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Total Dose Effects on Ge pMOSFETs with High-k Gate Stacks: On - Off Current Ratio

S.R. Kulkarni [1], R.D. Schrimpf [1], K.F. Galloway [1], Cor Claeys [2, 3], and Eddy Simoen [2]

[1]EECS, Vanderbilt University, Nashville, TN 37235,USA
[2]IMEC, Kapeldreef 75, B-3001 Leuven, Belgium and
[3]EE Department, KU Leuven, Kasteelpark Arenberg 10, B-3001, Leuven, Belgium

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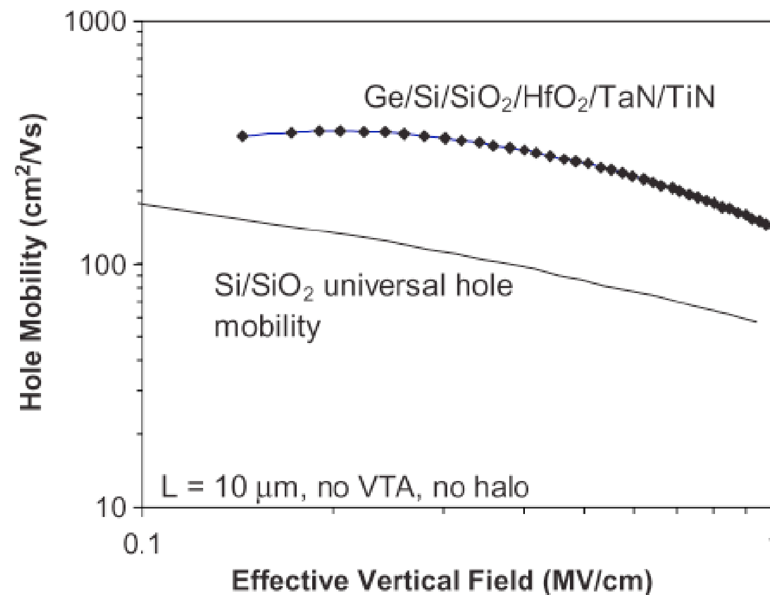
Motivation

