Rad Effects in Newly Available MOSFETS

Leif Scheick

Jet Propulsion Laboratory, California Institute of Technology, Pasadena, Ca

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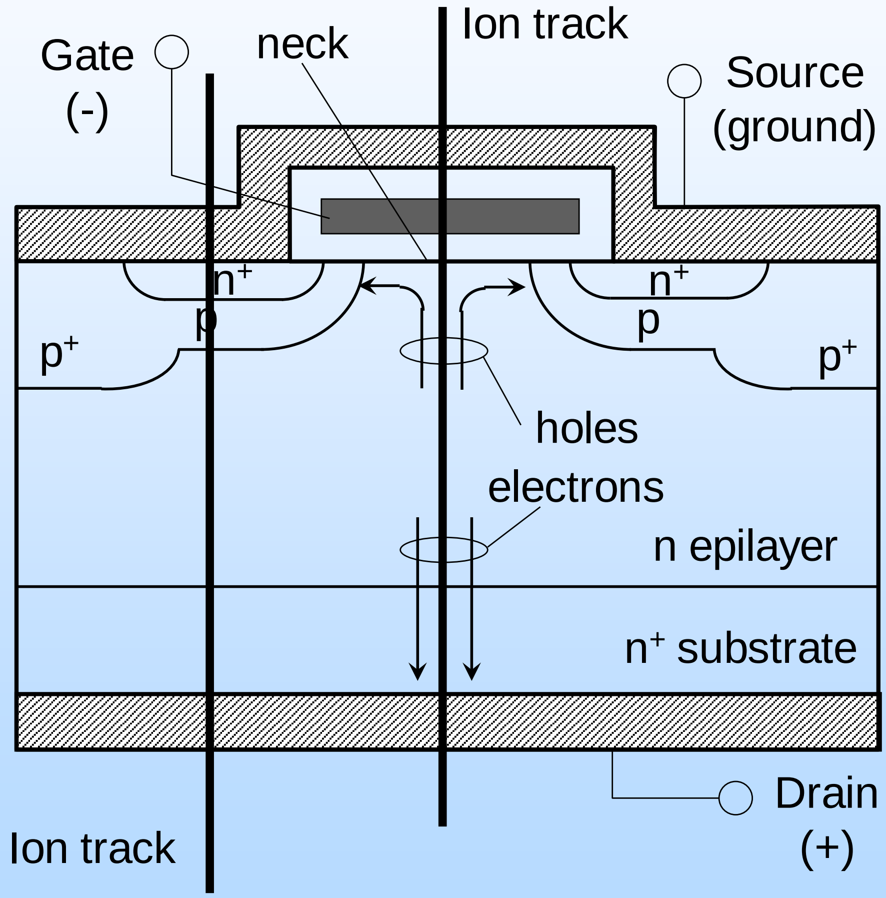
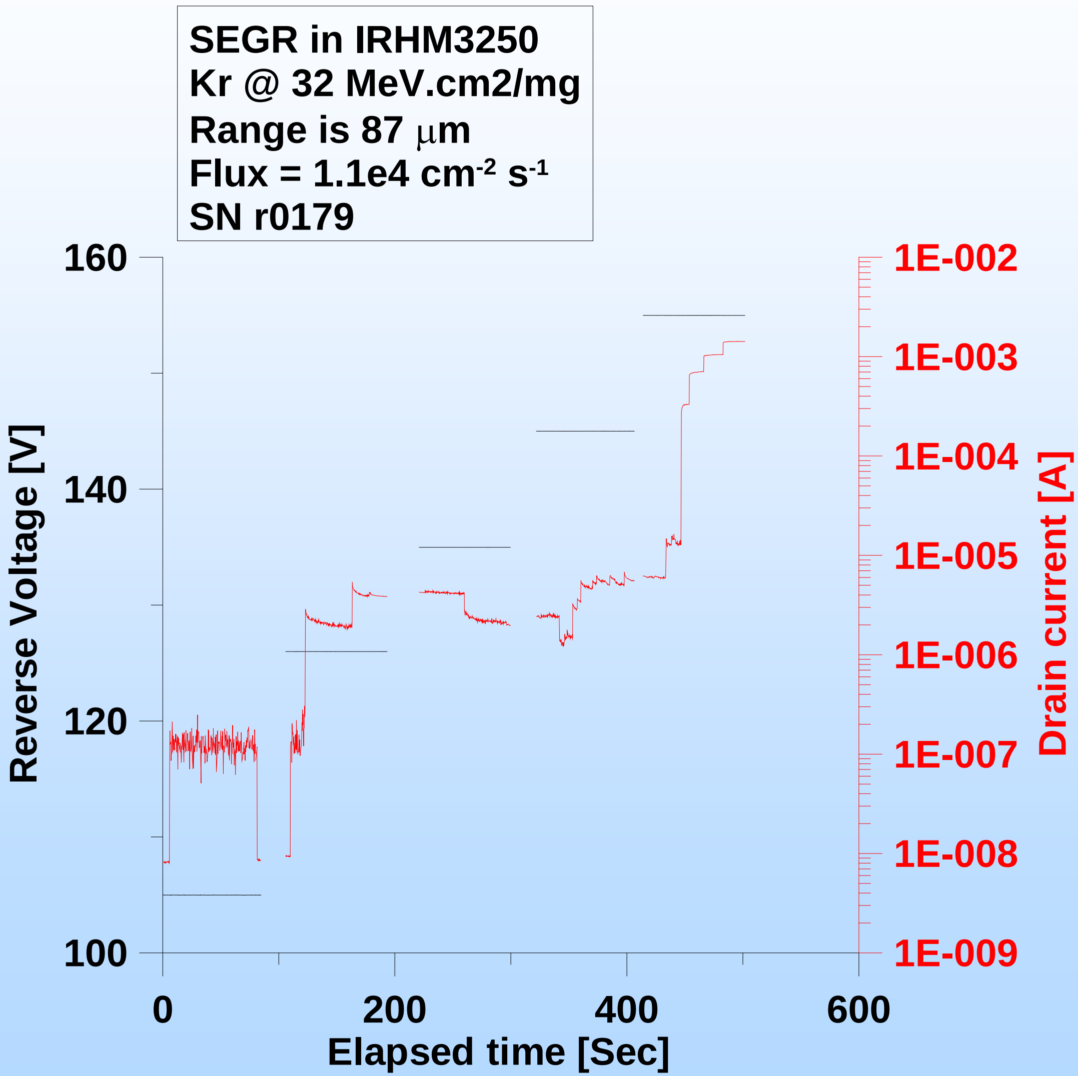
SEE in High-Voltage Power MOSFETs

