Radiation Characterisation of ST MOSFETs – Overview and Results

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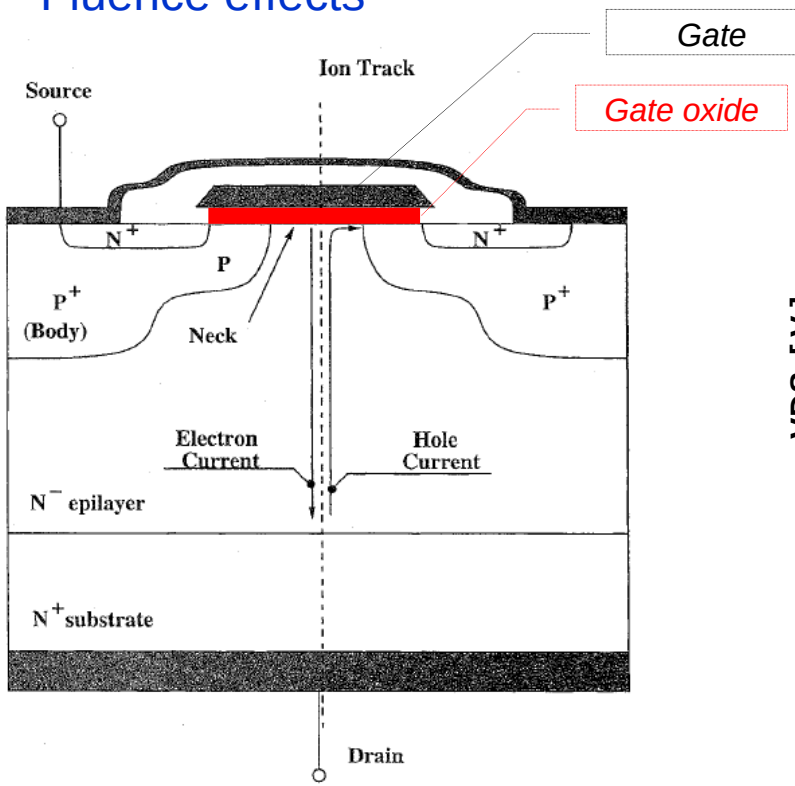
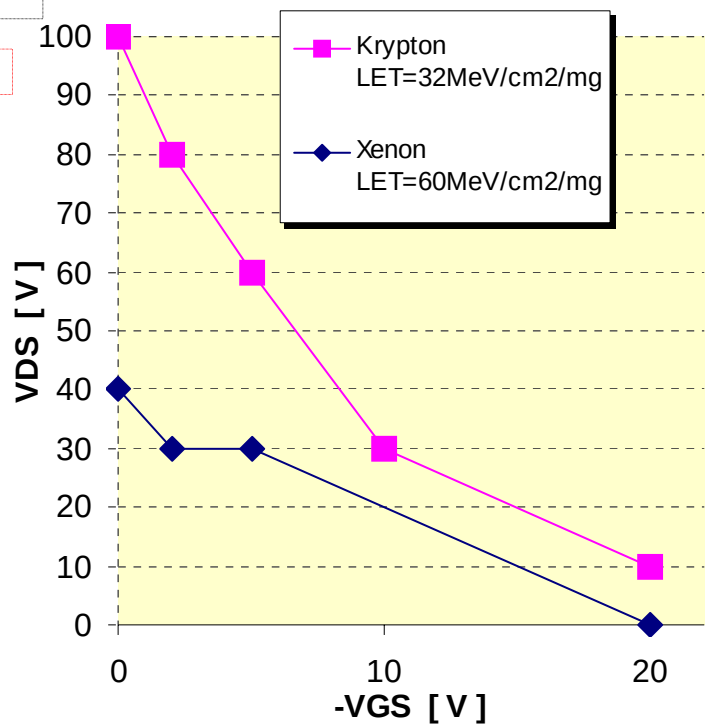
INTRODUCTION

- What is Single Event Gate Rupture in Power MOSFETs
- What can be hidden behind SEGR test data?
  - Latent oxide damage effects
  - Fluence effects



