TELEDYNE
DEFENSE ELECTRONICS
Everywhereyoulook™

Components for Military and Space Electronics
Technology Conference
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AlGaN/GaN Radiation Effects

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Teledyne Technologies - Quick Facts

TELEDYNE TECHNOLOGIES
Everywhere**you**look™

$5B
in revenue,
financially strong

TDY
Stock Symbol

~35%
of revenues
from A&D/Space

50+
years of
experience

>100
countries
exported to

>15,000
employees

64
Successful Technology
Company **Acquisitions**

>84,000
Traveling Wave
Tubes delivered

Partnering in
Space since the
birth of the Space
Program

Responsible
for operation of the
International Space
Station (Recent
$596M Award)

DMEA Accredited
Trusted Source for
Packaging, Assembly
and Test

Depth of the **Panama**
Canal is checked year-round with Teledyne
Echosounders.

>3,700
military qualified
semiconductors

Have parts still
working on the
furthest manmade
objects from earth

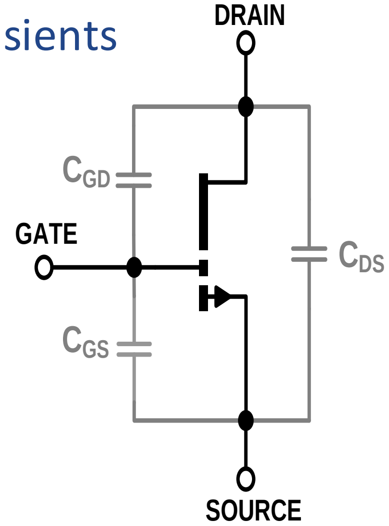
Own 5 Specialized
semiconductor
foundries
worldwide

TELEDYNE TECHNOLOGIES
Everywhere**you**look™

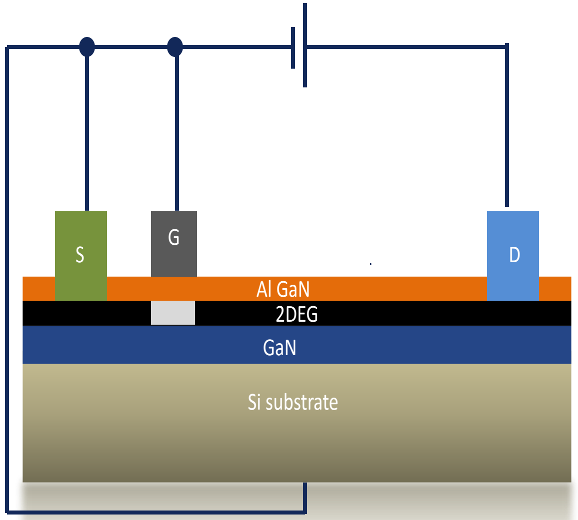
System Awareness with E-GaN HEMTs

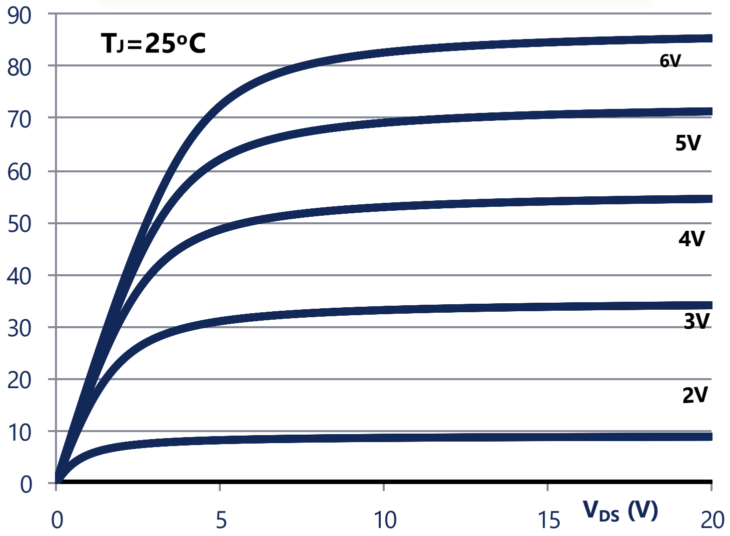
The system designer should be aware of:

- ESD (very low Gate capacitance)
- High Frequency Response
- Overvoltage (Drain/Source) VDS Transients
- Overvoltage (Gate-to-Source) 6V
- Continuous Overcurrent
- Low Static & Dynamic $R_{DS(on)}$
- Thermal Management
- Mechanical Stress
- Switch vs. Amplifier
- External Component Q
- Single Event Effects