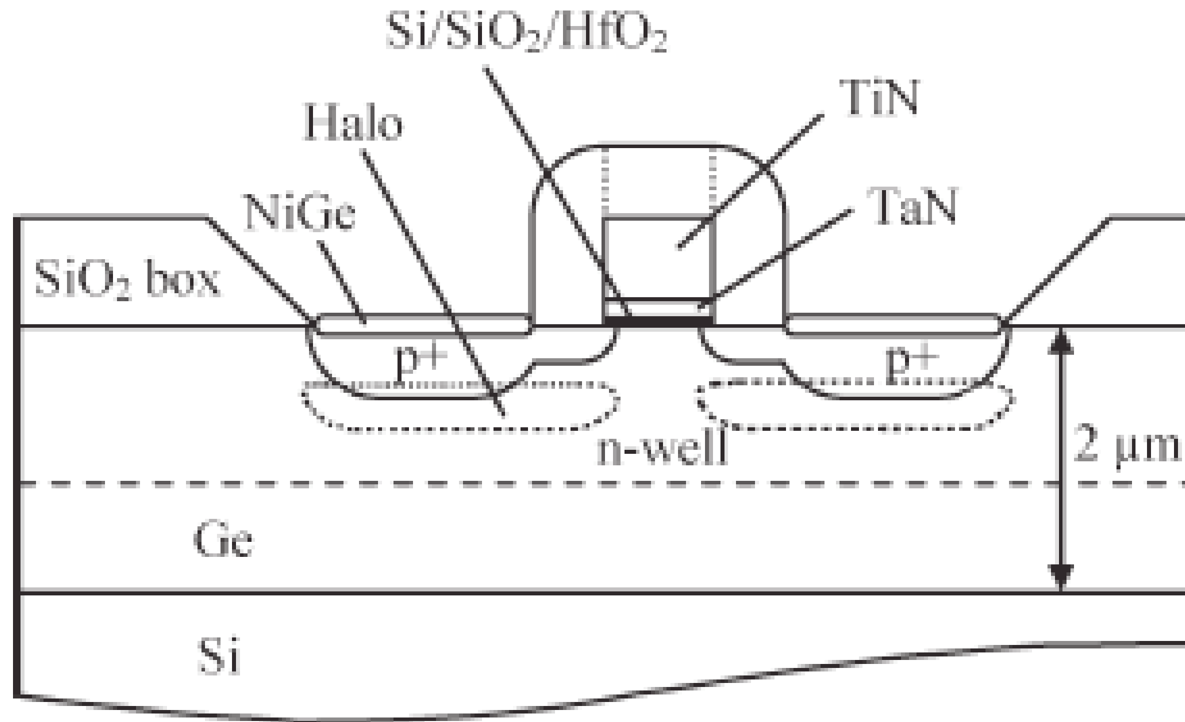


G. Nicholas, et al. IEEE Trans. Electron Devices, Vol. 54 pp 2503-2511 (2007)

To investigate the Total Ionizing Dose (TID) effects on Ge pMOSFETs with HfO_2 gate stacks

- Gate leakage current
- Change in transconductance
- Threshold voltage shift and
- On - Off Current Ratio

Device cross-section



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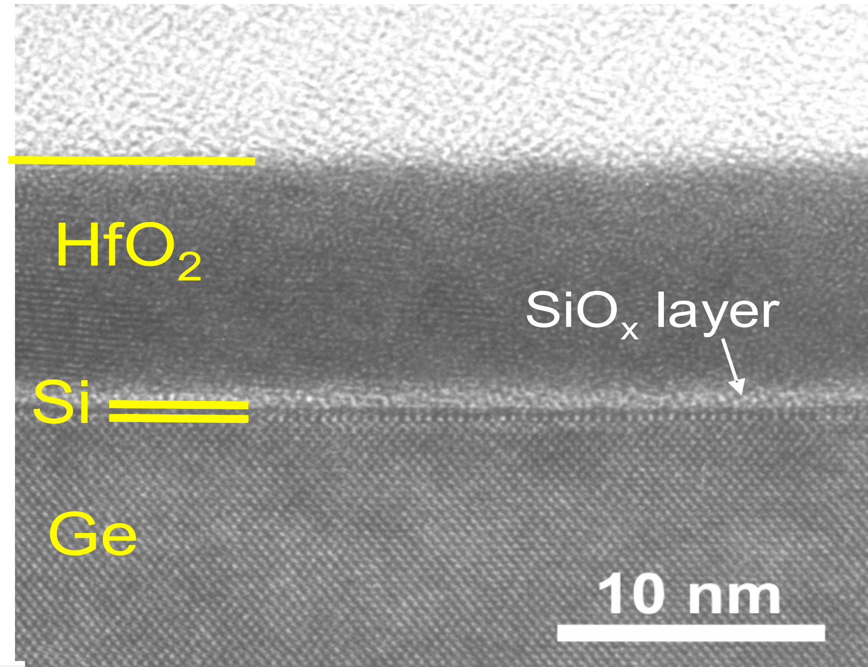
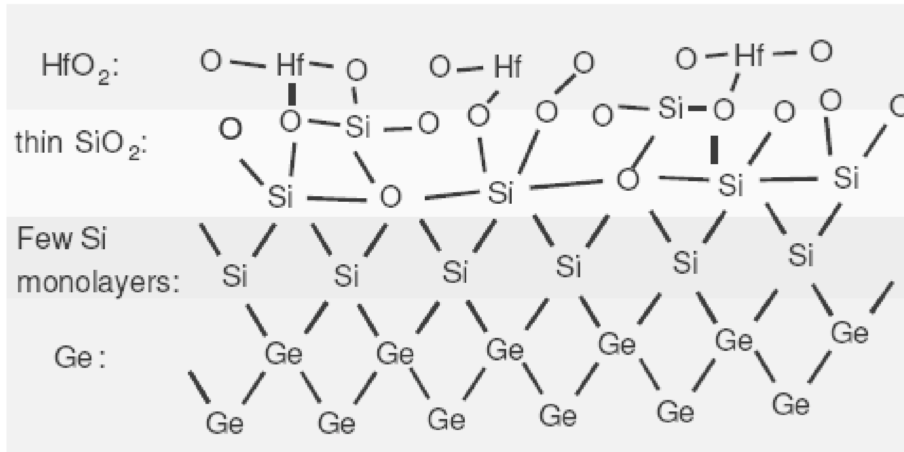
Interface layer structure

