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

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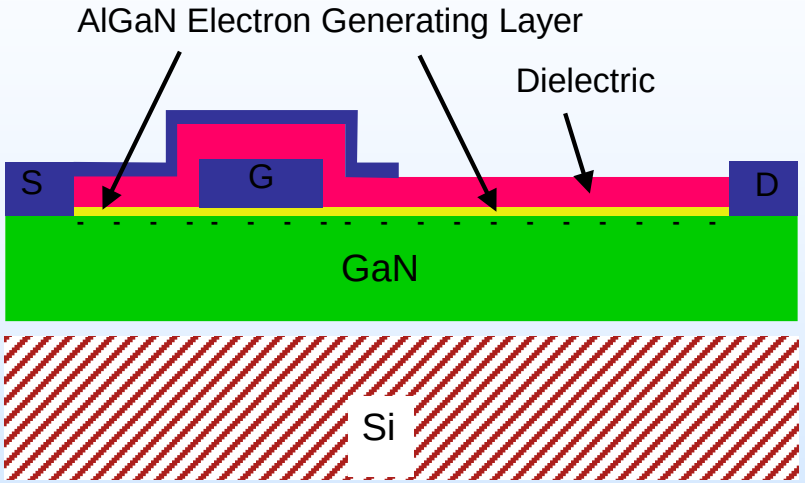
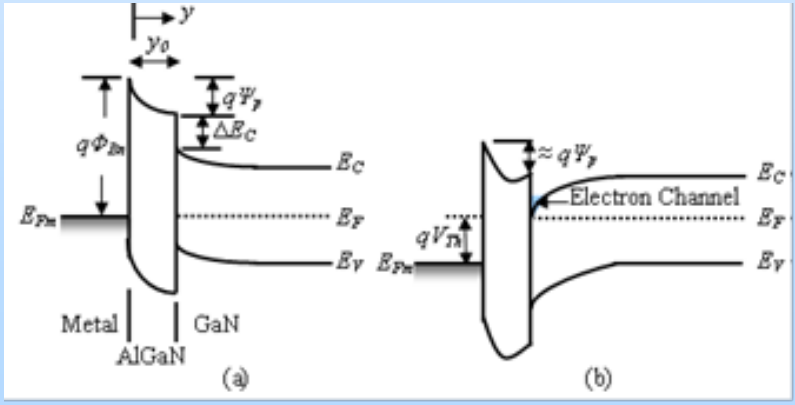
Current activities

- **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

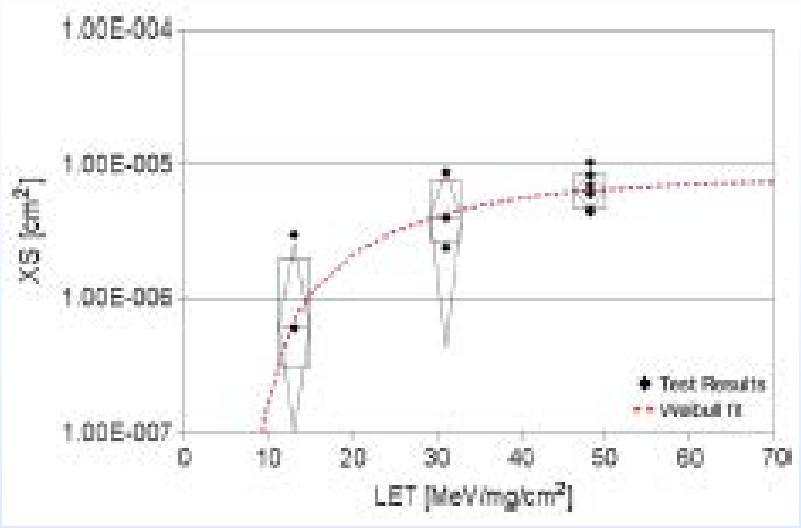
- **Current silicon power solutions are at their innate limits for space applications**
  - **Silicon devices are at efficiency limit**
  - **Best hi-rel devices are less then ~400 V drain-to-source**
- **GaN devices are becoming available**
  - **Reliability effects are a concern**
  - **Gate stress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



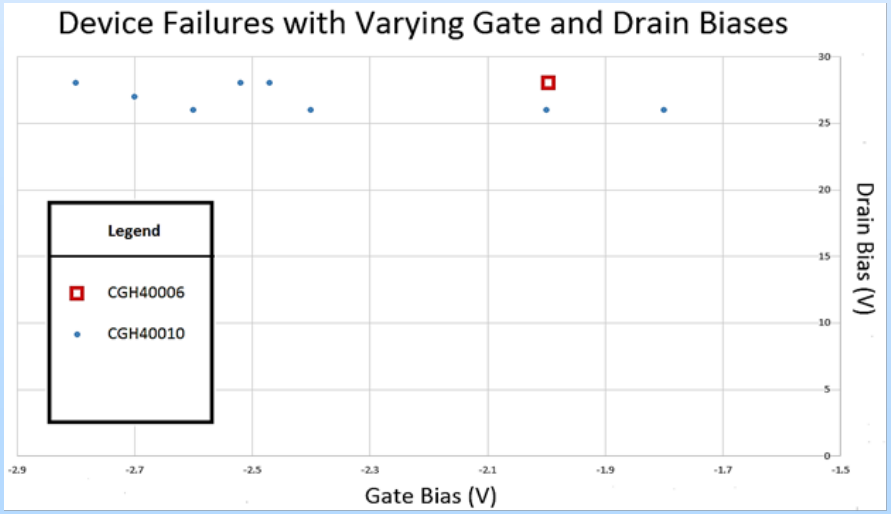


Destructive SEE have been seen in GaN HEMTs- RF GaN

- GaN substrate directly under gate experiences greatest electric field
  - Where 2DEG is reduced
- High electrical stress will exacerbate SEE
- SEE seen in RF devices
  - Tested in amplifier circuits
  - Depletion mode devices

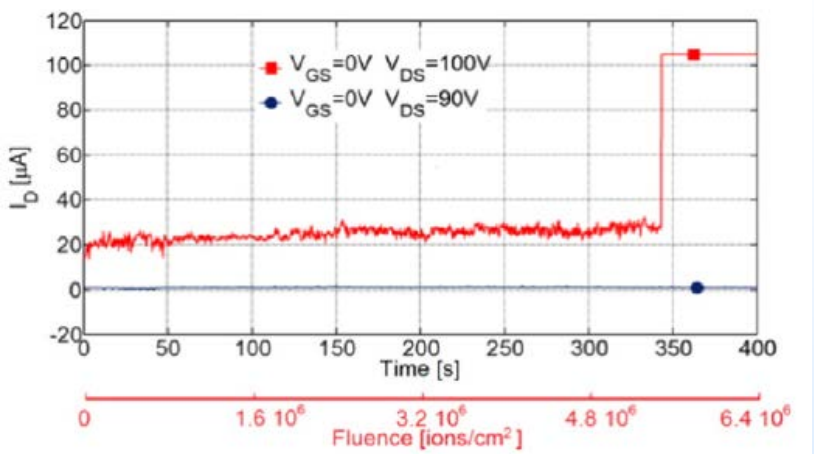


M. Rostewitz / Trans. Nucl. Sci, 2013

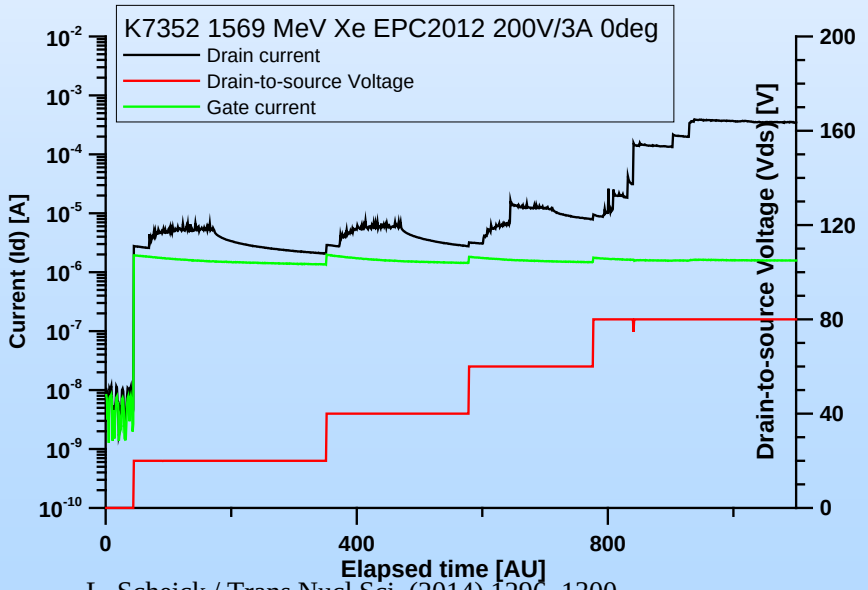


Destructive SEE have been seen in GaN HEMTs- eGaN

- Failure seen in 200 V eGaN from 40 V to 200 V
- A. Lidow et al / Trans. Nucl. Sci, 2014 did not observe
- Process variation or test interaction is suspected
- TID and DD are not issues

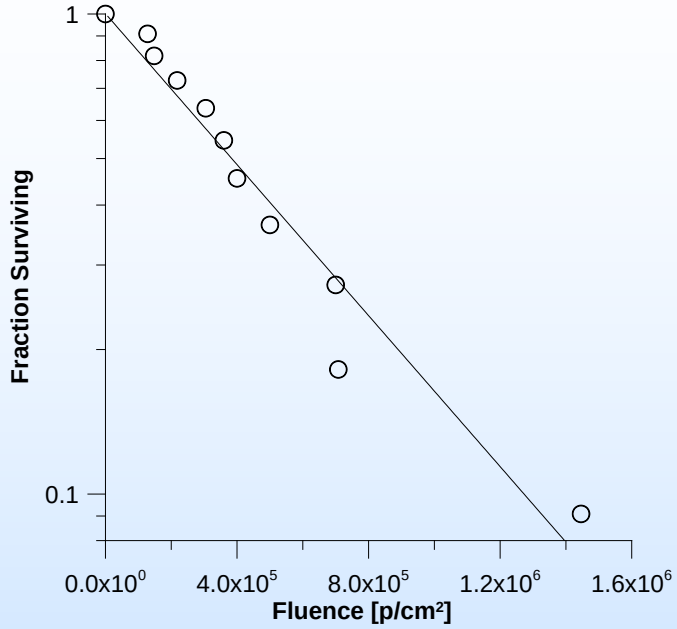


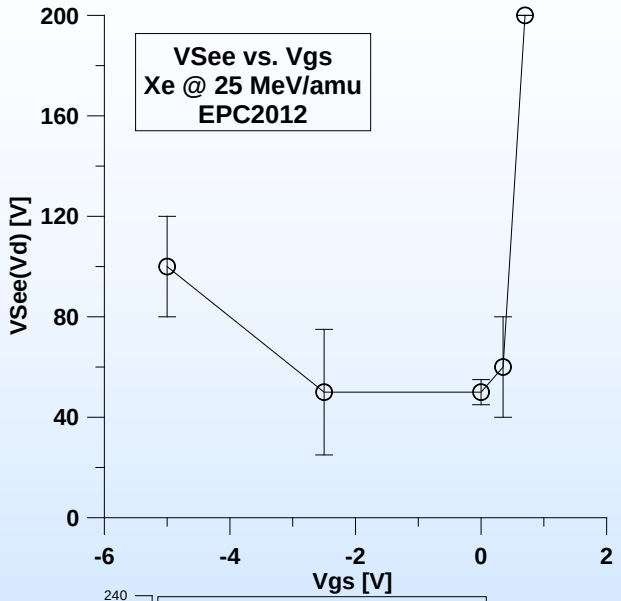
C. Abbate et al. / Microelectronics Reliability 55 (2015) 1496–1500