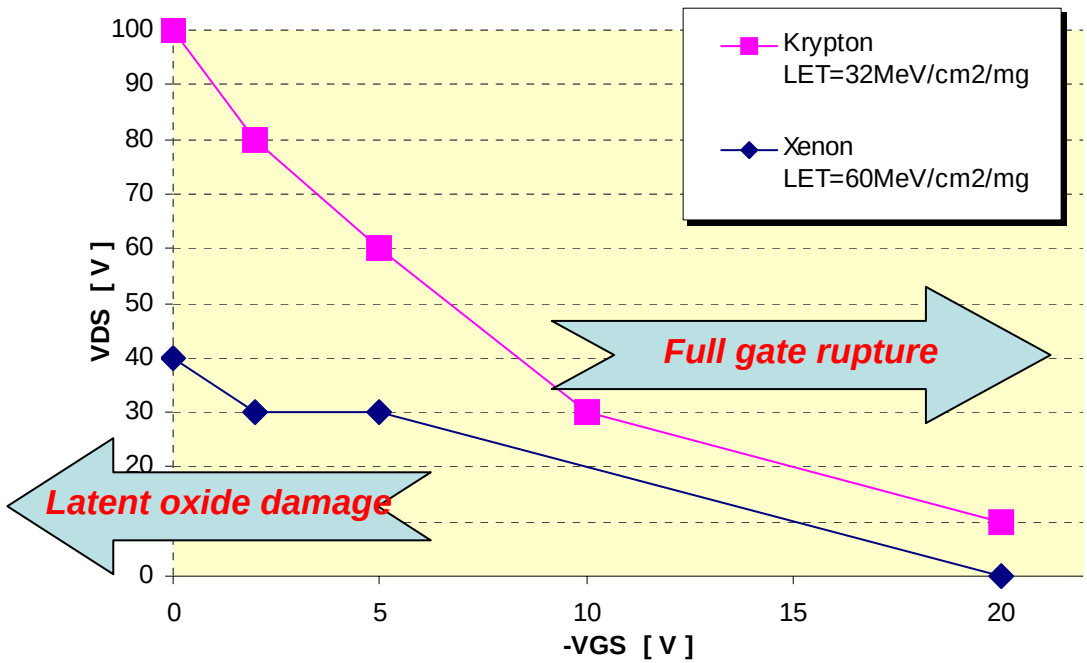


Safe Operation Area (SOA) Testing

- Test Object
  - Prototype from STM
  - SEB hardened
  - 100V N-channel
- Irradiation
  - RADEF, Jyväskylä, Finland
  - Xenon
    - 1217 MeV
    - Range(Si) = 89um
    - LET(Si) = 60.0 MeV-cm2/mg
- Post Irradiation Gate Stress test

Latent Oxide Damage

- SEGR effects can be divided into two categories
  - Full gate rupture
    - Achieved at high negative Gate voltages
  - Latent oxide damage
    - Achieved at low gate voltages