TEM photograph of the dielectric →



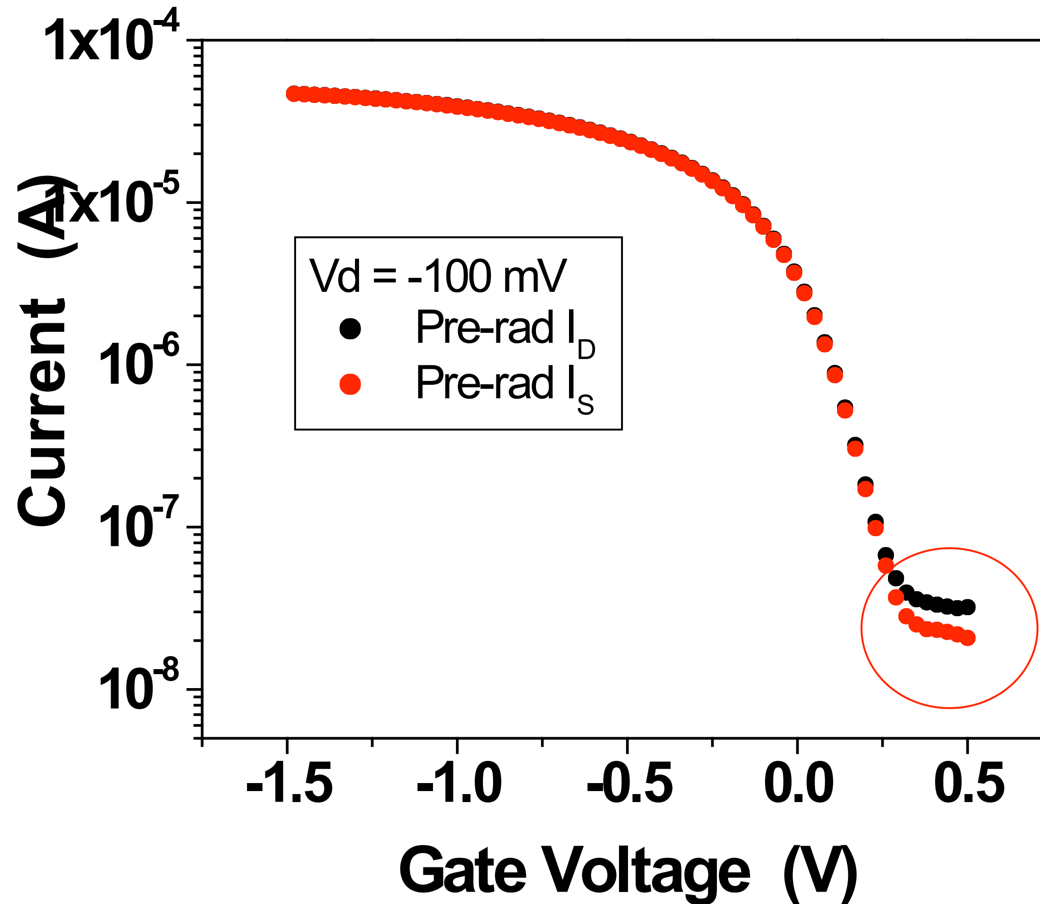
Si monolayer
SiO_x = 0.6 nm and
HfO_2 = 4 nm
EOT = 1.2 nm



← Schematic of the final multi-layer gate dielectric stack with epitaxial Si interface layer

Experimental Results

Pre-rad subthreshold curves



- V_{th} = 0.16 V
- SS = 130 mV/dec
- I_{on}/I_{off} ~ 10^3
- Difference in I_{off} of Drain and Source