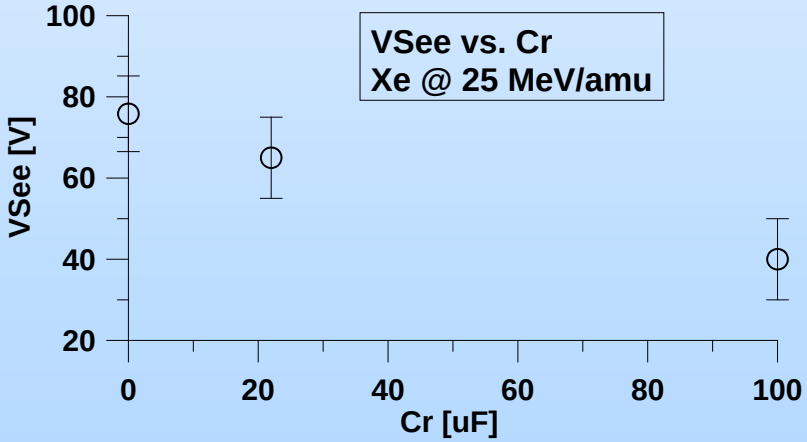


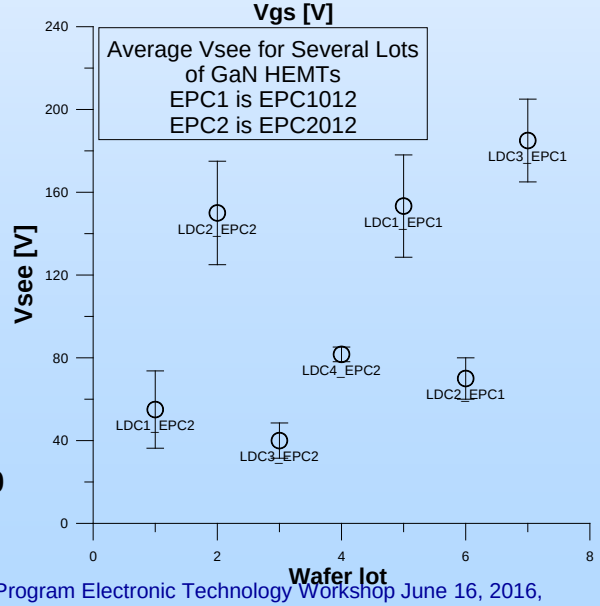
L. Scheick / Trans Nucl Sci (2014) 1296–1300

SEE in GaN are Very Complicated

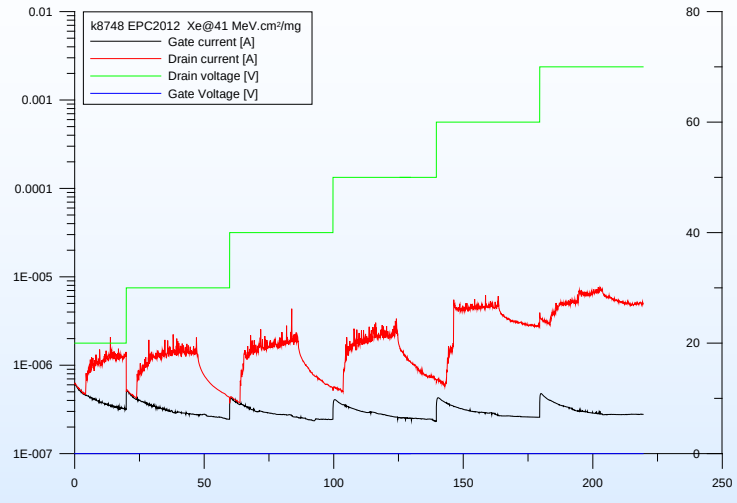


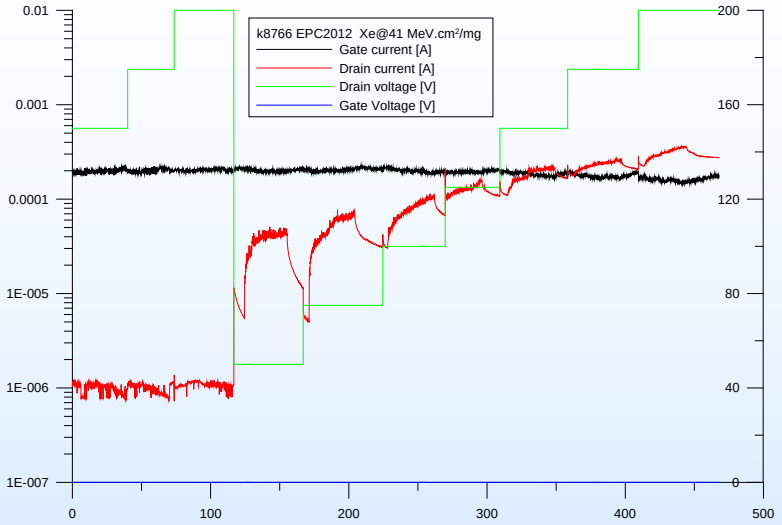






Effect of Test Circuit on V_{SEE}





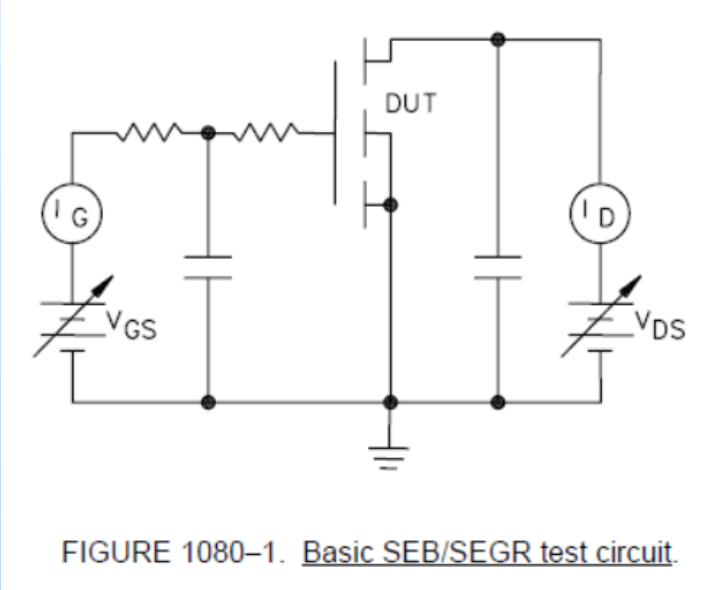


FIGURE 1080–1. Basic SEB/SEGR test circuit.

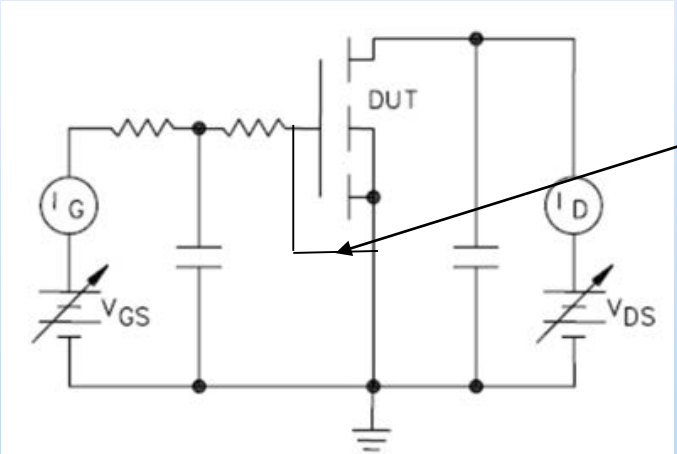
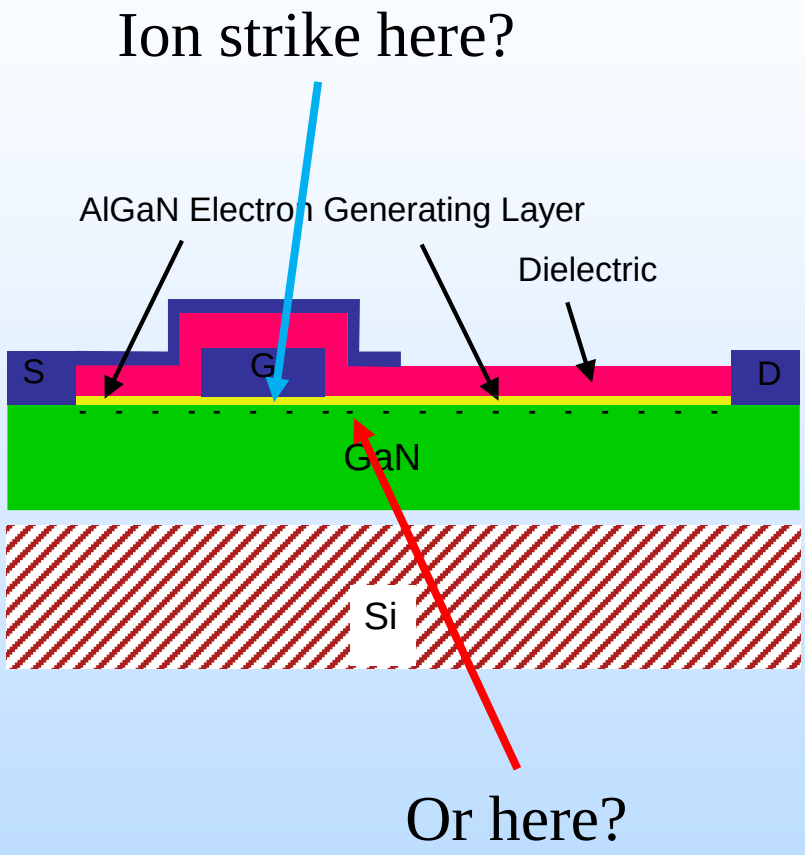


FIGURE 1080–1. Basic SEB/SEGR test circuit.

