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Anomalous Radiation Effects in Fully-Depleted SOI MOSFETs Fabricated on SIMOX

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Outline



- Motivation
- Device Structure and Technology
- Front-Gate Characteristics
- Back-Gate Characteristics
- Annealing Effects
- Summary



Motivation

- **Fully-Depleted SOI nFETs?**

- free from kink effect at room temperature
- excellent short-channel behavior
- a quasi-ideal subthreshold slope
- improved SEU tolerance over bulk CMOS

- **Radiation Experiment**

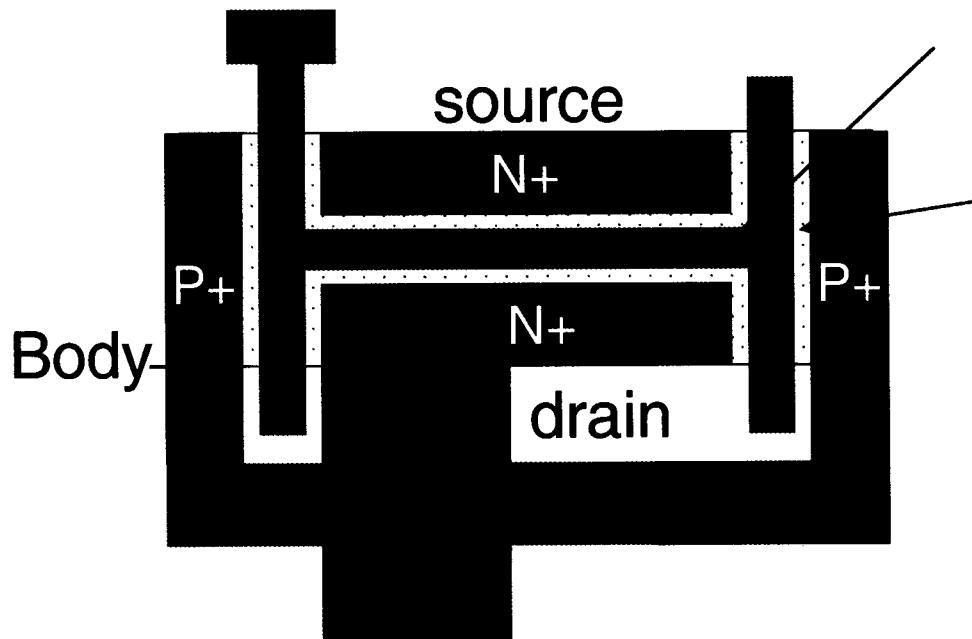
- 62.5 MeV protons (UC Davis)
- $V_G = +/- 2.0V$, $S=D=0V$ during exposure
- exposure to 500 krad