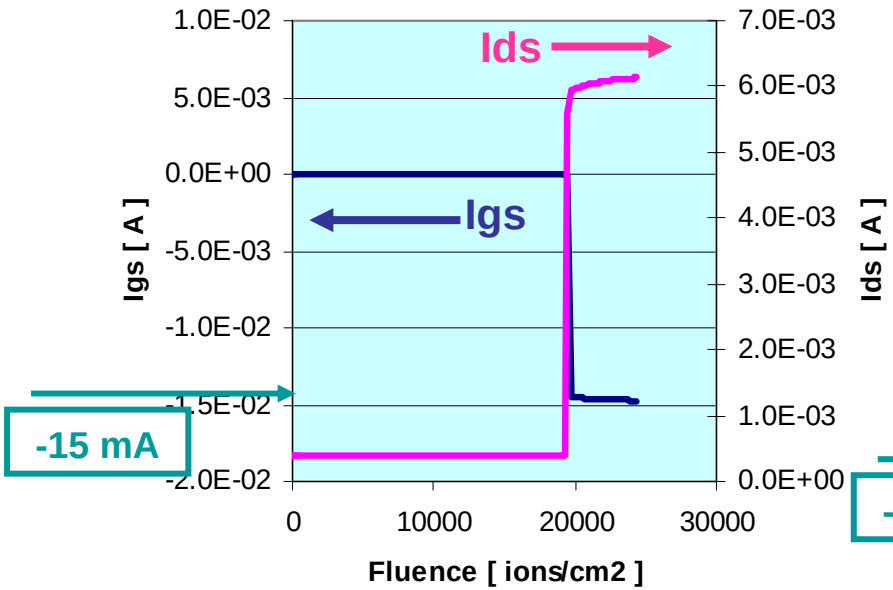


Latent Oxide Damage

- Example Full gate rupture
  - Vds = 20 V
  - Vgs = - 20 V

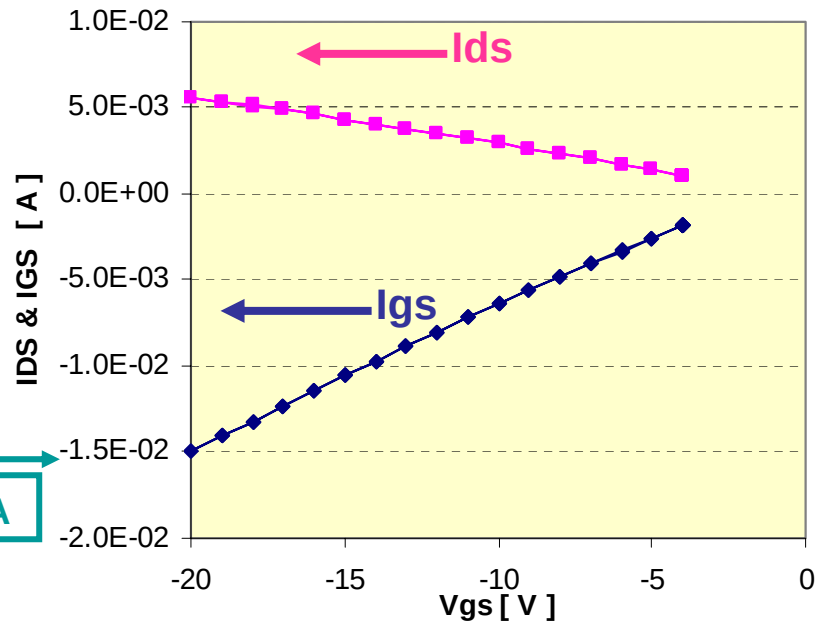
During Irradiation

- *Rupture drain & gate*



After Irradiation

- *Ohmic drain & gate*

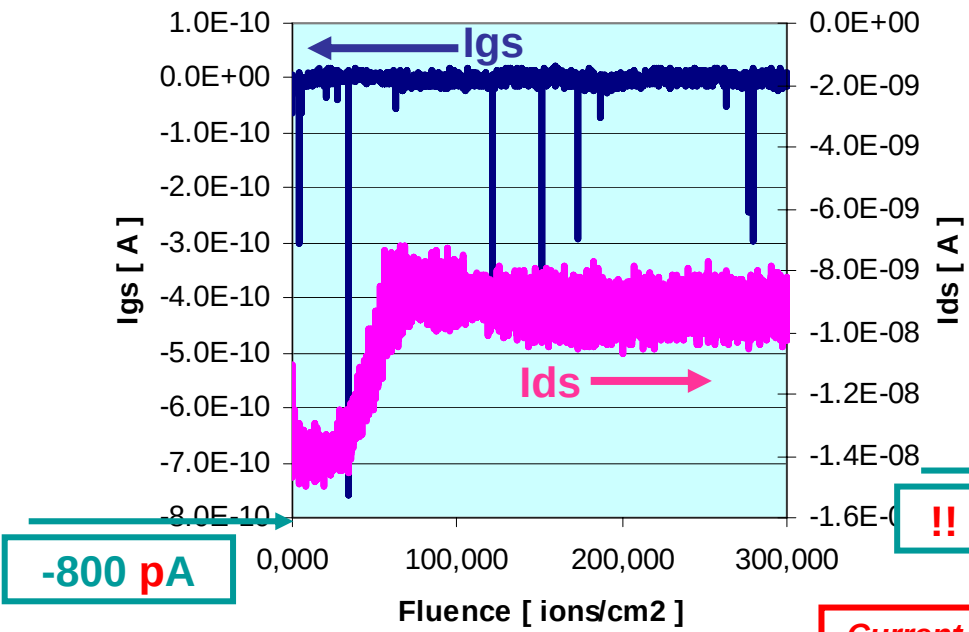


Latent Oxide Damage

- Example Latent Oxide Damage
  - Vds = 50 V
  - Vgs = 0 V

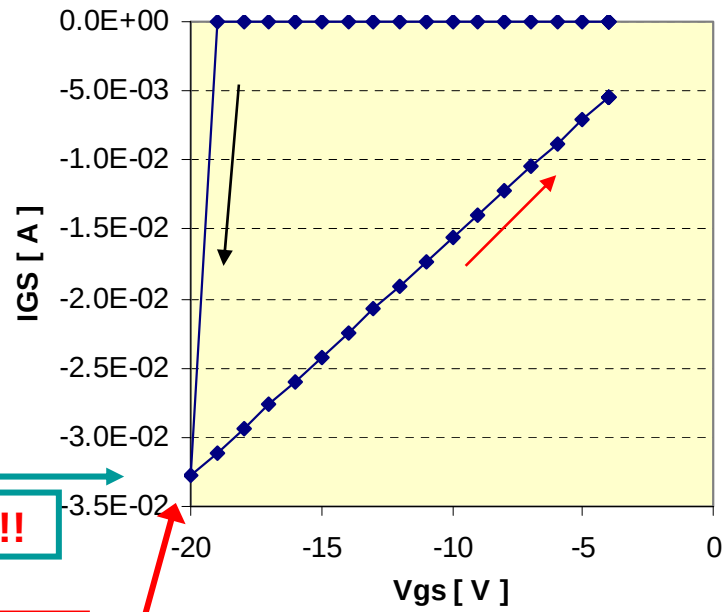
During Irradiation

- *No evidence of rupture*



After Irradiation

- *Rupture when applying -20V to gate*

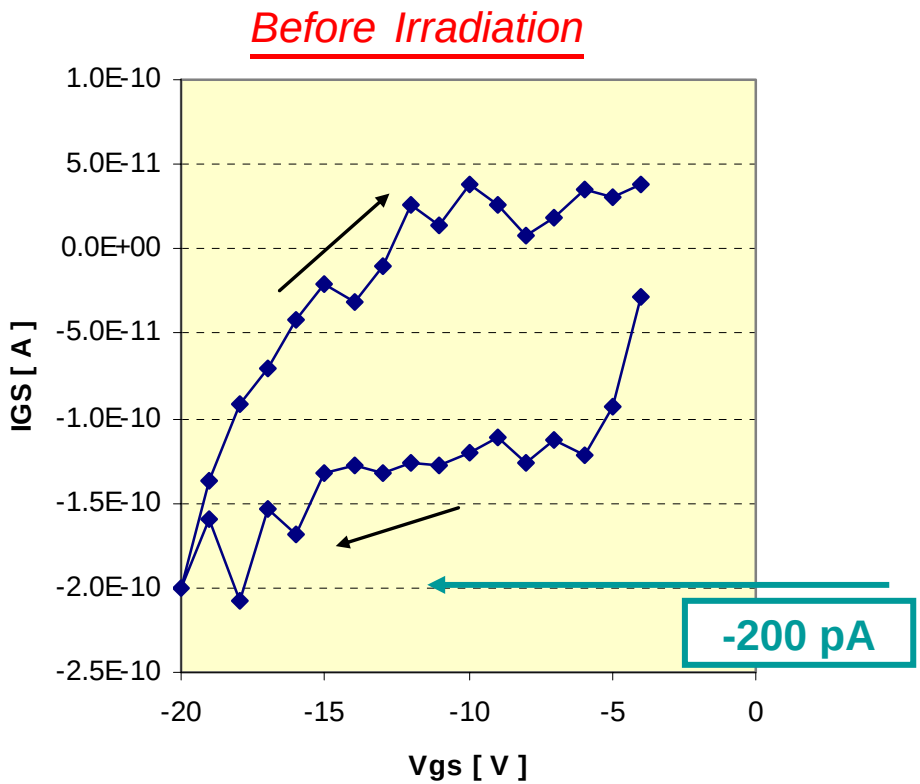


!! -33 mA !!