Shorted gate to source

Work to be done

- **Identification of SEE mechanism**
- **Establishment of SEE operating area**
- **Affect of local circuit on onset of SEE**
  - **Similar to SEB in power**
  - **Parameterization of test circuits**
- **Angular Effects**
  - **Devices are lateral, and some effects have been seen**



PGA26E19BA

TESTING OF PANASONIC PARTS

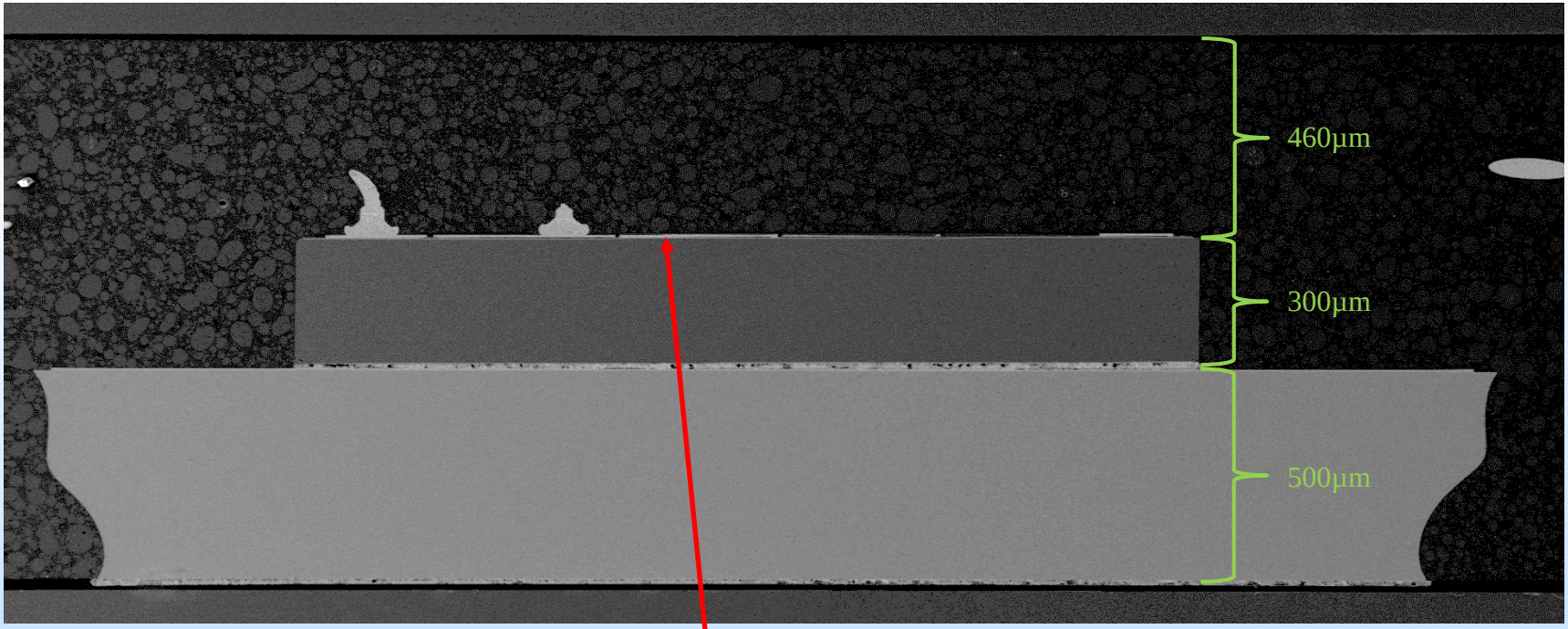
To be presented at the 7th NASA Electronic Parts and Packaging (NEPP) Program Electronic Technology Workshop June 16, 2016, NASA GSFC, Greenbelt, MD.

Optical Images

Front

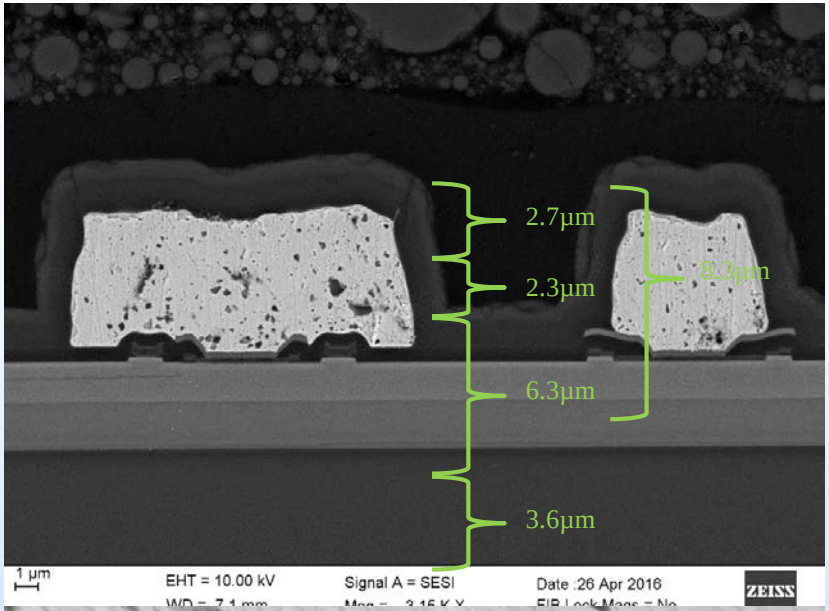
Back

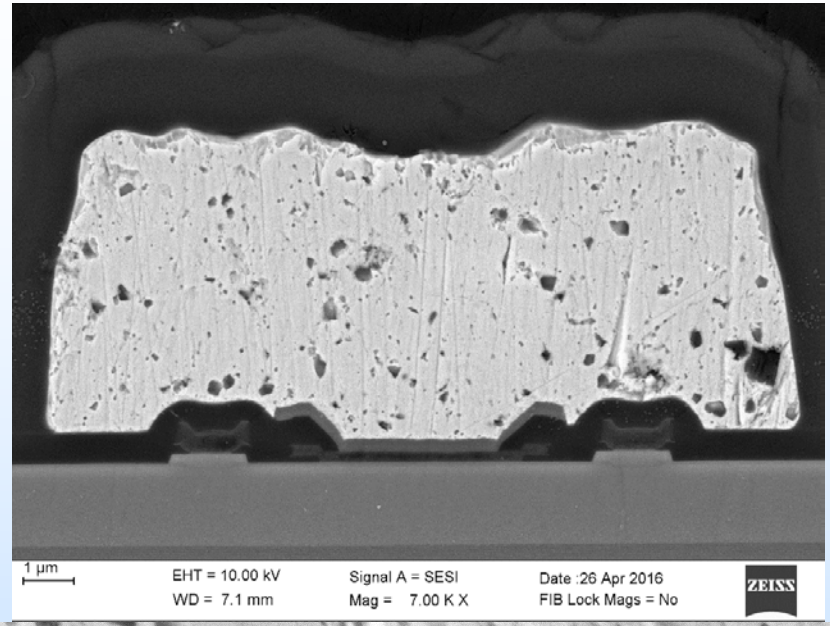
Package Cross Section Overview

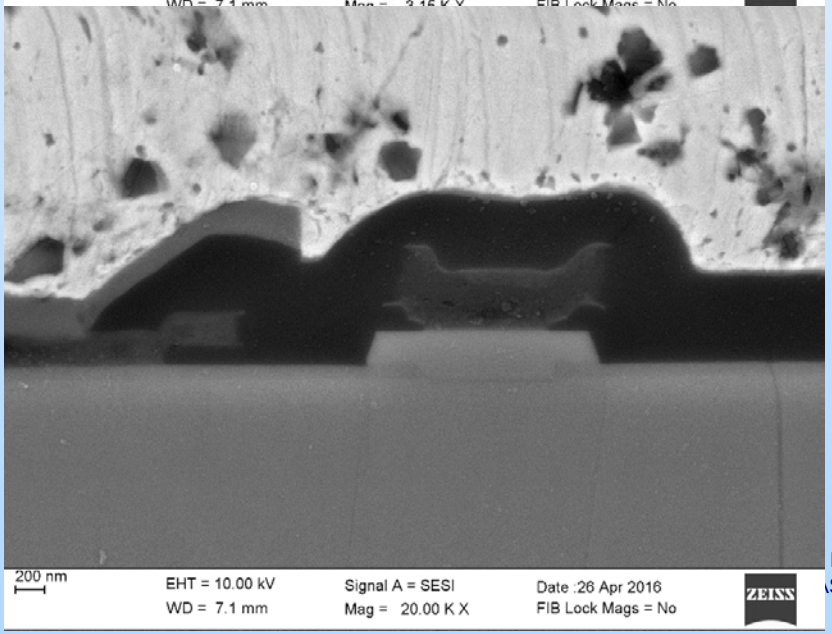


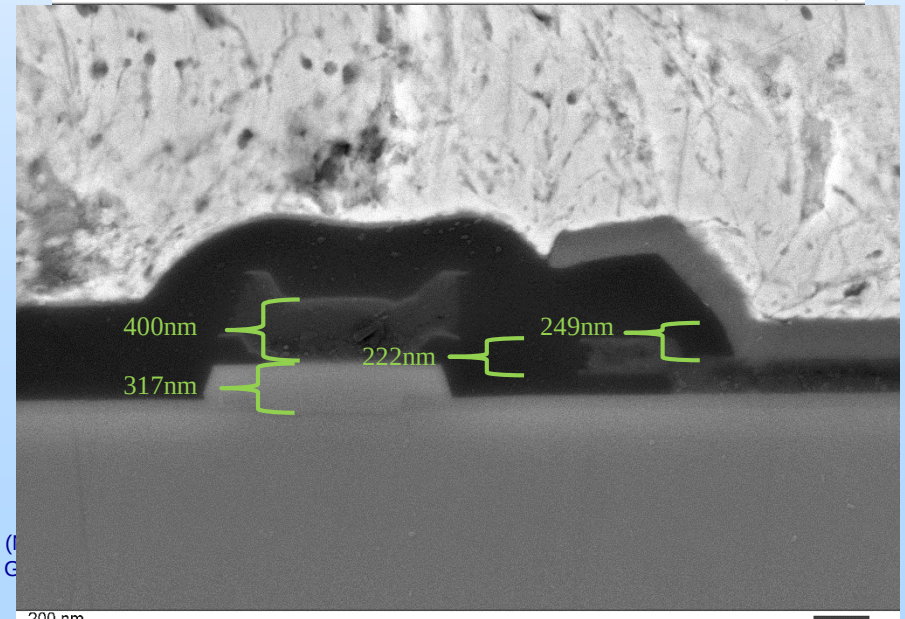
The active region is very thin.

