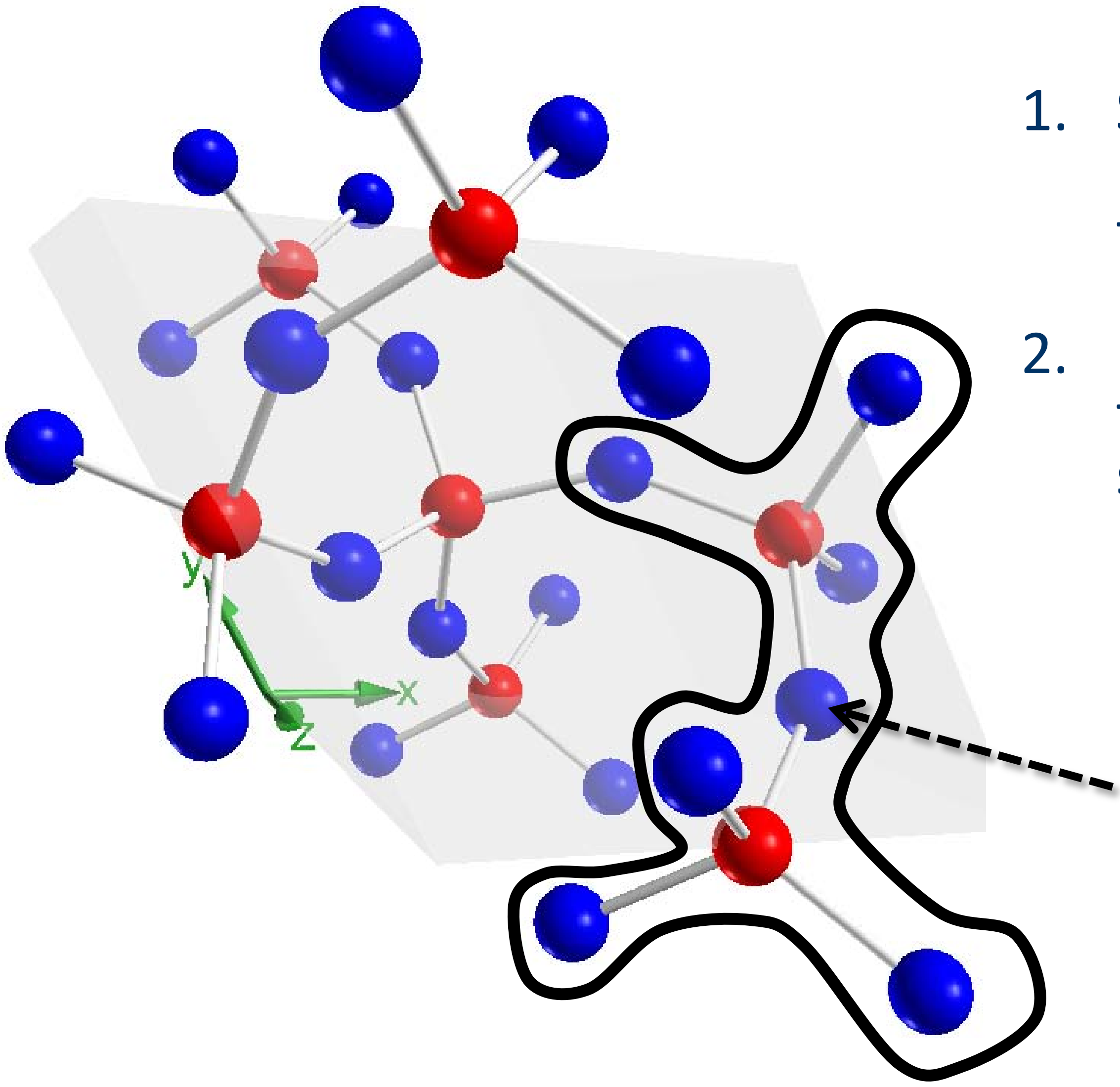

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2. Binding between two Si atoms is stretched and weak.

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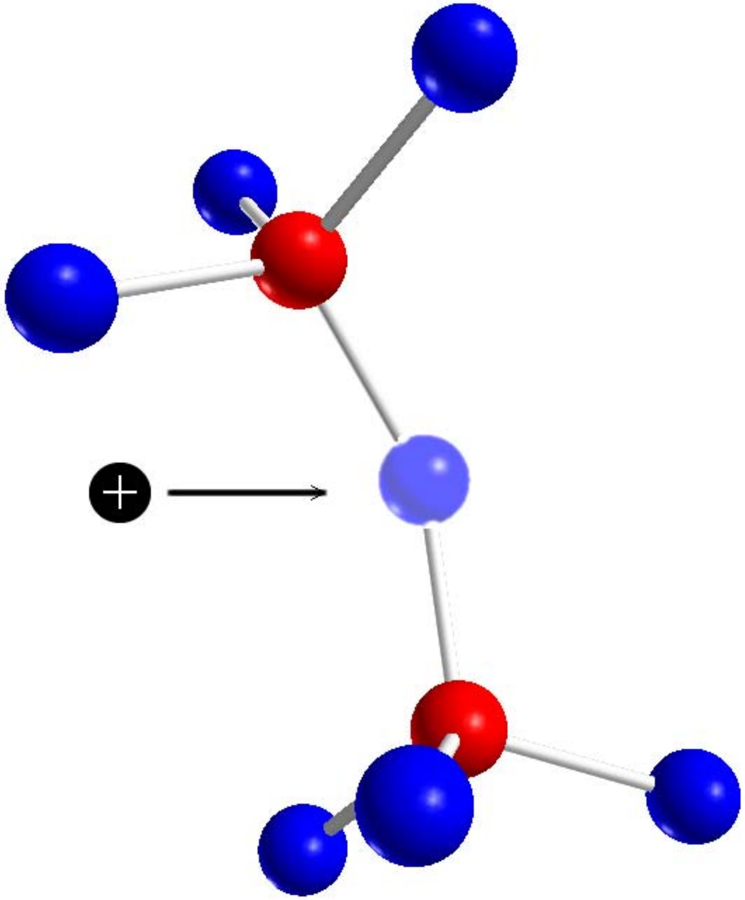

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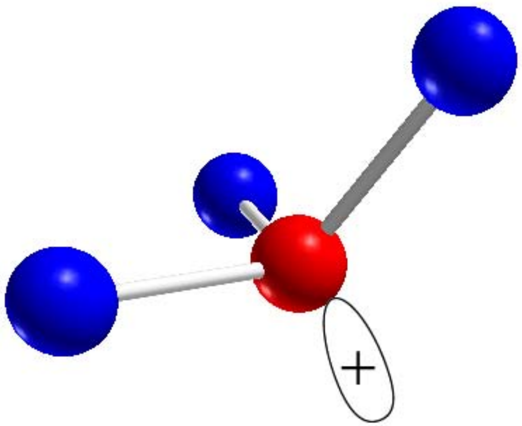

