Update to Radiation Effects in GaN

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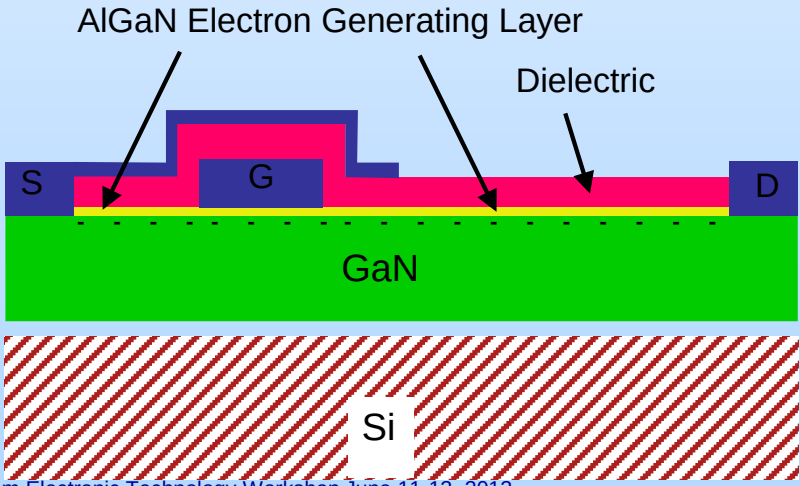
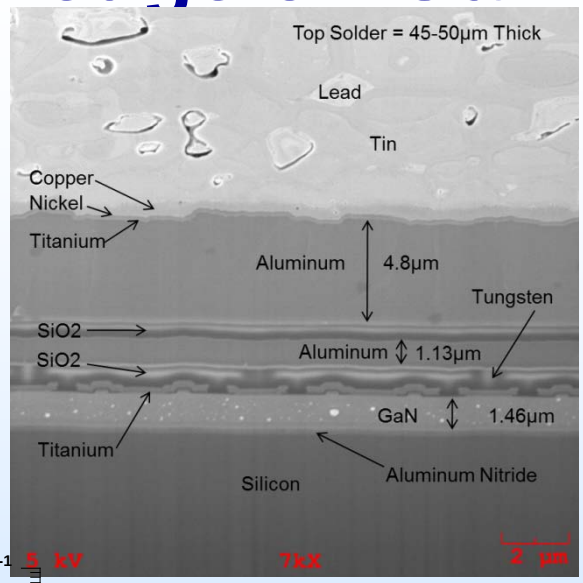
Previous body of knowledge on GaN

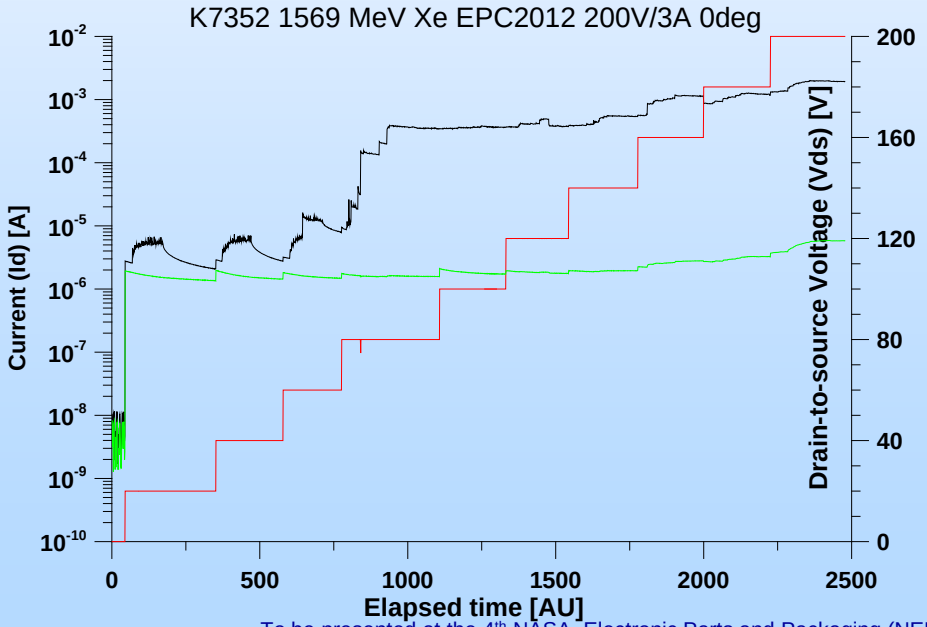
- **Current silicon power solutions are at their innate limits for space applications**
  - **Silicon devices are at efficiency limit**
  - **Best hi-rel devices are less then ~400 V drain-to-source**
- **GaN devices are becoming available**
  - **Reliability effects are a concern**
  - **Gate stress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