- **Caused by ion strike**
  - **More important for higher-voltage devices**
  - **Even hardened power MOSFETs are susceptible to SEGR**
- **SEGR from two effects:**
  - **Gate oxide breakdown**
    - **Ion damage and charging in gate**
    - **Increase in electric field in oxide due to epitaxial field collapse from charge collection**
  - **Dependent on ion angle**
  - **Failure is high gate leakage**
- **SEB from activation of parasitic bipolar transistor under source contact**
  - **Temperature dependent**
  - **Current limitable**
  - **Failure is high drain-to-source leakage**



SEE in High-Voltage Power MOSFETs

- Testing always occurs in situ
- Essentially testing is force a voltage and read a current
- Prompt spike in current signifies a SEE effect
  - Careful distinction must be made from TID effects
  - Small events may not effect parameters

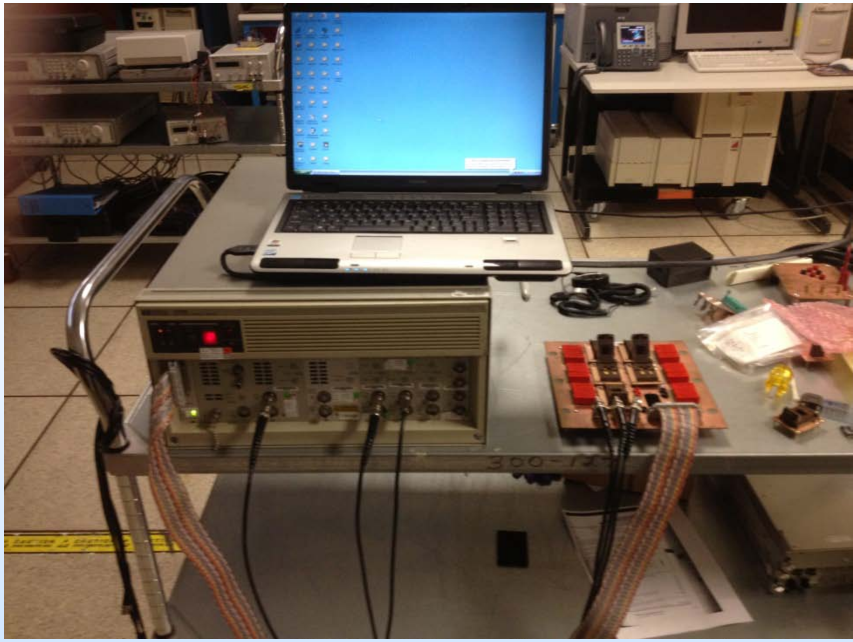


Candidate Devices

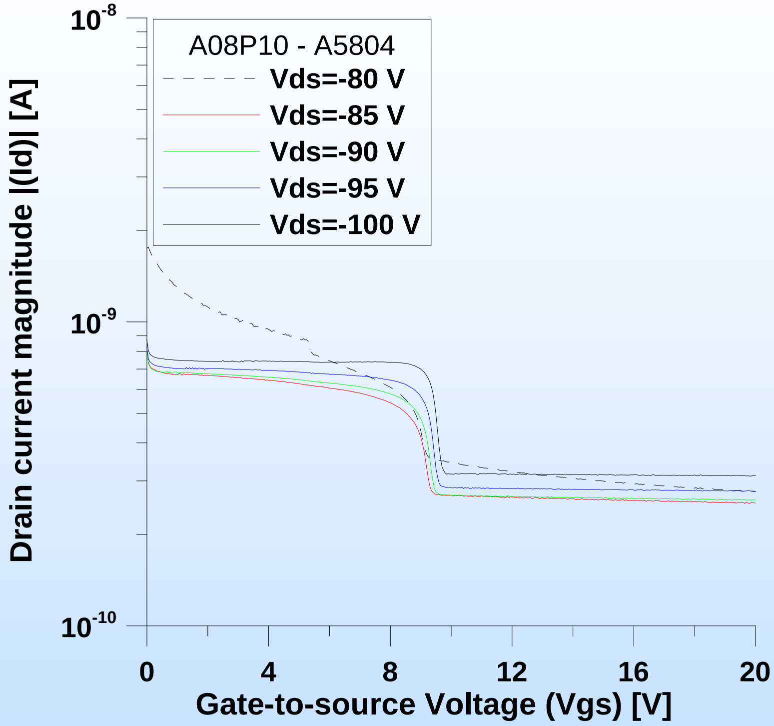
Rating (V)	Device	Man.	Availability
-100	2SJ1A03	Fuji	Q1FY12
-200	2SJ1A09	Fuji	Q1FY12
600	NSD1A01	Fuji	Q2FY12
60	2N7616	Semicoa	Q2FY12
30	2N7478	Semicoa	Q2FY12
-100	2N7425	Semicoa	Q3FY12
-60	**2N7626**	**Semicoa**	Q3FY12