Current limit of supply

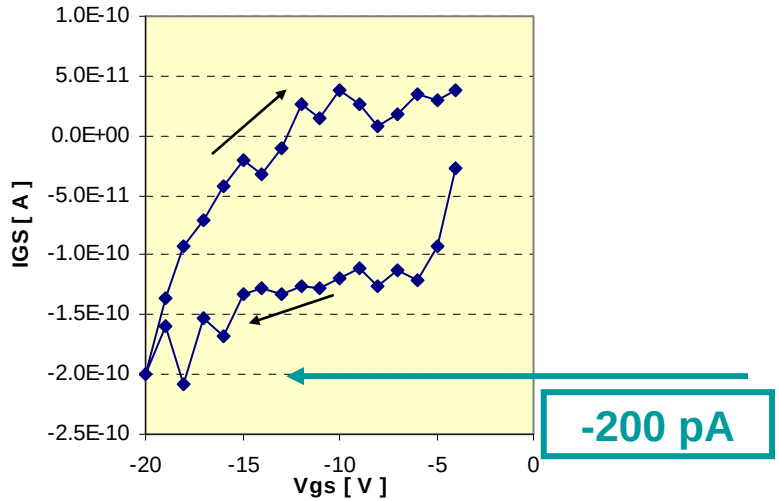
Post Irradiation Gate Stress Test

- Reveal Latent Oxide damage
  - By applying a high voltage to the gate oxide after irradiation
    - Voltage level
    - Time of stress
- Used Method
  - Ramping up and down Vgs to maximum rated gate voltage :
    - At each voltage step measure
      - Igs
      - Ids
    - 200 ms at each voltage step