Pre-rad $I_S - V_D$ curves

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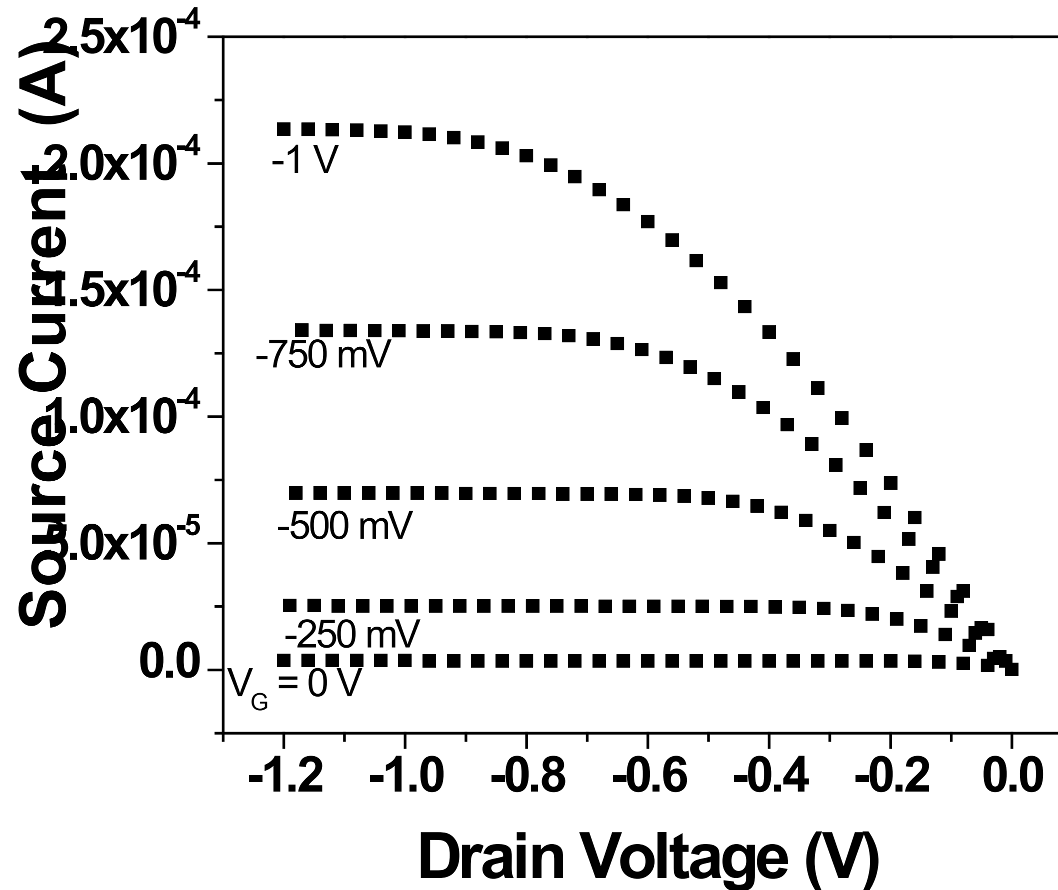