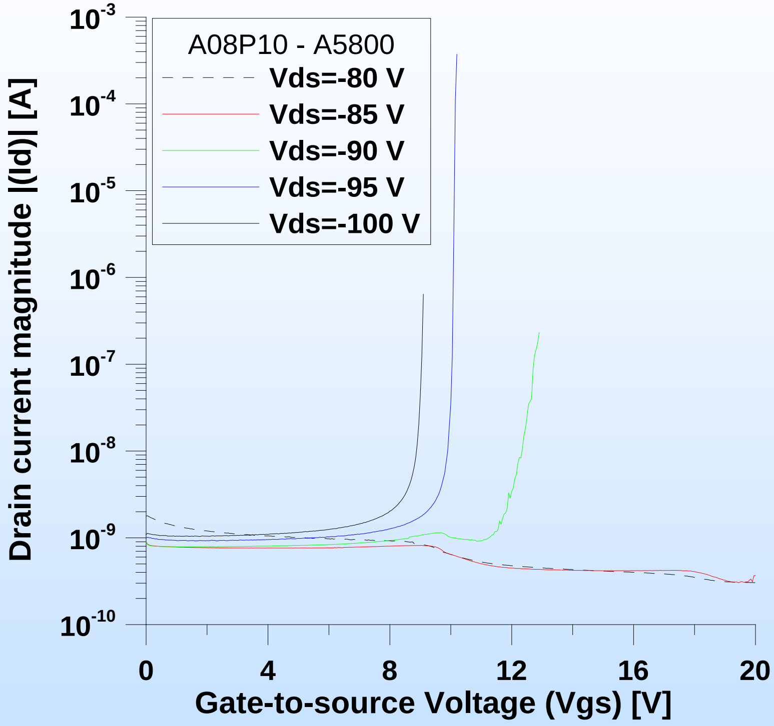
Test Methodology

- Used the NEPP guideline: The Test Guideline for Single Event Gate Rupture (SEGR) of Power MOSFETs [JPL Publication 08-10 2/08]
- Two variances
  - Post irradiation tests performed at full rate gate and 80% of rated drain
  - Fast Track Assurance Testing



Testing challenges – PIGS test limitations





- Full reverse gate bias and full drain bias results in some device exhibiting high leakage condition. This prevent full stress test, so it must be done piece-meal.

Fast Track Testing

Standard Method

- Test three devices for SEE Vds at each desired Vgs
  - Parts that survive used in post test FA
  - Do for each test condition, i.e., ion-energy, circuit etc.
- Requires 3 times the desired number of Vgs
  - 15 for 0, ± 5, ± 10, ± 15, ±20 V

Fast Track Method

- First part: test to failure at lowest magnitude Vgs (usually 0 V)
- Second part: verify first part pass level and test to failure with next highest magnitude Vgs (usually ±5V)
- Next parts: repeat until highest magnitude Vgs level is reached
- Last two parts: verify pass levels of all Vgs
  - If any fail, re-verify with lower pass level at said Vgs (need new part)
- Pros and cons:
  - Pro: can assure in half of the number (7 for 5 Vgs values)
  - Fewer parts for passing parts
  - Con: lose part failure data
  - Con: part-to-part variation will increase number of parts used

Fast Track Testing

Standard Method

Vgs1	Vgs2	Vgs2	Vgs3	Vgs4
SEE DUT: 1	SEE DUT: 4	SEE DUT: 7	SEE DUT: 10	SEE DUT: 13
SEE DUT: 2	SEE DUT: 5	SEE DUT: 8	SEE DUT: 11	SEE DUT: 14
SEE DUT: 3	SEE DUT: 6	SEE DUT: 9	SEE DUT: 12	SEE DUT: 15

Fast Track Method (ideal run)

Vgs1	Vgs2	Vgs2	Vgs3	Vgs4
SEE DUT: 1	SEE DUT: 2	SEE DUT: 3	SEE DUT: 4	SEE DUT: 5
Verify Pass* DUT: 2	Verify Pass DUT: 3	Verify Pass DUT: 4	Verify Pass DUT: 5	
Verify Pass DUT: 6	Verify Pass DUT: 6	Verify Pass DUT: 6	Verify Pass DUT: 6	Verify Pass DUT: 6
Verify Pass DUT: 7	Verify Pass DUT: 7	Verify Pass DUT: 7	Verify Pass DUT: 7	Verify Pass DUT: 7

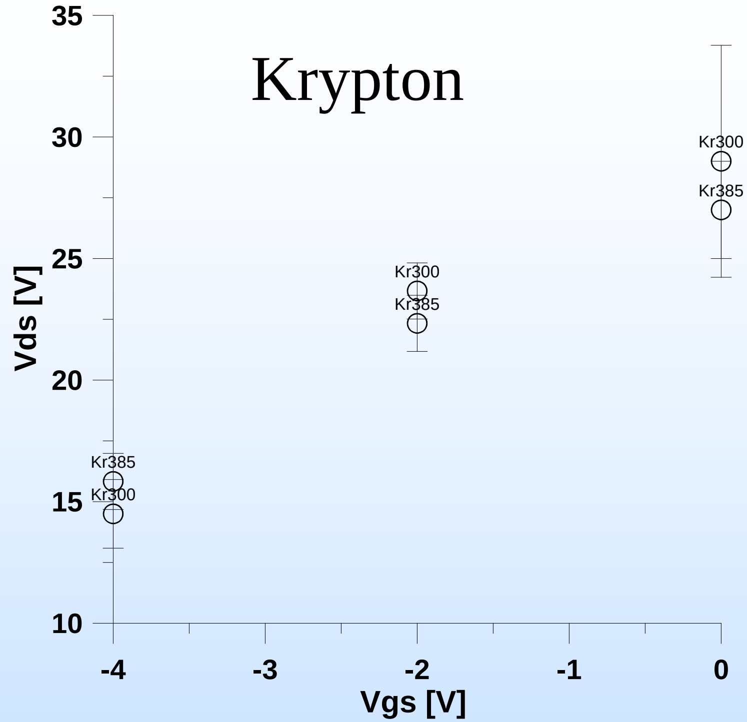
*Test at highest pass voltage

New Parts Have New Challenges

- Parts are supplied to be drop-in replacements to other (read competitor) parts
- Same part number has same slash sheet
- Testing conditions for radiation will not necessarily yield same results
  - Slash sheet stops being a standardized reference for production
- Case in point is the Semicoa 2N7616
  - Comparable to the IR 2N7616