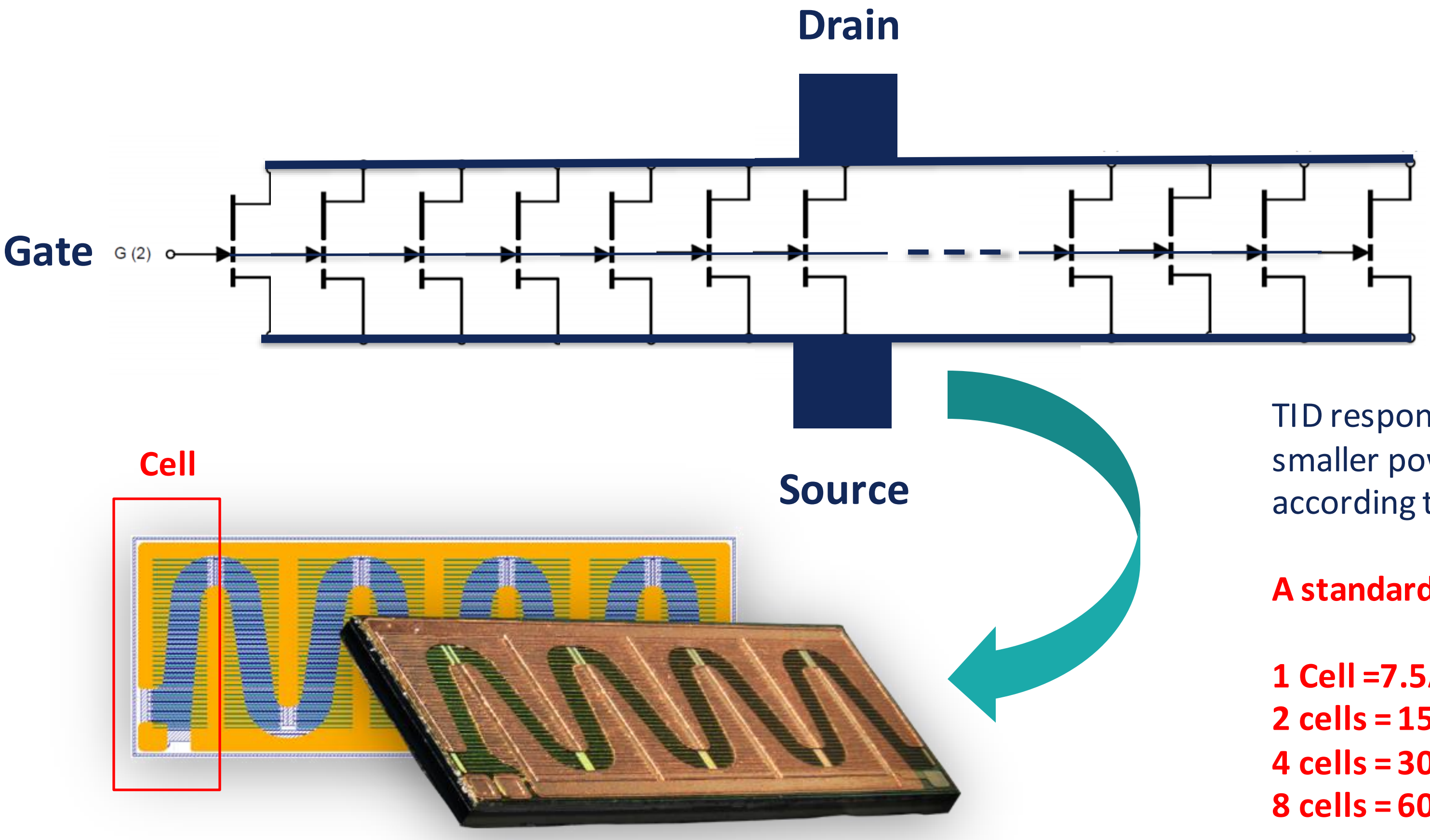
E-HEMT simplified circuit model





TDY E-GaN Technology TID Response

Like any power device, TDY GaN transistors are composed of thousands of parallel tiny transistors. Power MOSFET, vertical, lateral, BJT, HEMT, etc. use the same approach, with the end product being a large single discrete power device. For most power devices the layout is custom for each device. TDY GaN transistors are fabricated using a standard island cell. TID response follows data sheet delta parametrics, as the technology is Cell Based.



TID response is a function of technology in smaller power devices and scales according to current capability.