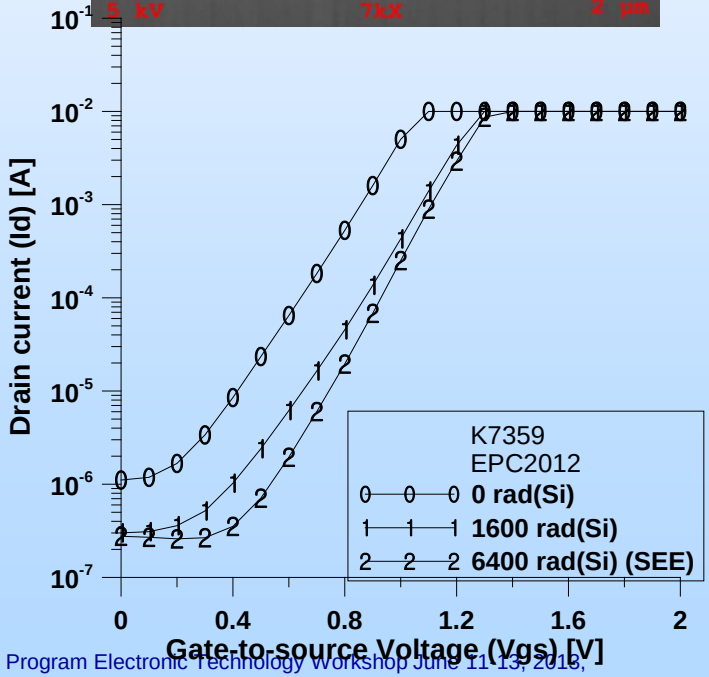


Previous body of knowledge on GaN

- **SEEs in GaN have been observed**
- **Used the NEPP guideline: The Test Guideline for Single Event Gate Rupture (SEGR) of Power MOSFETs [JPL Publication 08-10 2/08]**
  - **No post irradiation stress tests between**
  - **Testing at angle required**







