Status of the Gallium Nitride High Electron Mobility Transistor Radiation Testing for the NEPP Program

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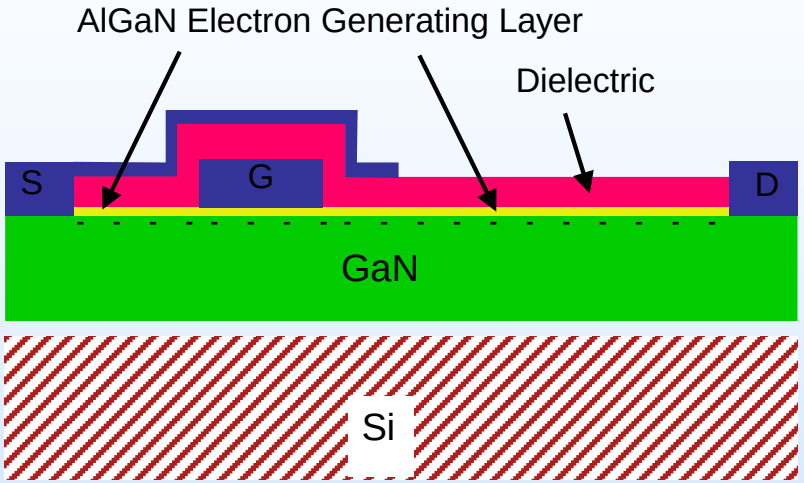
 This research was carried out in part by the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration under the NASA Electronic Parts and Packaging Program (Code AE). Other data was collected from NASA flight projects.

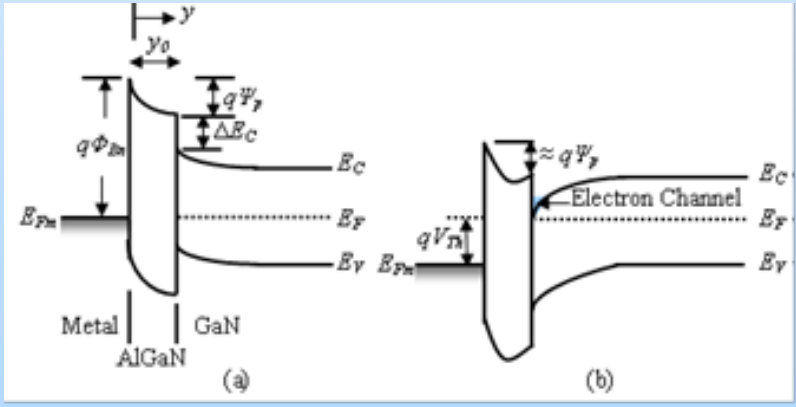
Current activities

- Working group discusses best methods for evaluating new wide band gap technologies for infusion into space
  - GRC, JPL, JSC, GSFC, AFRL
  - Monthly meeting to share data and resources for radiation effects testing and reliability analyses
- Previous efforts have been broad stroke testing
  - Heavy ion testing
    - Gallium Nitride HEMTs (JPL)
    - Silicon Carbide MOSFETs (GSFC)
  - Reliability screening
    - Temperature cycling of GaN and SiC
- On going and future efforts
  - Continues radiation testing and analysis
  - Reliability test screens for new devices
  - Guidelines for implementation and testing

GaN Basics

- **Current silicon power solutions are at their innate limits for space applications**
  - **Silicon devices are at efficiency limit**
  - **Best hi-rel devices are less then ~400 V drain-to-source**
- **GaN devices are becoming available**
  - **Reliability effects are a concern**
  - **Gate stress is limited (abs max of Vgs +6, -5 V)**
  - **Thermal effects and aging are under study at GRC**





PGA26E19BA

TESTING OF PANASONIC PARTS - CONTINUED

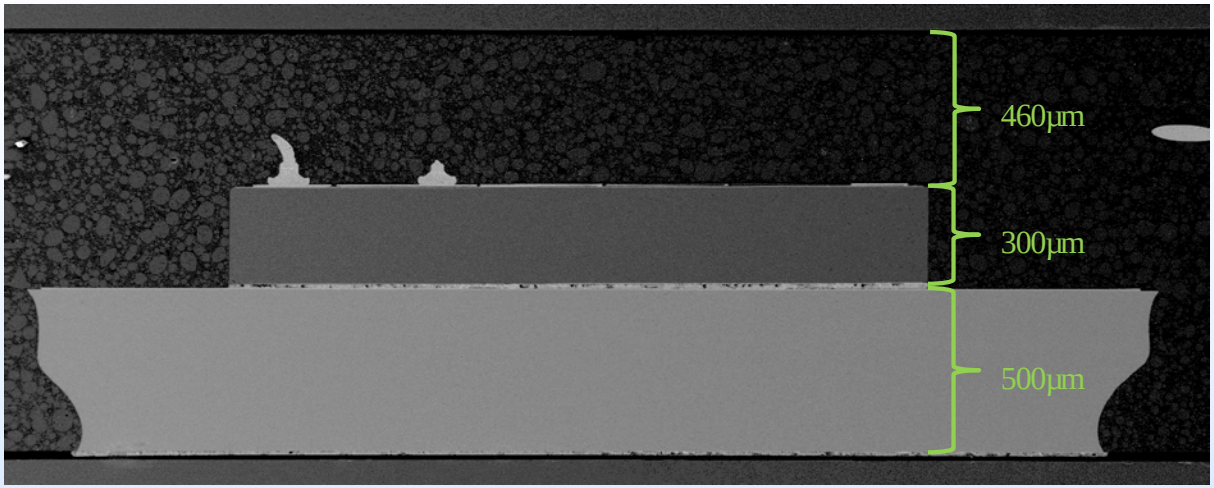
To be presented at the 8th NASA Electronic Parts and Packaging (NEPP) Program Electronic Technology Workshop June 26, 2017, NASA GSFC, Greenbelt, MD.