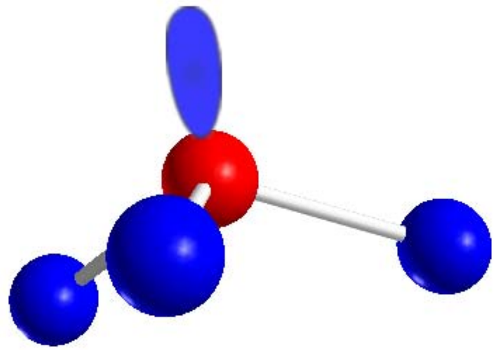

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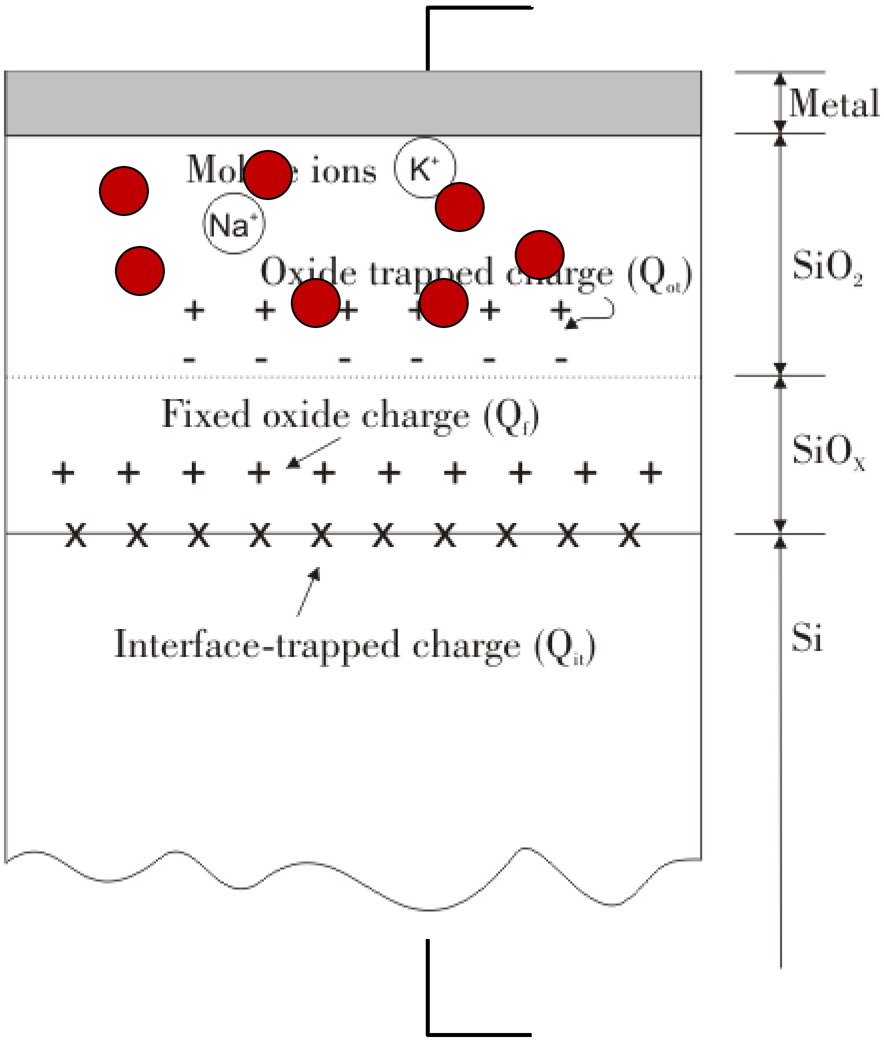
2. Binding between two Si atoms is stretched and weak.
3. Holes from e/h pairs (generated by ionizing radiation) travel to the interface…
4. …and destroy the binding. One Si atoms remains in a positive charge state → E' defect

Dependency of threshold shift



Amount of traps depend on:
- amount of precursors
- dose
- charge yield
- trapping probability

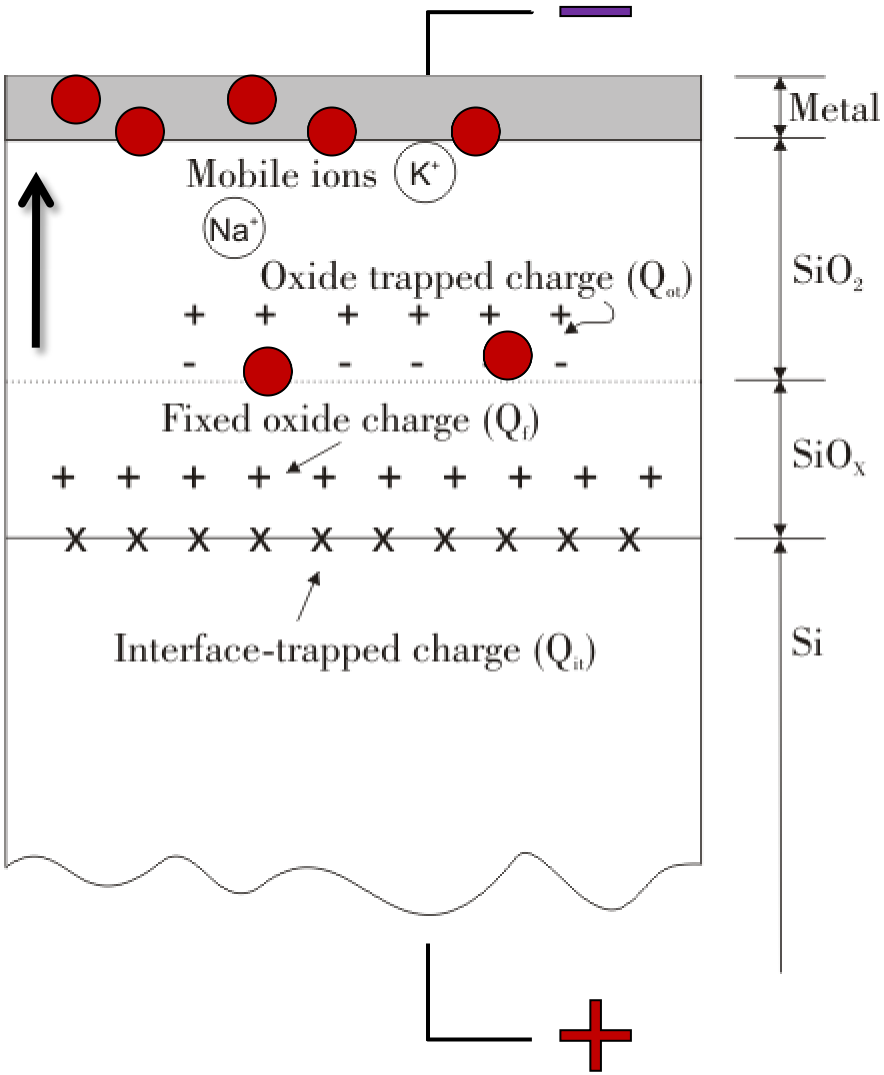
Important parameter:

$$V_{thshift} = \frac{Q_{ot}}{C_{ox}}$$

Improvement via:
1. C_{ox} bigger → use **thinner** gate dielectrics

2. Avoid trapping of charge: Voltage on gate influences charge yield and trapping

Dependency on gate voltage (negative)



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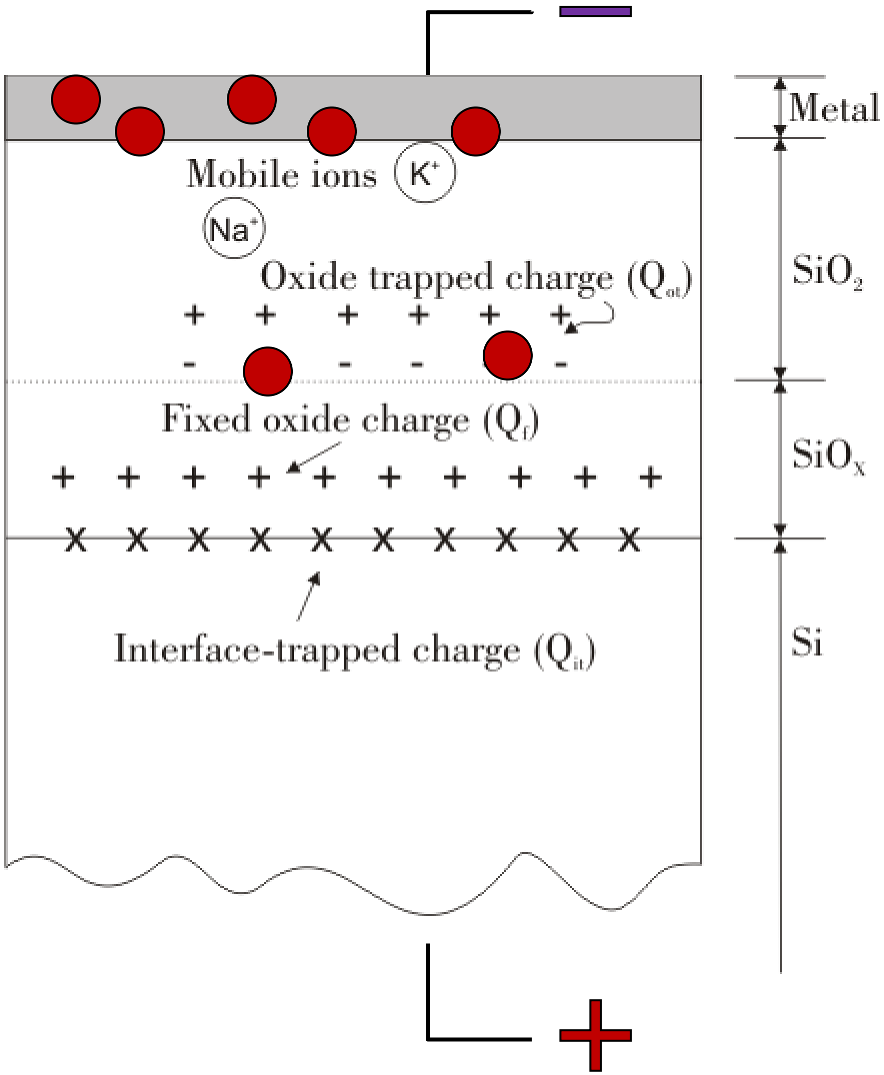