→ *How Does Radiation Affect Fully-Depleted SOI nFETs ?*



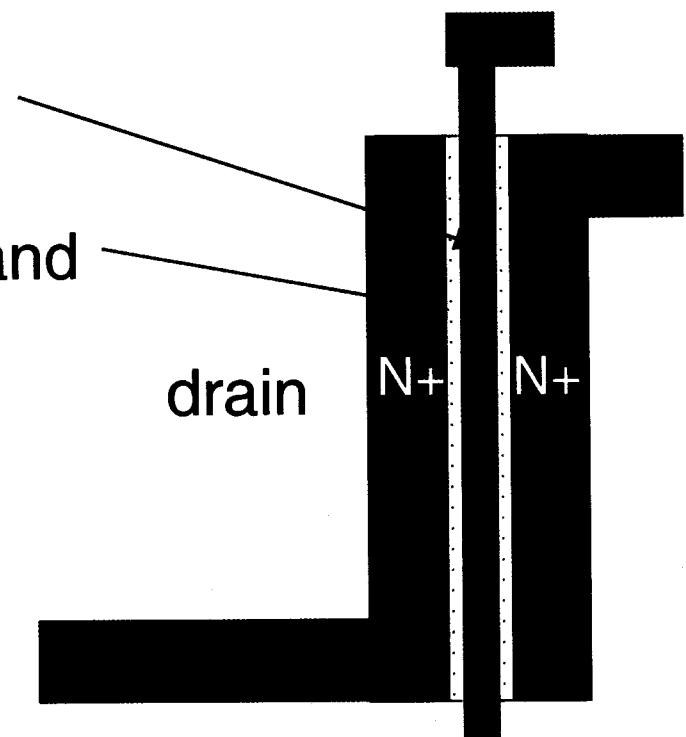
Device Structure

- H-gate Layout



H-gate: edgeless

- Regular Gate Layout

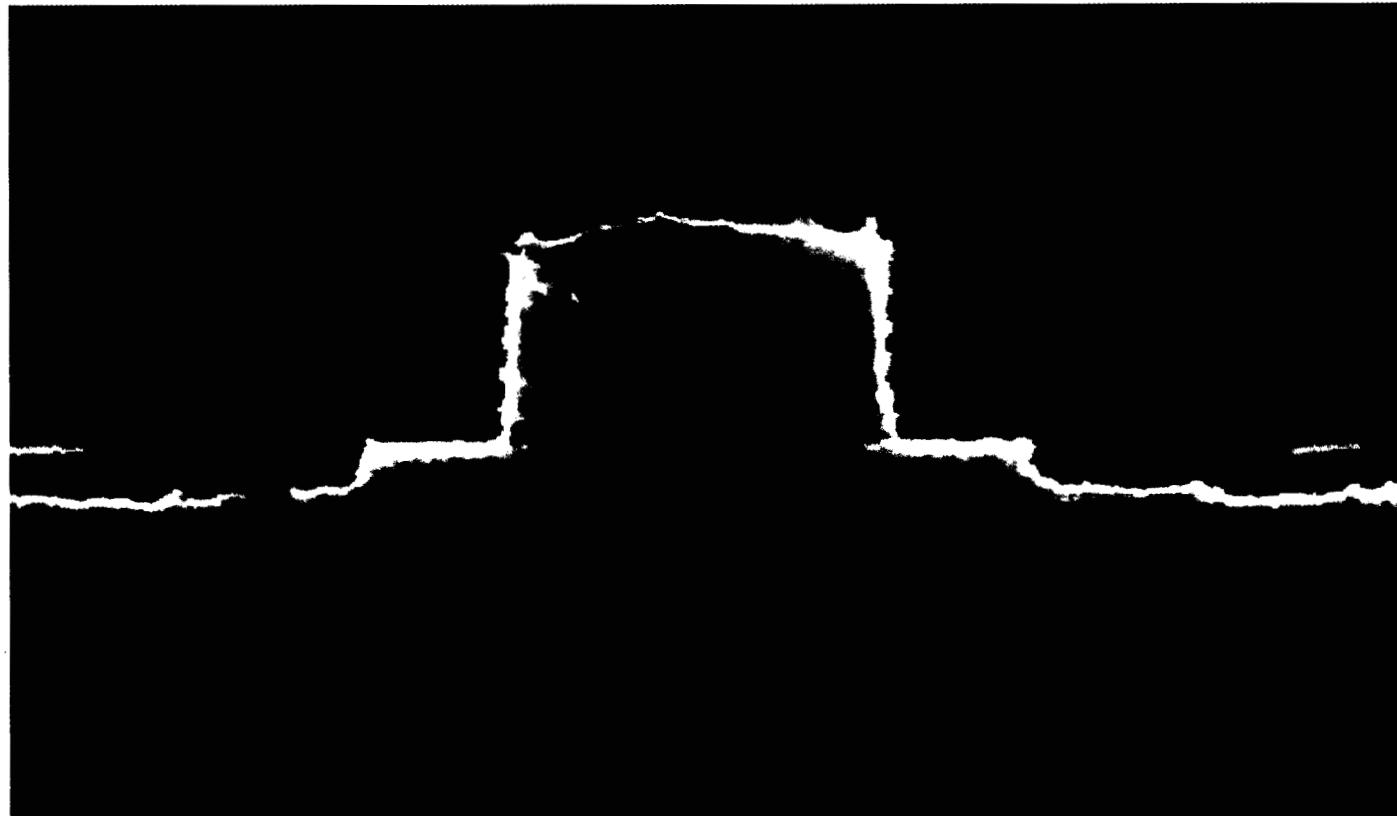


Mesa: edge

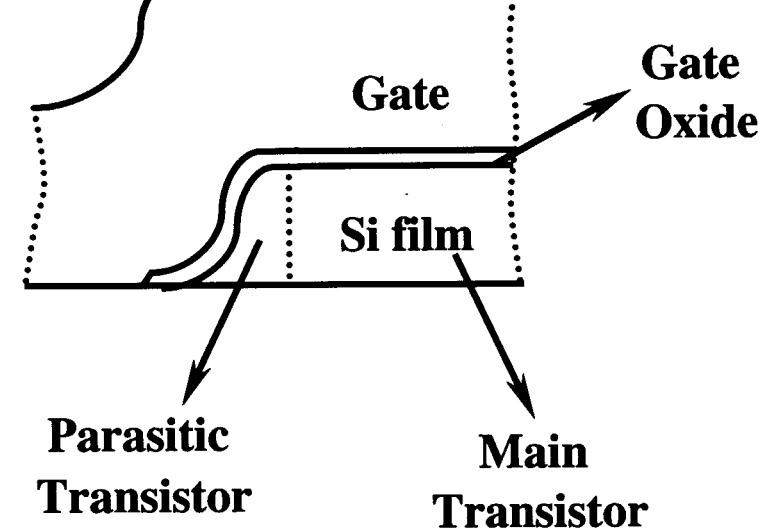
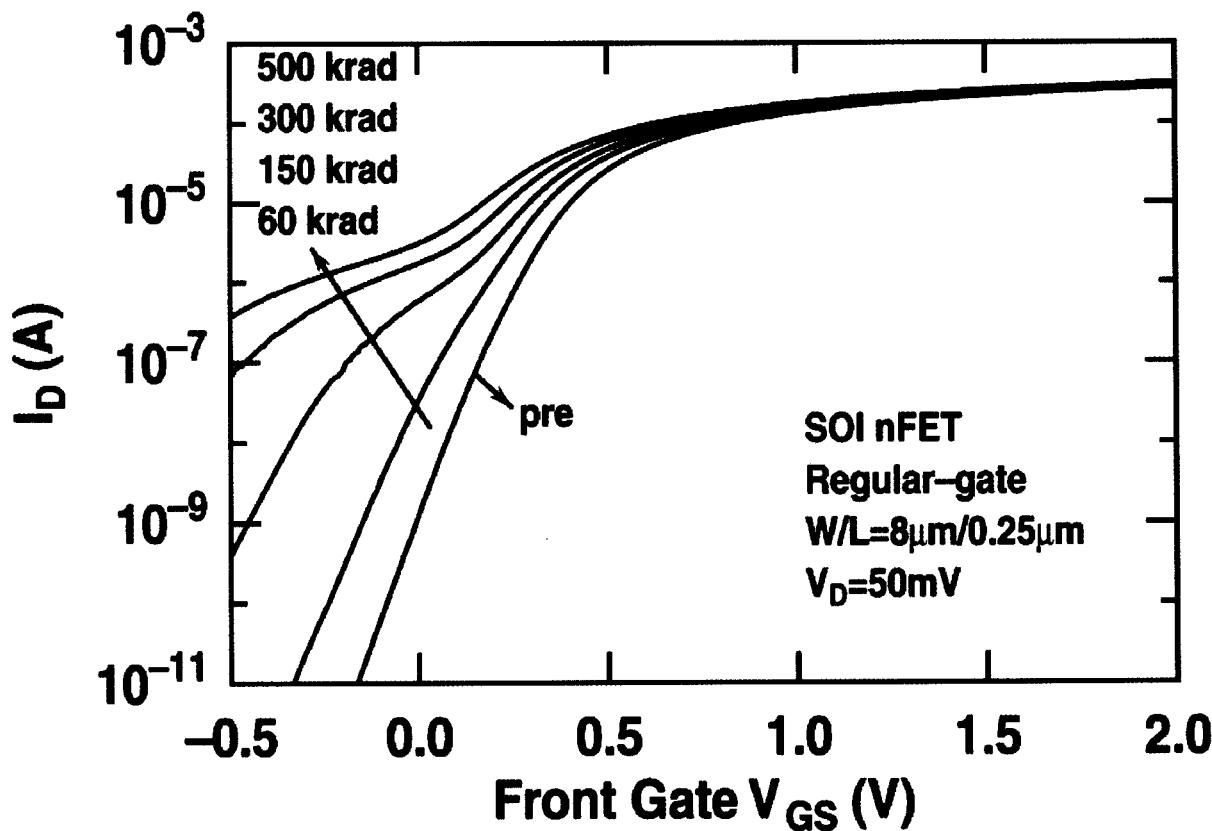
* *Fabricated at MIT Lincoln Labs*