Cross Section Perpendicular to Gate









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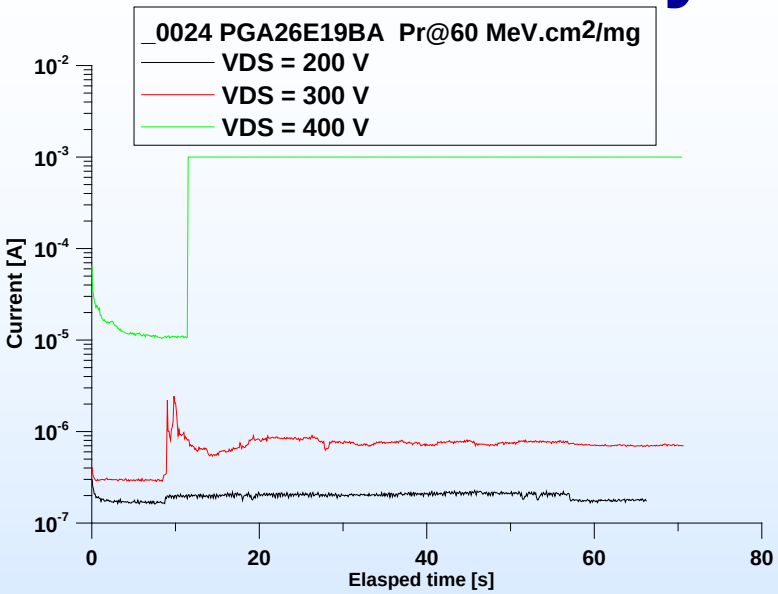
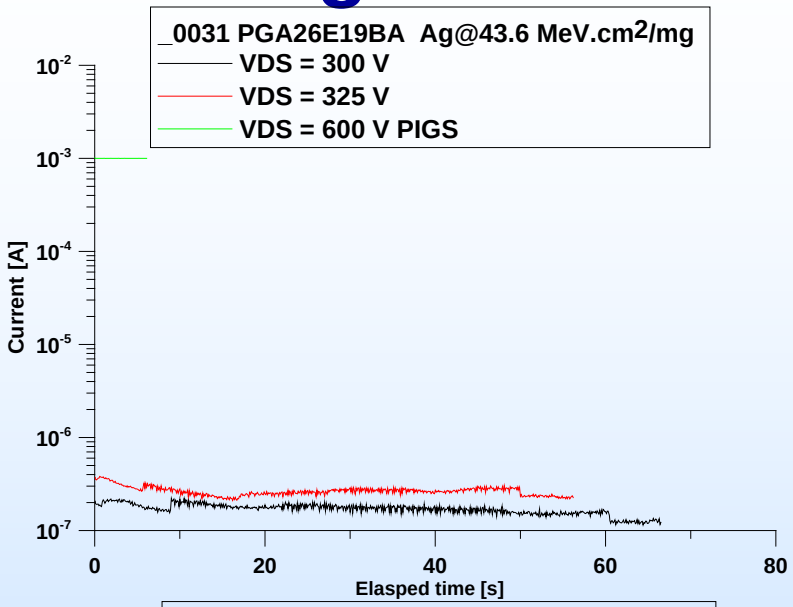
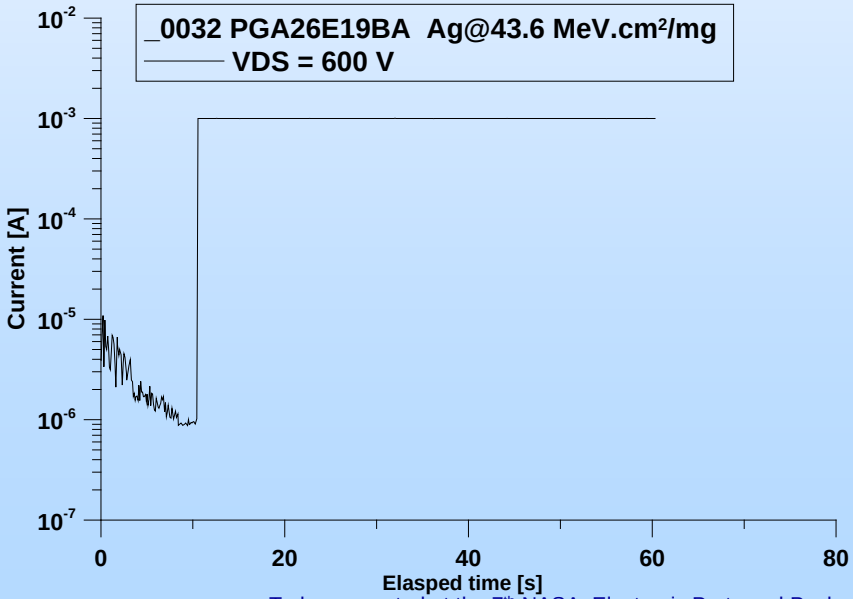
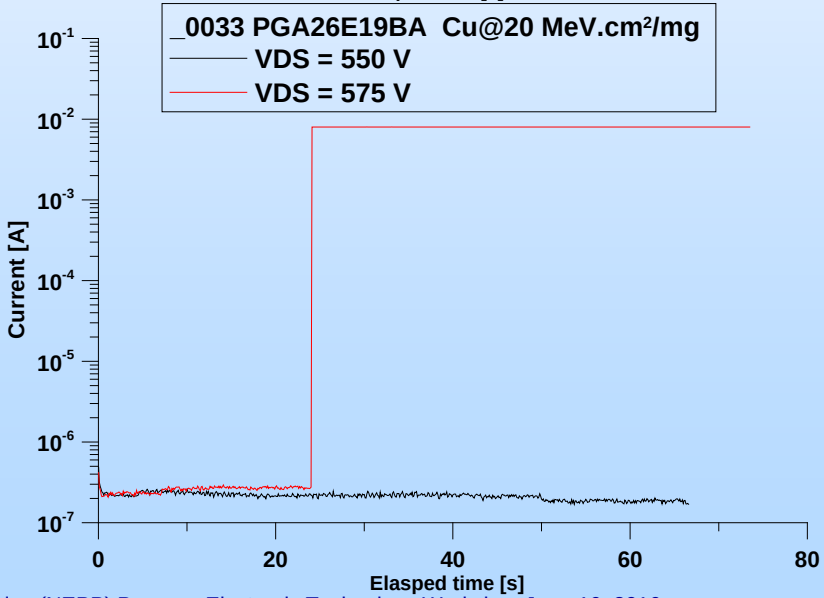
Heavy Ion Testing