A standard island cell is 7.5A

1 Cell =7.5A TDY650E7B
2 cells = 15A TDY650E15B
4 cells = 30A TDY650E30B,T
8 cells = 60A TDY650E60B,T

Displacement Damage (DD) total-ionizing-dose (TID) GaN Effects

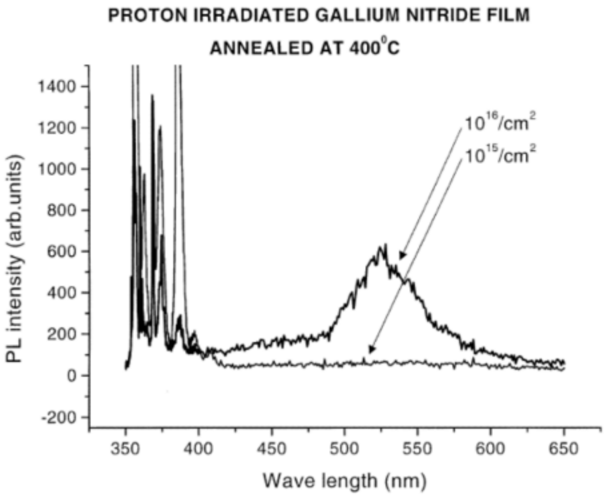
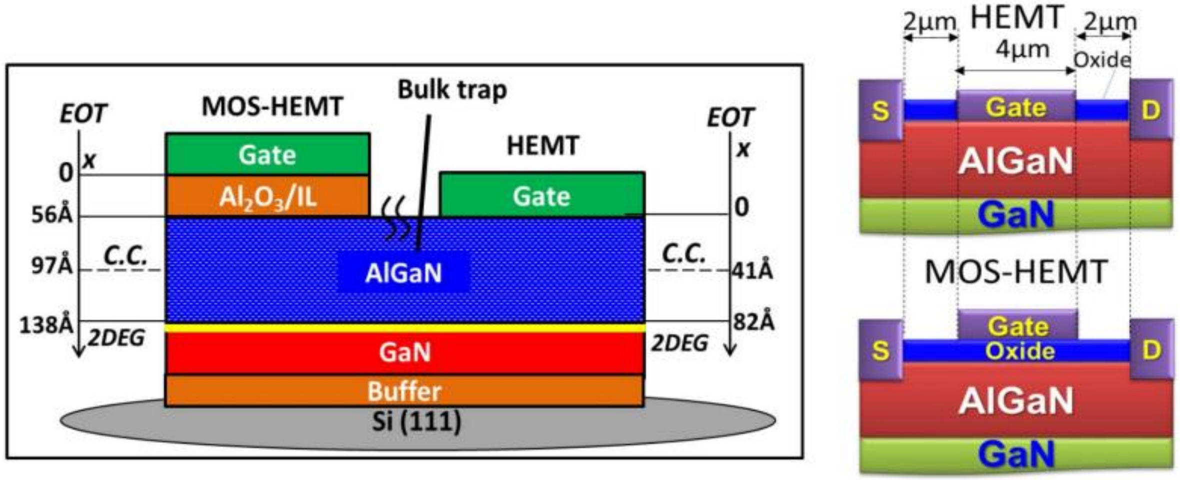


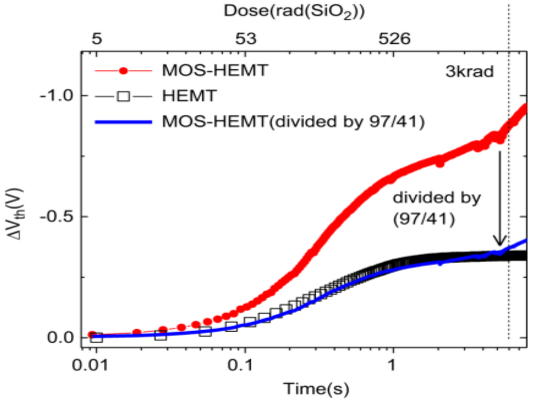
Fig. 2. Visible spectrum of proton-irradiated and annealed GaN films. The peak at 530 nm that appears in the sample irradiated with 2-MeV protons at a fluence of 10^{16}/cm^2 is most likely due to Ga vacancies. The shorter wavelength bands are associated with the Ga band edge

AlGaN/GaN materials and devices were typically found to be highly resistant to radiation exposure under exposure conditions that approximate even the most challenging space radiation environments [2], as illustrated in Fig. 2