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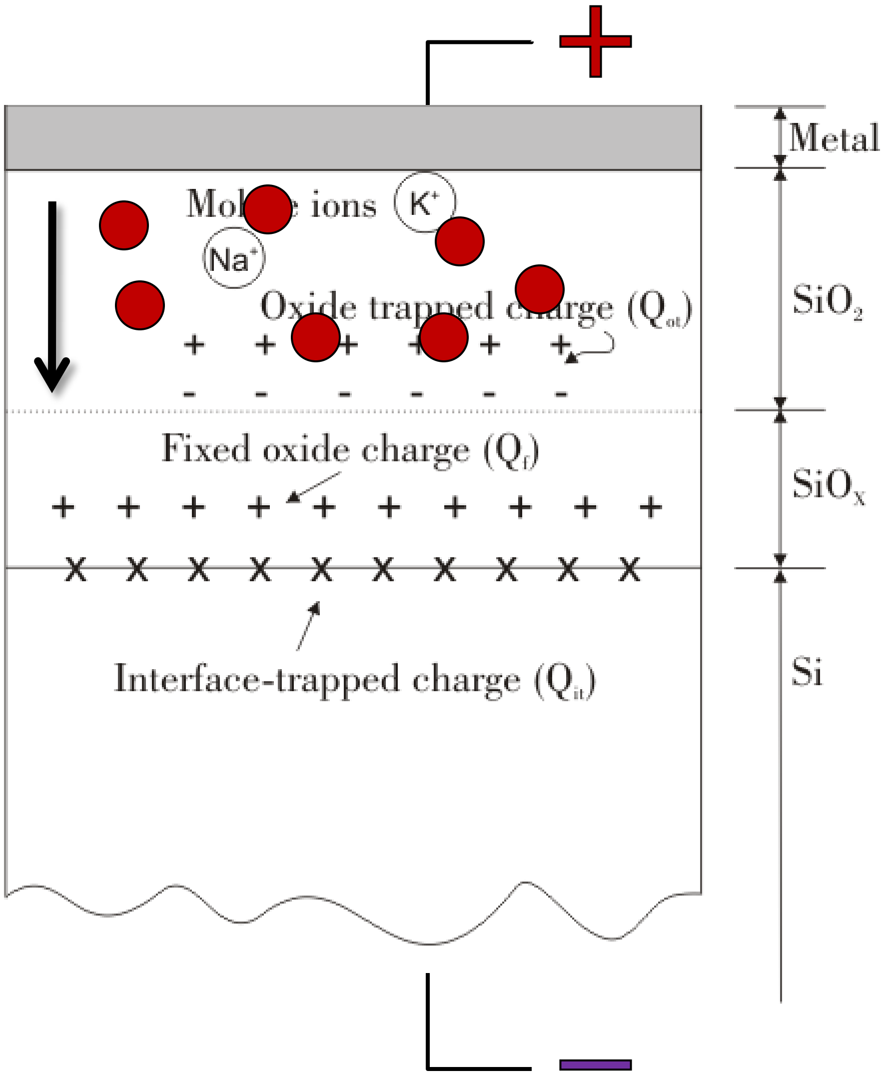

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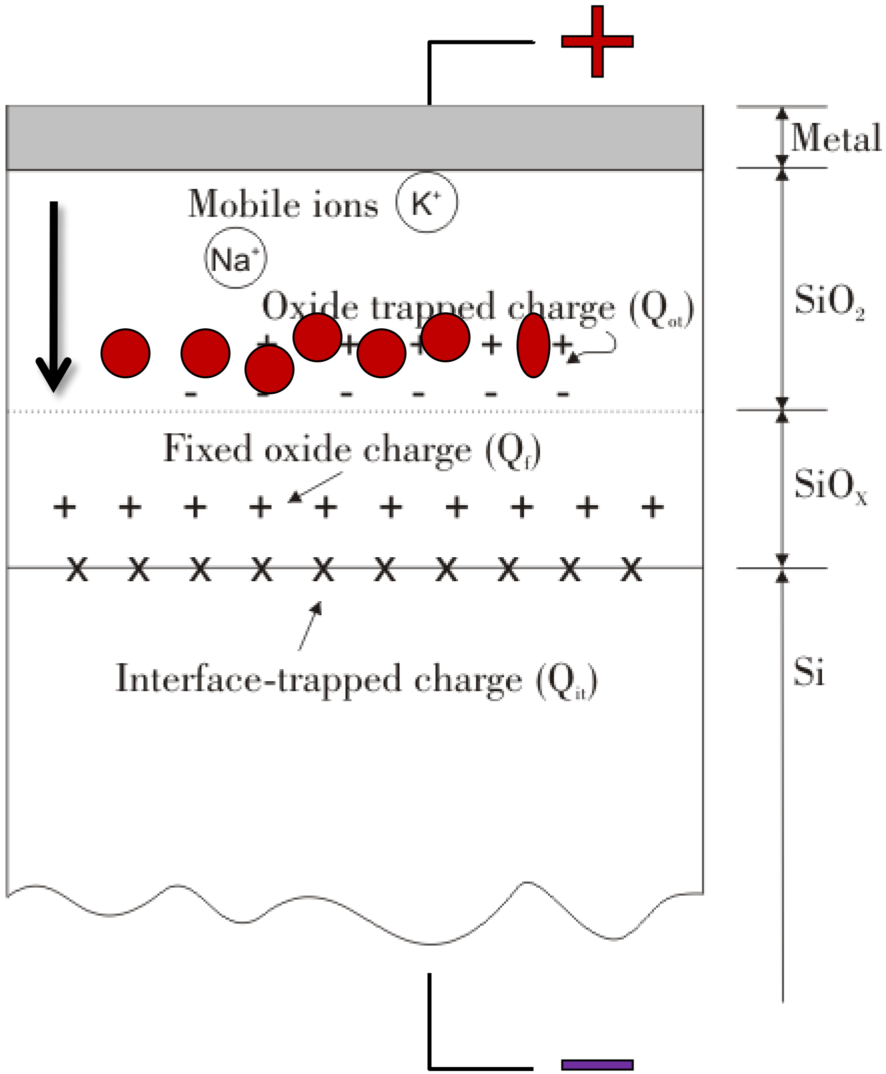