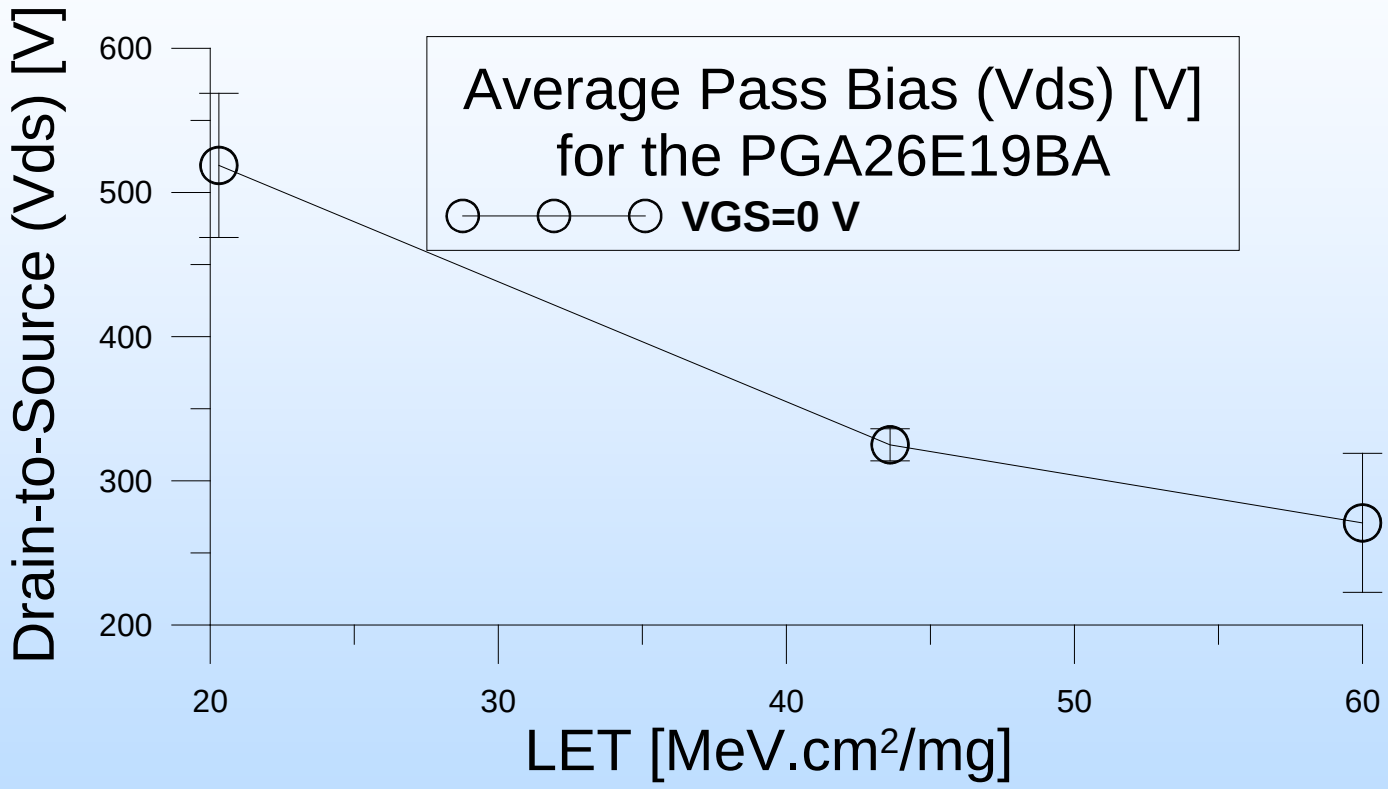






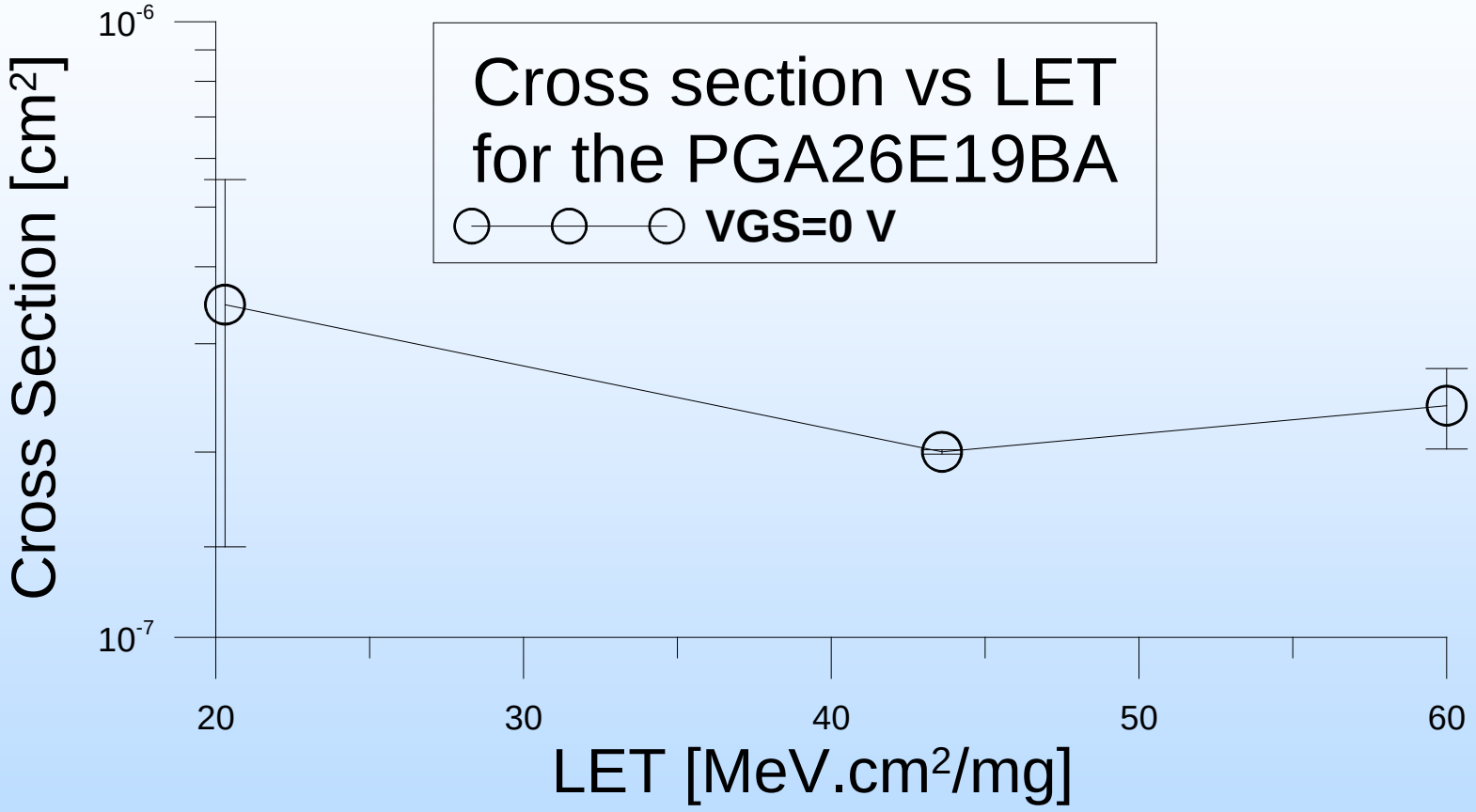


V_{SEE} as a Function of LET



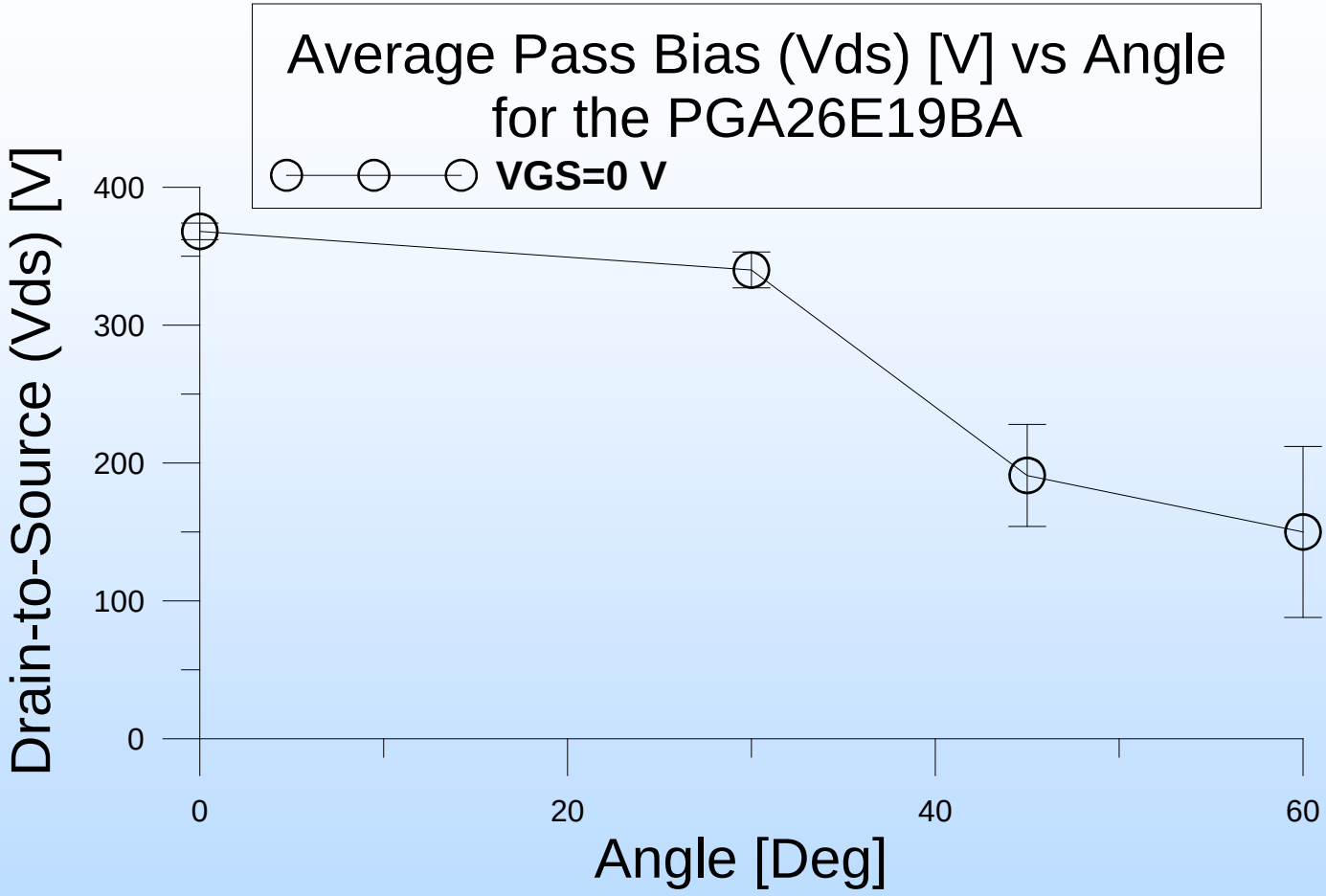
Higher LET results in lower SEE Vds.

Cross-section as a Function of LET



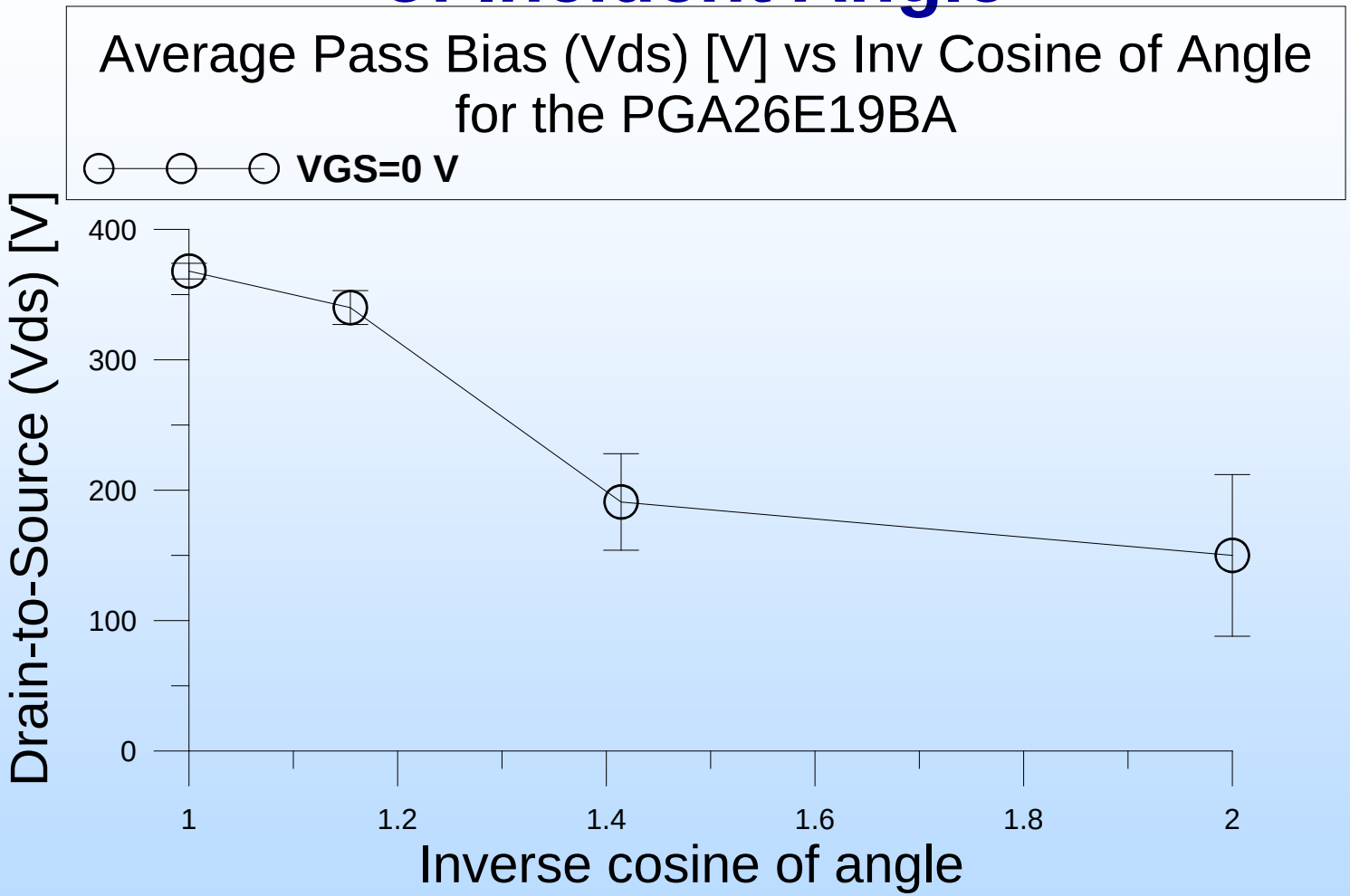
Preliminary: Cross-section not dependent on LET.