Total-ionizing-dose (TID) Effects for MOS-HEMT vs E-HEMT

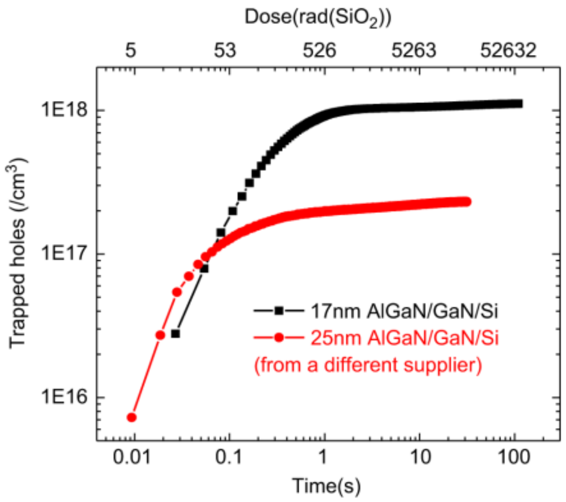


Cross sections of a MOS-HEMT and conventional HEMT side by side on the same Si substrate, perpendicular (left) and parallel (right) to the channel. The effective oxide thickness (EOT) is extracted by capacitance-voltage measurements. The location of the charge centroid (C.C.) in AlGaN is discussed in the text.



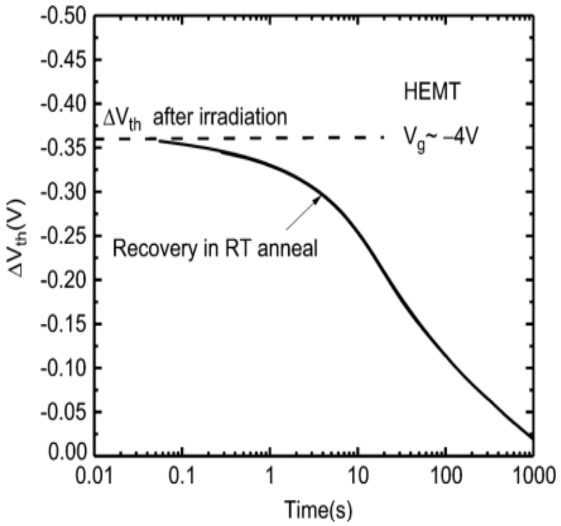
Charge Trapping in MOS indicated by Vt shift [3]

Total-ionizing-dose (TID) Charge Trapping E-HEMT



Density of net trapped positive charge in AlGaN as a function of radiation dose [3]

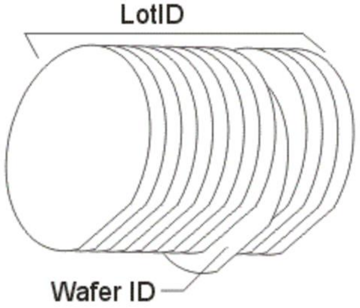
The saturation value of the rapid shift corresponds to a trap density in the mid range for the 17 nm AlGaN grown on Si, which is nearly two orders of magnitude higher than bulk trap densities in high-quality AlGaN/GaN structures on SiC [11]. In contrast, the 25 nm AlGaN/GaN structure on Si (from a different supplier) shows a much lower bulk trap density (in the low range)

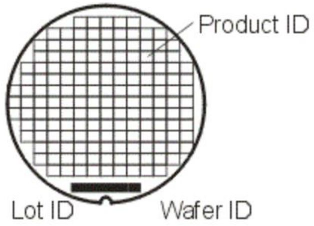


Vth recovery as a function of RT annealing time [3]

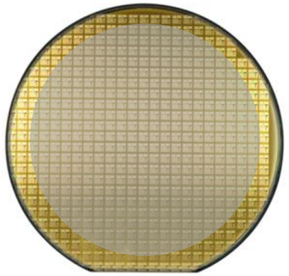
The recovery for the HEMT device during RT annealing, obtained by drain current sampling with gate biases near at a sampling interval of 10 ms. The rapid shift can be annealed effectively within a time of the order of 100 s. The recovery of during RT annealing is caused by release of trapped holes in the AlGaN layer, and/or their neutralization by electrons from the channel. [3]