- Current measured at the source to exclude the effect of drain junction leakage

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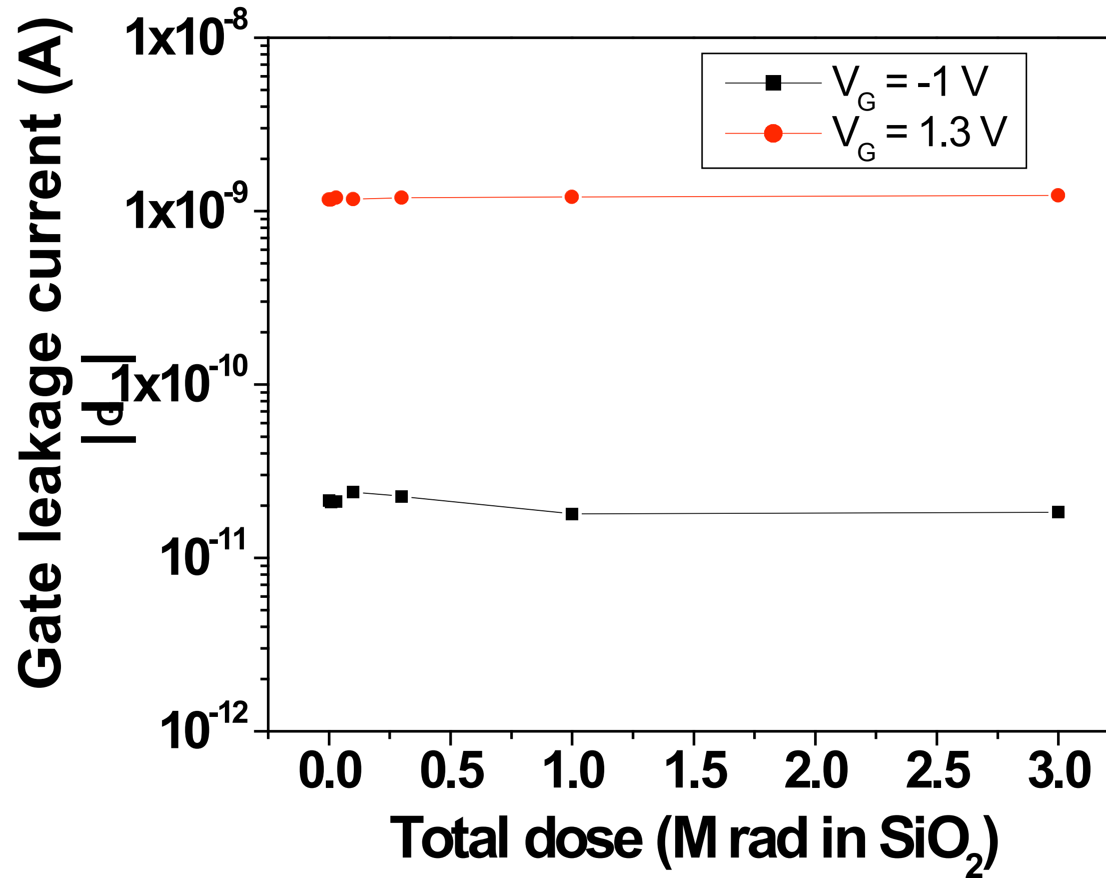
Gate leakage current for different TID



<u>Irradiation Details</u>

- 10 keV x-ray
- Dose rate = 31.5 krad/min in SiO_2
- V_G = 1.3 V

- No significant change in gate leakage current

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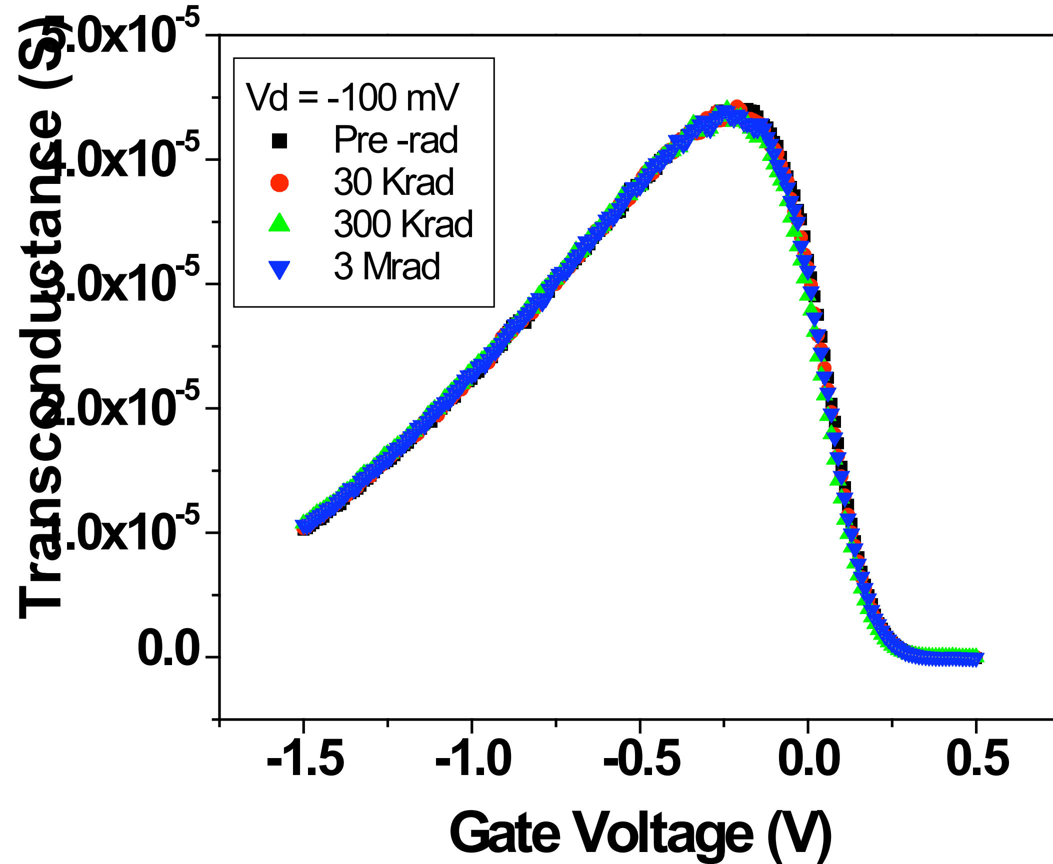
Transconductance for different TID