- **Regular Gate SOI nFET with W/L=8μm/0.25μm**
 - 7.5nm gate oxide, 50nm Si film, 190nm Buried Oxide
 - polysilicon gate

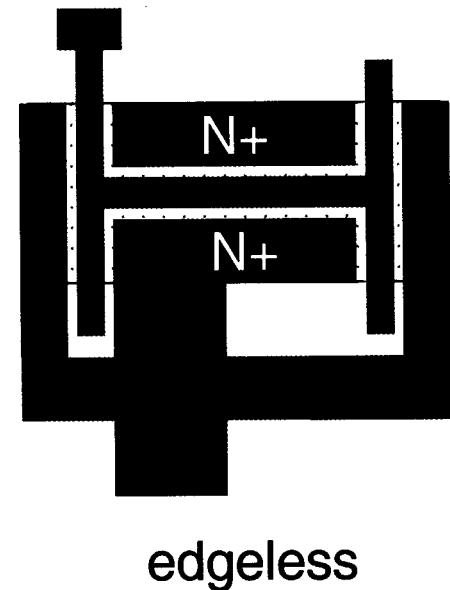
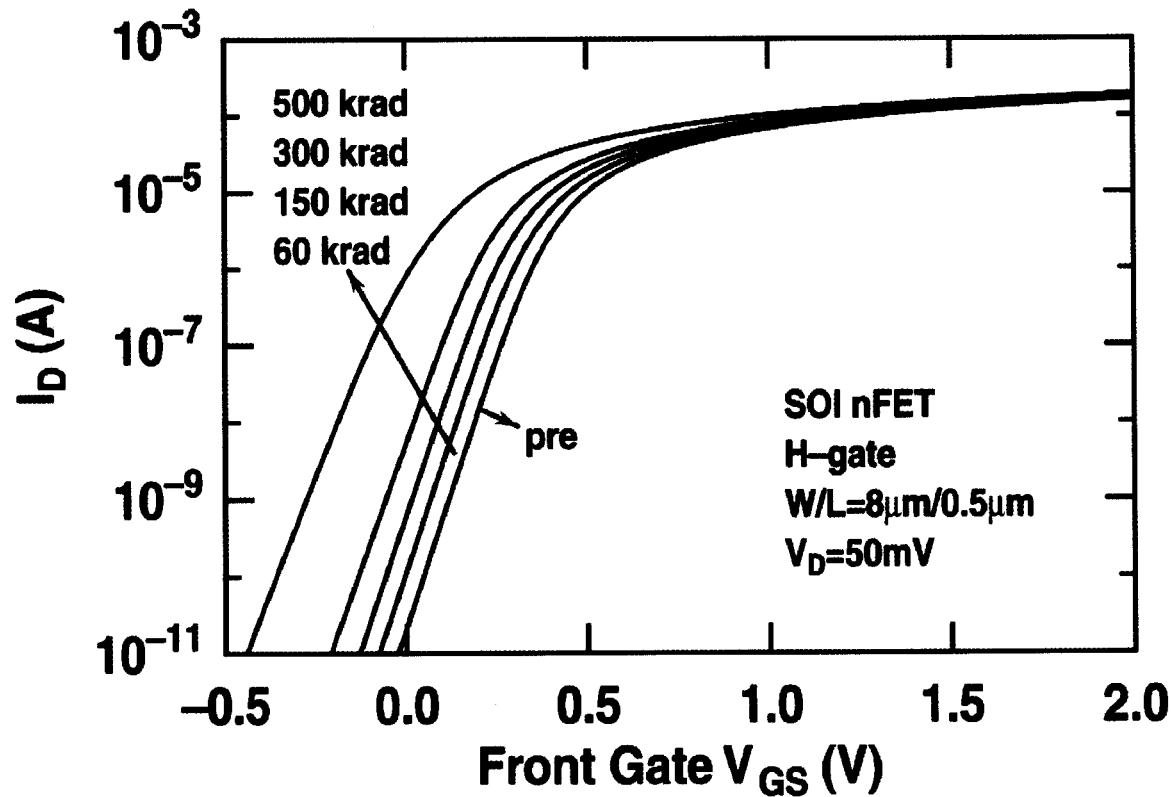