Traceability Critical for SEE Verification

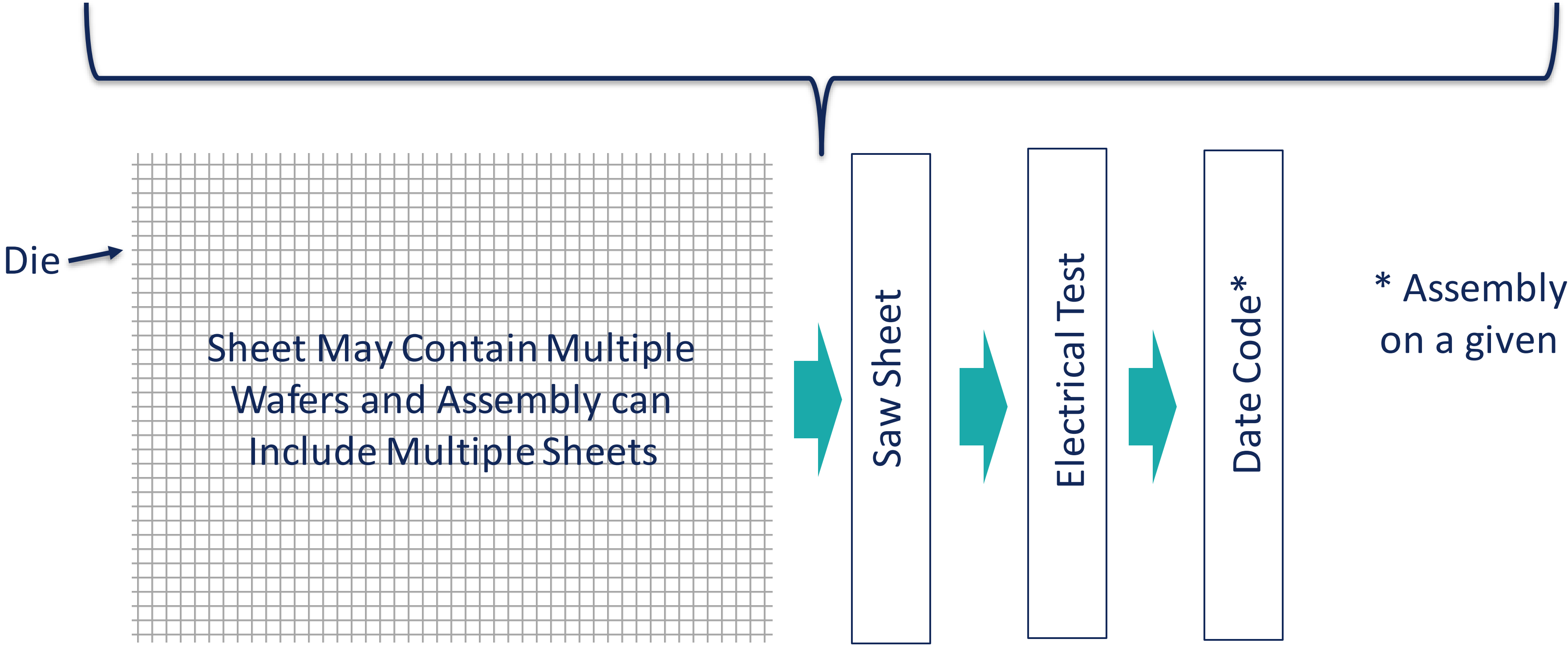




Wafer Maps (Die ID) Critical



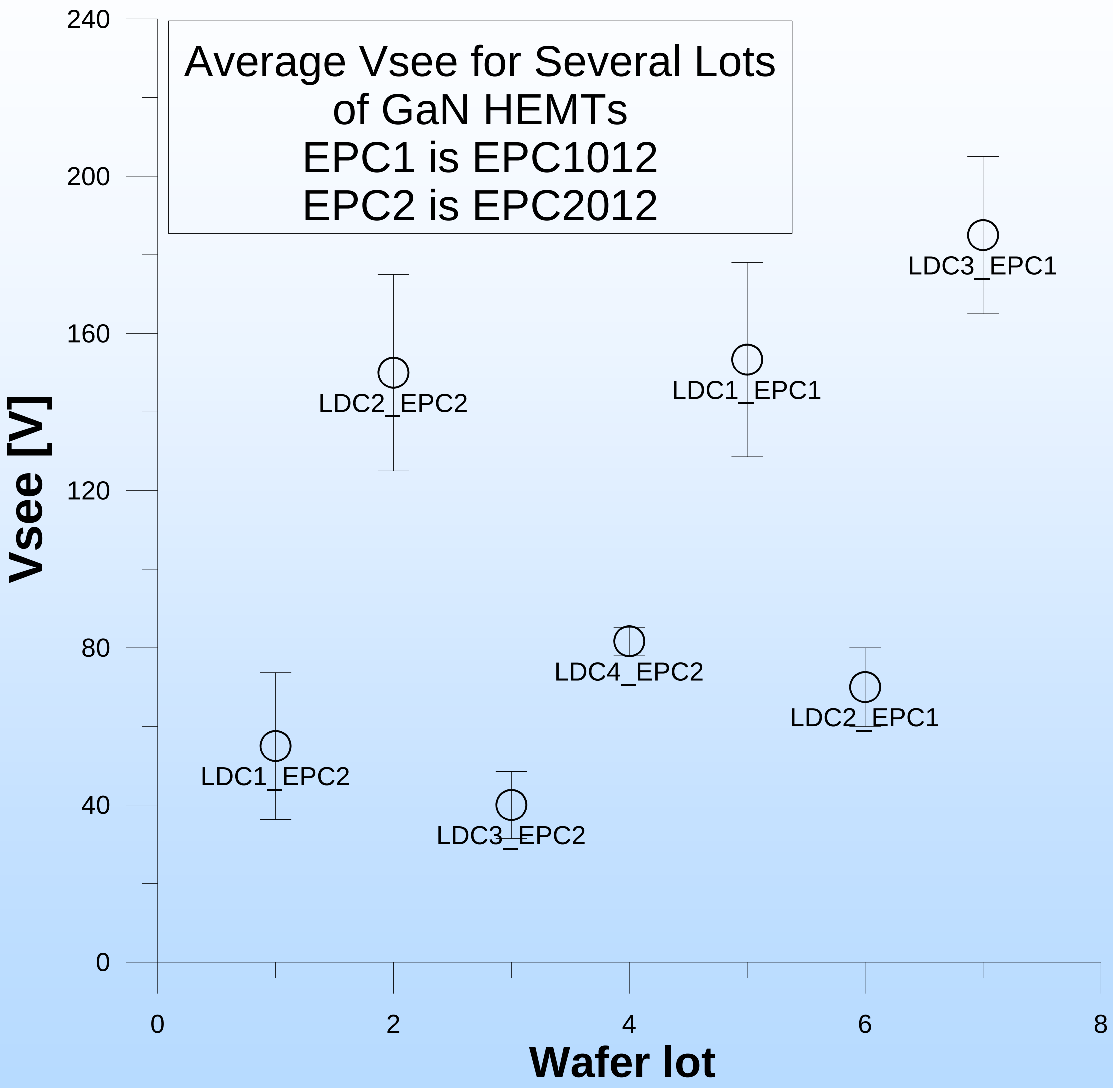