Previous body of knowledge on GaN

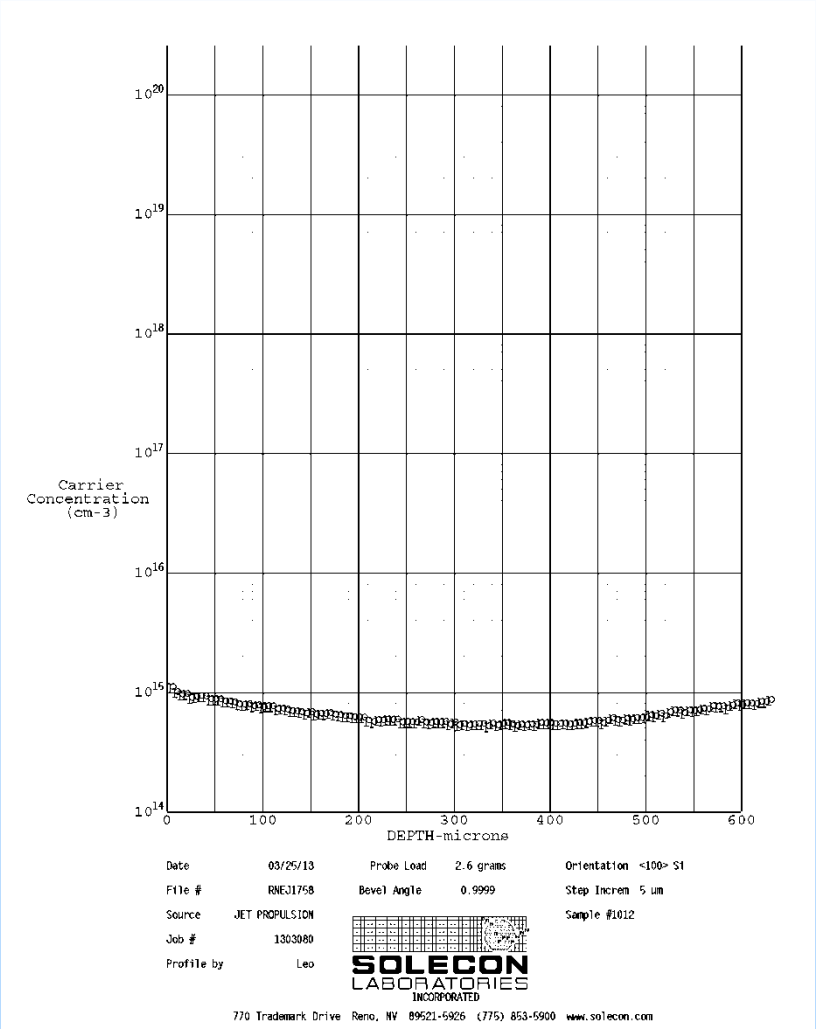
- **Devices with lower voltage rating were less susceptible to dose damage**
- **At normal incidence, the higher LET ion does more damage**
  - **Devices irradiated at 60° tilt showed little degradation**
  - **Devices irradiated at 60° roll showed some degradation**
- **Gen2 parts were more robust than Gen1**

V_{SEE} for GaN for all Vgs<Vth

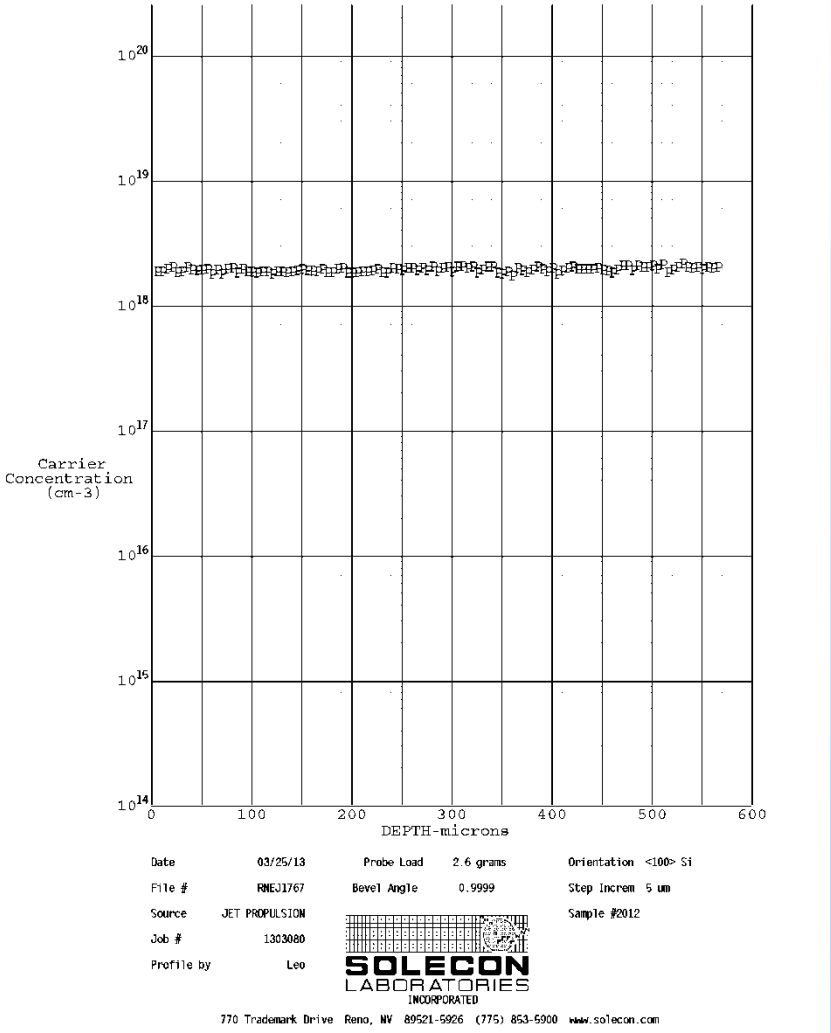
Vds [V]	Gen 1 V_{SEE} [V]	Gen 1 V_{SOA} [V]	Gen 2 V_{SEE} [V]	Gen 2 V_{SOA} [V]
40	40	30	40	30
100	40	30	60	45
200	40	30	80	60