VSEE as a Function of Incident Angle



Lateral devices like this HEMT are expected to have an angular dependence.

VSEE as a Function of Inverse Cosine of Incident Angle



SEE Vds has a strong angular response.

GS66516T

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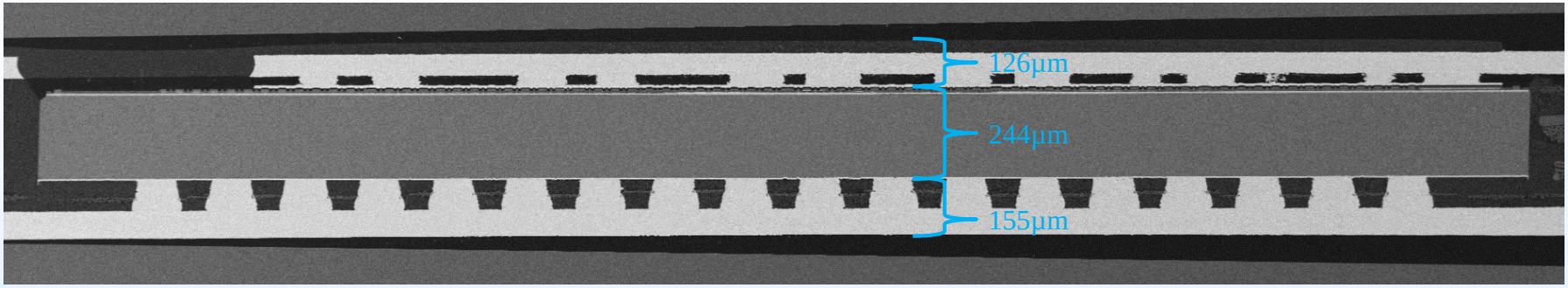
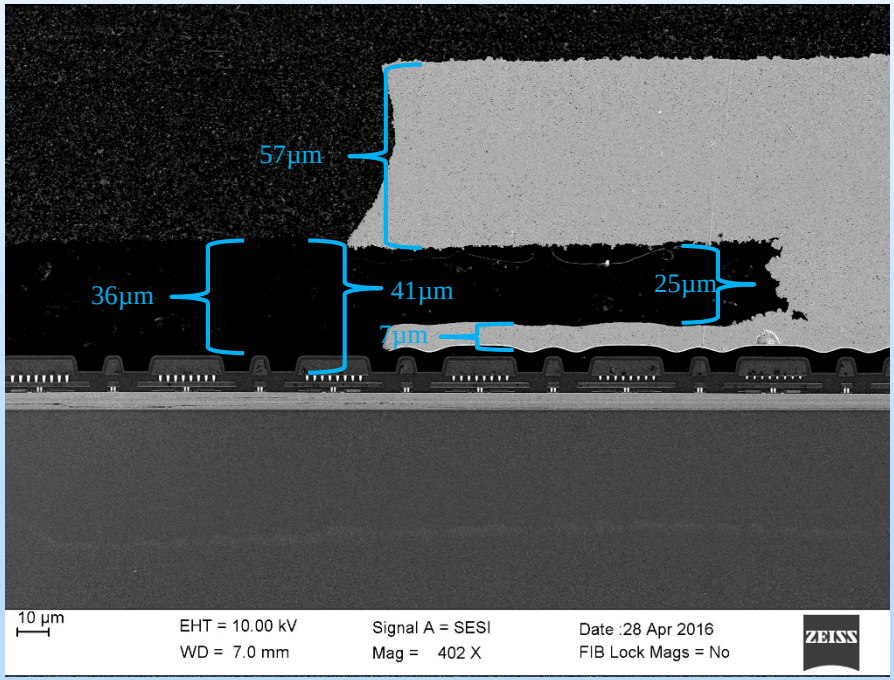
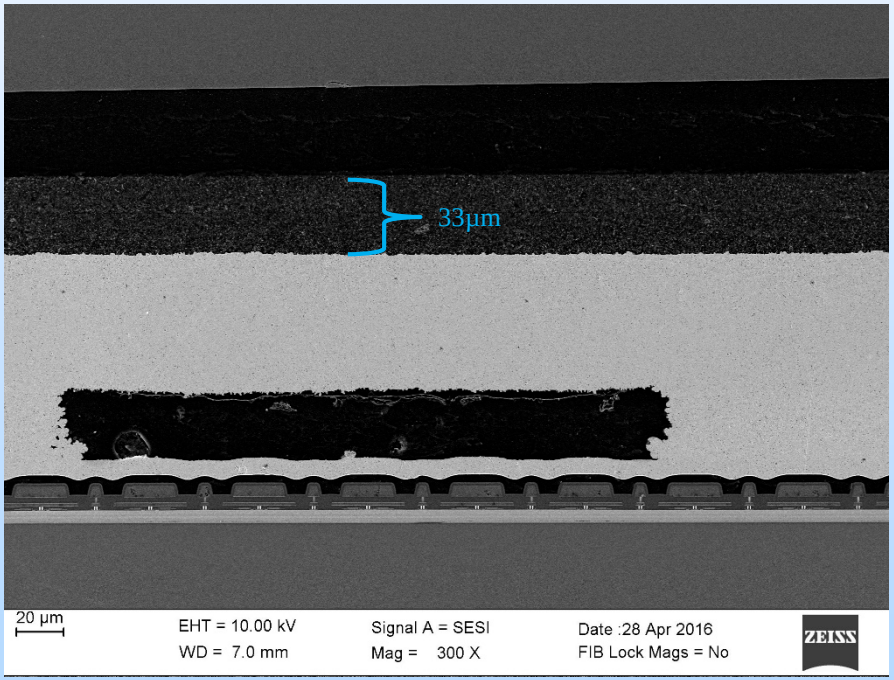
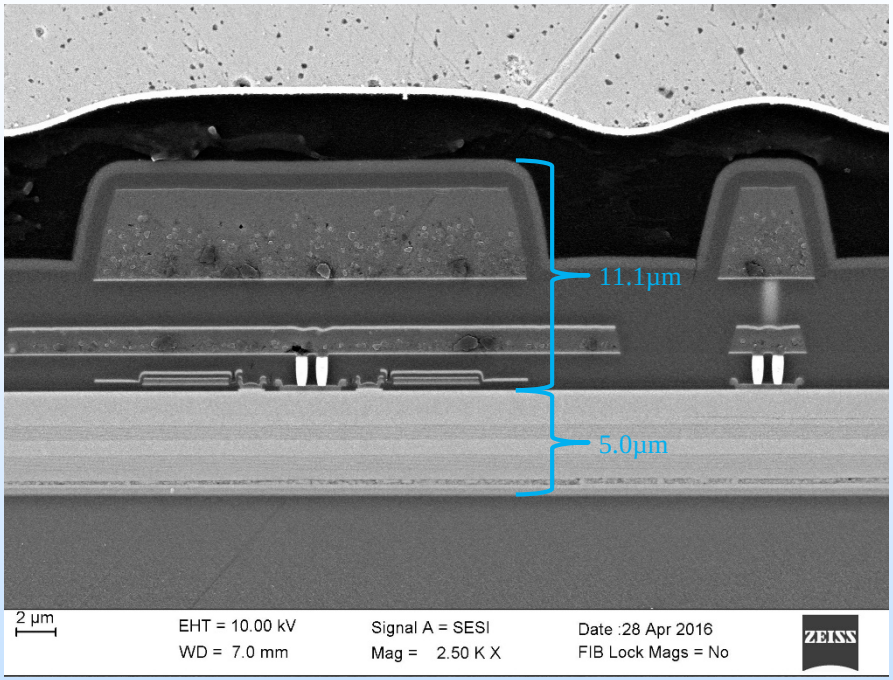