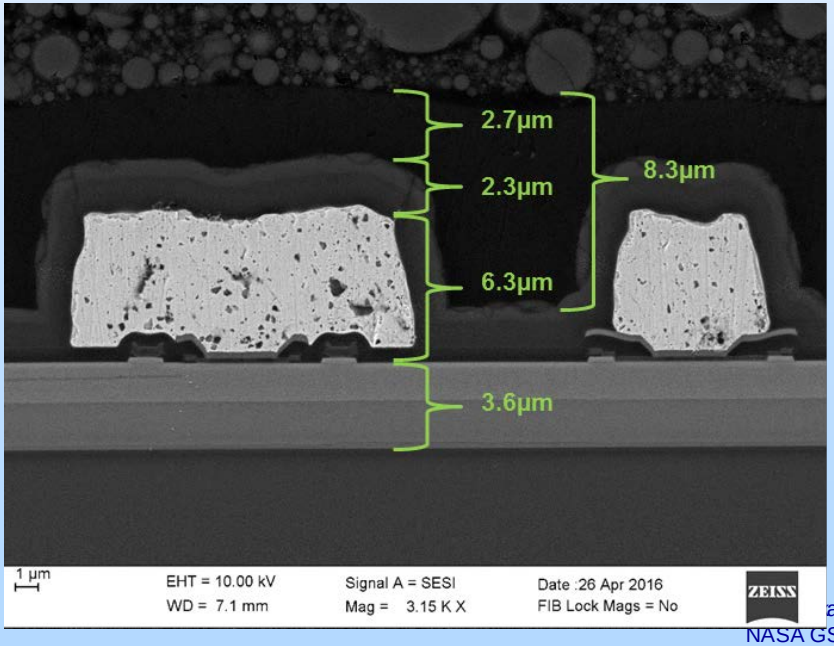
Optical Images

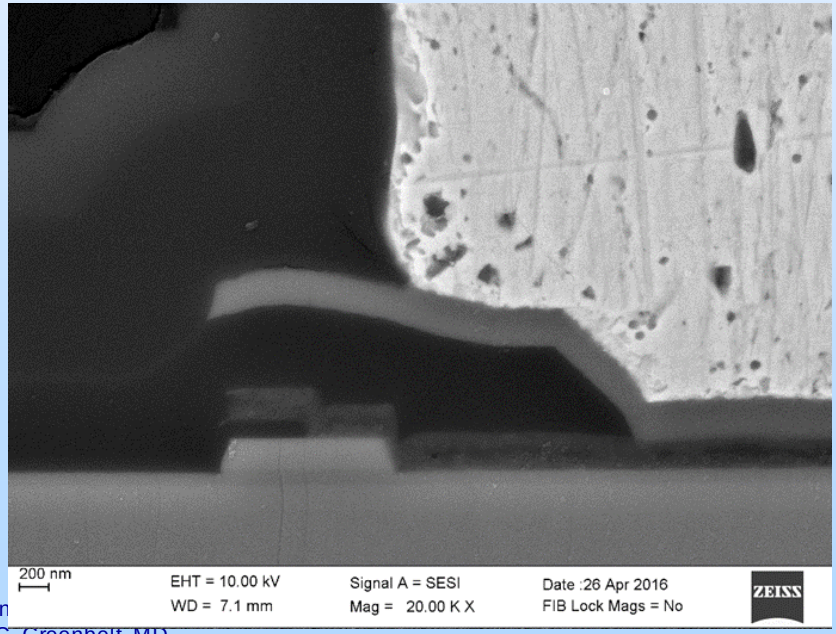
Front

Back

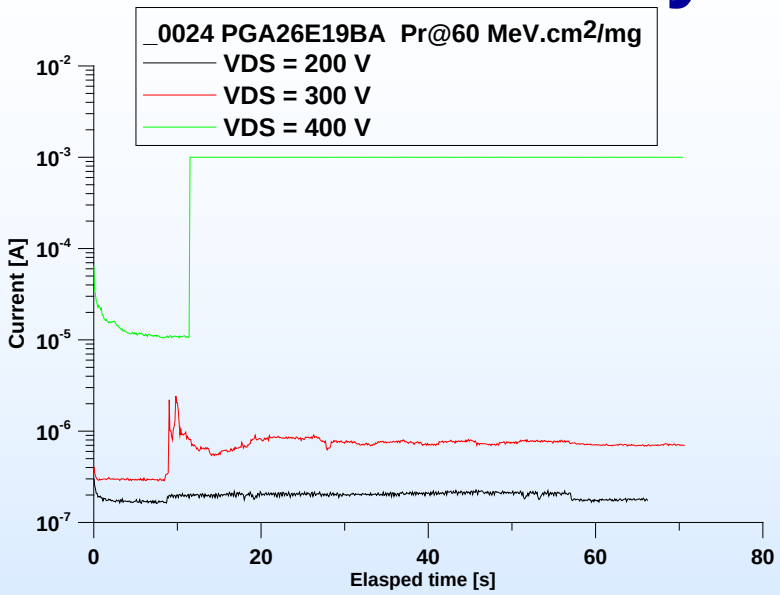
Accomplishments

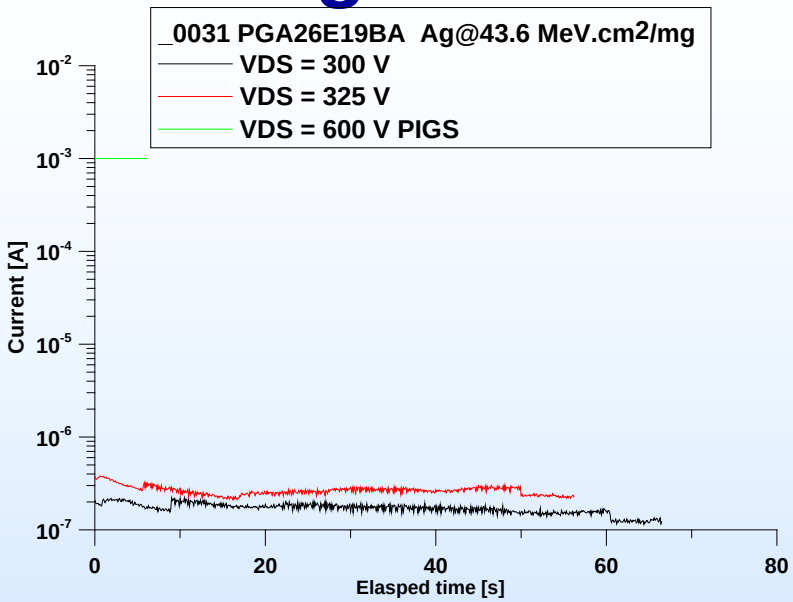


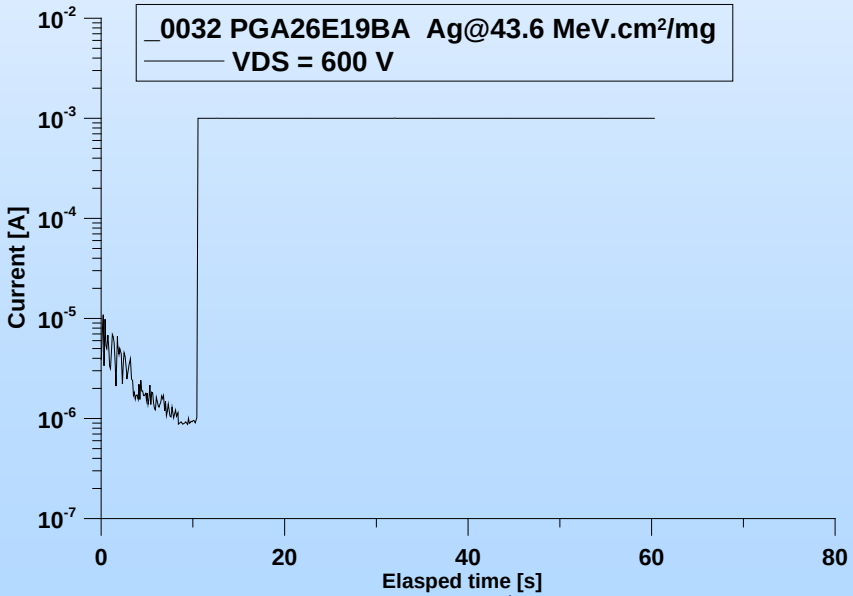


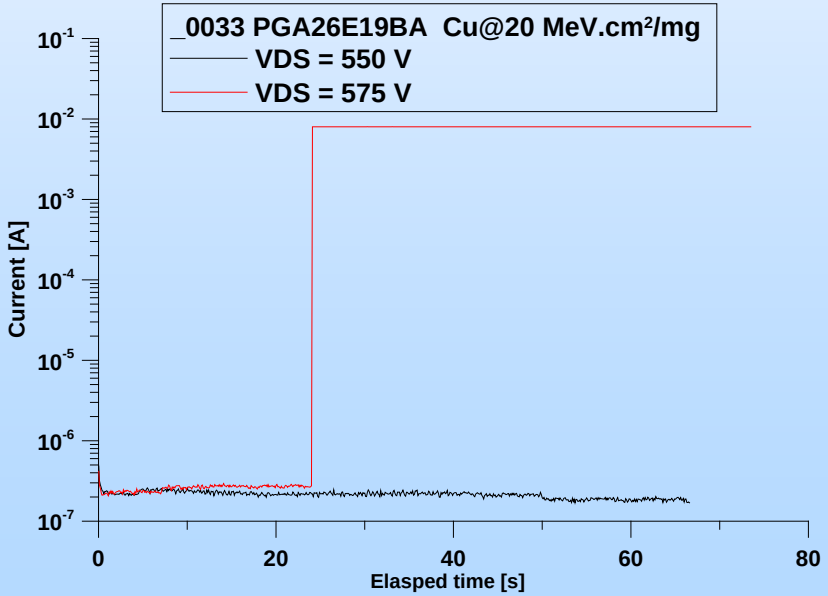


Heavy Ion Testing









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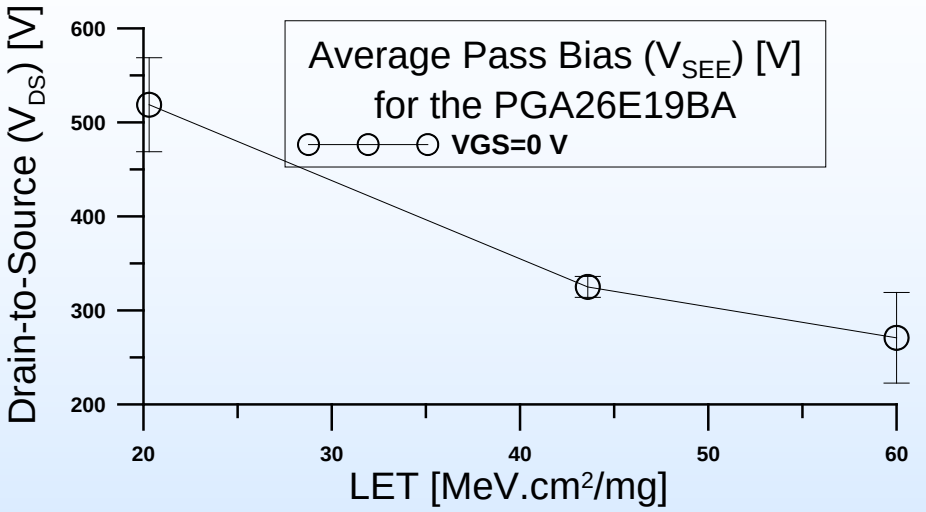