Keep Out Zones Defined
(May be more than one)



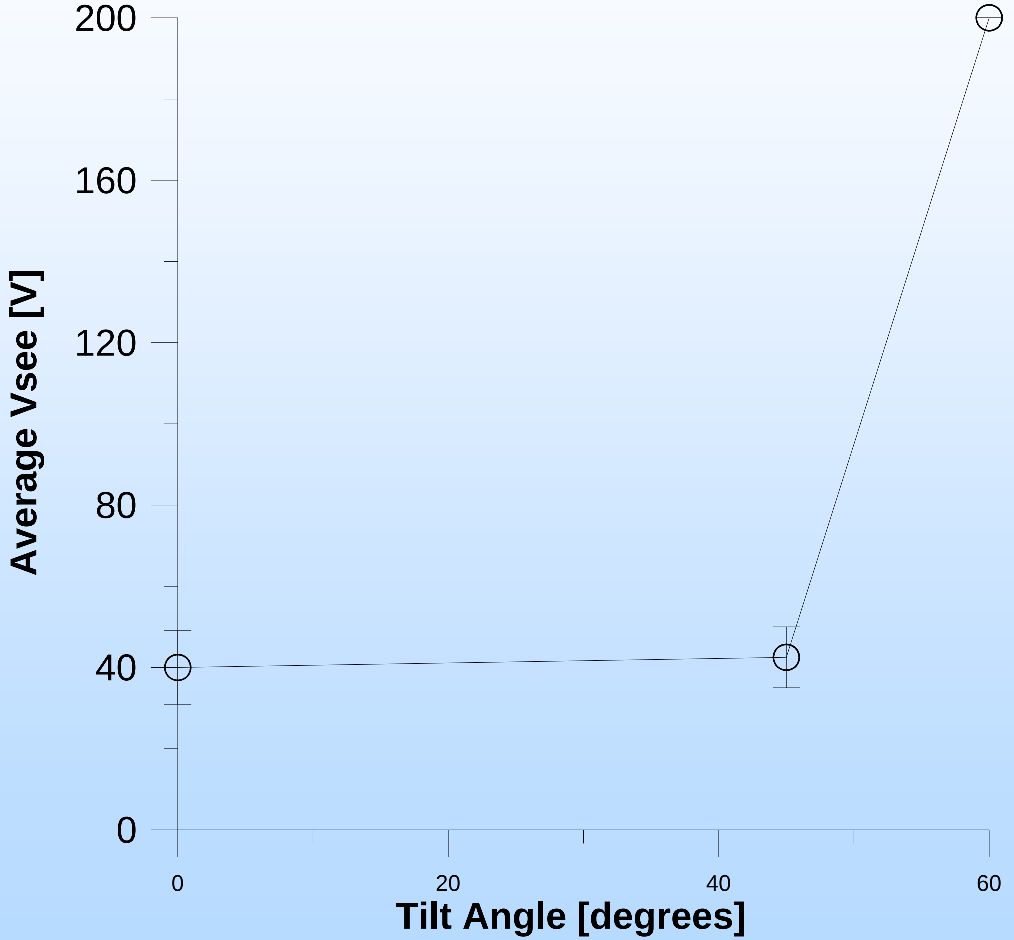
Sheet May Contain Multiple Wafers and Assembly can Include Multiple Sheets