2N7616 – Krypton SEE

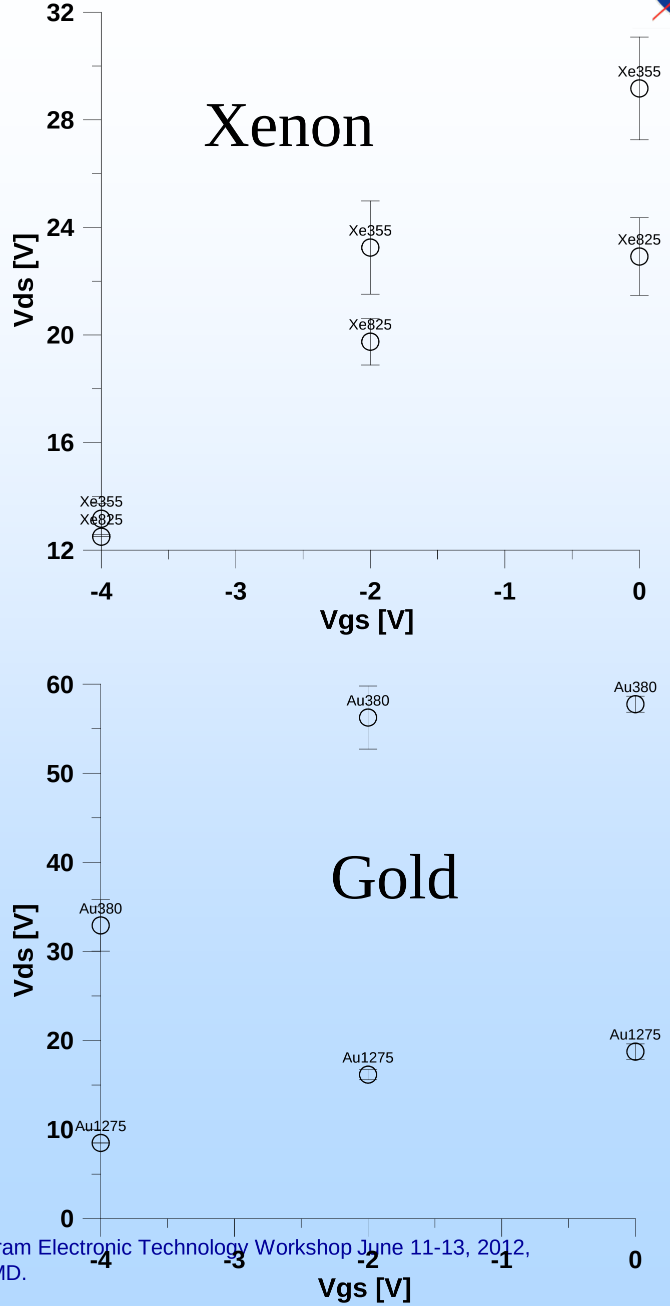
- **Au380, Kr300, and Xe355 are "slash sheet values" based on BNL data on IR's version**
- **The other energies are estimates of worst case based on epitaxial thickness and Titus-Wheatley estimators**
- **Krypton data for both are commensurate**



I-E	LET	Range
Au1275	91.4	70.7
Au380	87.5	28.8
Kr300	39.2	37.4
Kr385	37.6	46.9
Xe355	63.3	33
Xe825	59	65.9