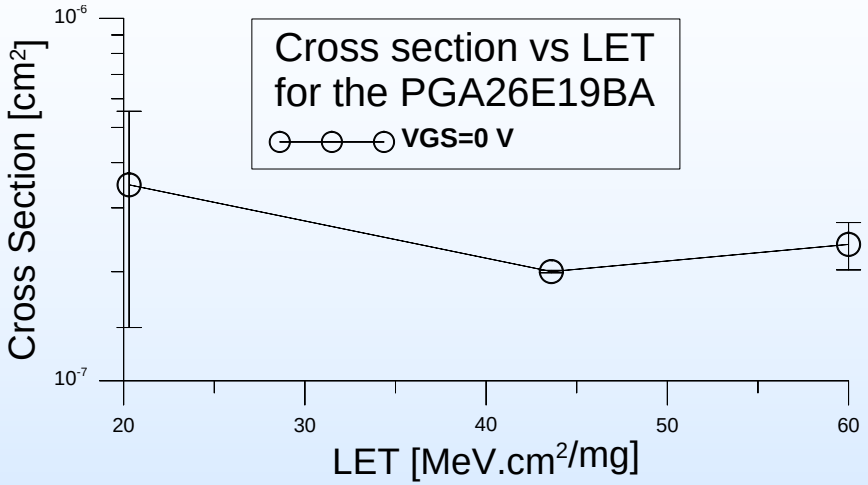

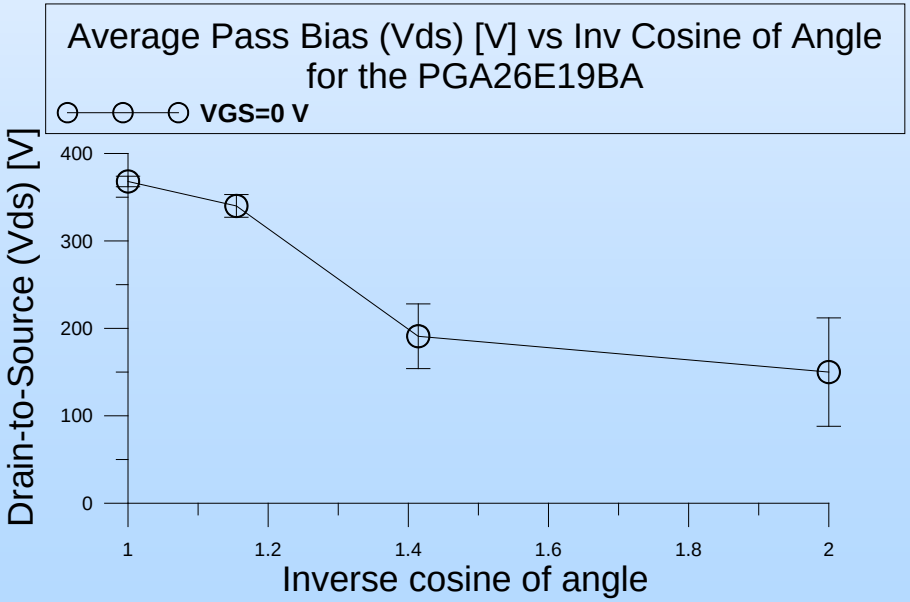

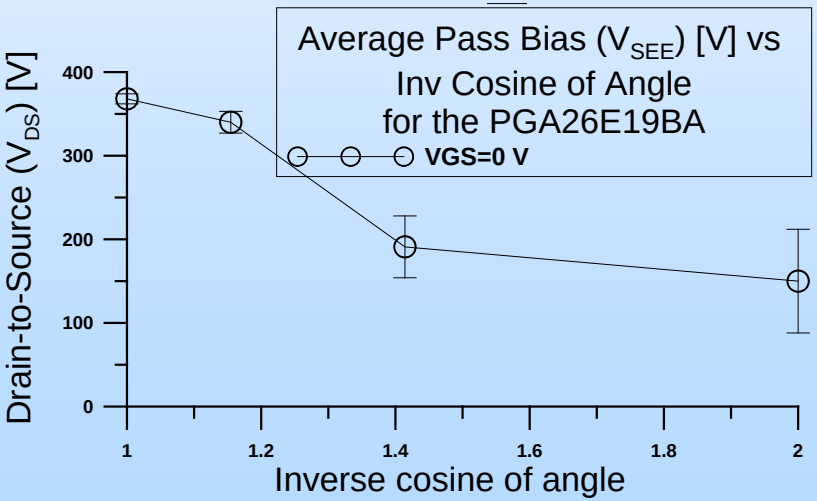

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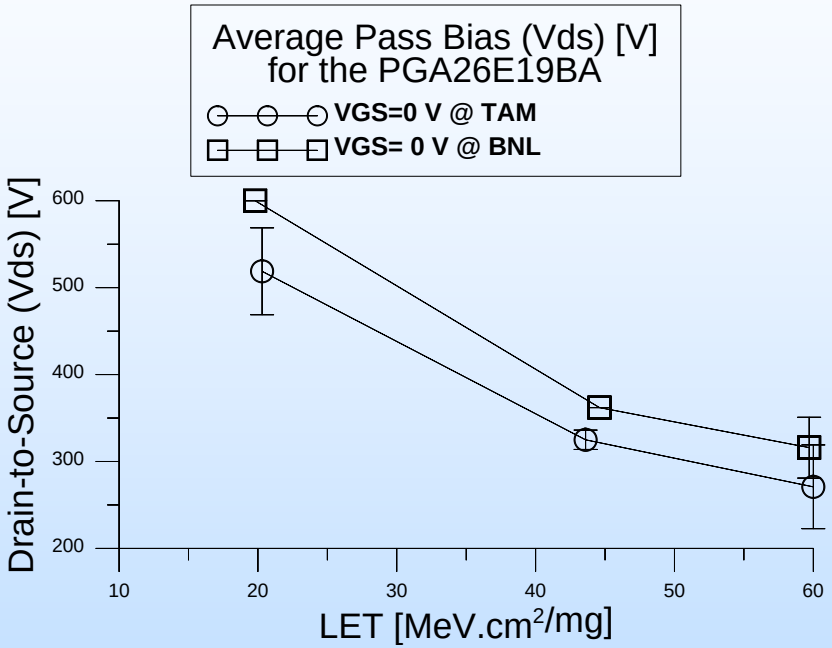
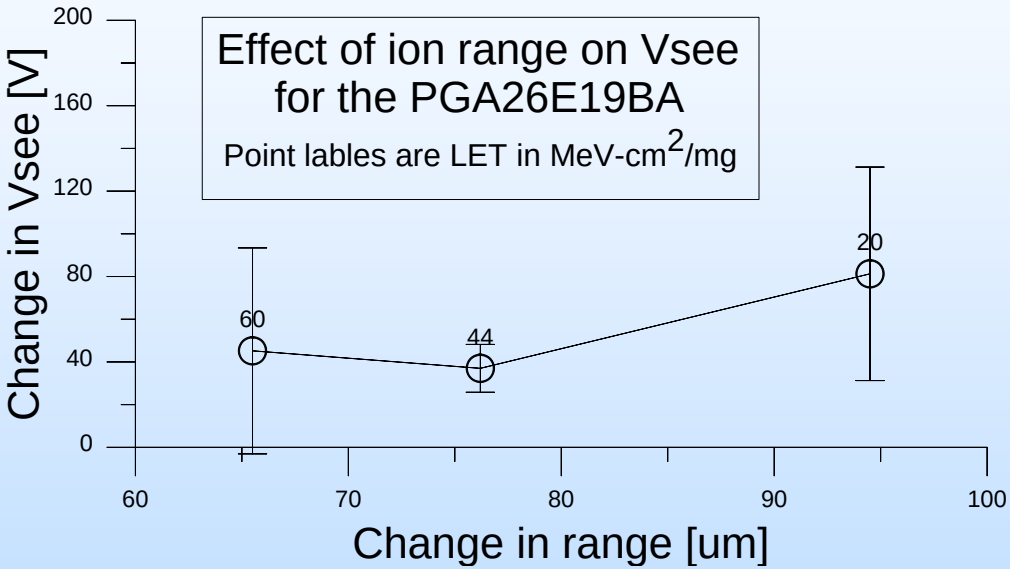
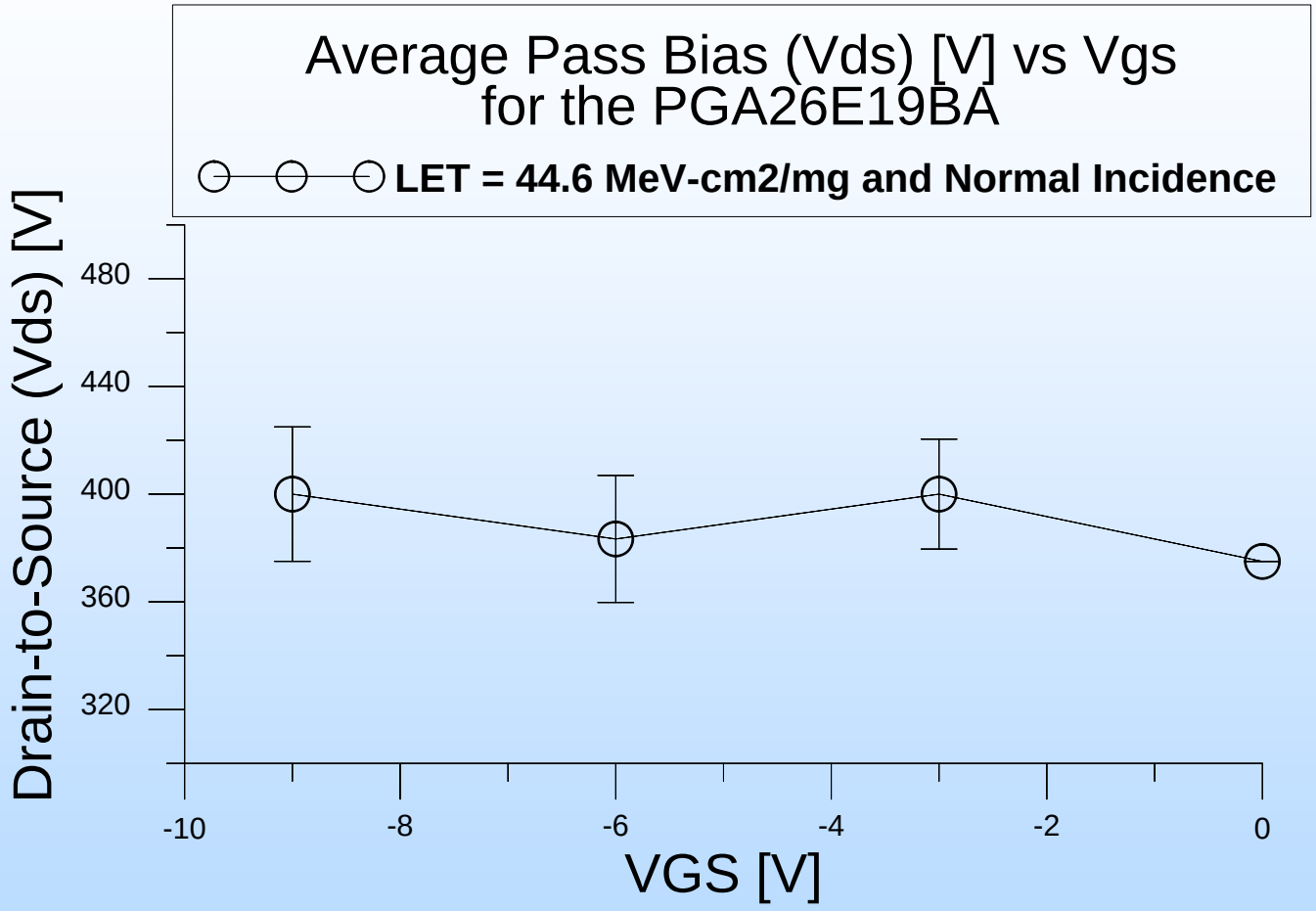