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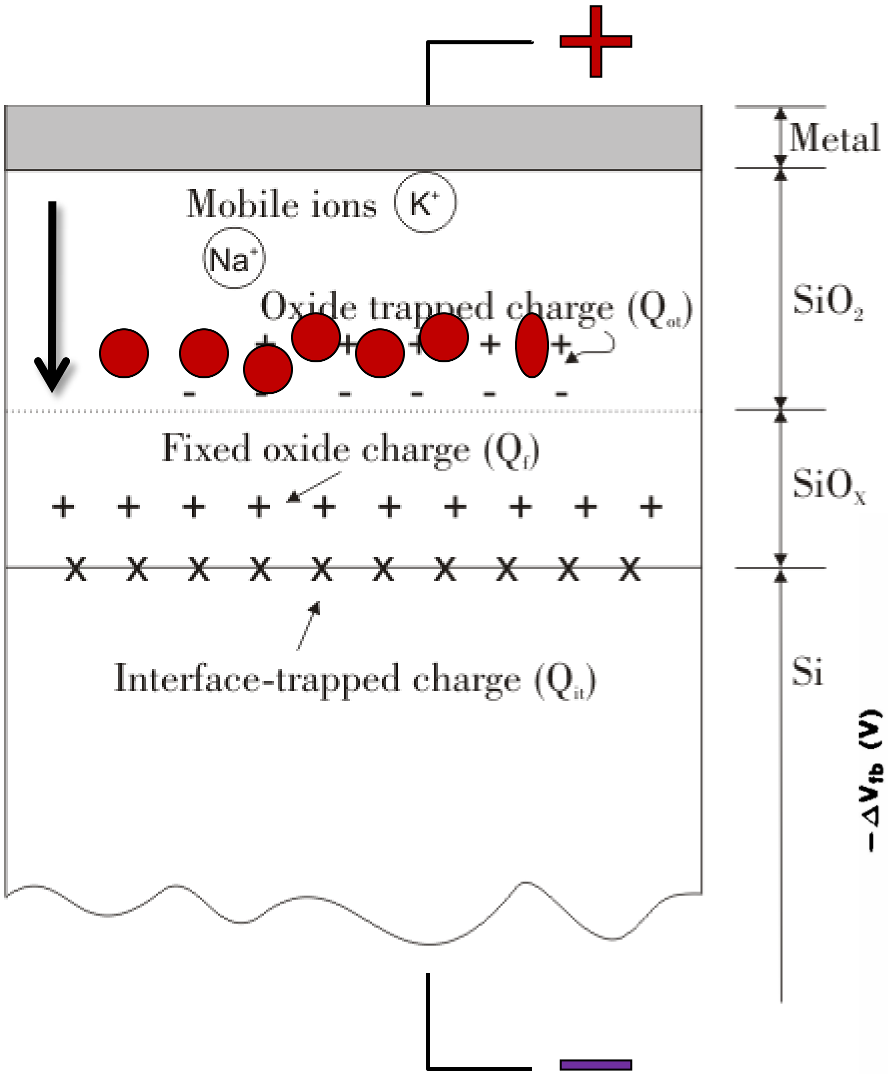

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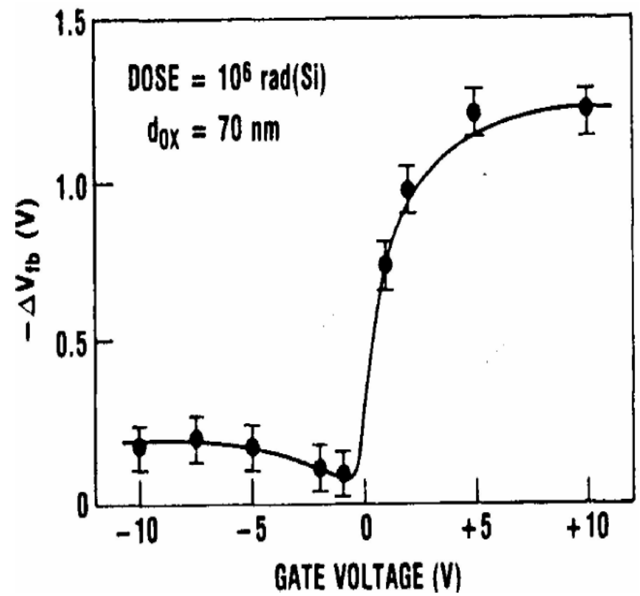
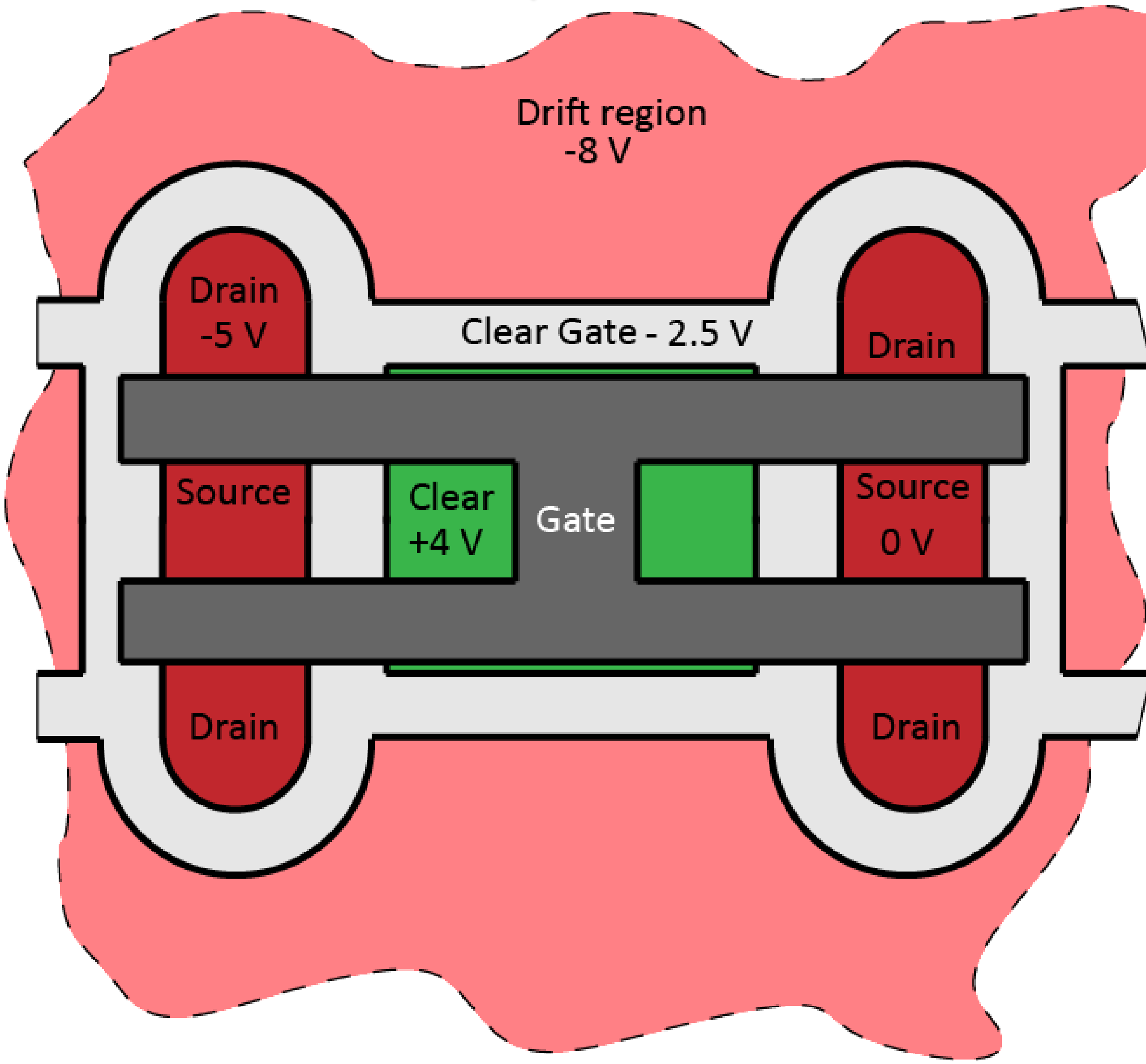
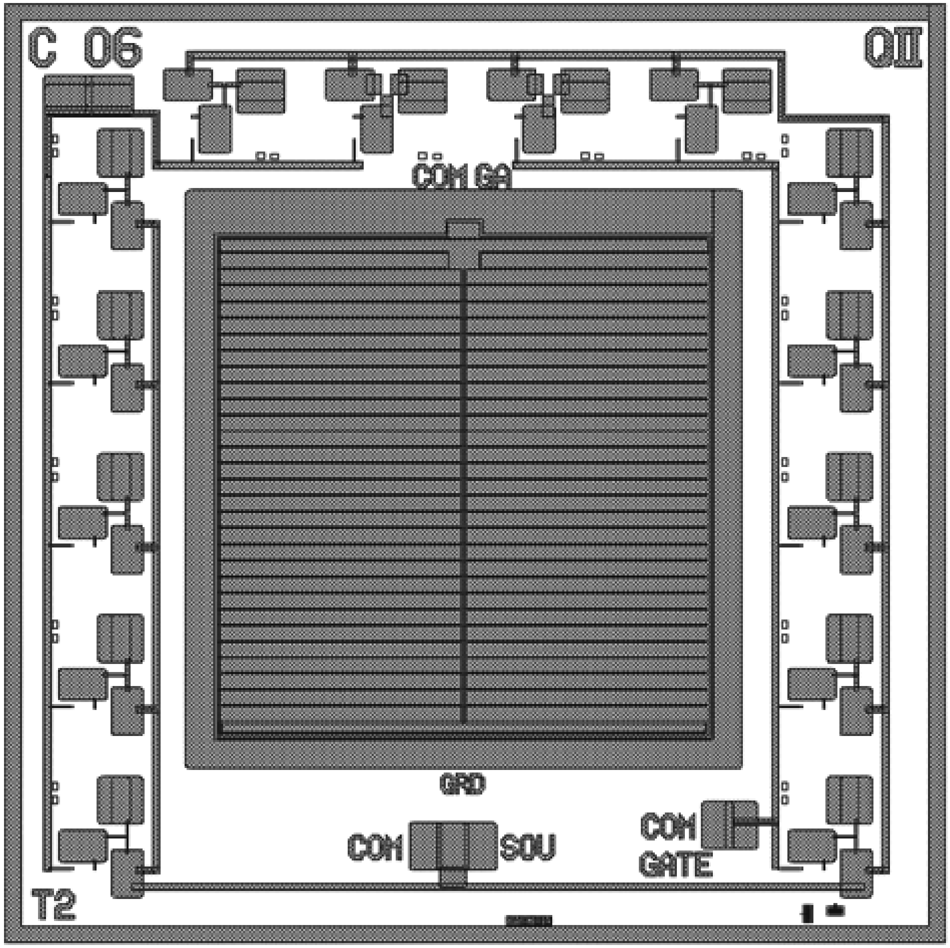