* Assembly took place on a given day only …

Lot-to-lot variation



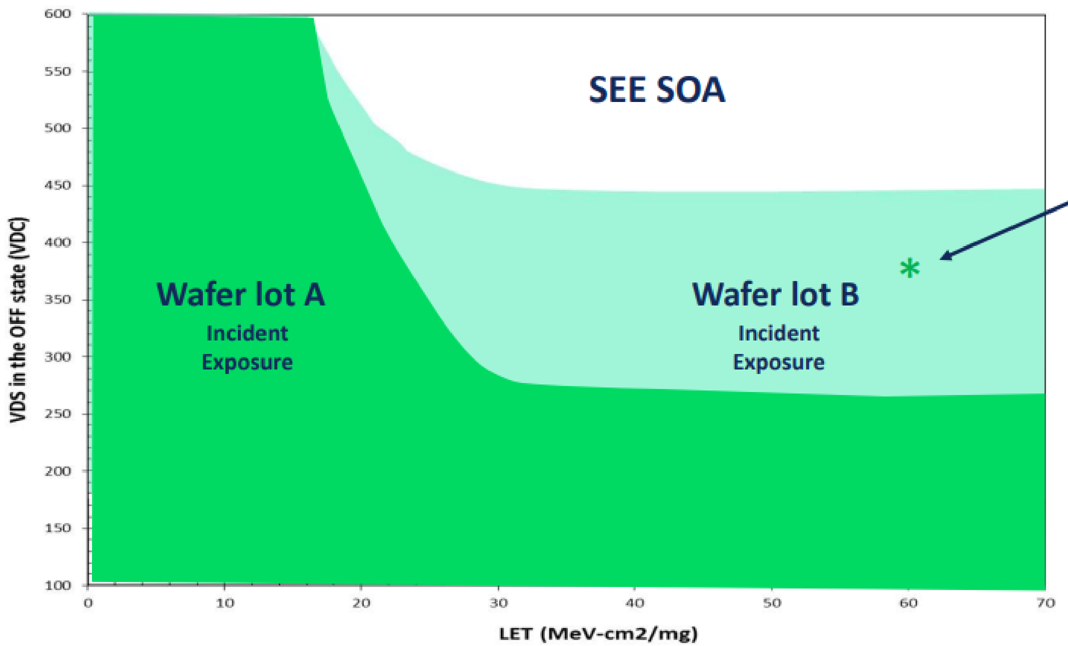
Effect of angle



To be presented at the 5th NASA Electronic Parts and Packaging (NEPP) Program Electronic Technology Workshop June 17-19, 2014,
NASA GSFC, Greenbelt, MD.