Spreading resistance measurement

EPC1012



EPC2012



Current investigations

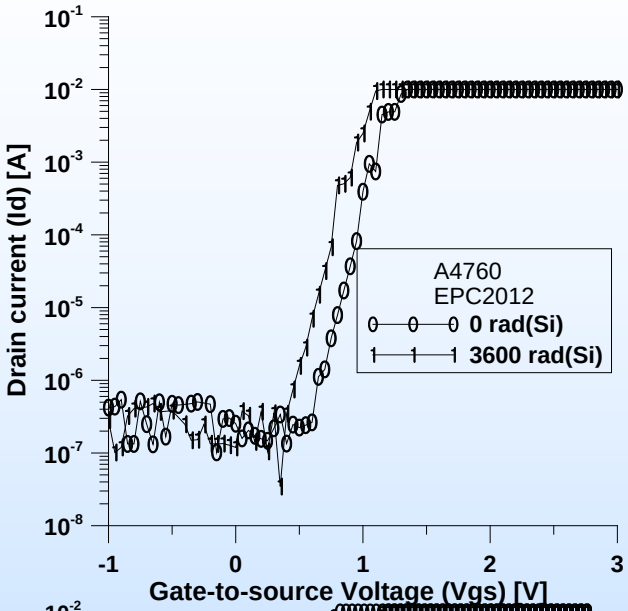
- **Proton damage**
  - **Upper limit for damage**
  - **SEE from spallation reactions**
    - **Tungsten in device structure will generate secondaries in that may replicate SEE effects**
- **Recommended testing/assurance methods**
  - **1080 test circuit**
  - **Prioritization of test matrix**
  - **Ion conditions**
- **Failure mechanism identification**
  - **Failures manifesting in drain-to-source leakage have been seen**
    - **Role of isolation oxide under scrutiny**
  - **Failures in gate-to-source leakage have been seen**
- **EPC1012 and EPC2012 are the most sensitive and therefore the best candidates**

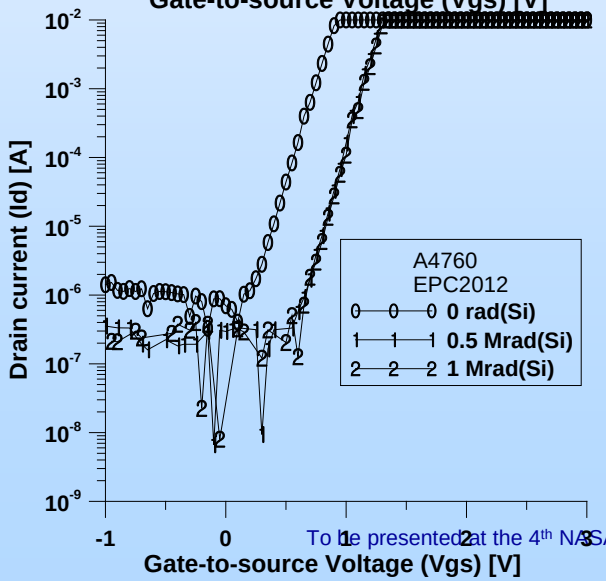
PROTON EFFECTS

To be presented at the 4th NASA Electronic Parts and Packaging (NEPP) Program Electronic Technology Workshop June 11-13, 2013, NASA GSFC, Greenbelt, MD.