Ma/Dressendorfer

Why voltages on gates are important – Possible Layout of Belle II pixel matrix



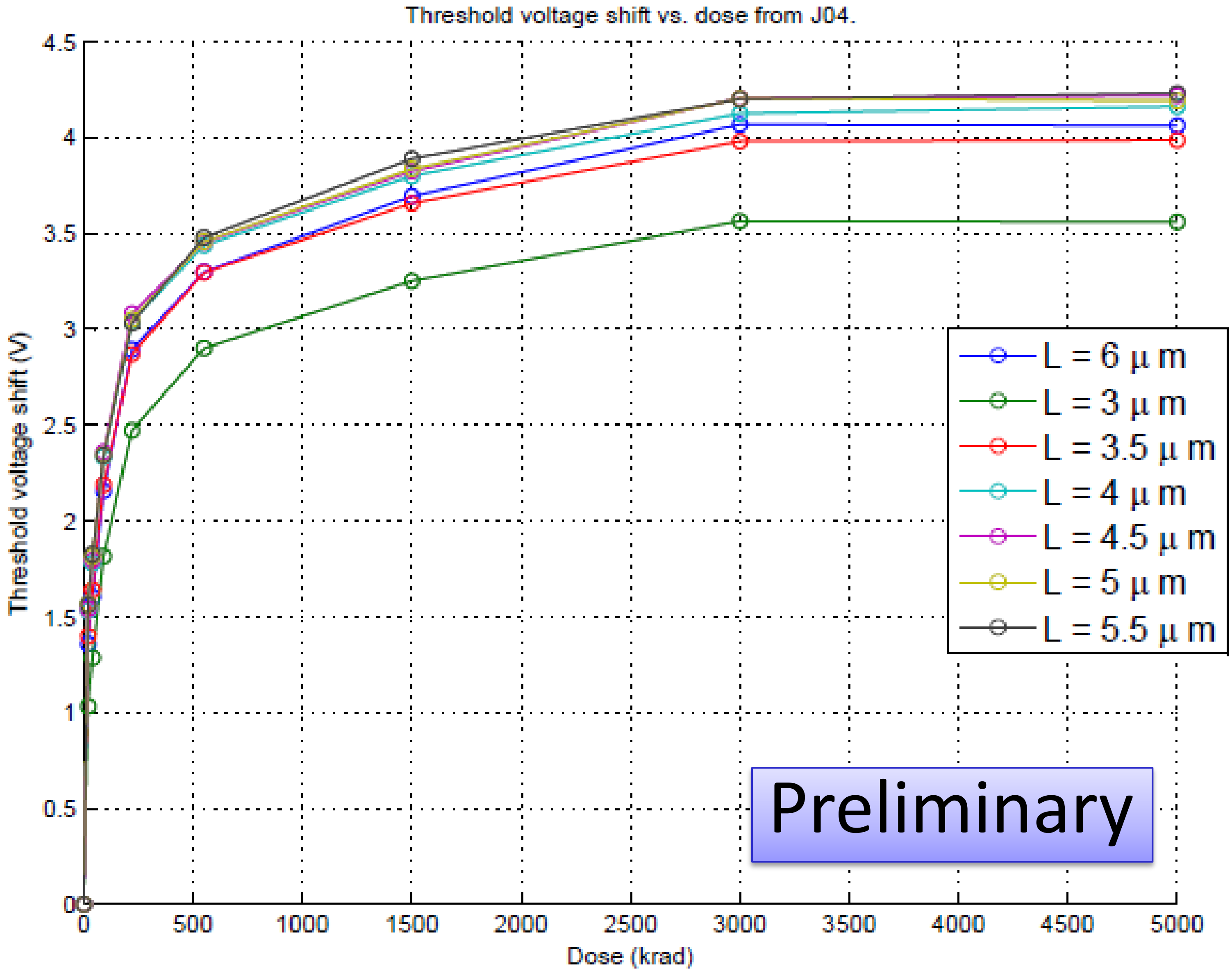
Layout of thin oxide test devices



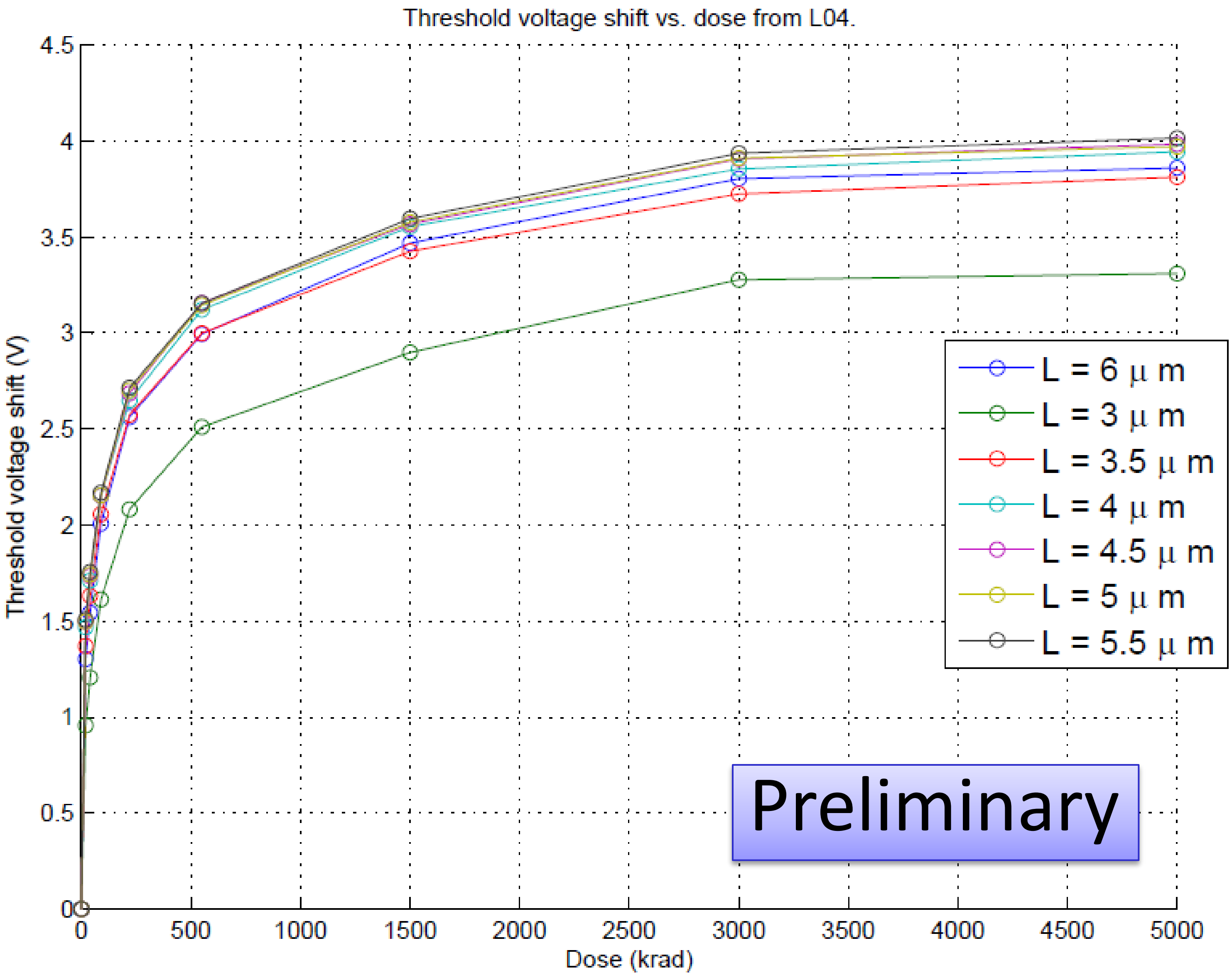
Characteristics of thin oxide structures:

- Central device: capacitor or gate controlled diode
- 14 transistors (=2x7), with diff. gate length and width
- Different doping profiles available

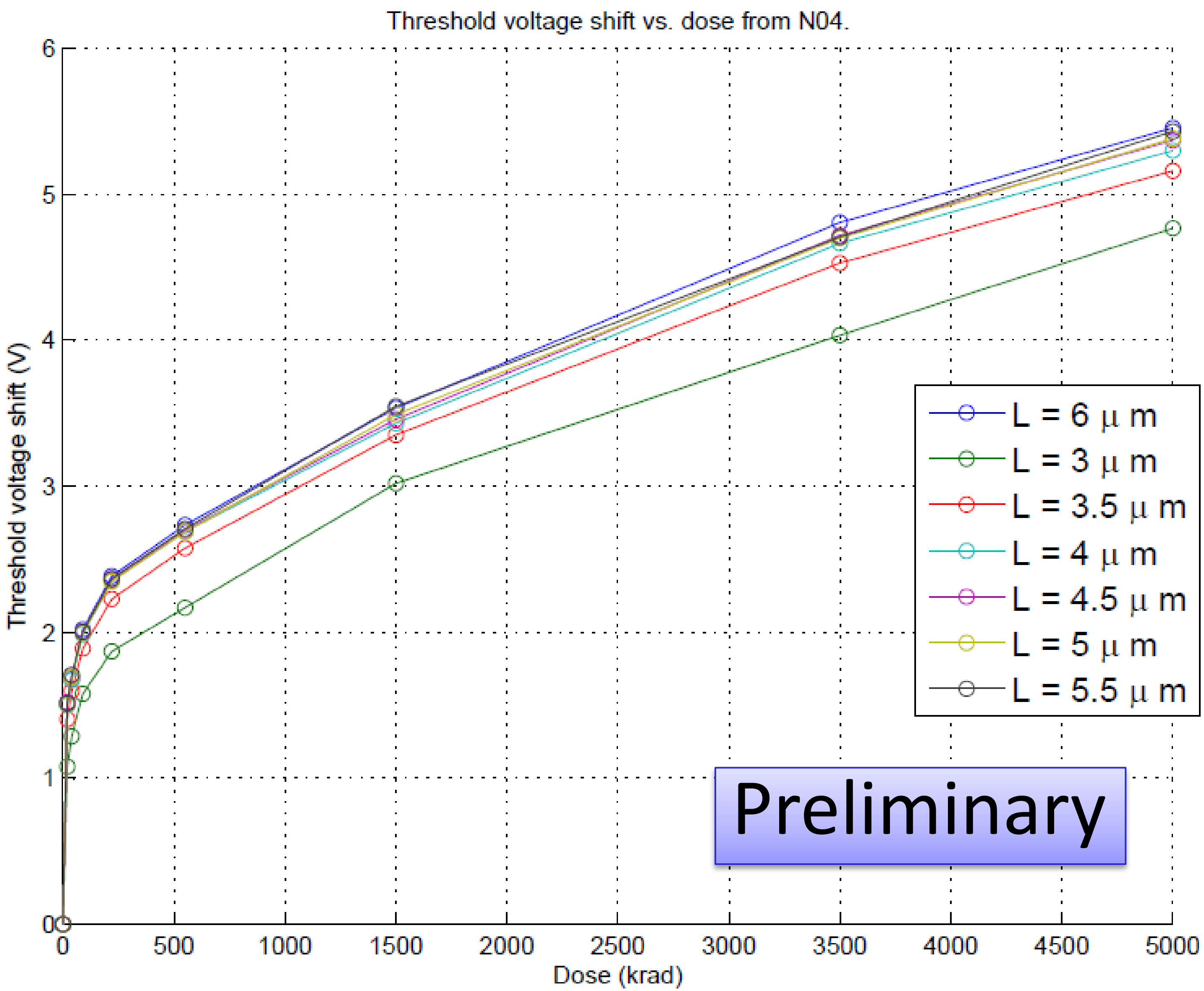
Clear Gate Results, -5 V during Irradiation