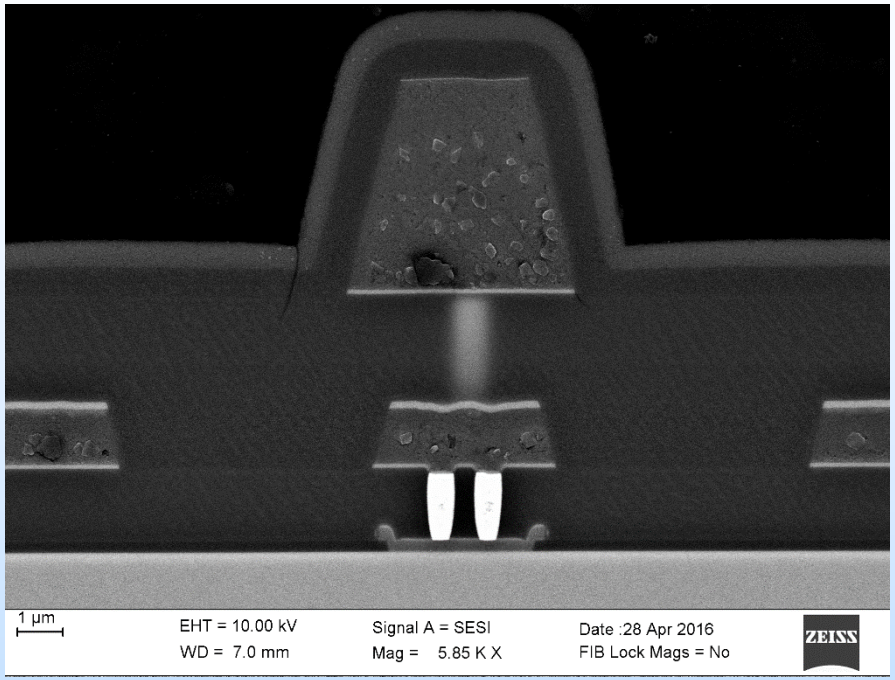




Cross Section Perpendicular to Gate



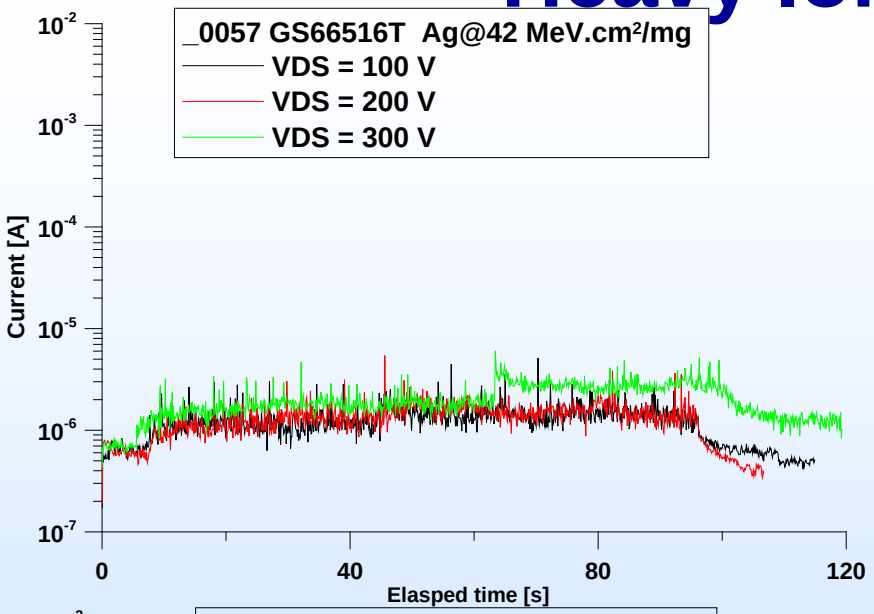
Active contacts and gates

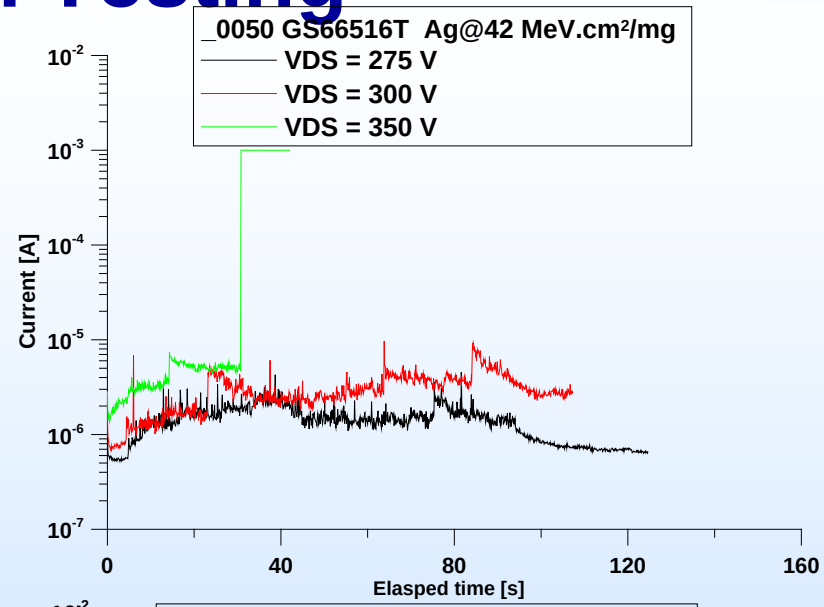


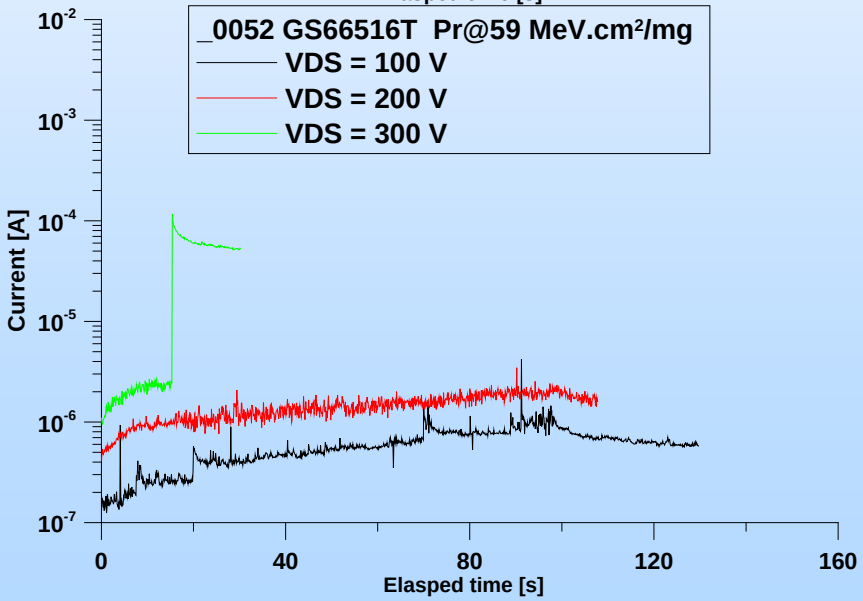
Active contact

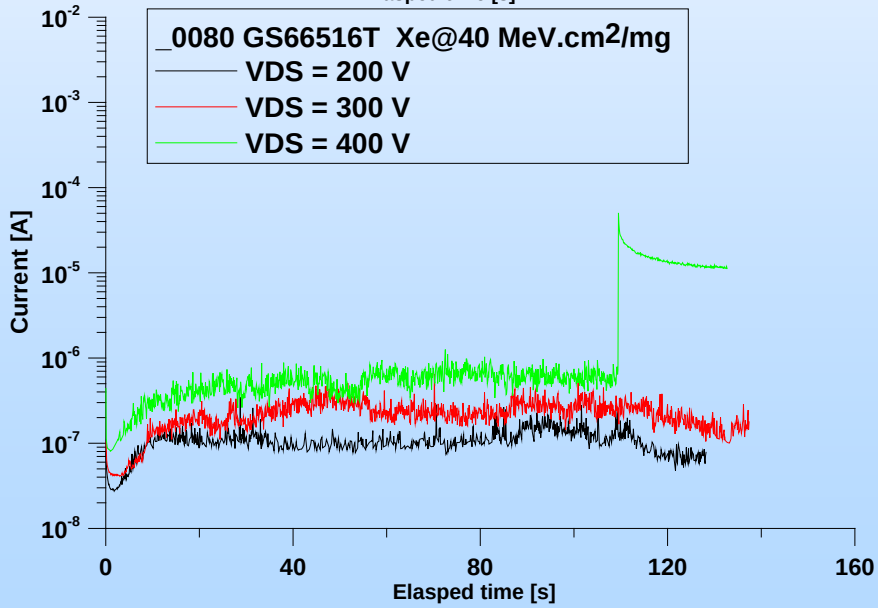
Gate areas are small and more complex in newer devices.

Heavy Ion Testing









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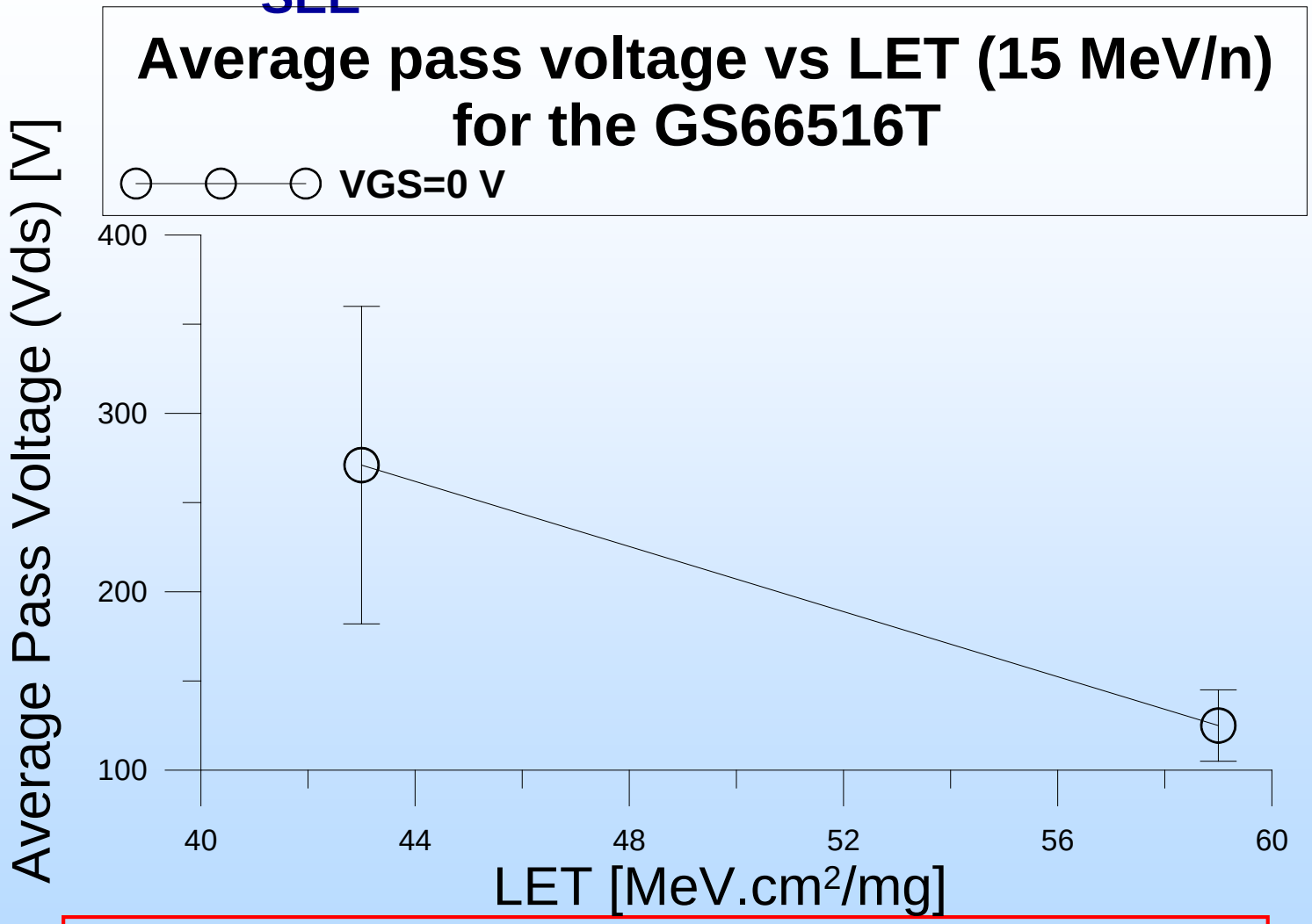
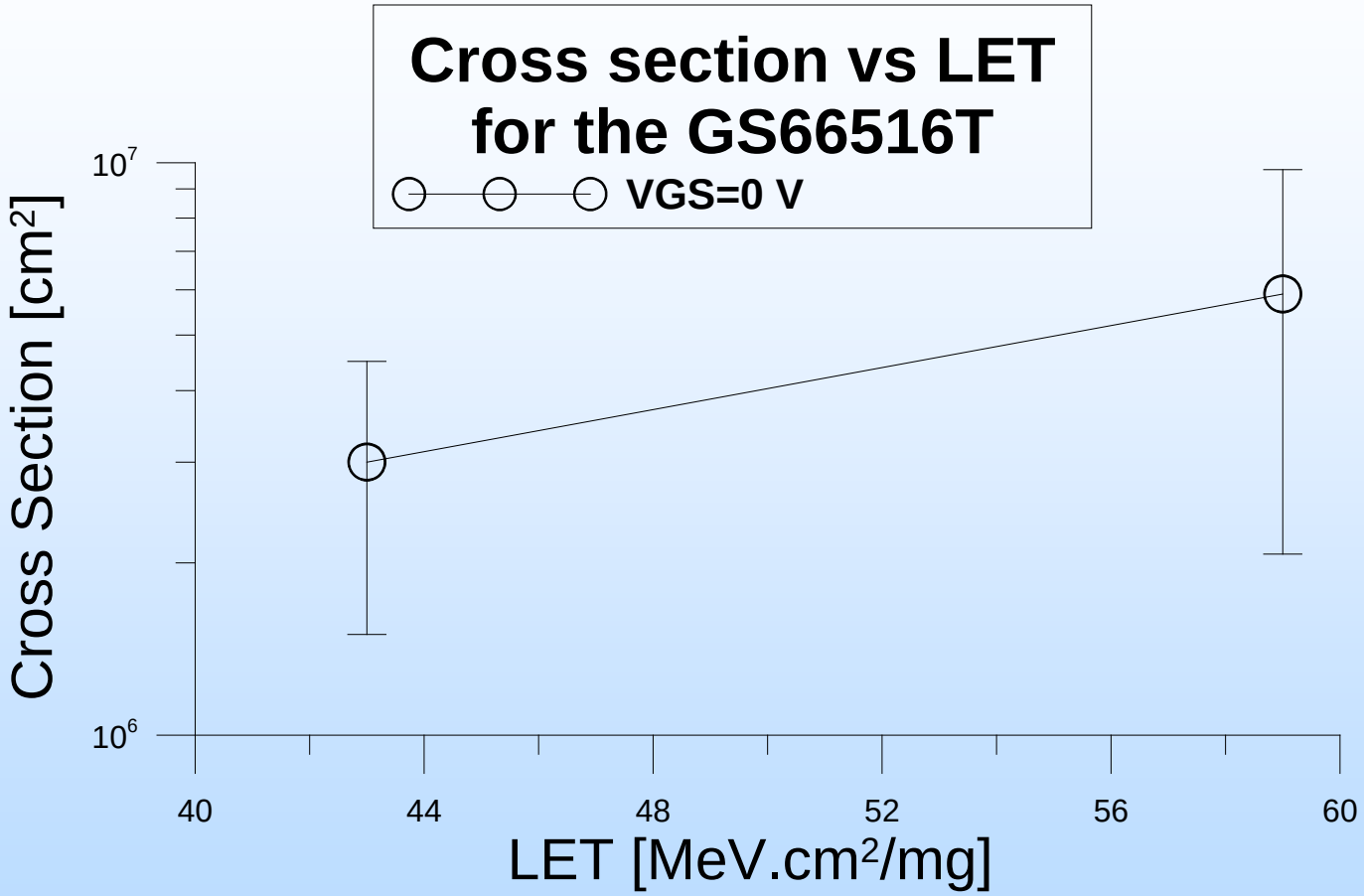
V_{SEE} as a function of LET