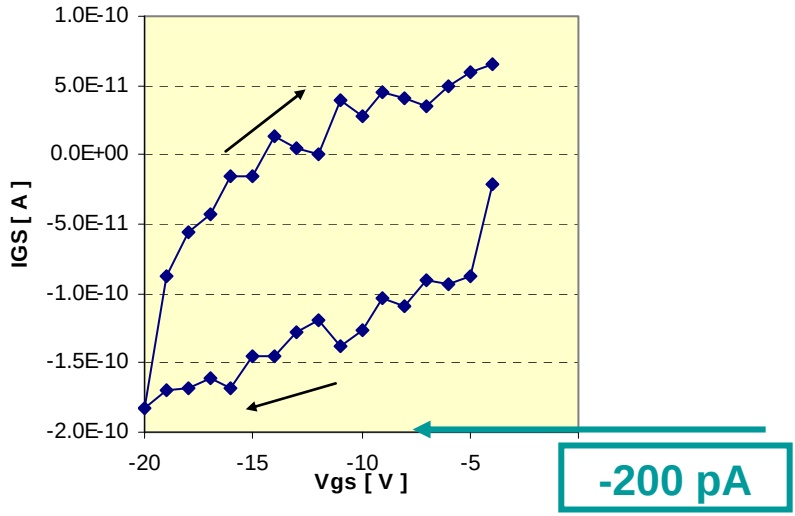


Post Irradiation Gate Stress Test

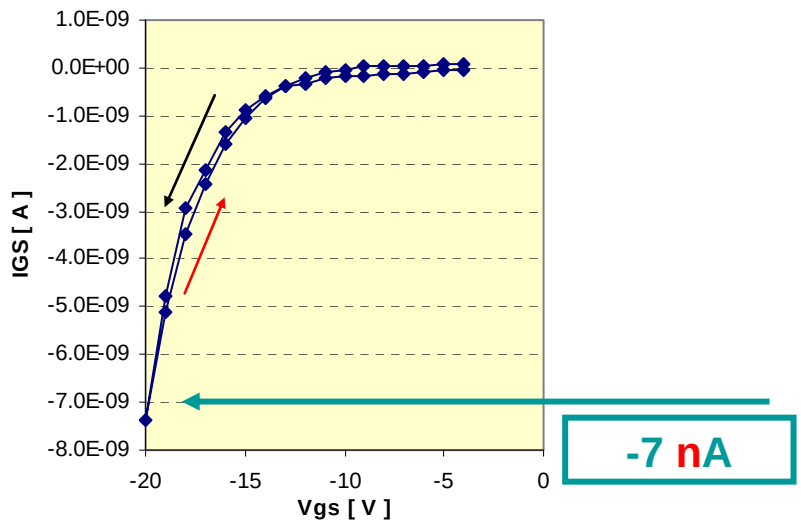
Pre Irradiation



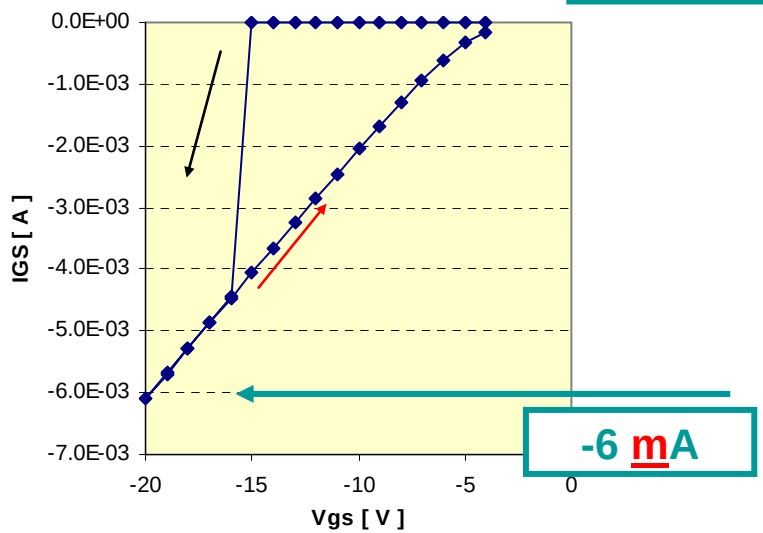
No change Post irradiation



Leakage Post irradiation



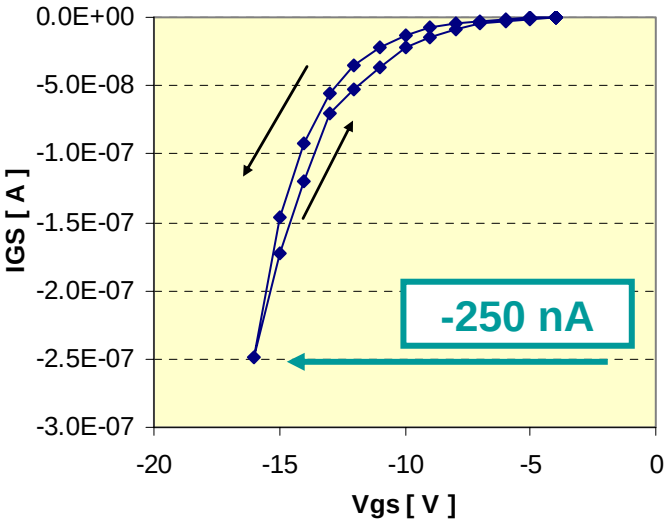
Rupture Post irradiation



Post Irradiation Gate Stress Test

Voltage Ramp

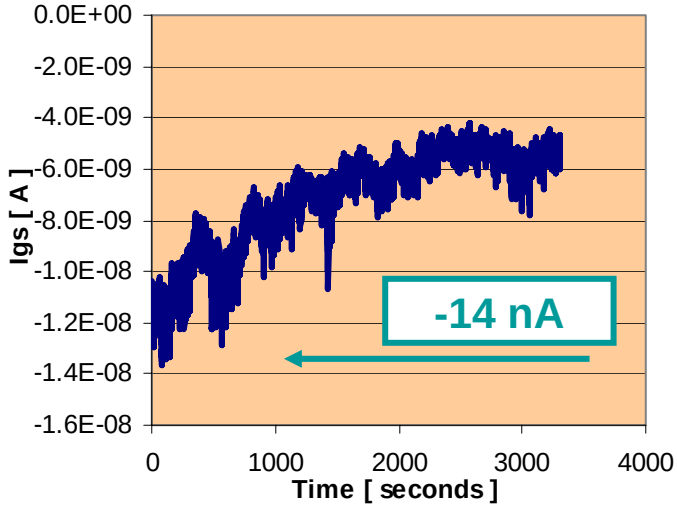
Tstep = 200ms



Constant voltage

T = 1 hour

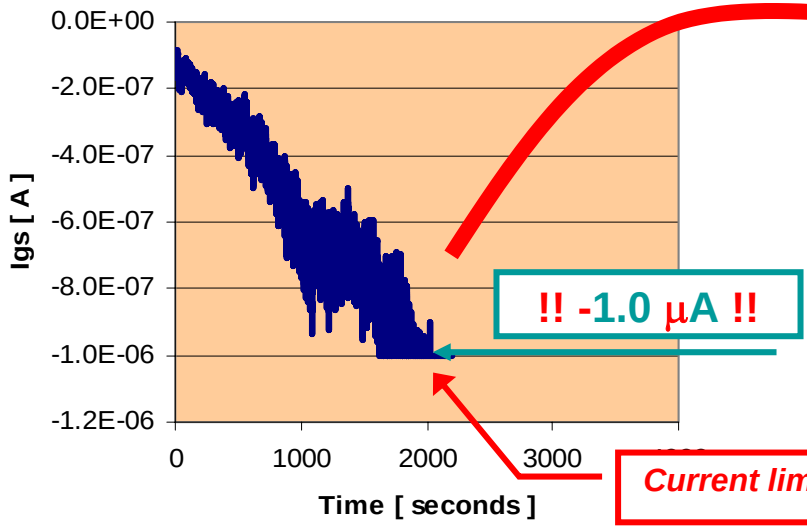
Vgs = -12V (75% of Max)



Constant voltage

T = 1 hour

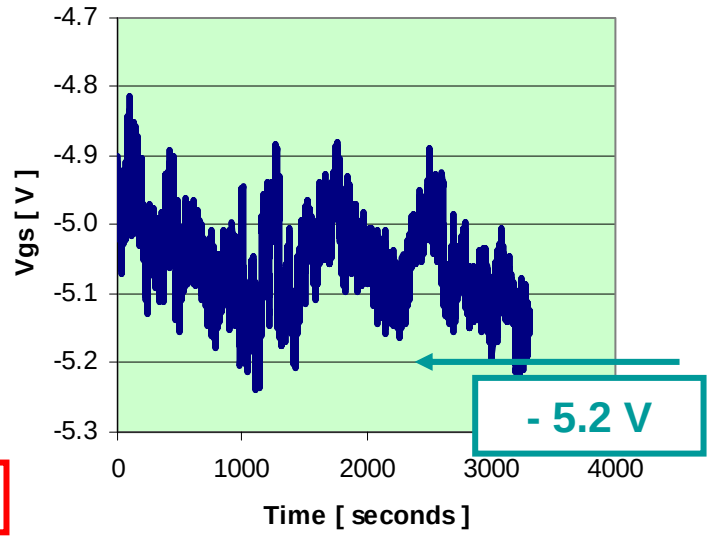
Vgs = 16V (100% of Max)