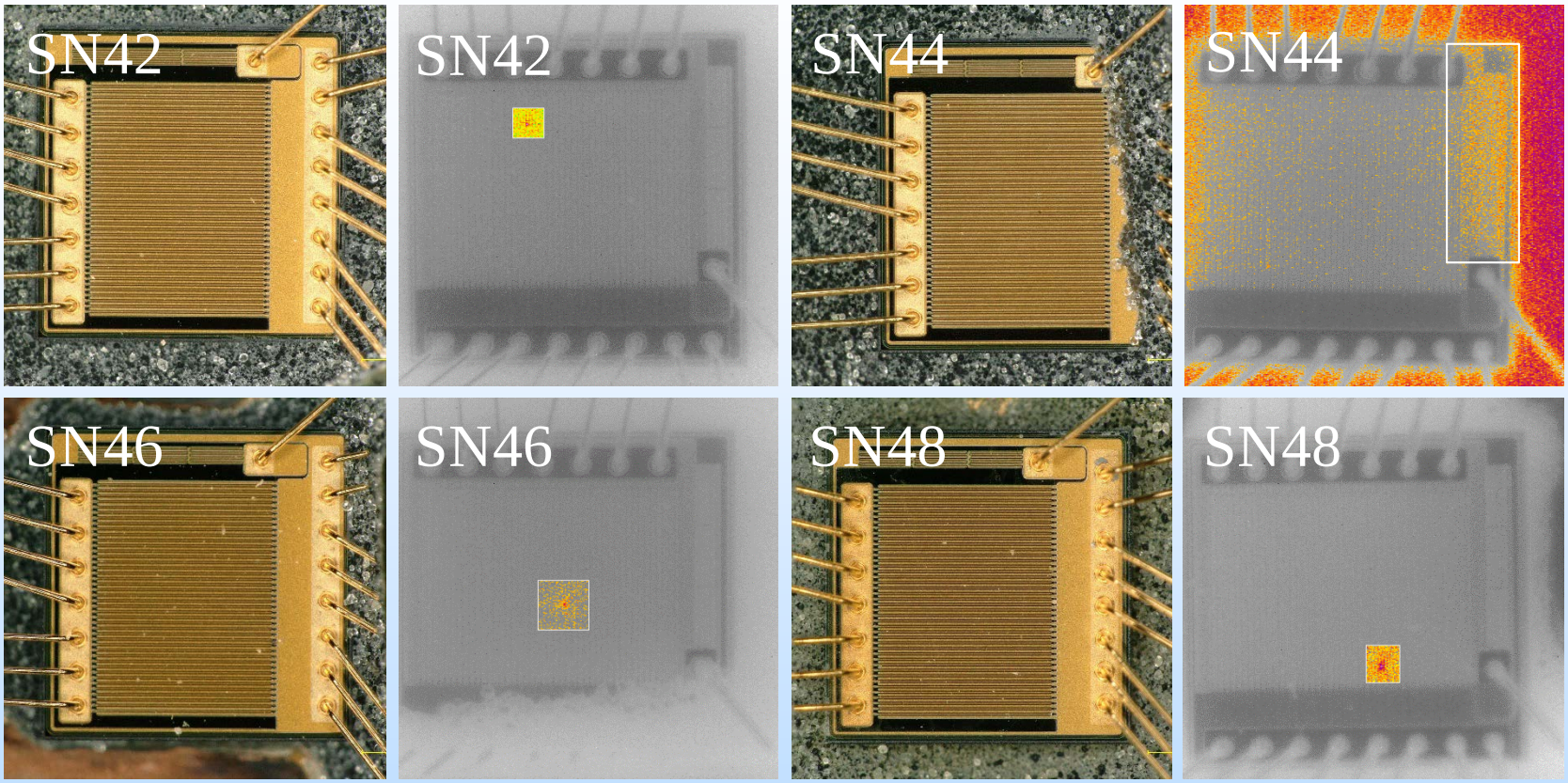
Deeper ion penetration decreases Vsee

Heavy Ion Testing



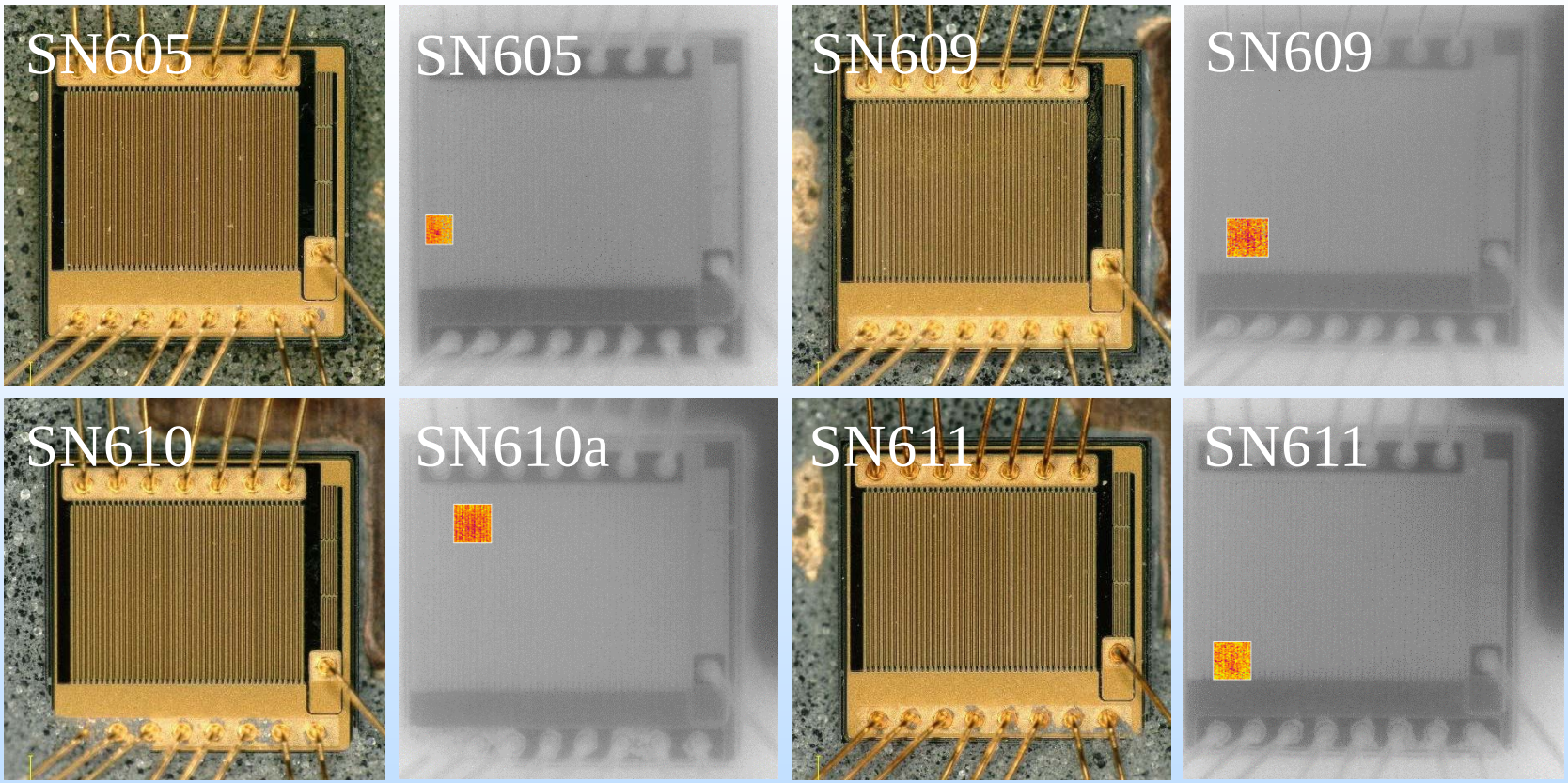
Gate-to-source voltage has no effect on Vsee

Optical and Infrared Images with Hot Spots



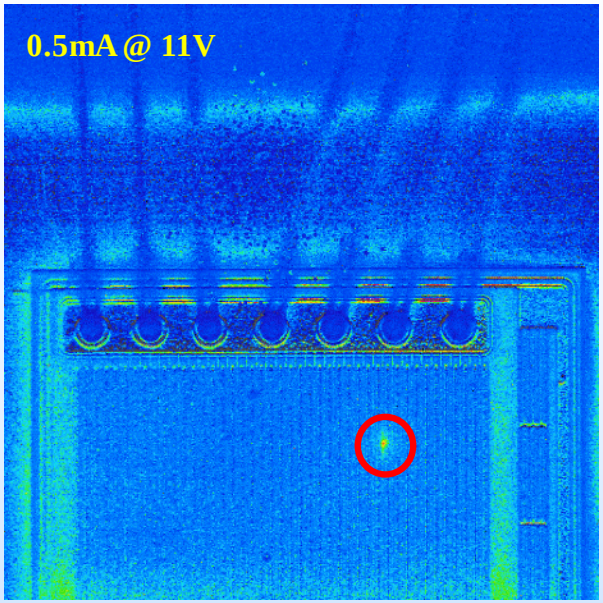
- **Hot spot in boxed region**

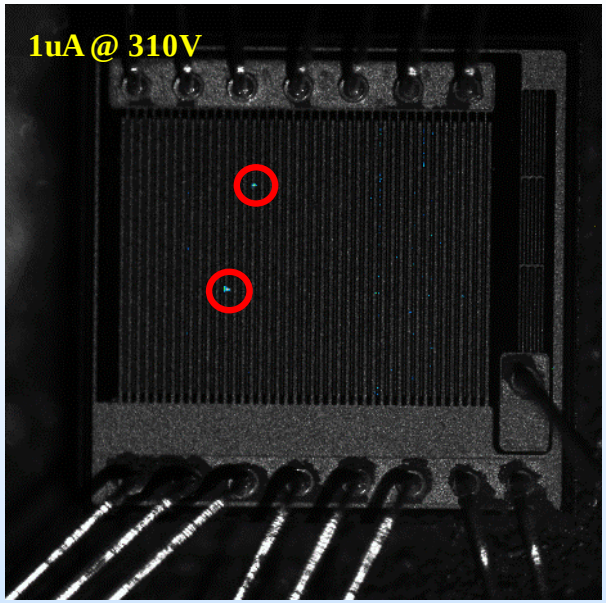
Optical and Infrared Images with Hot Spots