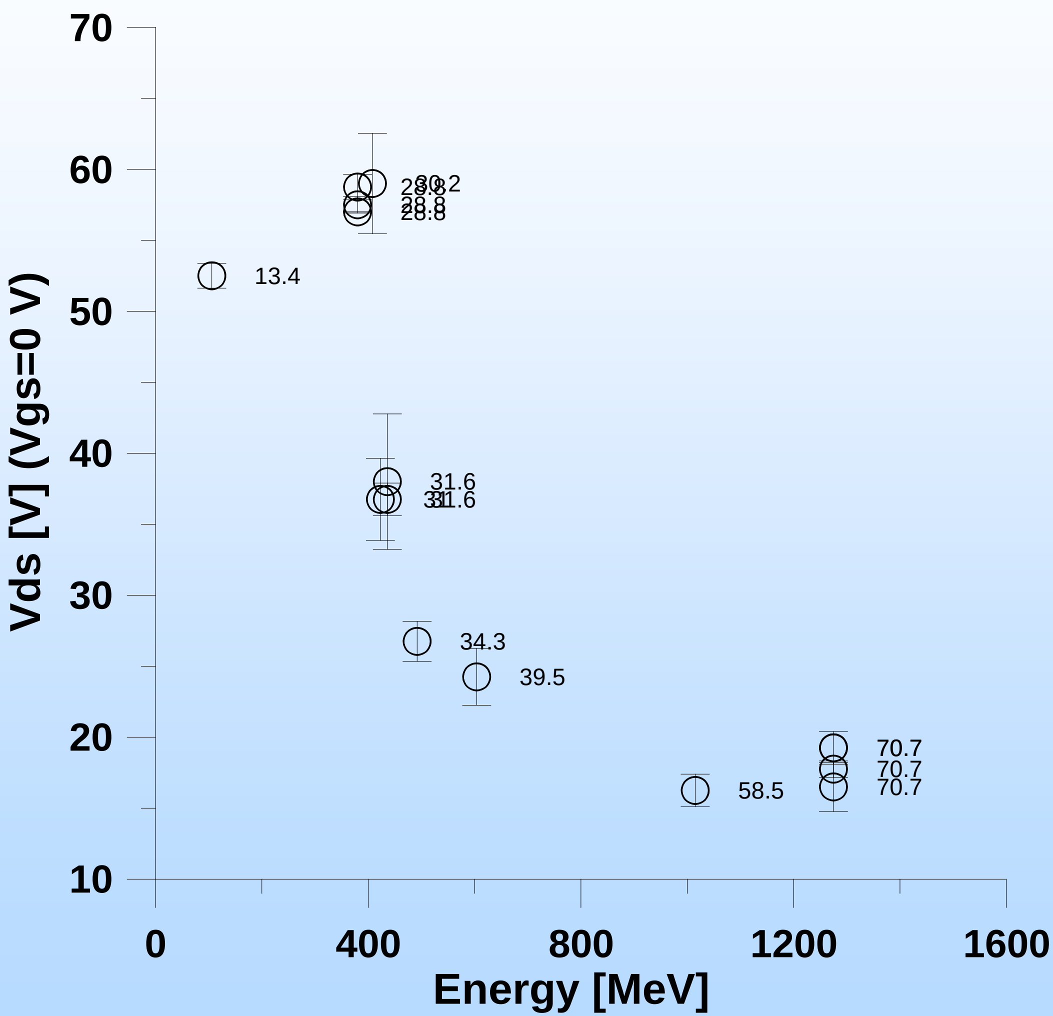
2N7616

- **As the atomic number increases the deviation between the worst case and the slash sheet value increases**
  - **Especially pronounced for gold**
- **Slash sheet for alternates to IR version is not, therefore, an adequate assurance asset across multiple suppliers**
- **Titus-Wheatley not good predictor for some architectures**

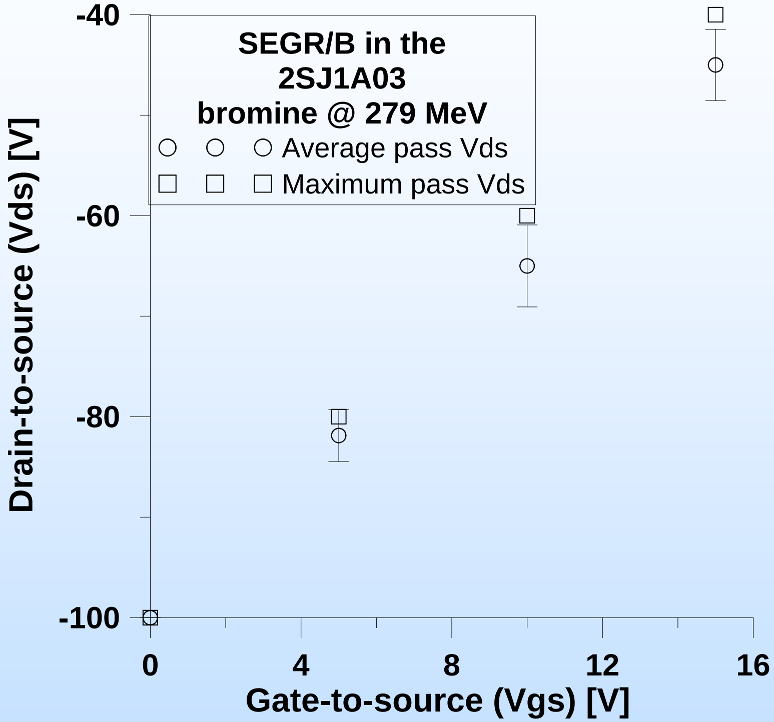


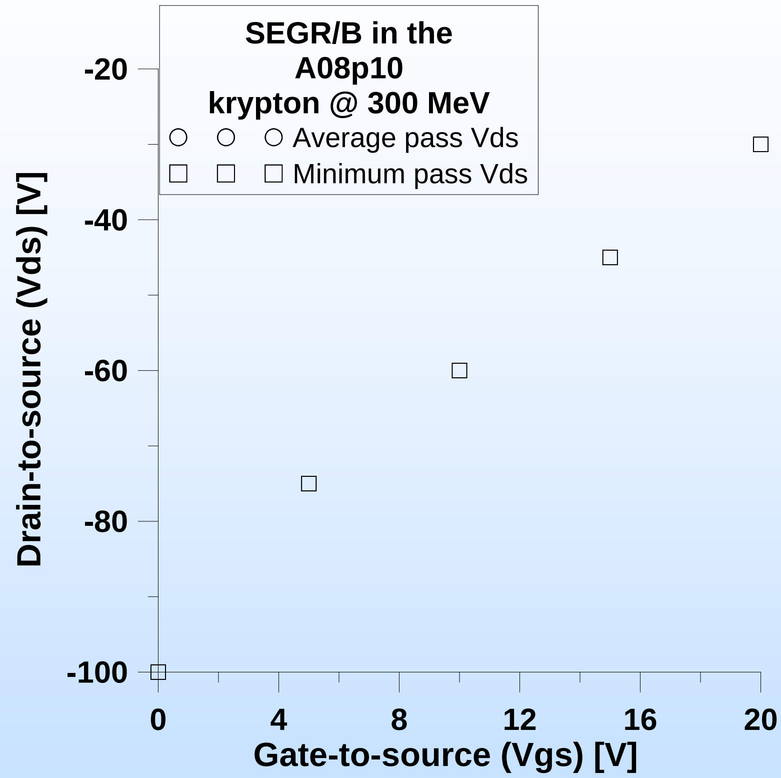
2N7616 – Titus Curve with Gold

- **Varying ion energy shows the worst case for SEE is well away from the slash sheet for this product**
- **Slash sheet would underestimate risk in using this part**
- **Ion ranges in um shown in point labels**