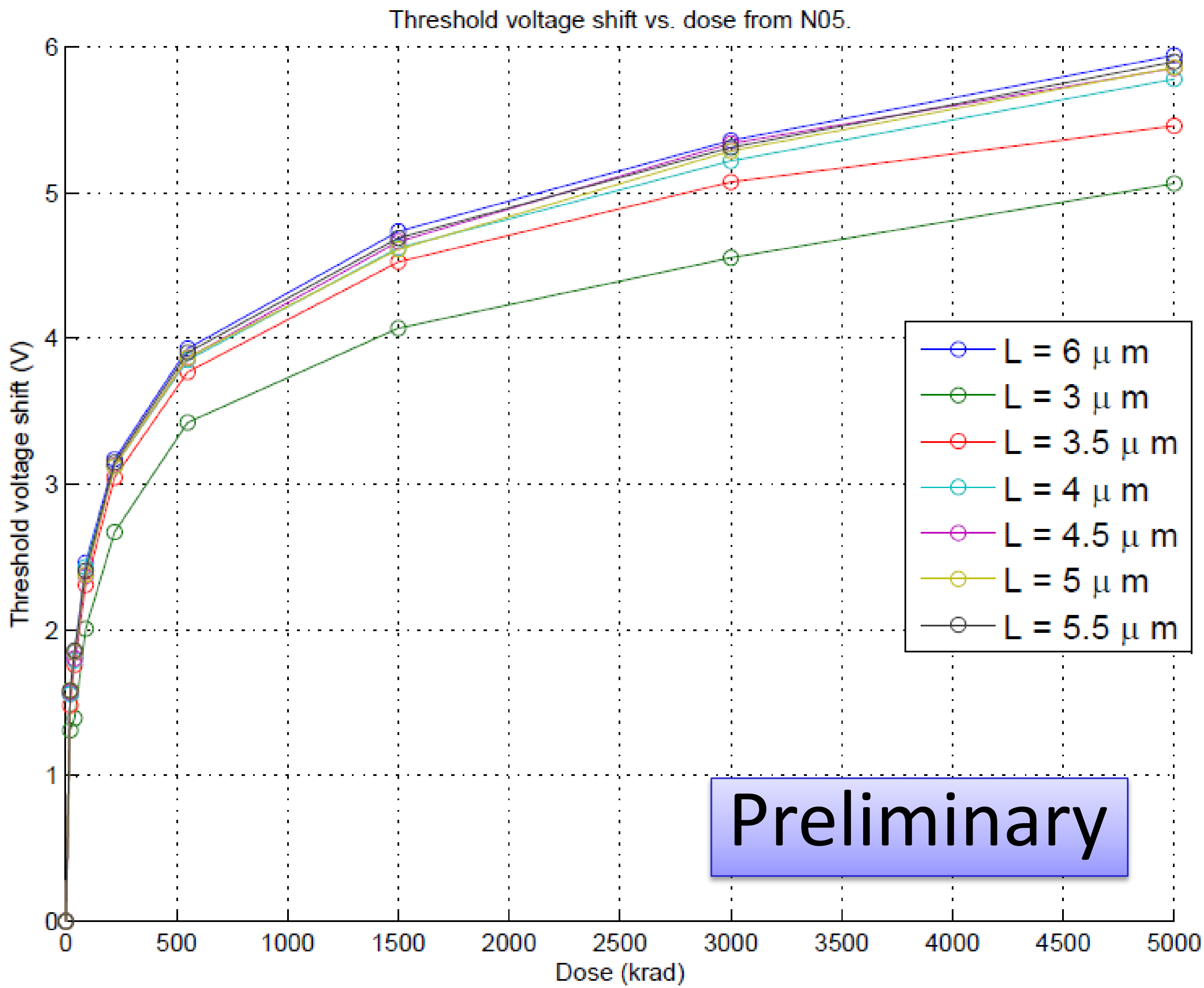
Clear Gate Results, -2.5 V during Irradiation



Clear Gate Results, 0 V during Irradiation



Clear Gate Results, +2.5 V during Irradiation



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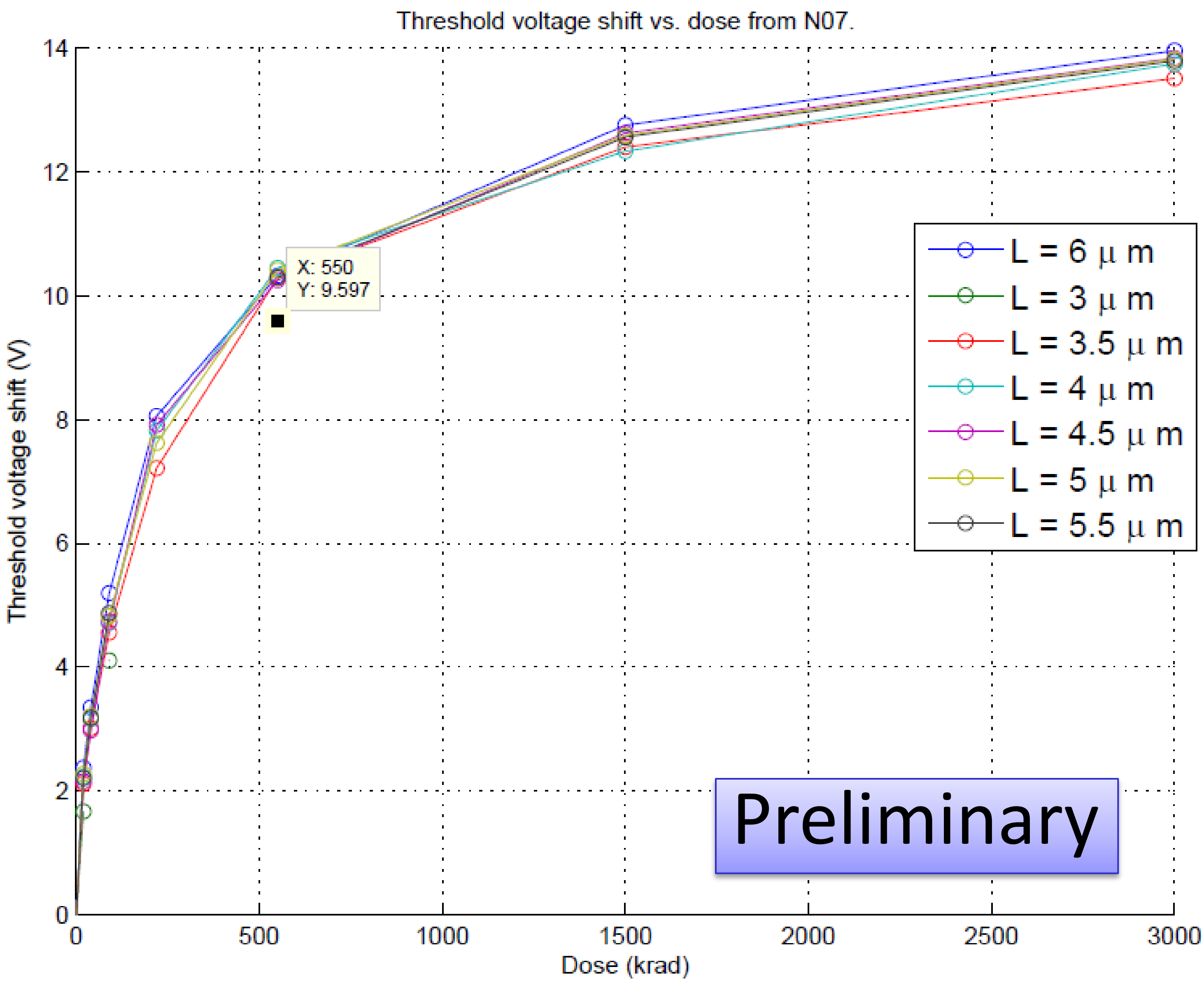
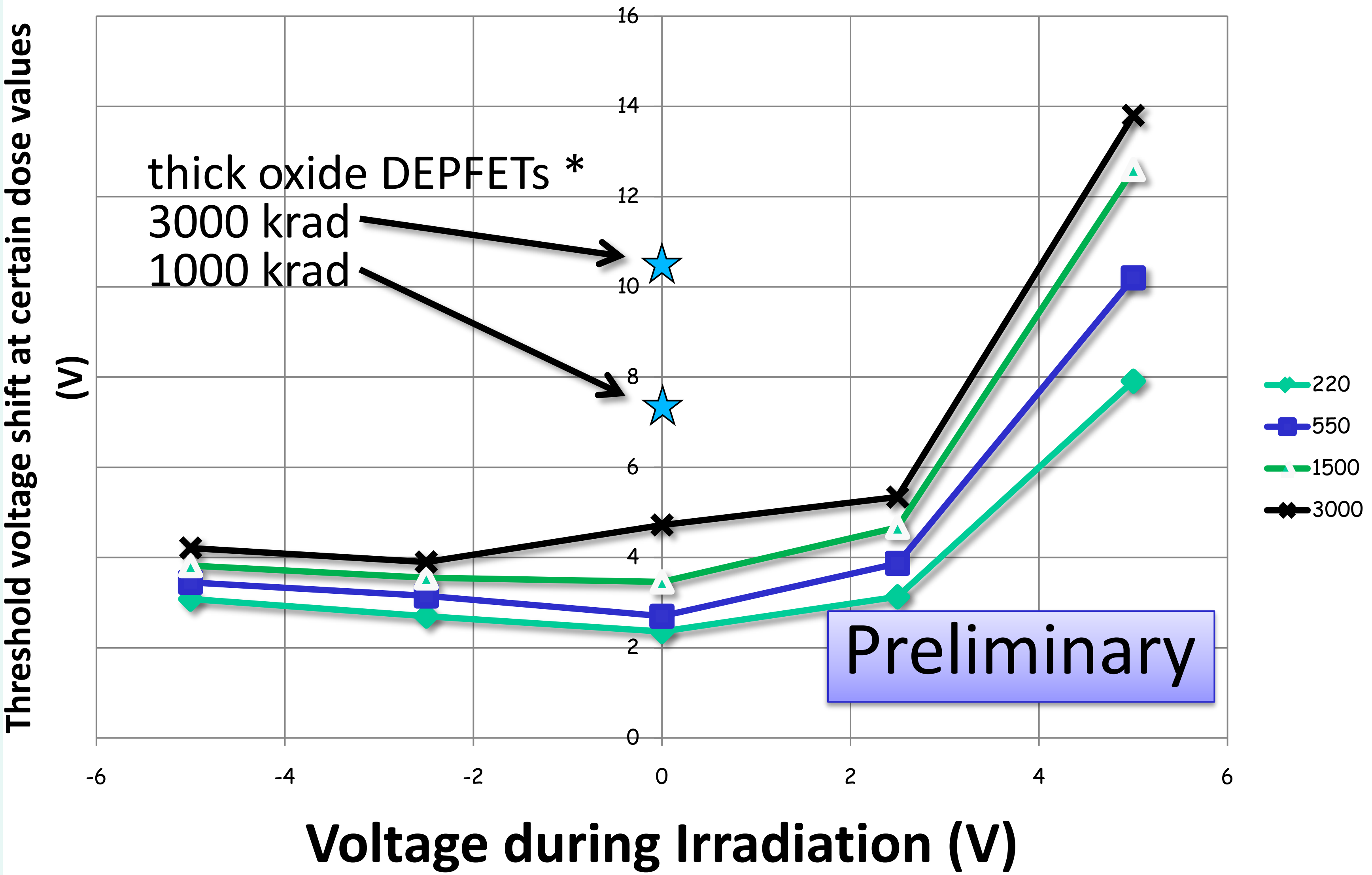