Constant Current

T = 1 hour

Igs = 1.0 uA



Post Irradiation Gate Stress Test

- Test Object
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    - Range(Si) = 89um
    - LET(Si) = 60.0 MeV-cm2/mg
- Post Irradiation Gate Stress test
  - Voltage ramp to -20Vgs
  - Vds = 0 V
  - T = 200 ms per voltage step
- Pass criteria for SOA
  - No SEGR during irradiation
  - Igs below 100nA in Post Irradiation Gate Stress test

CONCLUSION

- Post irradiation gate stress test must be performed in SEGR testing
- Degradation from SEGR can wrongly be interpreted to total ionising dose degradation
- Voltage and time are critical parameters

Fluence Effects

- Test Object
  - Prototype from STM
  - SEB hardened
  - 100V N-channel
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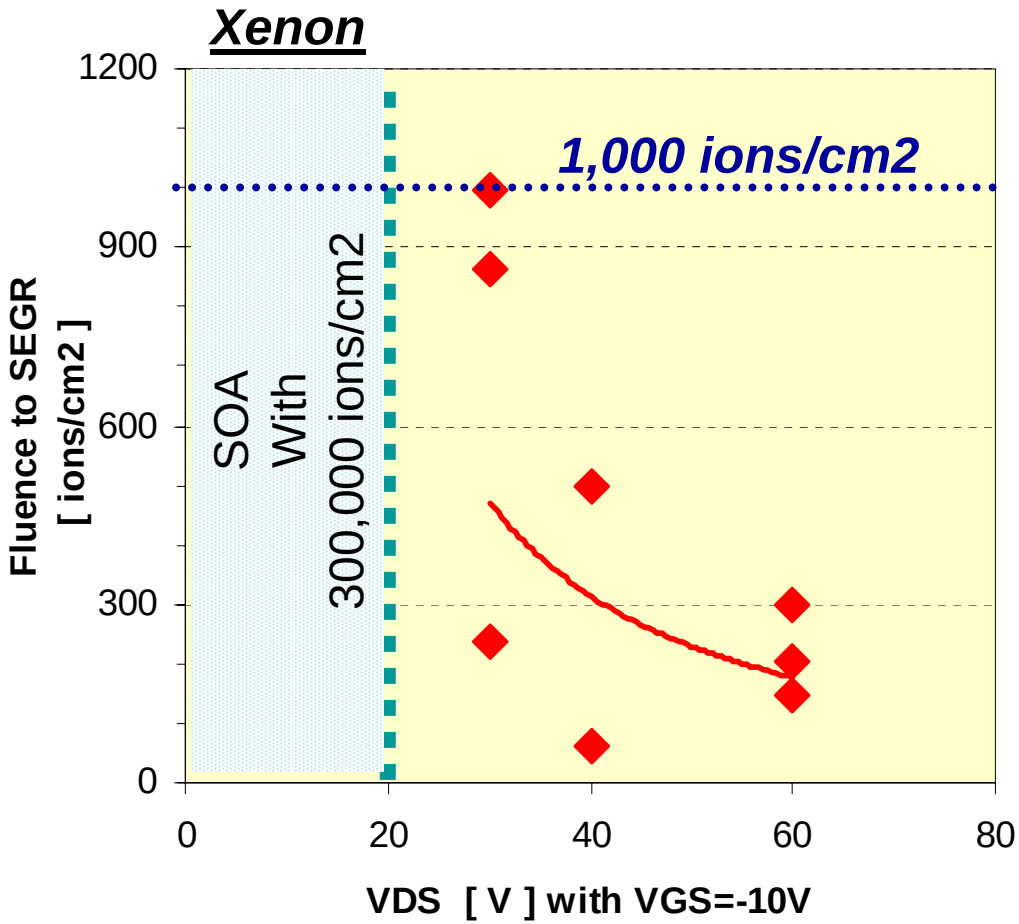
  - Voltage ramp to -20Vgs
  - Vds = 0 V
  - T = 200 ms per voltage step
- Pass criteria for SOA
  - No SEGR during irradiation
  - Igs below 100nA in Post Irradiation Gate Stress test