- Parasitic Transistor Located at the Mesa Edge
 - I_D (parasitic transistor) + I_D (main transistor)



H-Gate nFET

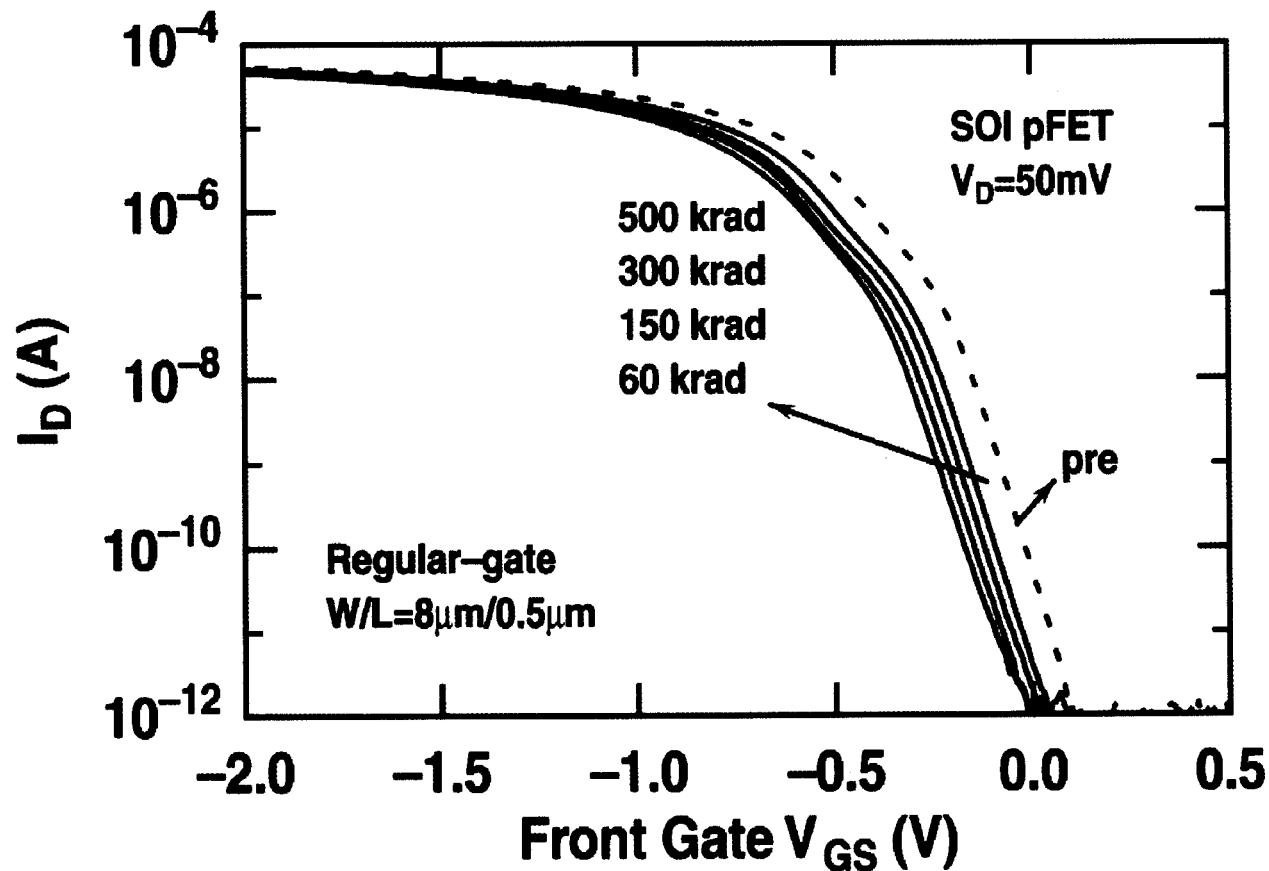
- Edgeless → Subthreshold Leakage Eliminated
- Threshold Voltage Shift