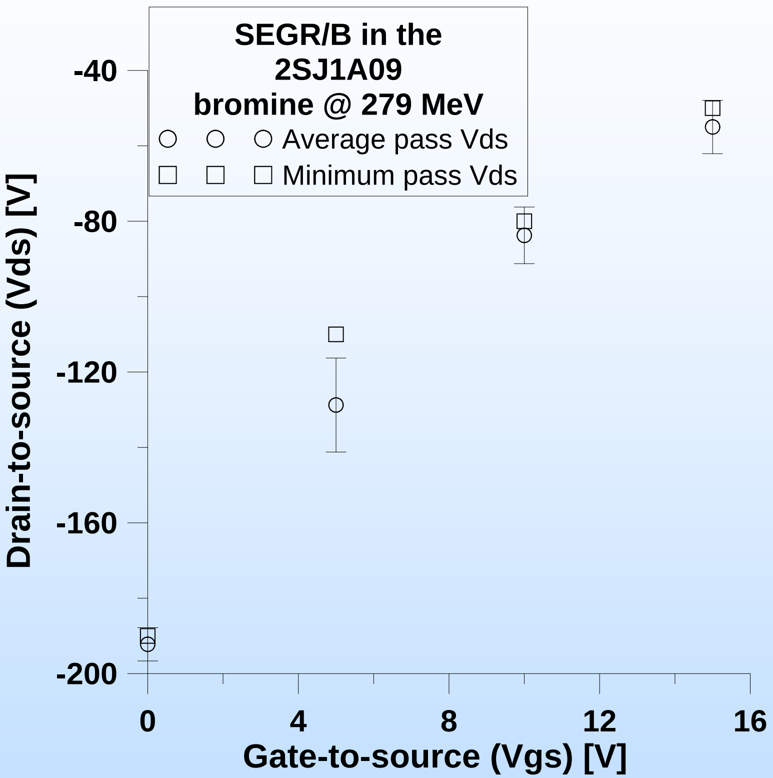
Fuji 100 V – BNL/TAM comparison

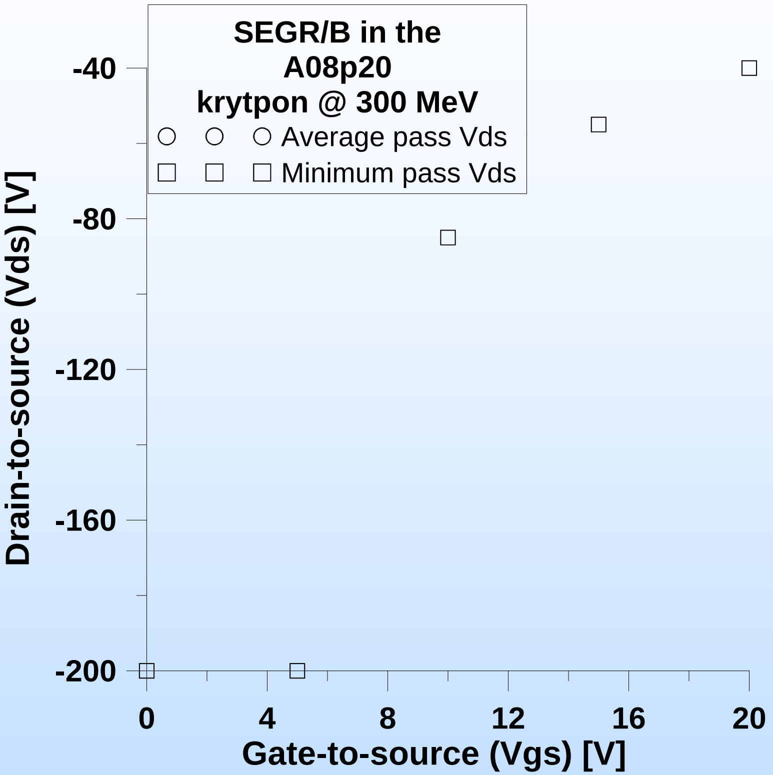




- **Testing with two comparable ions from TAM and BNL on 100 V p-channel devices. The SEE effects are commensurate.**