Proton testing results

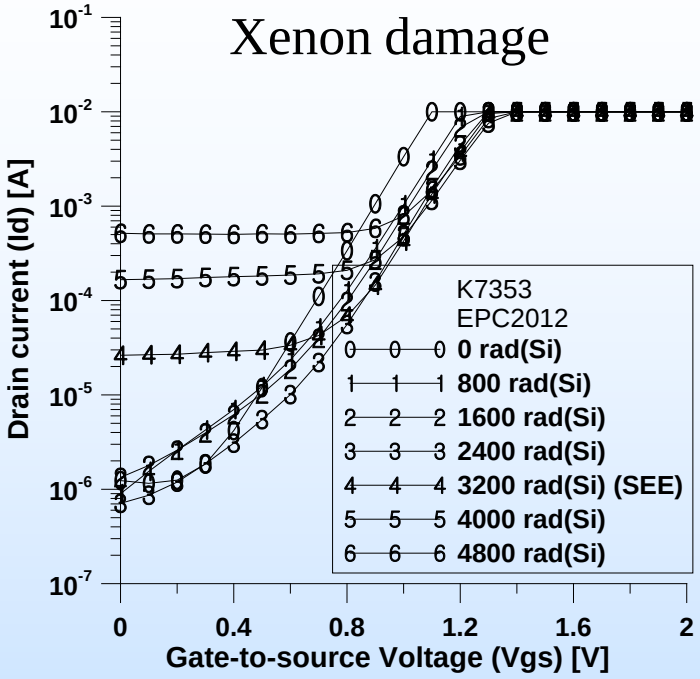
Proton damage

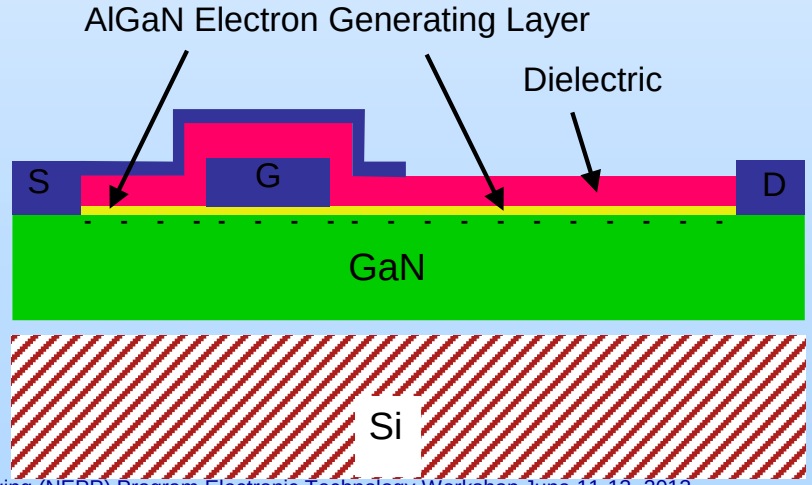




No SEE from protons.