- No change in transconductance

  ⇒ No change in channel mobility

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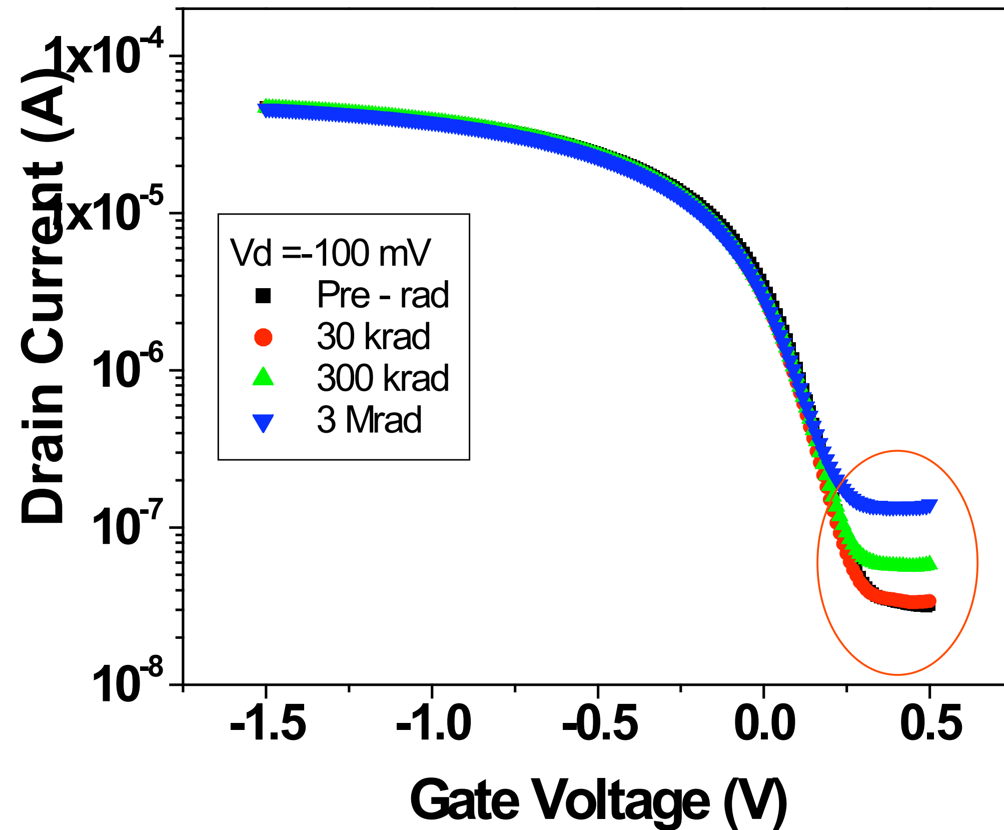
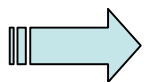
Subthreshold curves for different TID