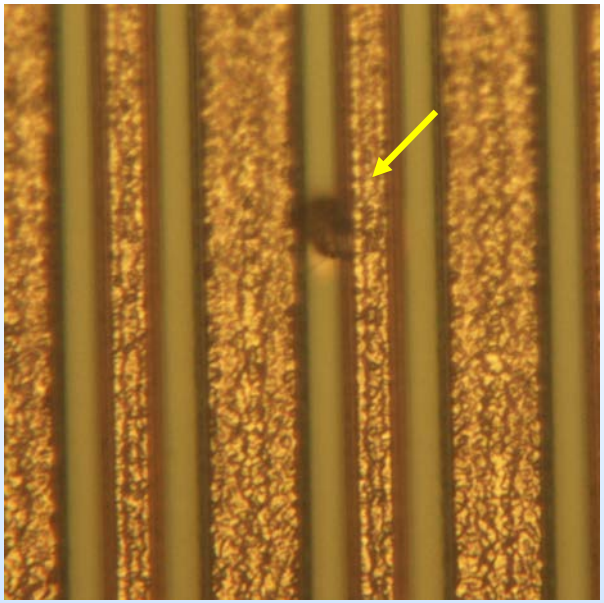


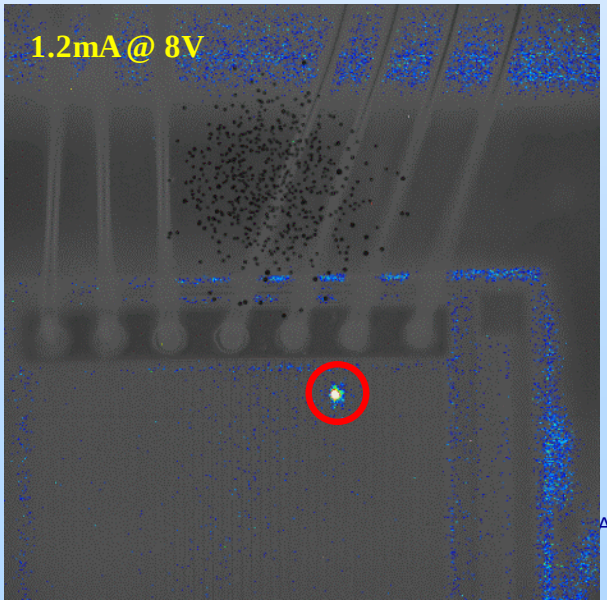
- **Hot spot in boxed region**

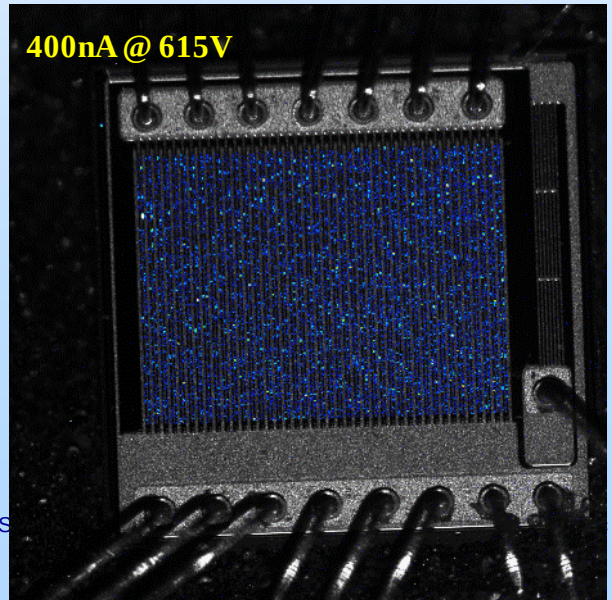
Failed Die Analysis

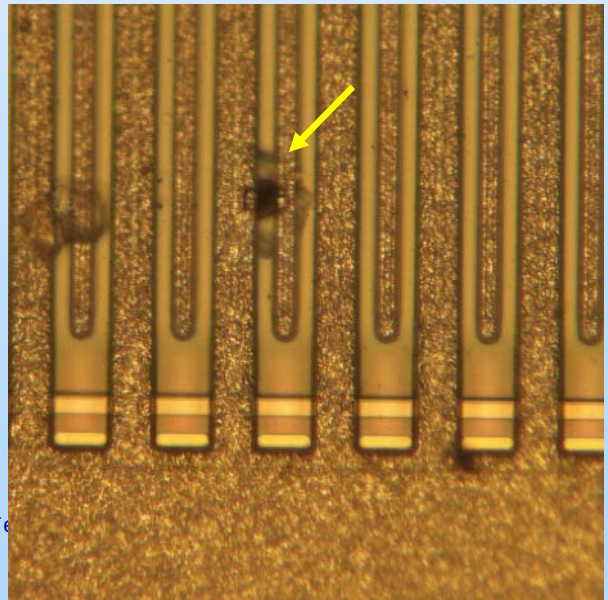






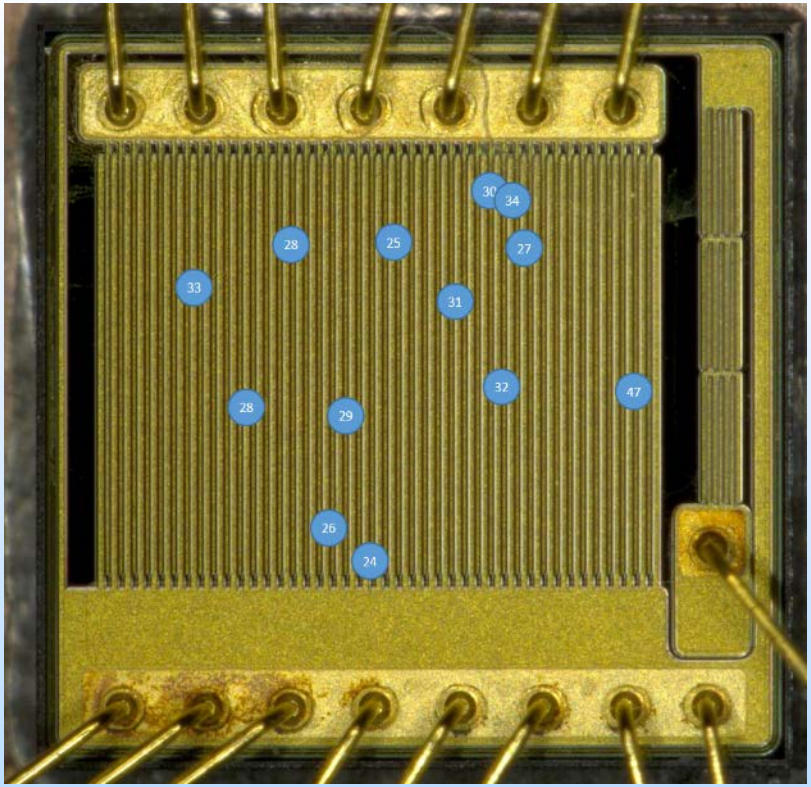






SEE population

- SEE on this devices are very telling
- They all occur on the gate
- It appears that all are on the drain side although damage is quite large
- Randomly dispersed



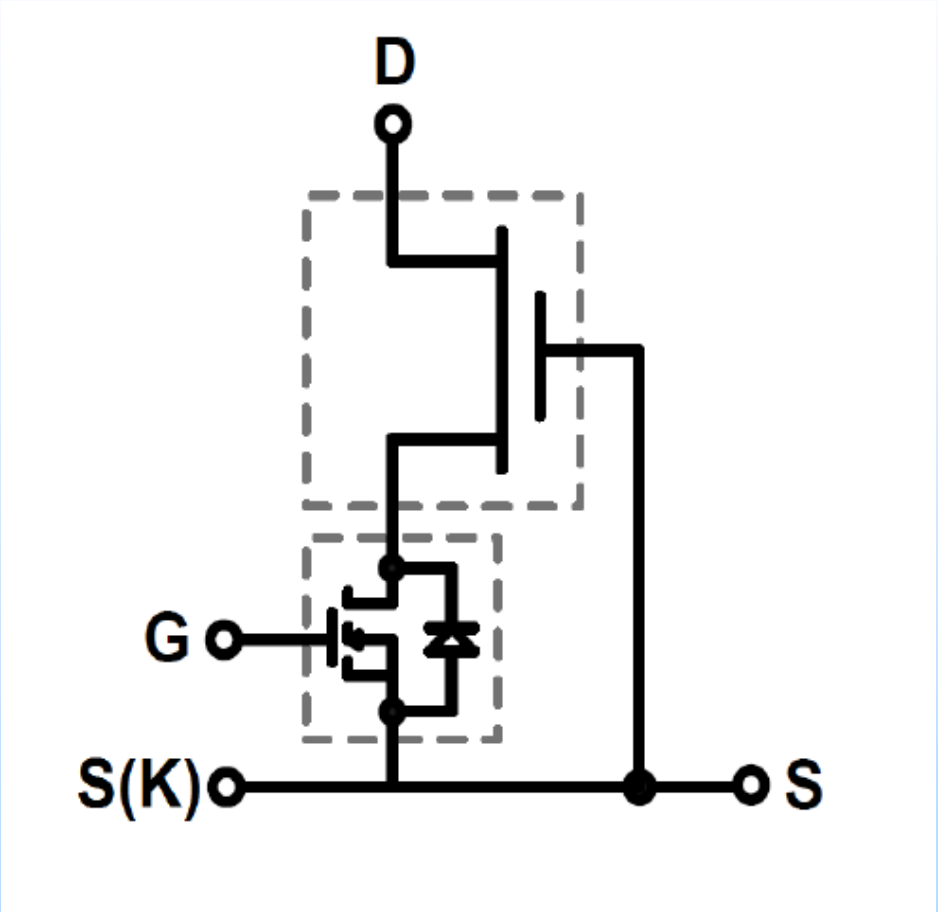
TPH3208 and TPH3202

TESTING OF TRANSPHORM CASCODE HYBRIDS

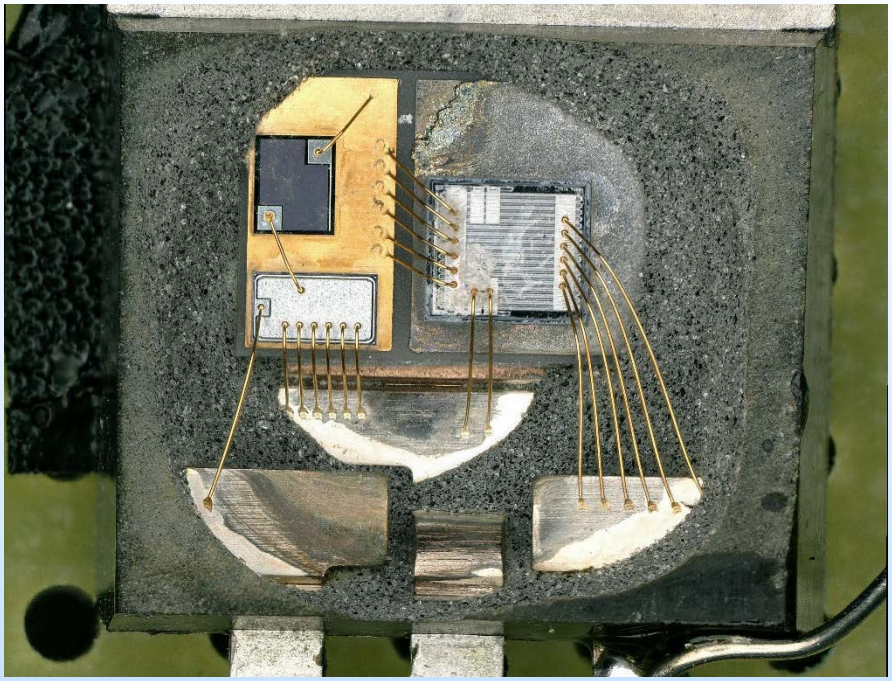
To be presented at the 8th NASA Electronic Parts and Packaging (NEPP) Program Electronic Technology Workshop June 26, 2017, NASA GSFC, Greenbelt, MD.

Cascode Hybrids

- Cascode configuration allows for a depletion mode HEMT (Vth<0 V) to emulate an enhancement mode FET (Vth> 0V)
- Advantages are high gain, high bandwidth, high slew rate, high stability, and high input impedance
- Disadvantage is being a hybrid the device may be hard to assure