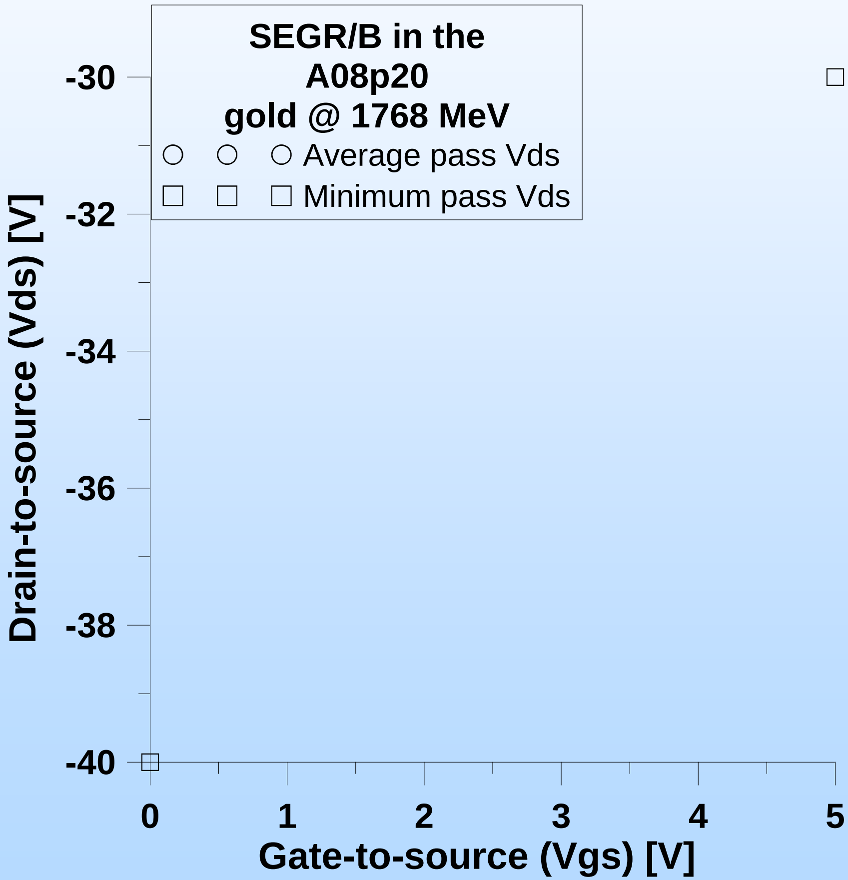
Fuji 200 V – BNL/TAM comparison

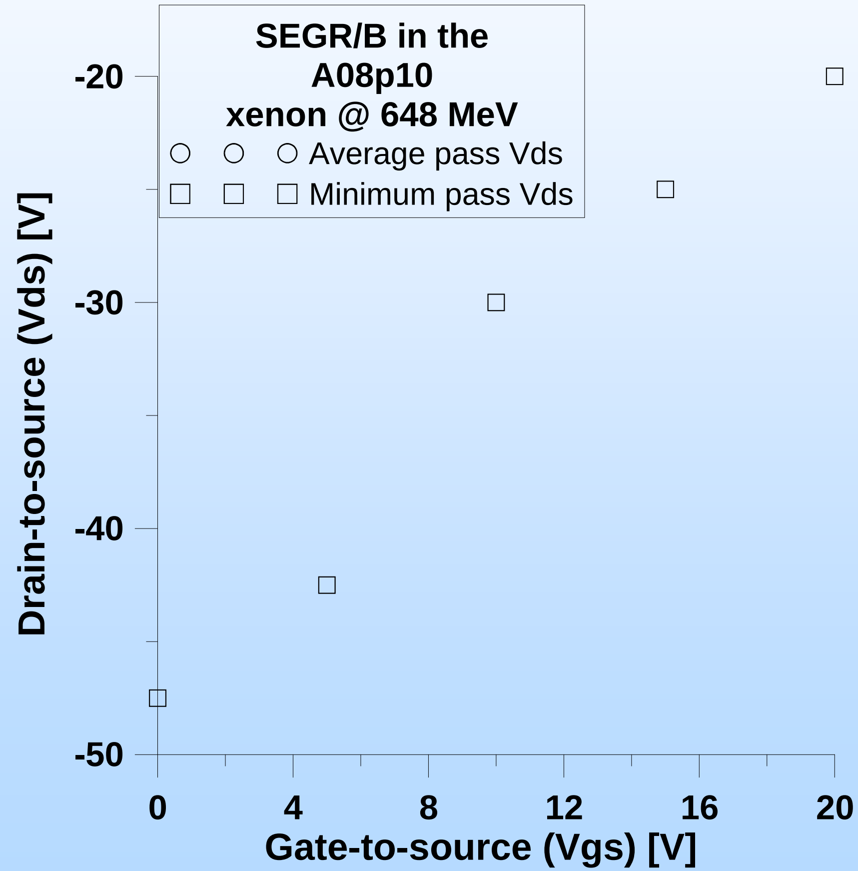




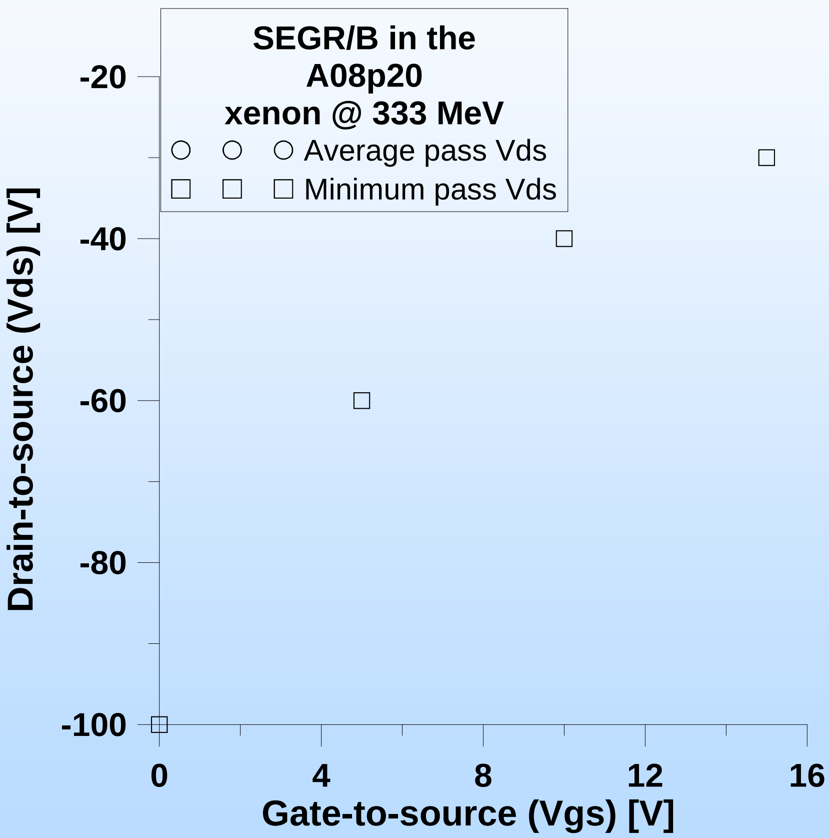
- **Testing with two comparable ions from TAM and BNL on 200 V p-channel devices. The SEE effects are commensurate.**