➢No stretch-out or translation of subthreshold curves



No significant charge trapping

➢Increase in OFF-state current as a function of TID

➢But no change in ON state current

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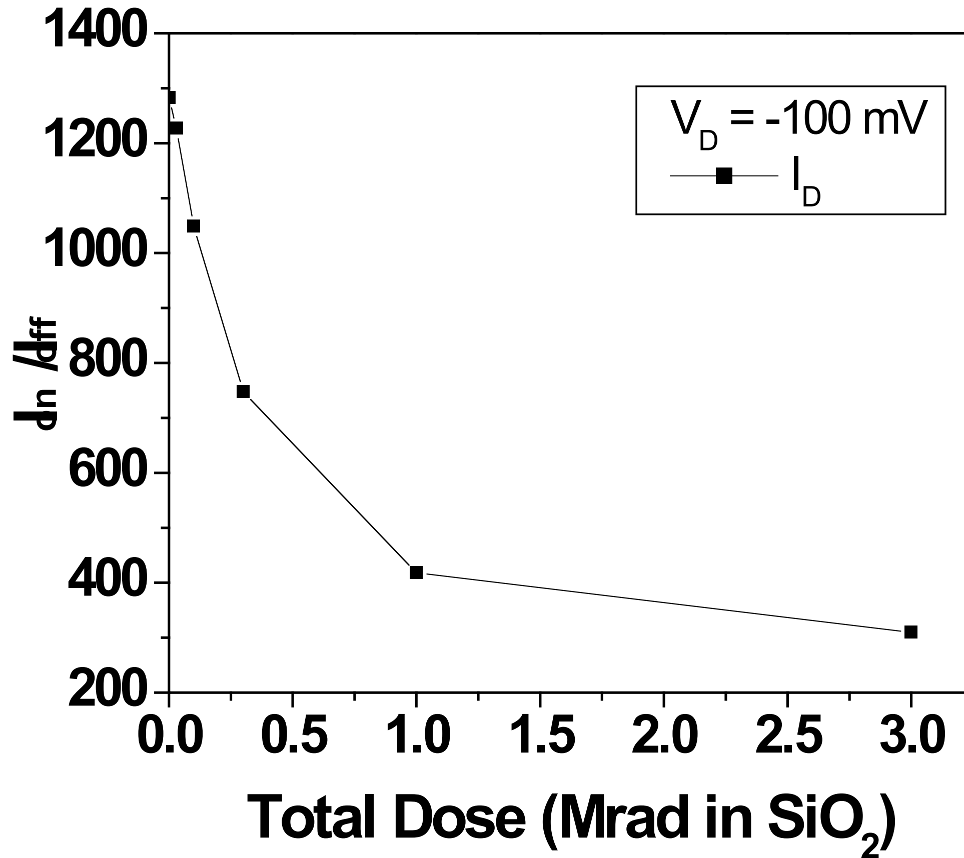
I_{on} / I_{off} ratio as a function of TID



The reduction in the **I_{on} / I_{off}** is due to an increase in the drain to body leakage current in the device