Regular Gate pFET

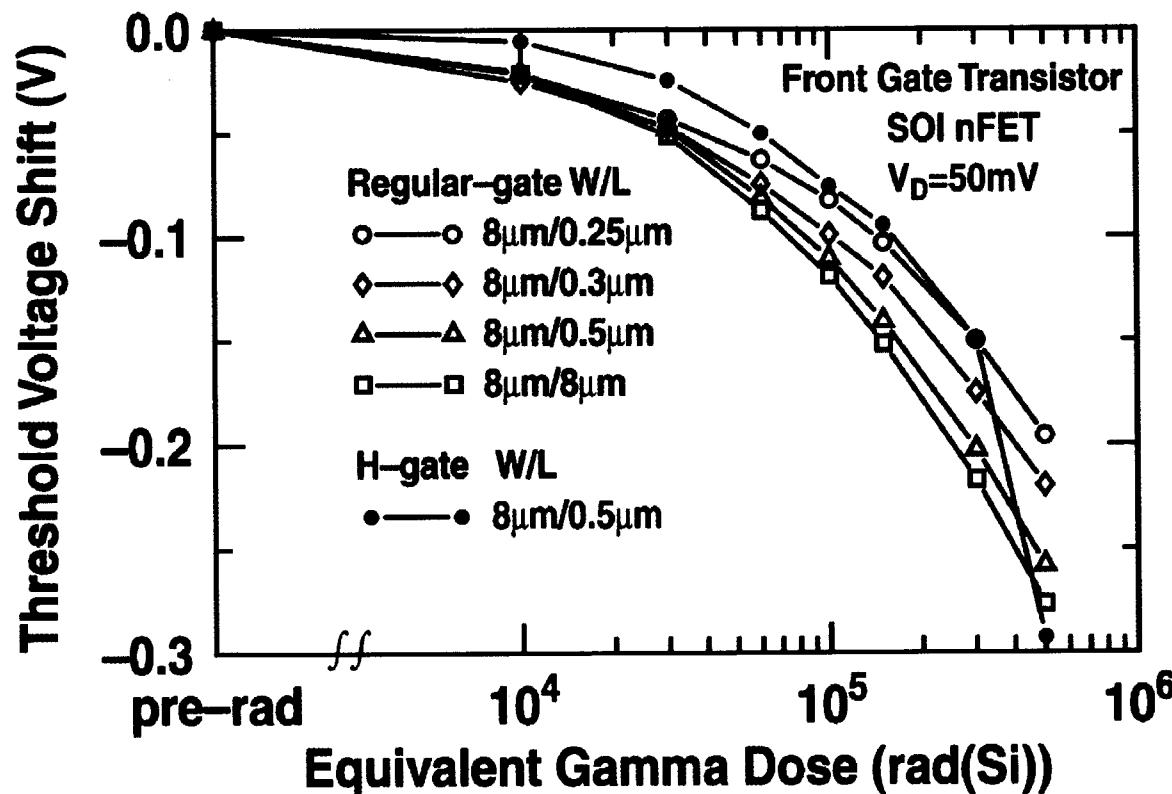
- **Radiation Hard Compared to nFET**

- no subthreshold leakage
- subthreshold kink
- threshold voltage shift



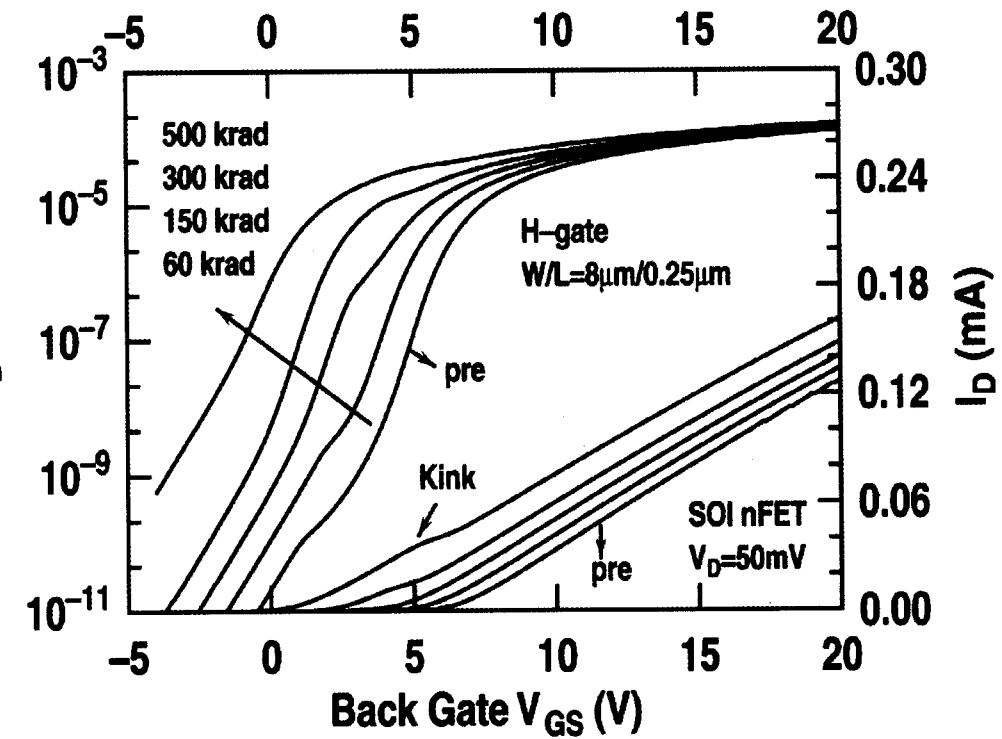
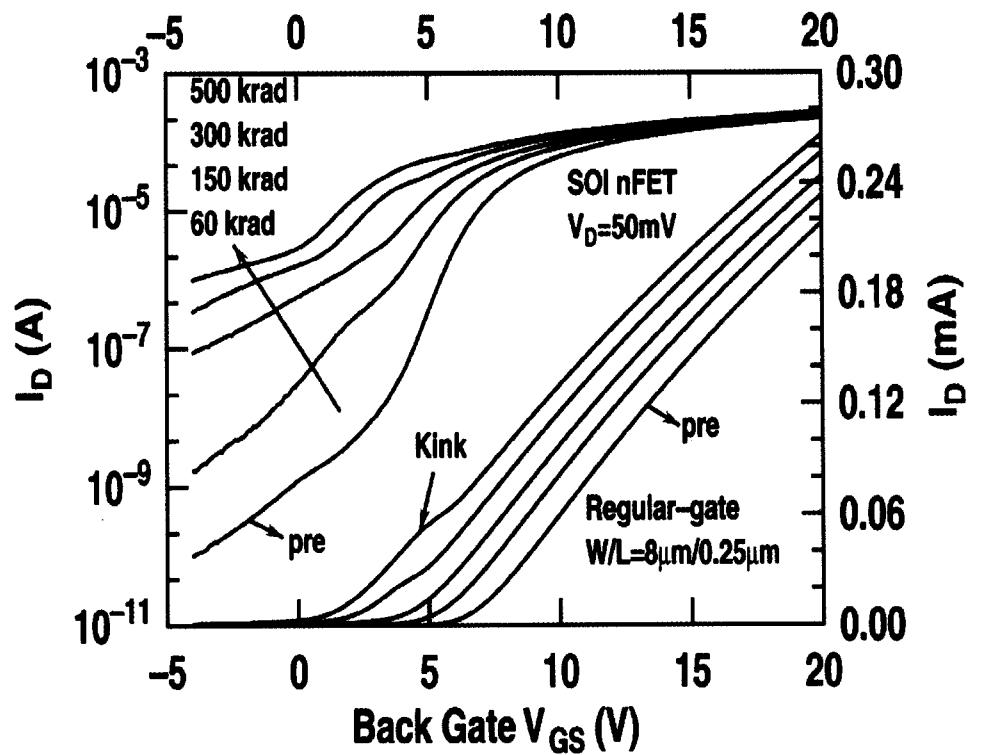
- Due to the Coupling Between Front and Back Gates