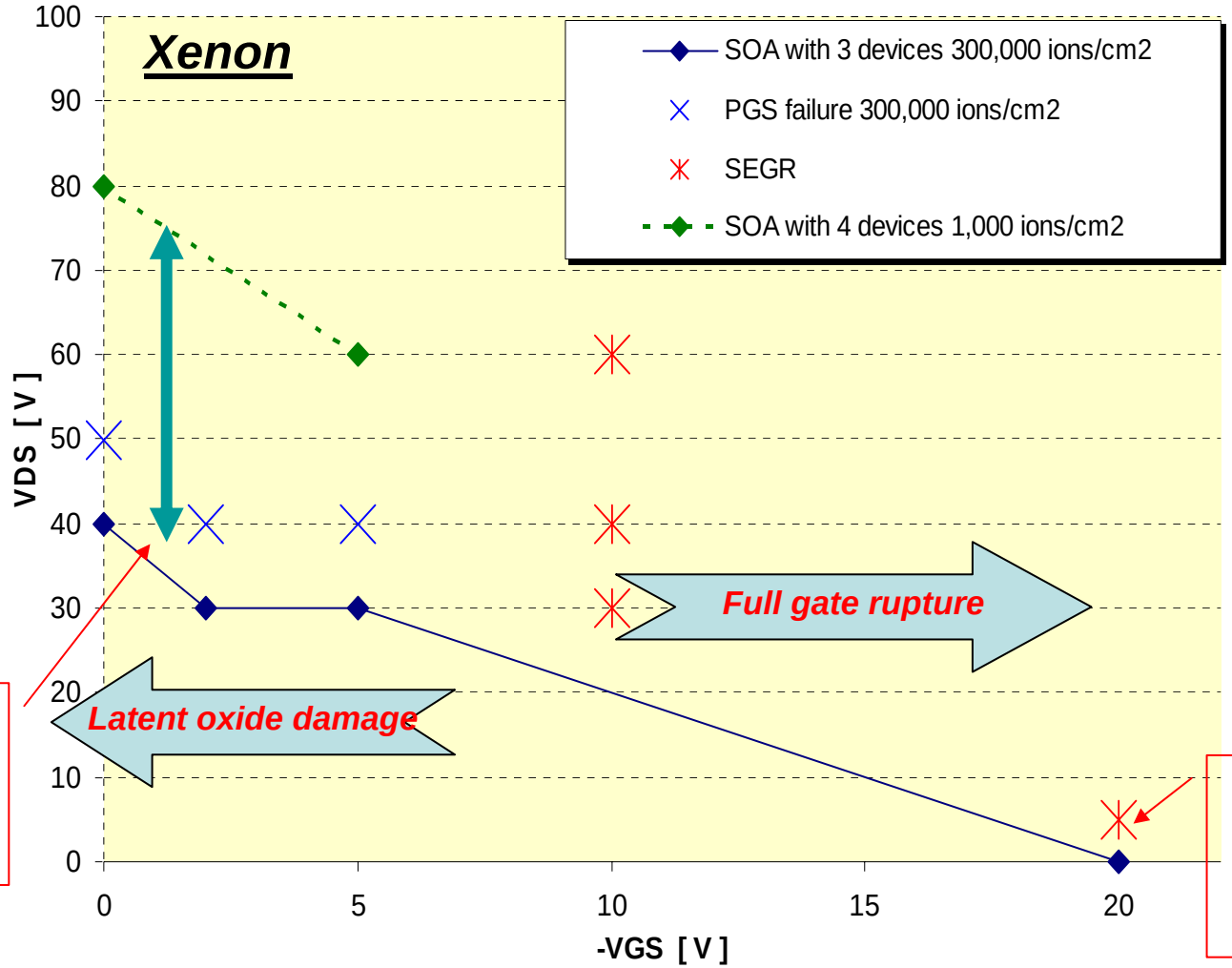
- SEGR Safe Operation Area as function of
  - Vds and Vgs
  - Two Cases:
    - High Fluence
      - 300,000 ions/cm2
      - 1000 ions/cm2-s
      - 3 devices per bias condition
    - Low Fluence
      - 1,000 ions/cm2
      - 10 ions/cm2-s
      - 4 devices per bias condition

Fluence Effects



- SOA with 1,000 ions/cm2 exclude all possible fluence effects
- Total fluence with 4 devices is 4,000 ions/cm2
  - Well above measured cross section for SEGR