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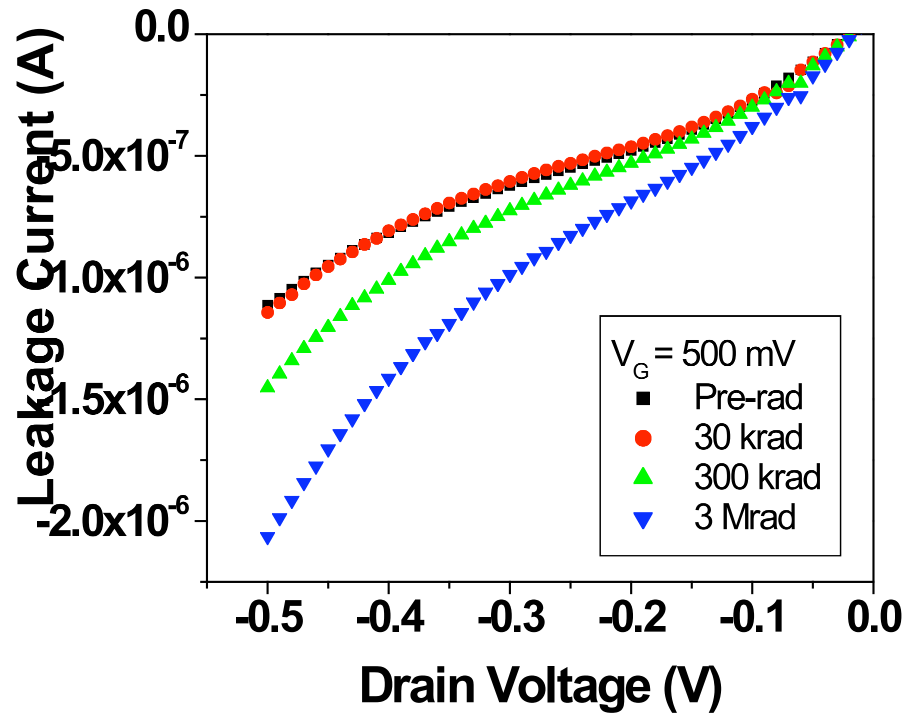
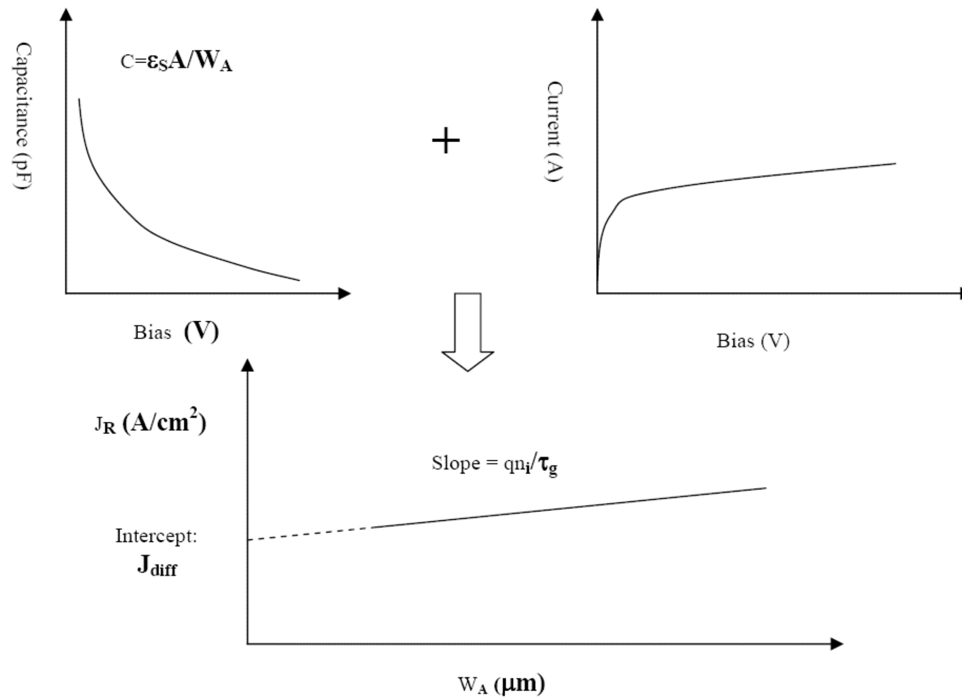
Drain to body leakage current for different TID



$$J = J_{diff} + J_g + J_{sg}$$



Diffusion and generation parts of the leakage currents are separating using analytical method developed by Murakami and Shingyouji

Murakami and Shingyouji, J. Appl. Phys. 75(7), p 3548, 1994

Conclusions

- Threshold voltage, channel mobility and gate leakage current appear to be unchanged up to TID of 3 Mrad (SiO_2). Thus, this is a relatively hard technology for fabricating pMOSFETs
- The pre-rad $\mathbf{I_{on}/ I_{off}}$ ratio of ~ 10^3 is reduced to 300 after 3 Mrad(SiO_2).
- The reduction in the $\mathbf{I_{on}/ I_{off}}$ value or increase in the off-state current of the transistor is due to an increase in the drain to body leakage current in the device.
- The mechanism of junction leakage current increase as a function of total ionizing dose is under investigation.