Xenon damage





BEST TEST METHODS

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Effect of 1080 test circuit

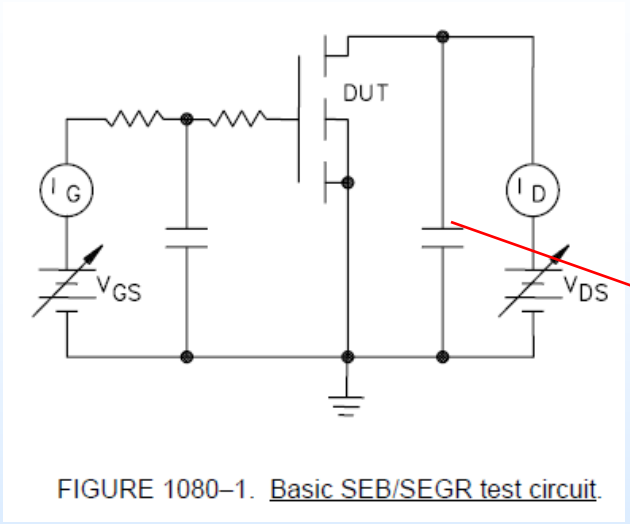
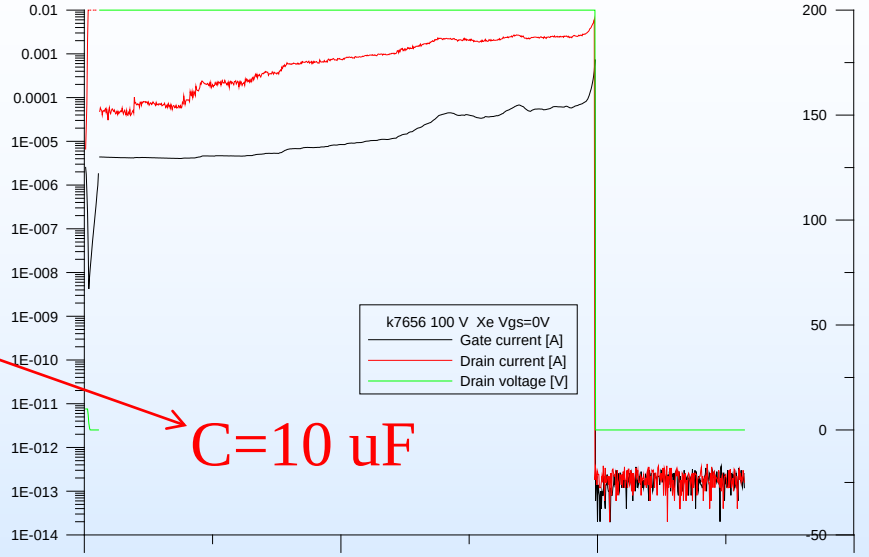
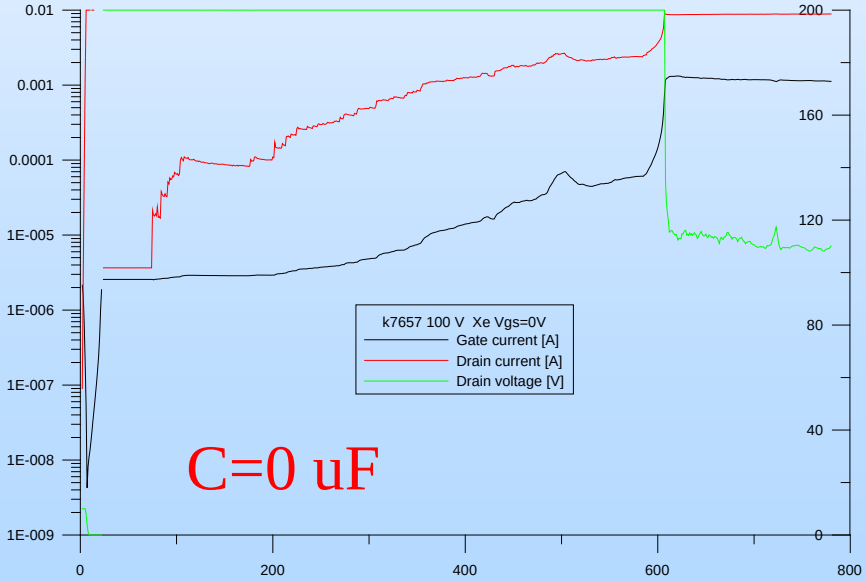
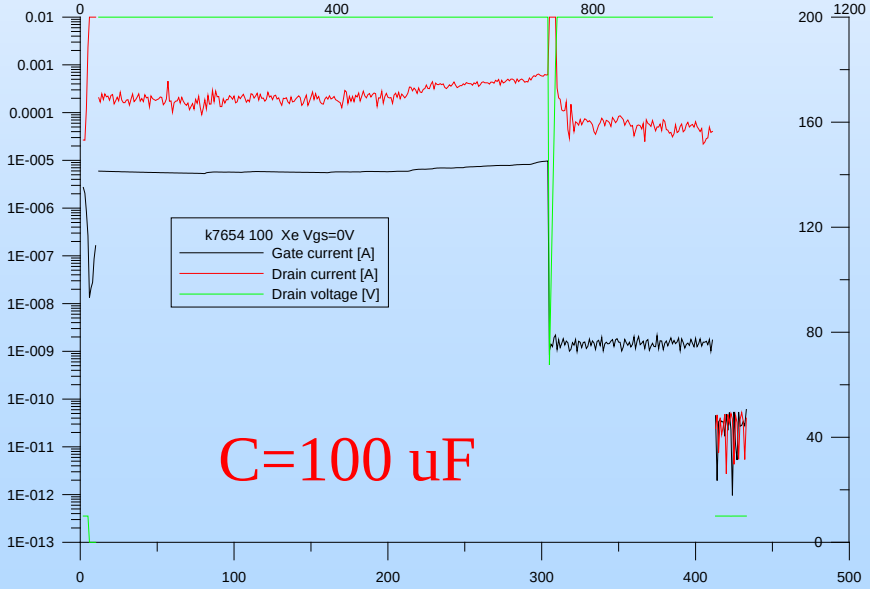