Fluence Effects



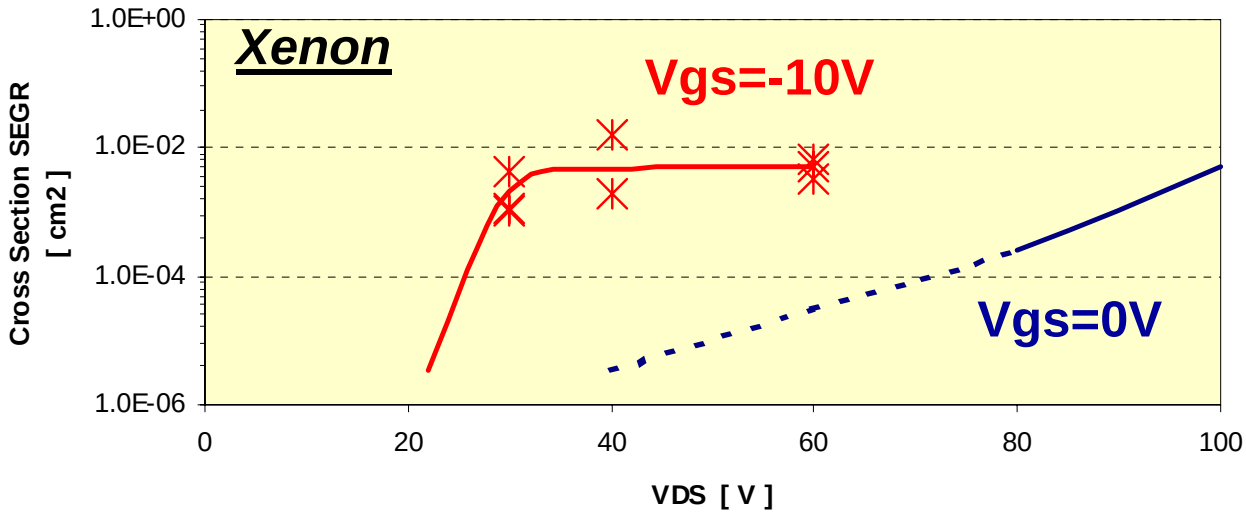
Large Fluence Effect

NO Fluence Effect

Discussion Fluence effects

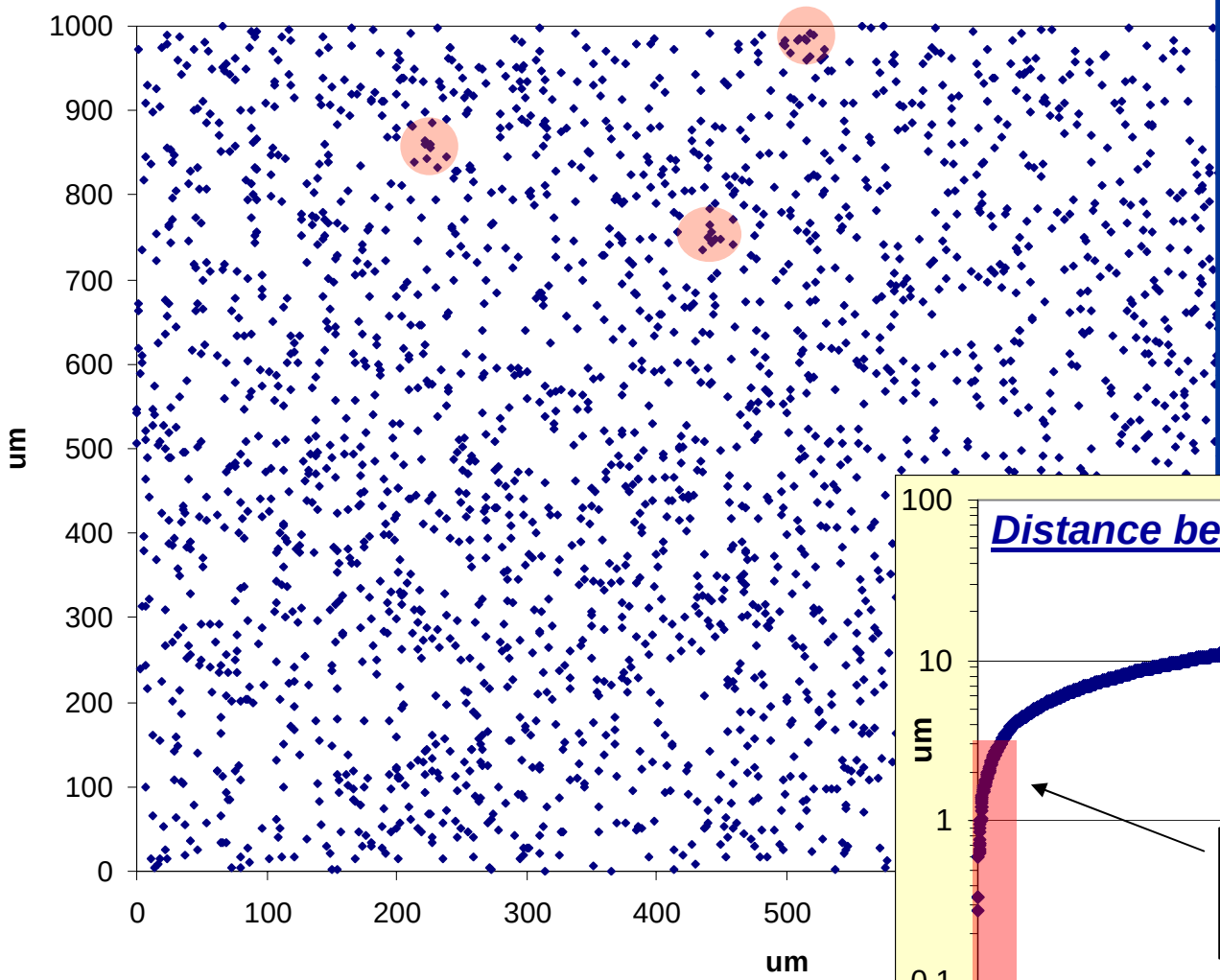
Possible explanations:

- Wide threshold of SEGR vs Vds
  - Only at low gate voltages
    - Abrupt threshold at higher negative gate voltage



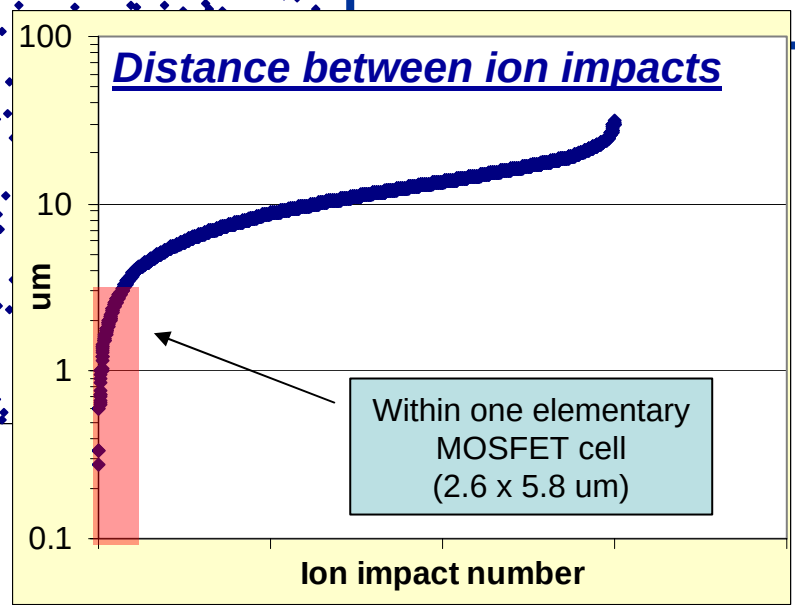
- Or artifact from Cumulative effects
  - The probabiliy for ion impacts from more than one ion in an elementary cell increases with increased fluence

Discussion Fluence effects



Simulation

- Area:
  - 1mm2
- Fluence:
  - 300,000 ions/cm2
  - =3000 ions/mm2



Fluence Effects

➢ CONCLUSION

- Fluence effect observed in SOA
  - Multi impact effects can not be excluded
    - Miss experimental evidence & physical mechanism behind

- Fluence effects and Post Irradiation Gate stress will be further studied at ESA and CNES

Results Safe Operation Area Krypton