Change in threshold voltage shift due to certain Gate voltages



* measurements by Peter Müller

Comparison and summary

Thin oxides have proven to be a good candidate to reduce threshold shift (5 V shift with thinned oxide vs. 10.5 V at 3000 krad)

Only one gate voltage available, but different electric potential along pixels → Improve technology / adapt layout

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Thank you

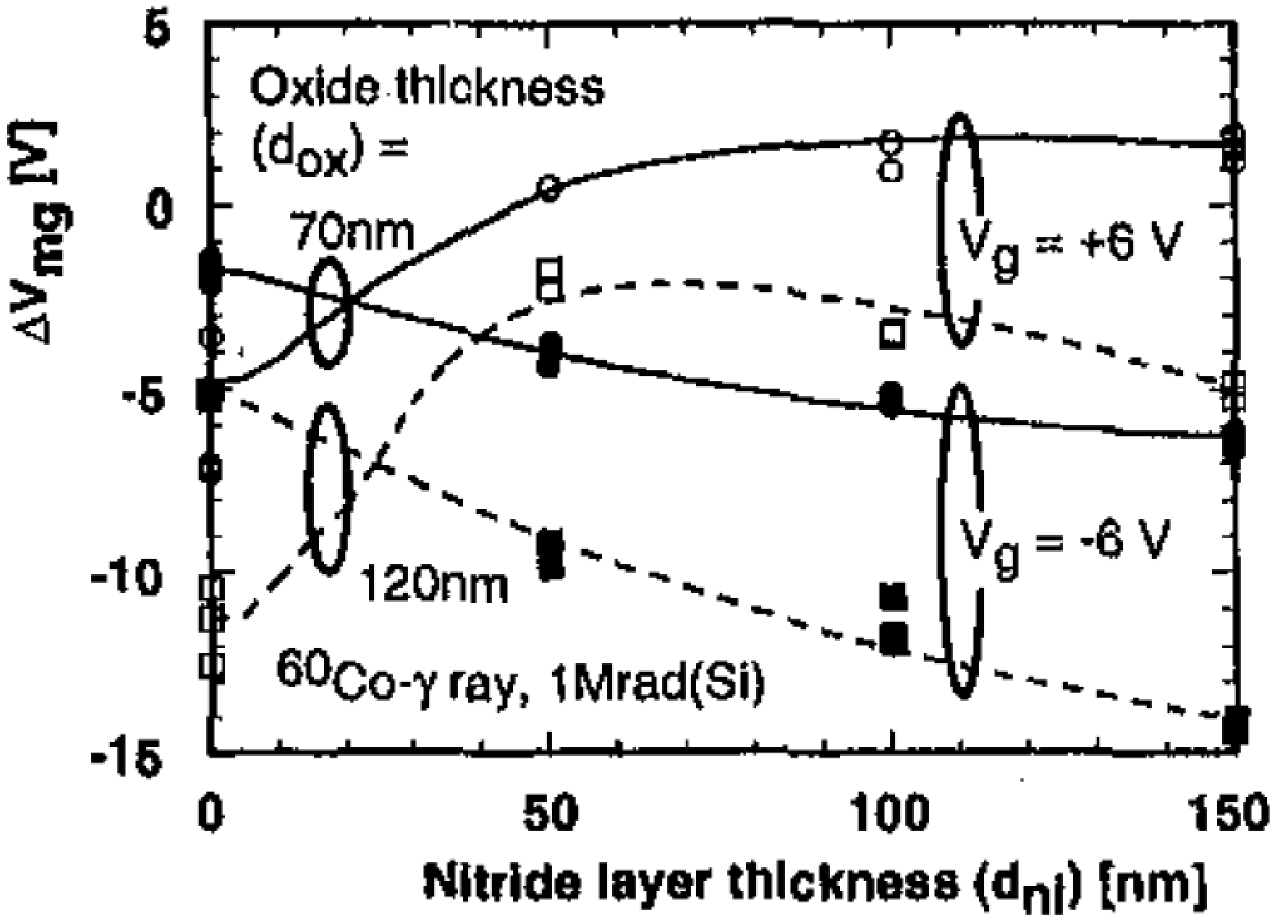
Special thanks to Inst. f. Experimentelle Kernphysik from KIT for their x-ray tube

Backup

Thick nitride and Gate voltages

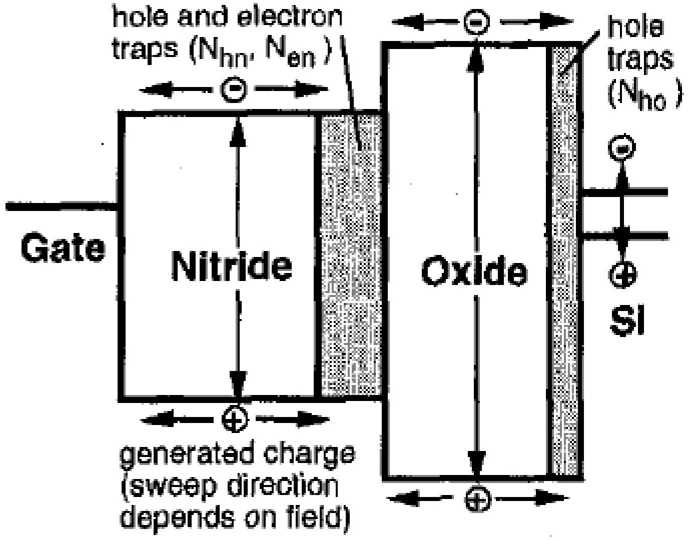
Thicker nitride could be a solution to the problem at hand.

Up to now, only irradiations on diff. nitride thicknesses (TO chips) were conducted with zero gate voltages during irradiation.



Radiation-Induced Trapped Charge in Metal-Nitride-Oxide-Semiconductor Structure; Takahashi et. al.
IEEE TRANSACTIONS ON NUCLEAR SCIENCE, VOX 46, NO 6, DECEMBER 1999

Trapping in insulator layer



$+V_G$

1. Holes in oxide to Si-SiO_2 interface
2. Holes in Si_3N_4 and electrons from SiO_2 to N-O interface
3. Recombination rate in Si_3N_4 higher than in SiO_2 → more e^- trapped at N-O
4. Build-up of e^- reduces field in oxide → saturation

$-V_G$
Field always present

Thick Si_3N_4
→ Reduces field in ox → saturation