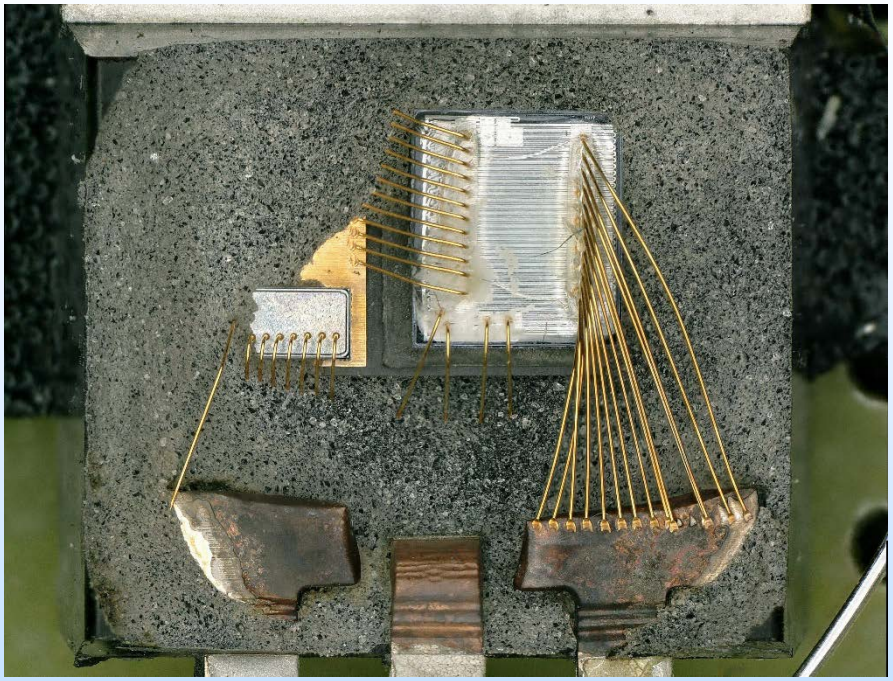


Optical Images



TPS3202

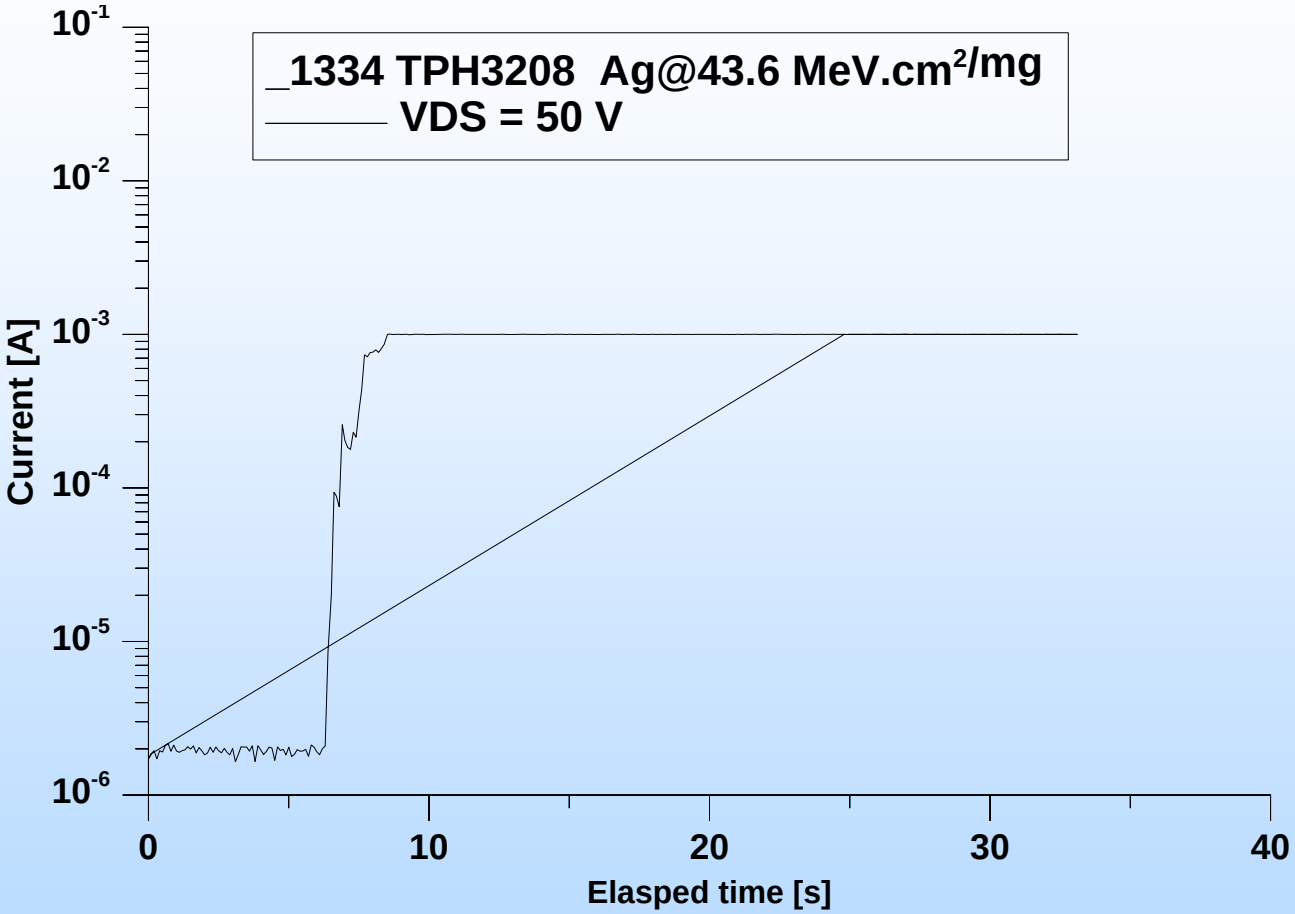
Gate Source Drain



TPH3208

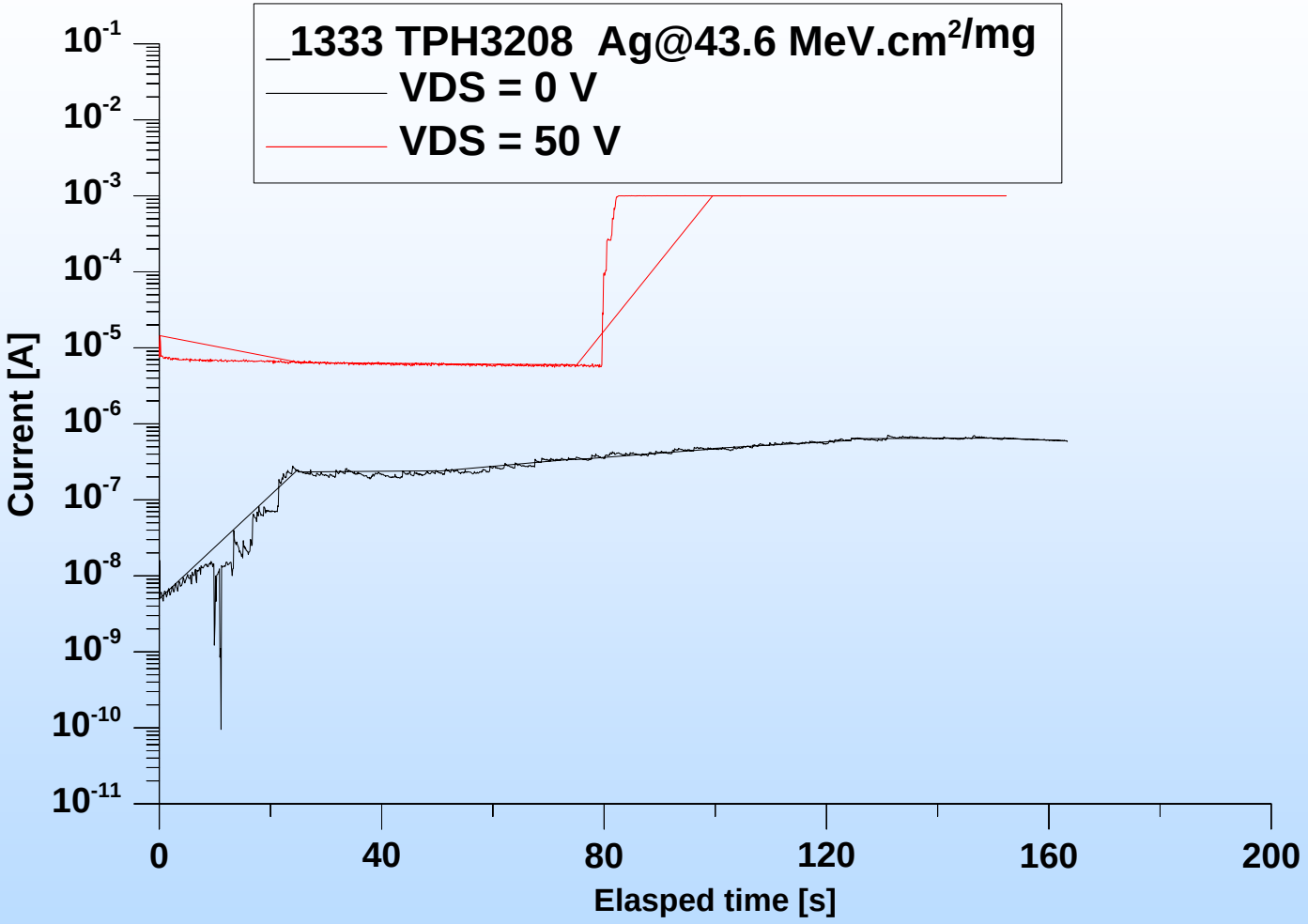
Gate Source Drain

Heavy Ion Testing



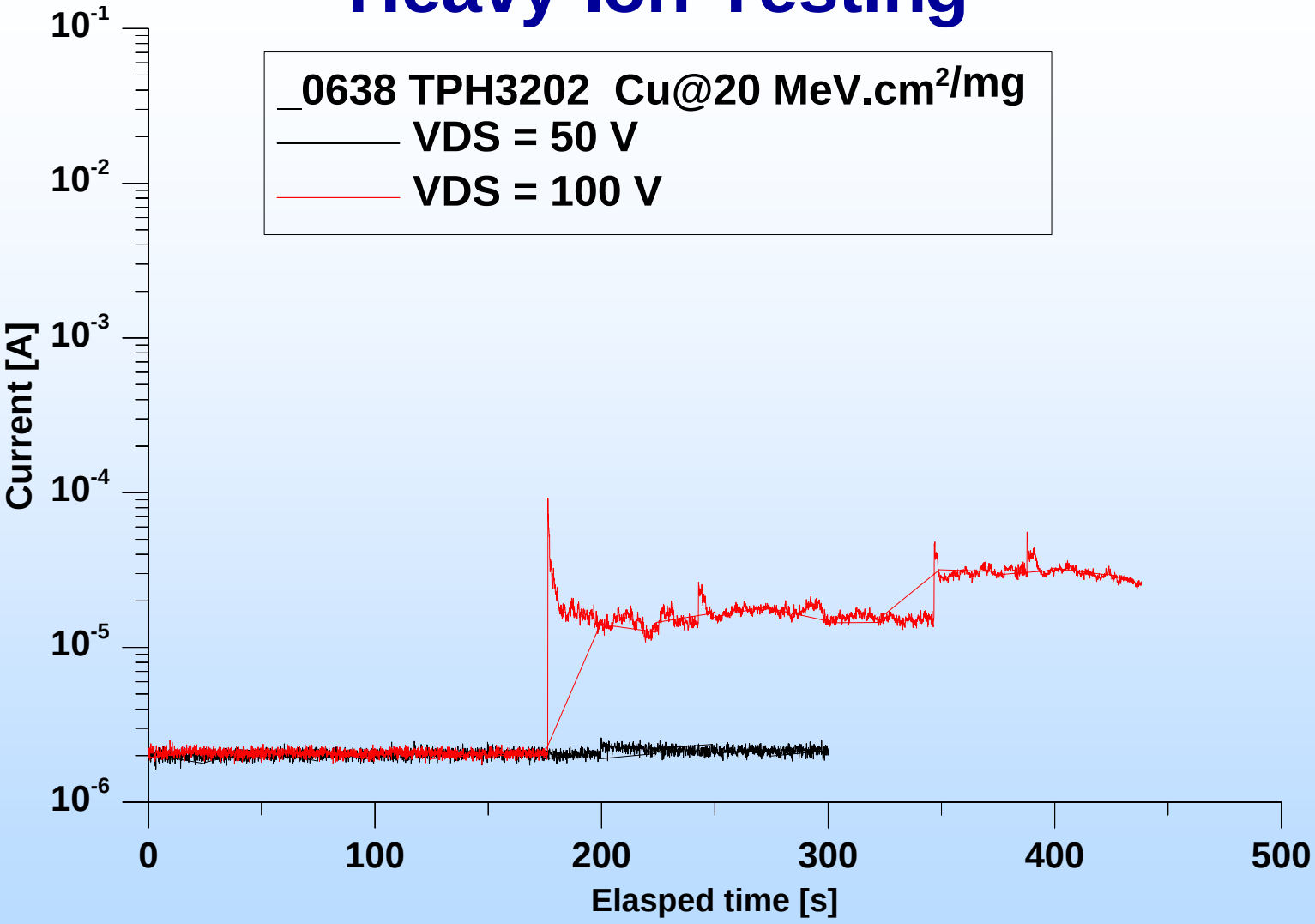
These devices are very soft to ion damage