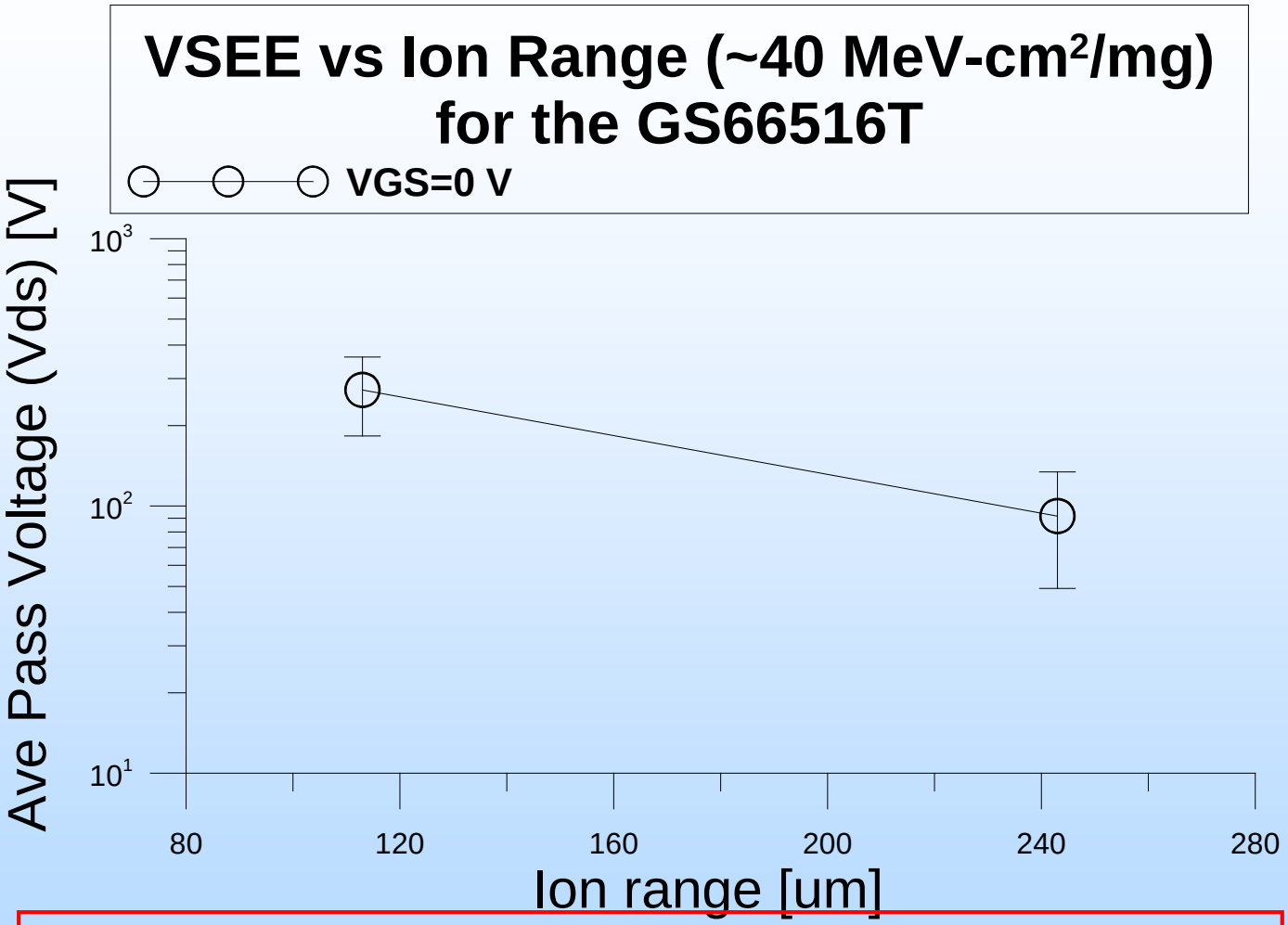
Preliminary: Higher LET results in lower SEE Vds.

Cross-section as a function of LET



Preliminary: Cross-section not dependent on LET.

V_{SEE} as a function of ion range



Preliminary: Longer range ions are more damaging Xe versus Ag.

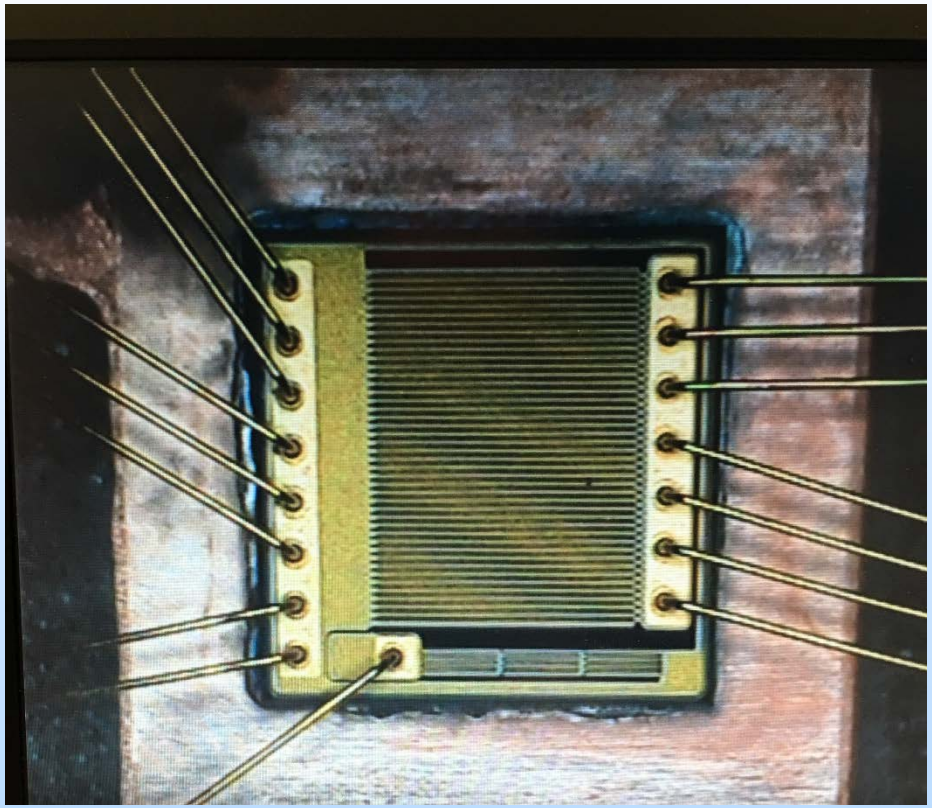
FUTURE WORK

More testing…

- **Testing of emerging parts**
  - **GaNSystems**
  - **Freebird Semi**
  - **Panasonic**
  - **Northup Grumman**
- **Collaboration with other entities**
  - **NASA**
  - **DOE and DOD**
  - **Vendors**

More GaN devices are becoming available every day.

EMMI and IR SEE site recovery



This will identify SEE location to establish trends and identify mechanism.

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**
  - **GaNSystems have more complicated SEE response**
- **Future plans**
  - **Measurement of LRC circuit in testers**
  - **Development of an SOA**
  - **High voltage issues are becoming more visible**
  - **Continual search for GaN IGFET**