FIGURE 1080–1. Basic SEB/SEGR test circuit.







FAILURE ANALYSIS

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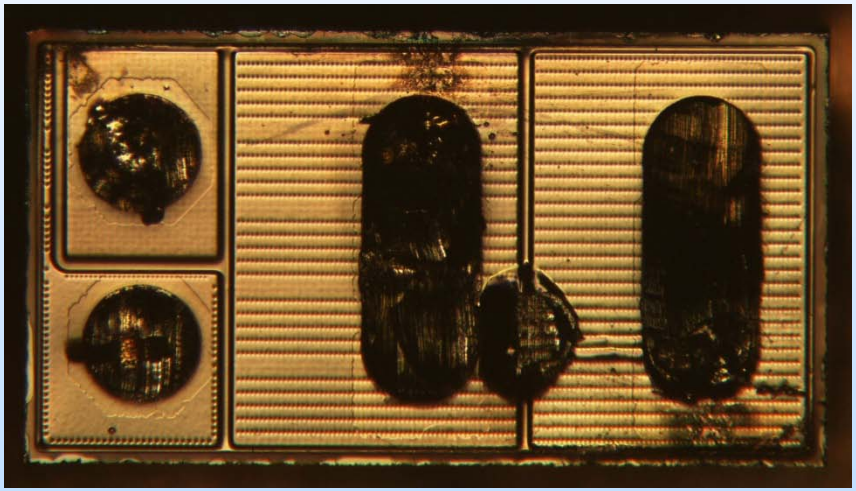
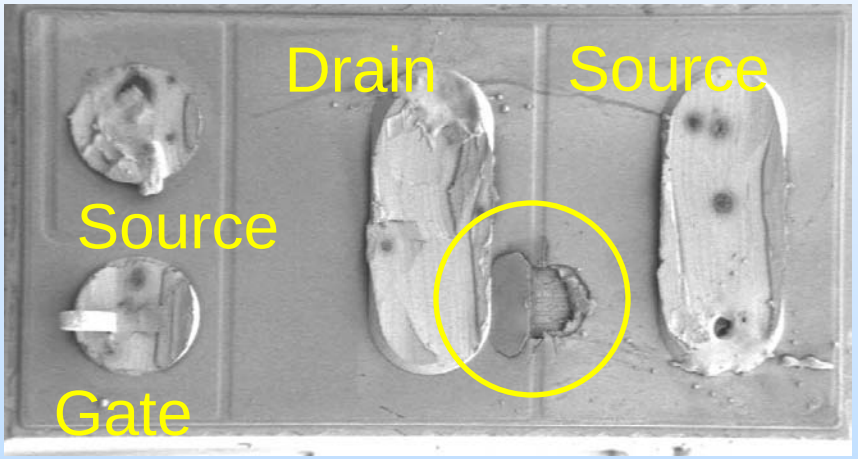
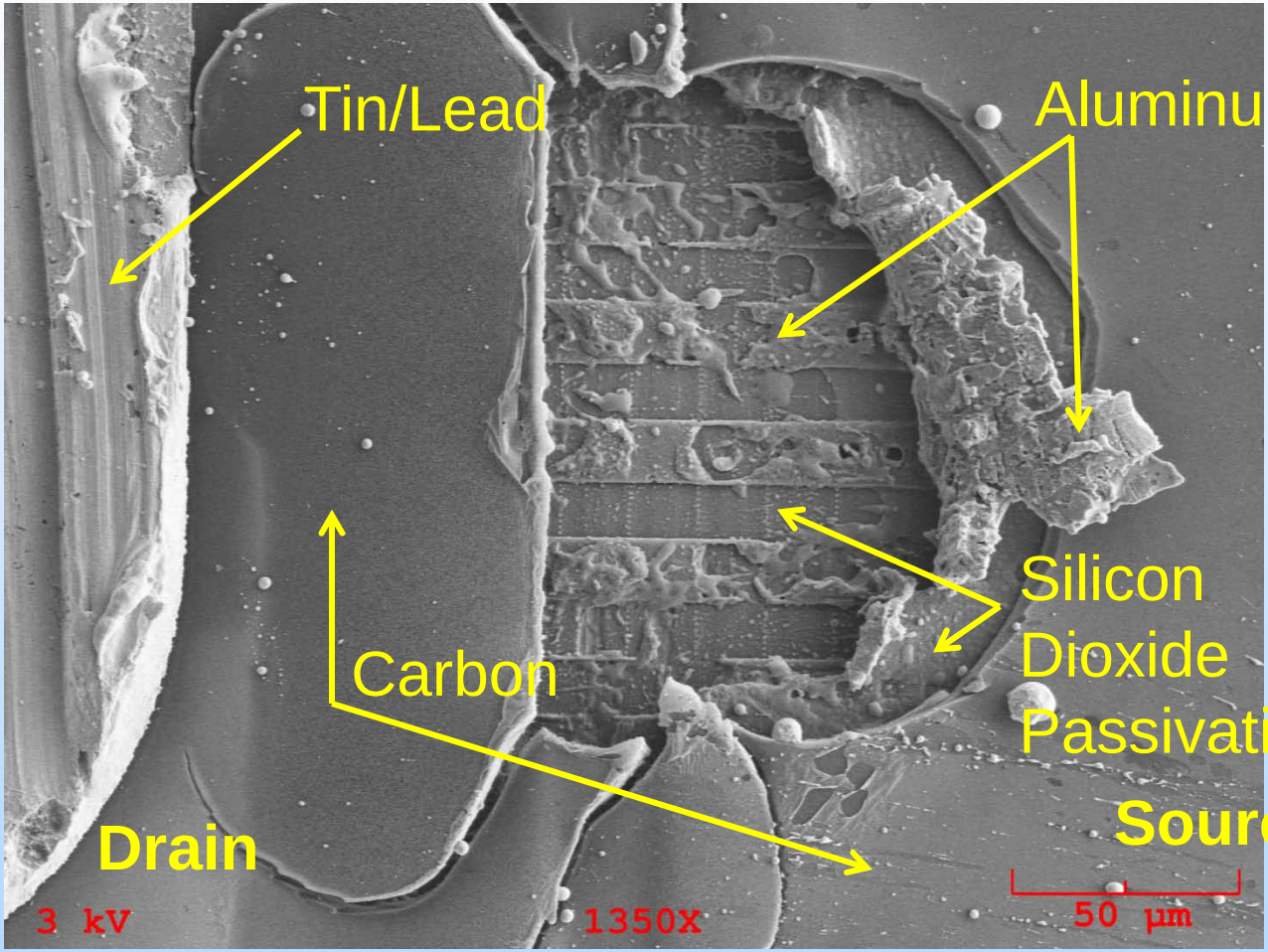
Optical and SEM of EPC2012 Circle Encompassing Damaged region





Closer SEM View of Drain to Source Damaged Region for EPC2012



Conclusion

- **Proton damage**
  - **DDD and proton SEE apparently not an issue for GaN**
  - **Observed effects may be architecturally dependent**
- **Recommended testing/assurance methods**
  - **Stiffening capacitance is recommended for worst case**
- **Failure mechanism identification**
  - **Isolation oxide is the drain-to-source path**
  - **SEE mechanism under study**
- **Future work**
  - **Identification of the SEE mechanism with follow on modeling**
    - **Include angle, ion-energy, and bias effects**
  - **Gate SET and RF testing**