Heavy Ion Testing



Ions cause damage when unbiased

Heavy Ion Testing



No incremental damage was seen

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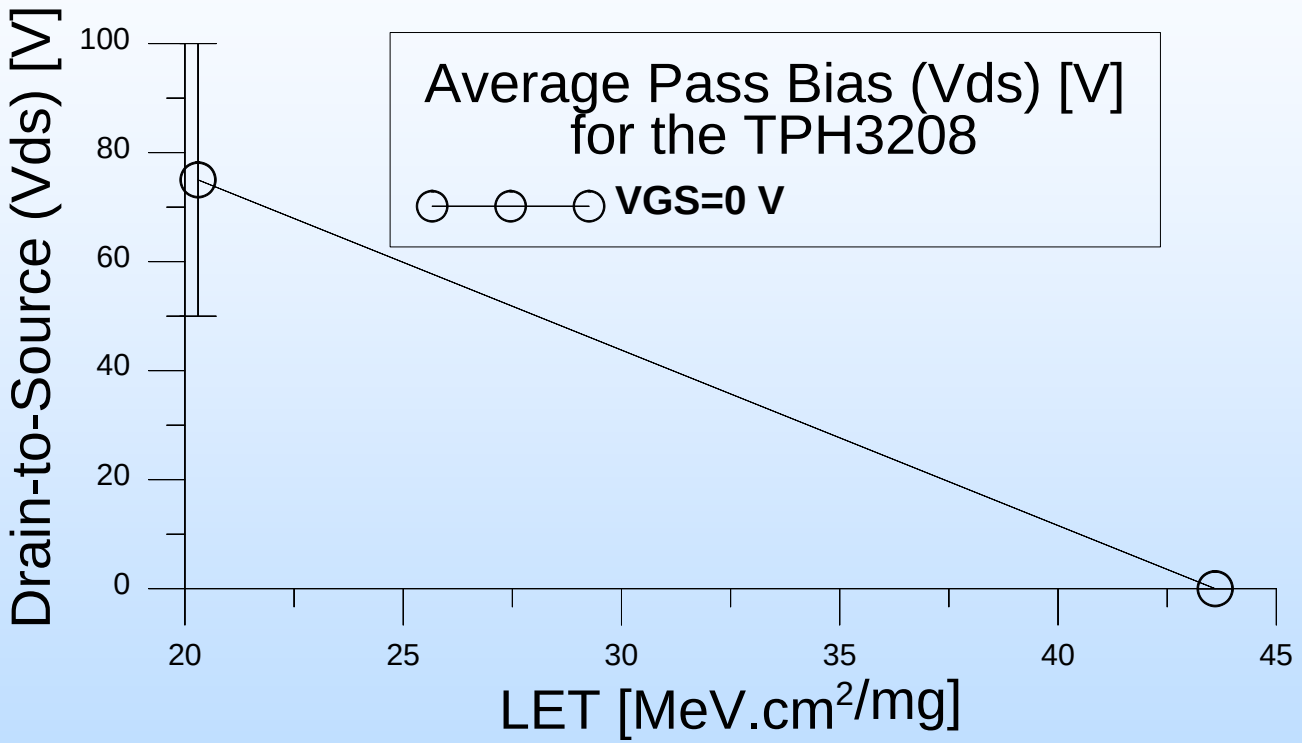
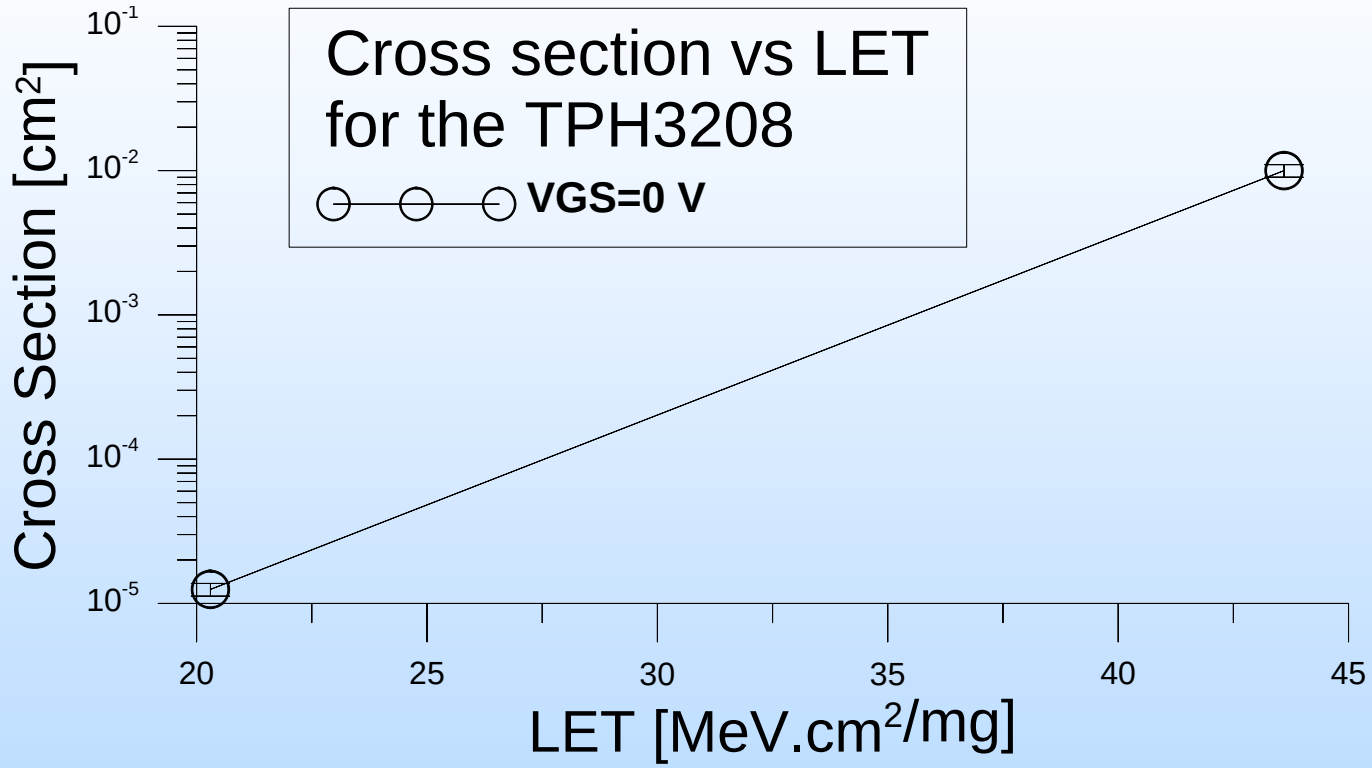
V_{SEE} as a function of LET



Vsee is essentially 0 V due to ion incremental damage

Cross-section as a function of LET



Cross-section is dependent on LET

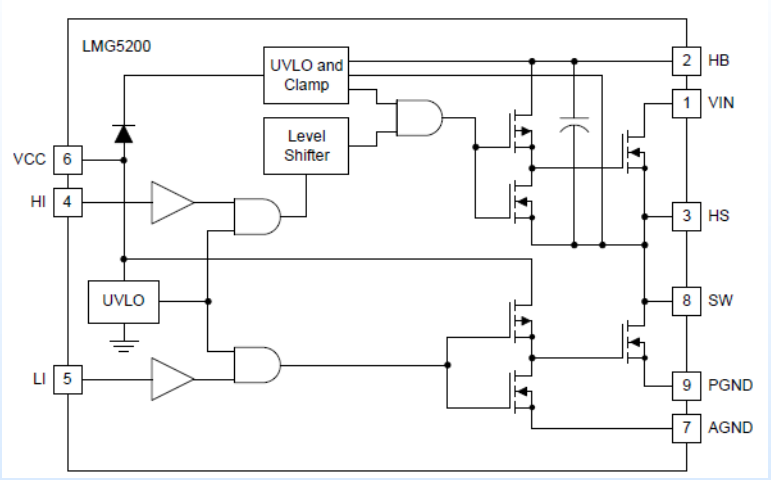
LMG5200

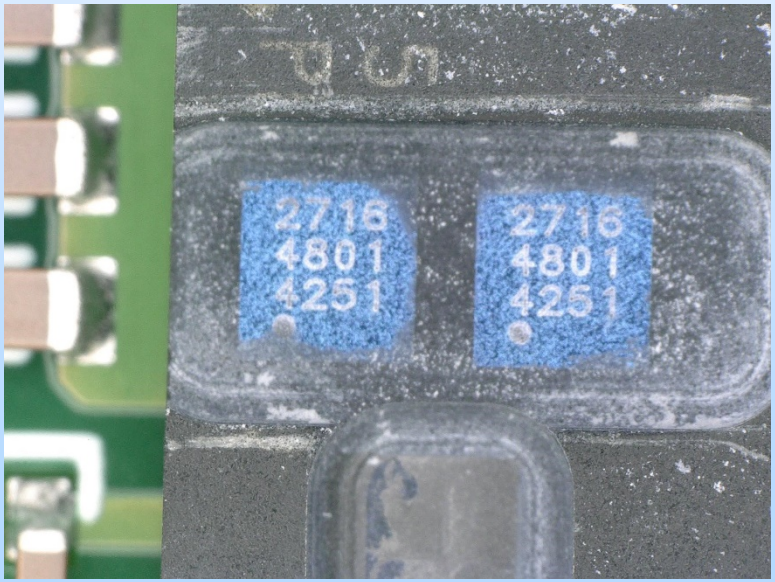
TESTING OF TI HYBRID POWER CONVERTER

To be presented at the 8th NASA Electronic Parts and Packaging (NEPP) Program Electronic Technology Workshop June 26, 2017, NASA GSFC, Greenbelt, MD.