- $V_{th,shift} \downarrow$ as $L \downarrow$ for regular-gate nFET
- smaller $V_{th,shift}$ for H-gate nFET in the low dose range



● Anomalous Kink for nFET

- in the strong inversion region for regular and H-gate devices
- occurs at high dose (300krad and 500krad)

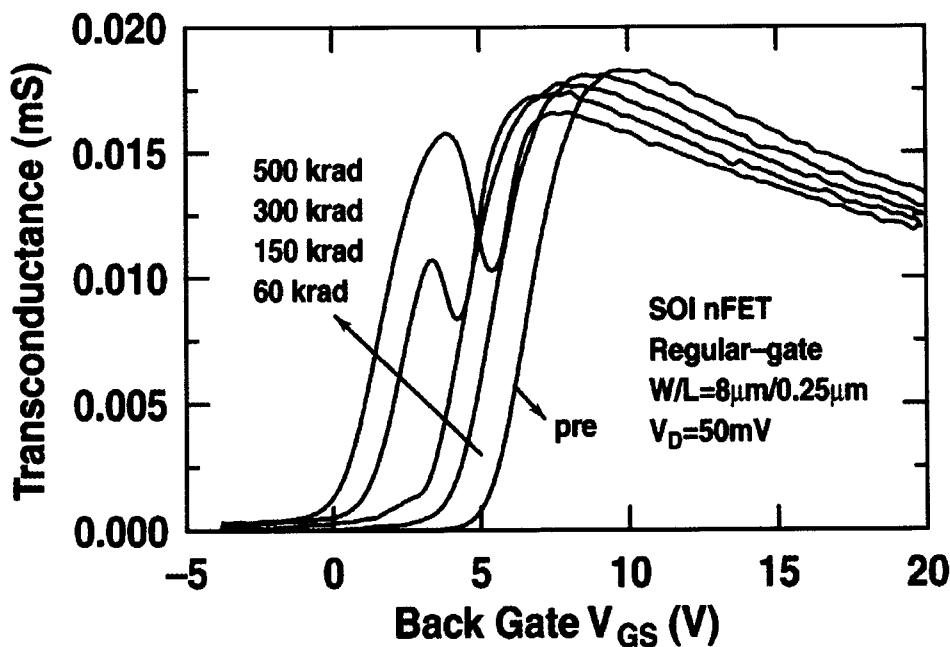


→ What Causes This Anomalous Radiation Kink?