650Volts GaN 15 Amp SEE SOE TAMU & RADEF

Worst case is incidence beam – Field plate rupture which is similar to SEGR*

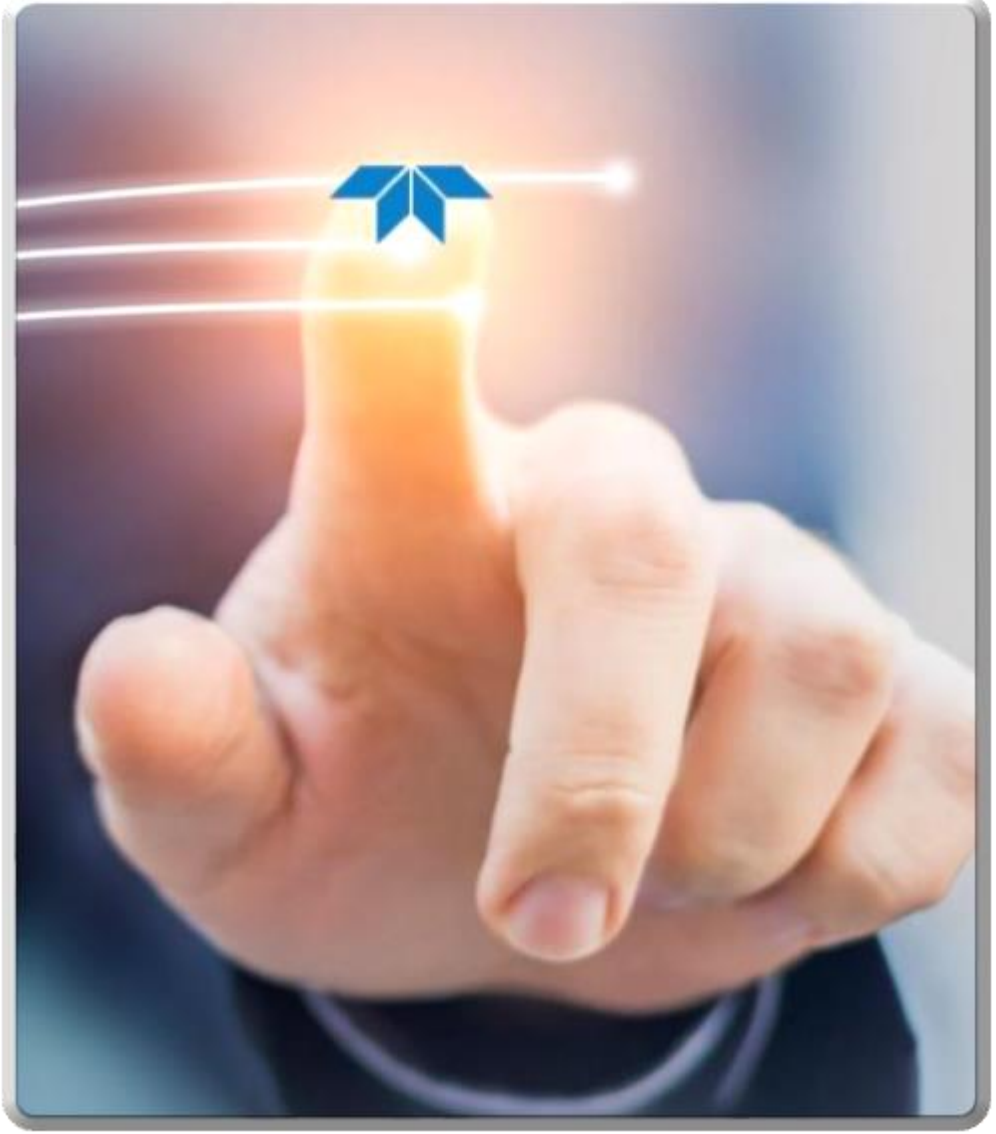


60 degrees
Lot A Exposure
Pass

- At LETs = >37 MeV-cm^2/mg, V_{DS} > 275V show susceptibility to SEB for Lot A
- Susceptible V_{DS} decreases rapidly after LETs > 20 MeV-cm^2/mg for Lot A
- At 60 degrees device passes 400V at LET > 55 MeV-cm2/mg * For Lot A
- SEE data is based on two wafer Lot diffusions (A & B). Lot B performed better….

Summary

- **GaN E-Mode HEMT Power Devices**
  - Both D-GaN and E-GaN Have their Place
  - GaN Use is Growing Rapidly
  - More Designers Becoming Familiar
  - Lot Traceability is Critical
  - Proper Characterization is Critical
  - Proper Testing is Critical
  - SEE Testing is Critical
  - In Summary GaN is a Critical Technology



Acknowledgement

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References

[1] Daniel M Fleetwood et al., Radiation Effects in AlGaN/GaN HEMPT IEEE Transactions on Nuclear Science Vol 69 NO. 5 May 2022

[2] S.J.Pearton et al., Ionizing radiation damage effects on GaN Devices J. Solid State Sci Technol., vol. 5 no. 2, pp. Q35-Q60 2016

[3] Xiao Sun et al., TID Radiation Effects in AlGaN/GaN IEEE Transactions on Nuclear Science, vol. 60 NO. 6 Dec 2013