LMG5200

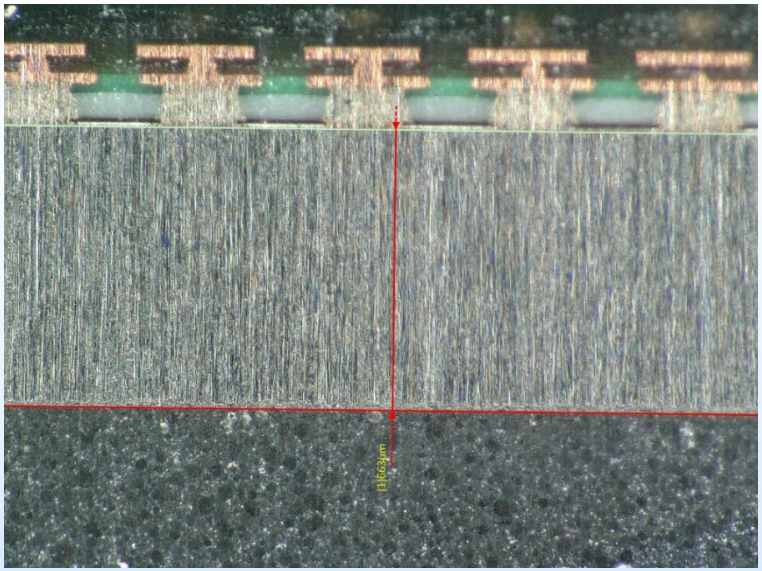
- **Texas Instrument's LMG2500 is a Half-Bridge Power Stage**
- **Needs a PWM on the inputs to operate at a power converter**
- **Use two 80V enhancement mode GaN HEMTs for switches**

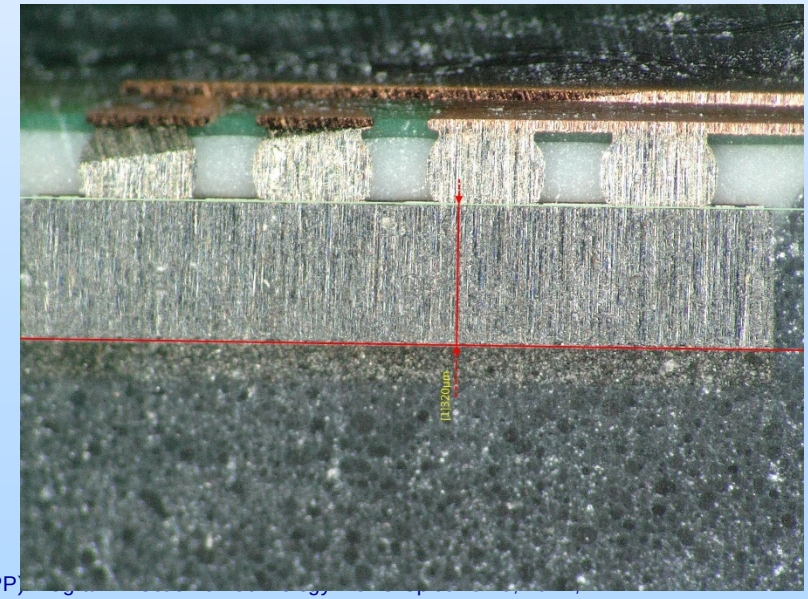




LMG5200

- GaN HEMTs had to be milled down for ion penetration
- SEB type failure seen with Kr at 36.3 MeV-cm^2/mg with Vin > 70 V
- SET on the gate maybe the cause
- Piece-part testing is planned

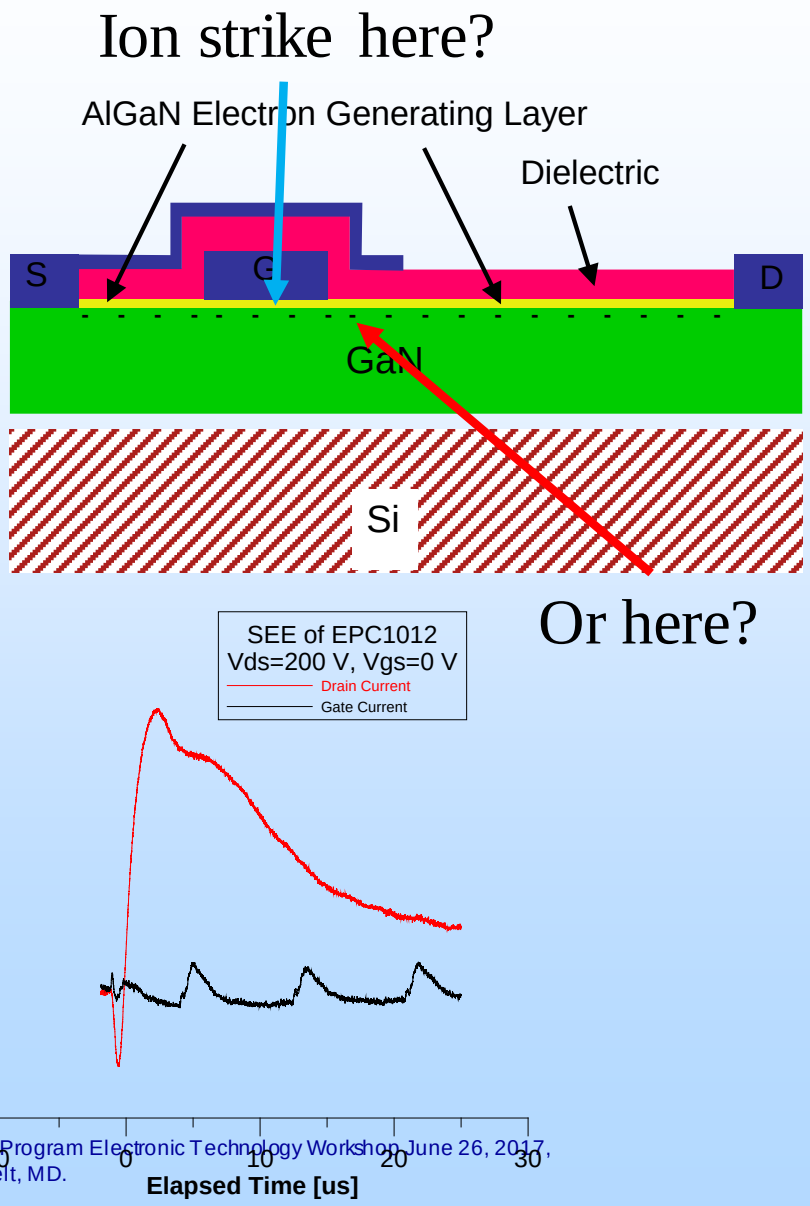




FUTURE WORK

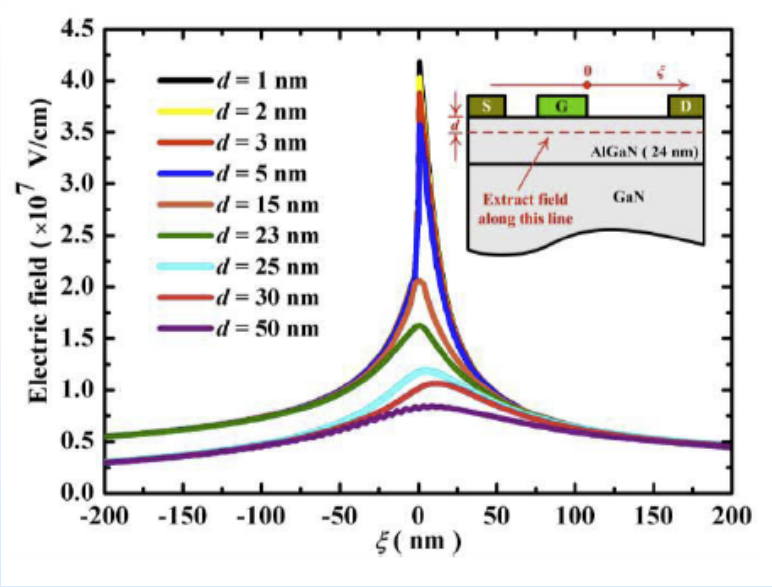
SEE Mechanism

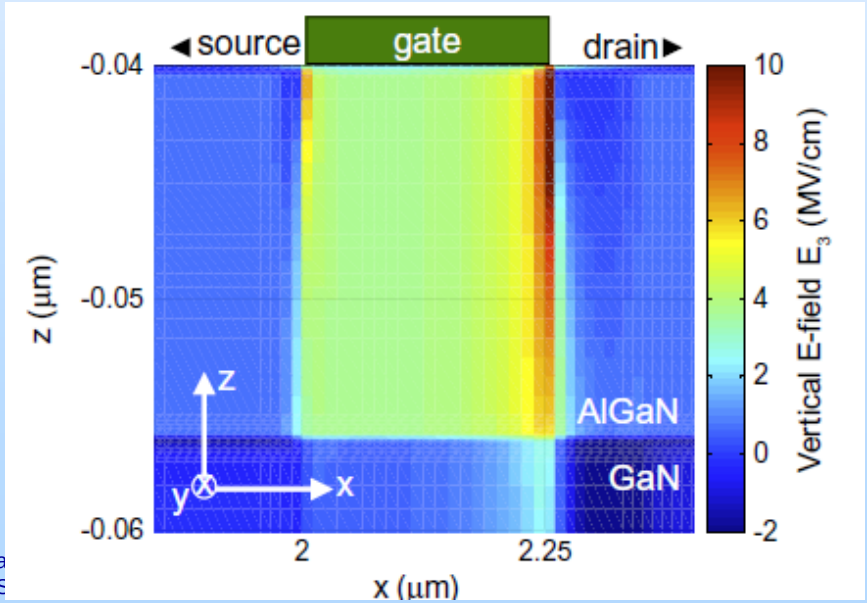
- **Since this effect is voltage dependent, we look to the spot with the largest electric field**
- **This is under the drain side of the gate**
- **A gate transient occur before an SEE**



SEE Mechanism

- The electric field magnitude extends into the GaN substrate
- Very narrow region of very high field
- Resulting strain on junction will make it easier to have SEE





More testing

- **Panasonic parts**
  - **Best vehicle for mechanism investigation**
- **Transphorm**
  - **They are so soft, may also yield mechanism clue**
- **TI parts**
  - **TPS53632G and LMG3410 are on deck for SEE**
- **Freebird Semi**
  - **Resping of EPC product line – include higher voltage parts – worth another look**

Conclusion

- **SEE in GaN HEMTs are complex**
  - **Mechanisms and underlying device physics are still under study**
- **New devices show similar effects**
  - **Panasonic parts seem more robust**
  - **Transphorm devices show that GaN can be very soft and there is no natural low voltage threshold**
- **Future plans**
  - **Body of Knowledge document with GRC**
  - **Testing guideline in works**
  - **Collaborate with NASA flight projects and external customers**