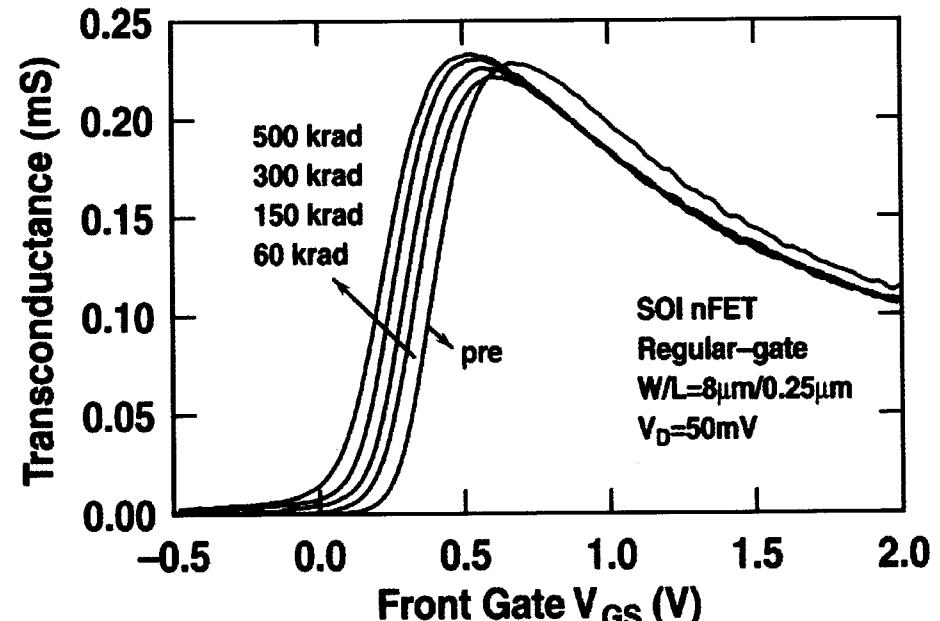


Transconductance

- Double peaks at 300 krad and 500 krad for back gate device



- No double peaks for front gate device

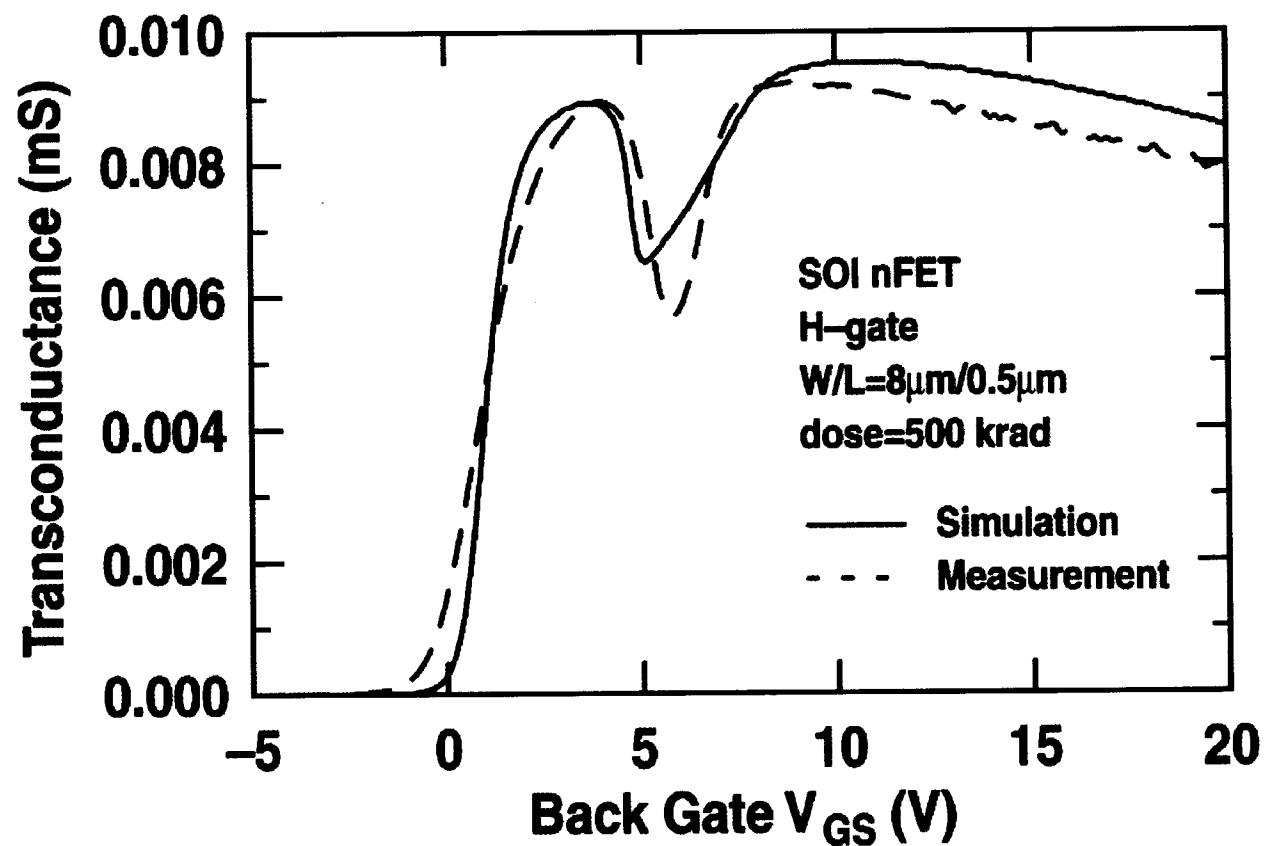
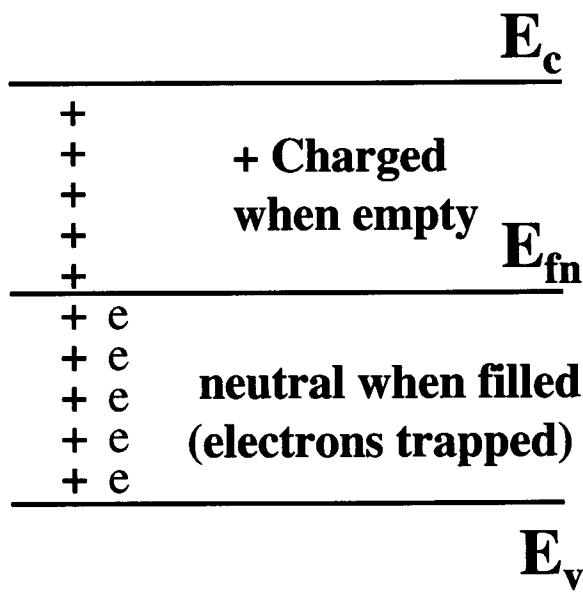