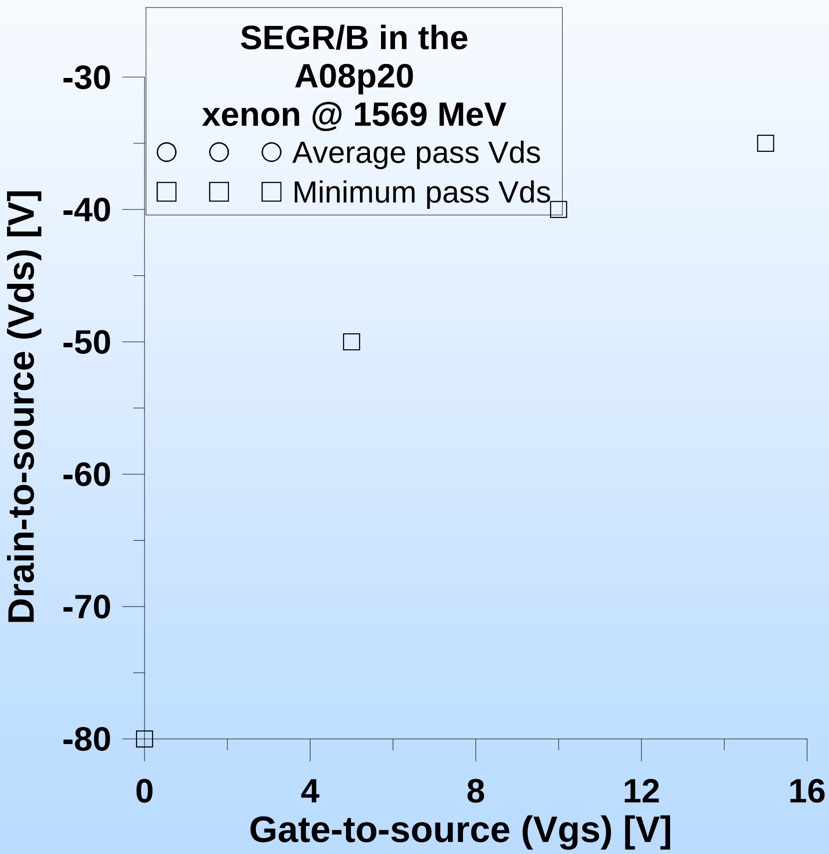
Fuji 100 and 200 p-chan



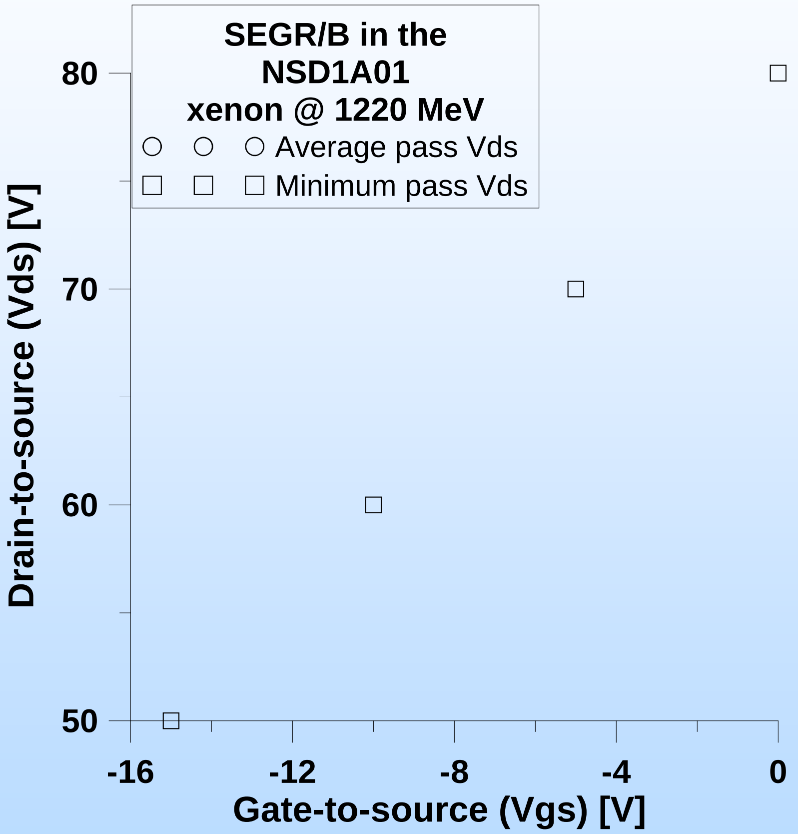


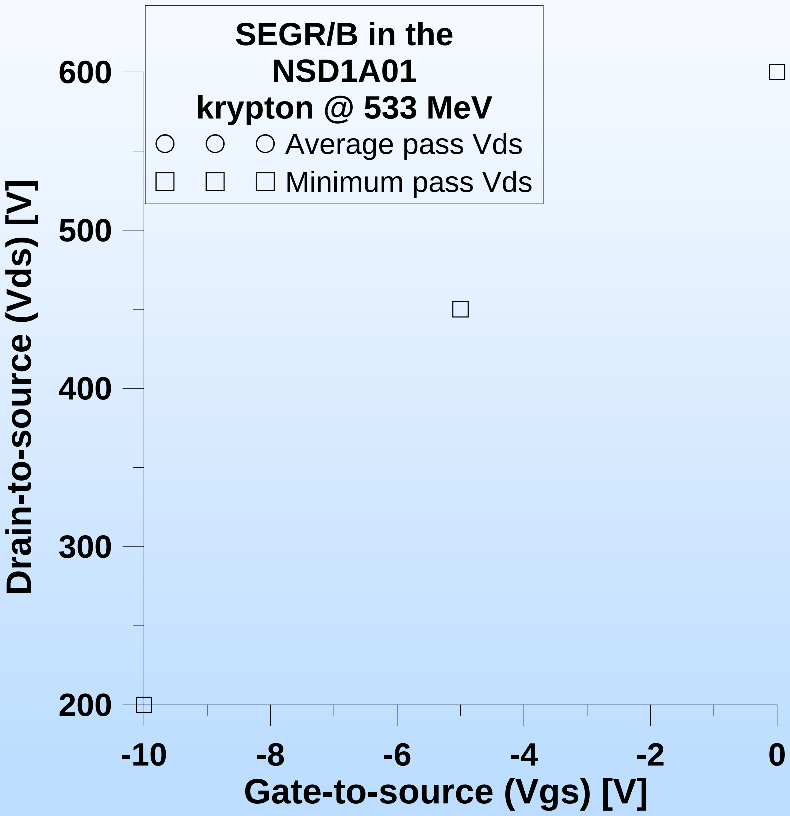
Fuji 200 p-chan





Fuji 600 V N-chan





Acknowledgement

- We would like to thank Fuji corporation and Semicoa corporation for providing test samples and technical information
- We would also like to acknowledge Jean Marie Lauenstein and Megan Casey of the Goddard Space Flight Center for many useful discussions on device testing and effects

Conclusion

- **Power device technologies still suffer from growing pains in regards to radiation effects**
  - **Higher rated parts may be limited by radiation effects**
  - **Derating (Design margin) on the SOA is the most used approach**
- **Lesson learned**
  - **New applications yield uncovered effects**
    - **All radiation issue should be revisited after new design**
    - **Or new environment, technology, or mission profile**