→ Physical Origin of the Double g_m Peak Lies at
the Silicon/buried Oxide Interface!

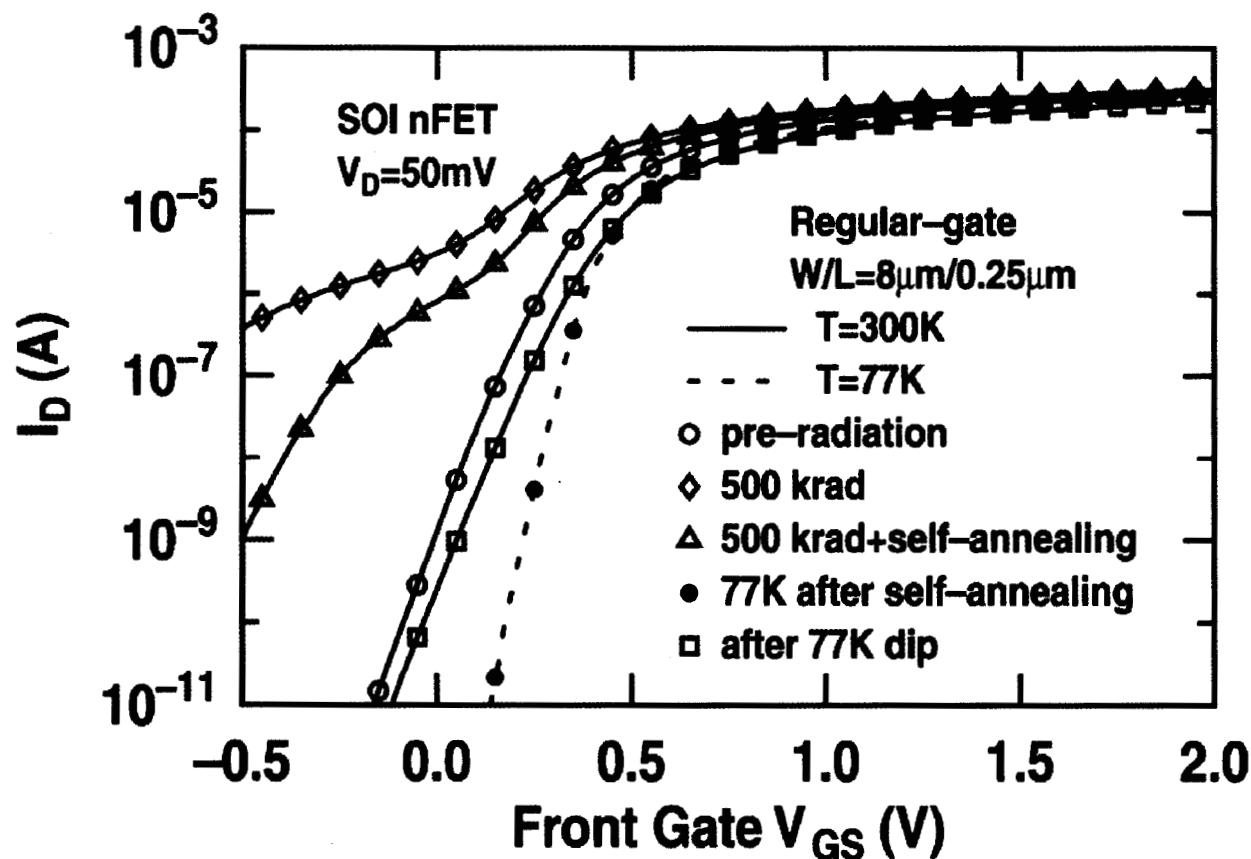


- Using MEDICI

- charged electron traps at Si/buried oxide interface
- Si-O bond weakened by irradiation



- Anomalous Annealing of Radiation-Induced Traps



→ We Are Currently Exploring The Physics Underlying
This Apparent Annealing Effect at Low Temperature



Summary

- **Front-gate Characteristics**

- edge leakage current for regular-gate transistor
- H-gate is edgeless and hence no edge leakage current
- smaller threshold voltage shift for H-gate transistor

- **Back-gate Characteristics**

- anomalous I-V kink at high dose for nFETs
- 2-D numerical simulation used for understanding
- charged electron traps at Si/buried oxide interface

- **Anomalous Low Temperature Annealing Effect**

- apparent annealing with cooling
- physical origin still being explored

