Wide Band Gap (WBG) and Power Device Testing Updates 2023

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Acronyms/Abbreviations

- AFRL: Air Force Research Laboratory
- AMP: Amplifier
- APL: Applied Physics Lab
- DC: Direct Current
- DDD: Displacement damage dose
- DUT: Device Under Test
- FRIB: Facility for Rare Isotope Beams
- GSFC: Goddard Space Flight Center
- HEMT: High Electron Mobility Transistor
- HV: High Voltage
- IMAP: Interstellar Mapping and Acceleration Probe
- JEDEC: Joint Electron Device Engineering Council
- JHU: Johns Hopkins University
- LLRF: Low Level Radio Frequency
- LET: Linear Energy Transfer
- LuSTR: Lunar Surface Technology Research
- MSU: Michigan State University
- NEPP: NASA Electronics and Packaging Program
- NRL: Naval Research Lab
- nSEE: neutron Single Event Effects
- NSRL: NASA Space Radiation Laboratory
- PIGS: Post Irradiation Gate Stress
- REAG: Radiation Effects and Analysis Group
- RF: Radio Frequency
- SEB: Single Event Burnout
- SEE: Single Event Effects
- SBIR: Small Business Innovation Research
- SRHEC: Strategic Radiation-Hardened Electronics Counsel
- SRIM: Stopping Ranges of Ions in Matter
- TAMU: Texas A&M University
- TID: Total Ionizing Dose
- TM: Test Method
- VU: Vanderbilt University
- WBG: Wide Band Gap

Outline

- **AFRL β-Ga_2O_3**
- **RF GaN HEMTs**
  - **Aerospace Corp**
  - **JHU APL - IMAP**
- **SBIR SiC Schottky Diodes**
- **NEPP WBG Community Updates**

AFRL β-Ga_2O_3

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TABLE I. Calculated prime transistor parameters for a 1.2 kV rated vertical power transistor. Assumptions for the calculation are listed in Fig. 5. The prime transistor figures of merit $R_{ON} \cdot Q_{OSS}$ and $R_{ON} \cdot E_{OSS}$ are ~3× better than for 4H–SiC and ~20% better than for bulk GaN.

V_{RATING} = 1200 V						
Parameter	Unit	Si	Si SJ	4H–SiC	Bulk GaN	β-Ga_2O_3
R_{ON}	(mΩ cm^2)	227	6.84	1.8	0.589	0.189
Q_{OSS}	(nC/cm^2)	313	6260	2150	2710	7080
E_{OSS}	(μJ/cm^2)	125	250.4	857	1082	2829
$R_{ON} \cdot Q_{OSS}$	(mΩ nC)	71 051	42 818	3870	1596	1338
$R_{ON} \cdot E_{OSS}$	(mΩ μJ)	28 375	1713	1543	637	535

Andrew J. Green et al., "β-Gallium oxide power electronics", APL Materials 10, 029201 (2022) https://doi.org/10.1063/5.0060327

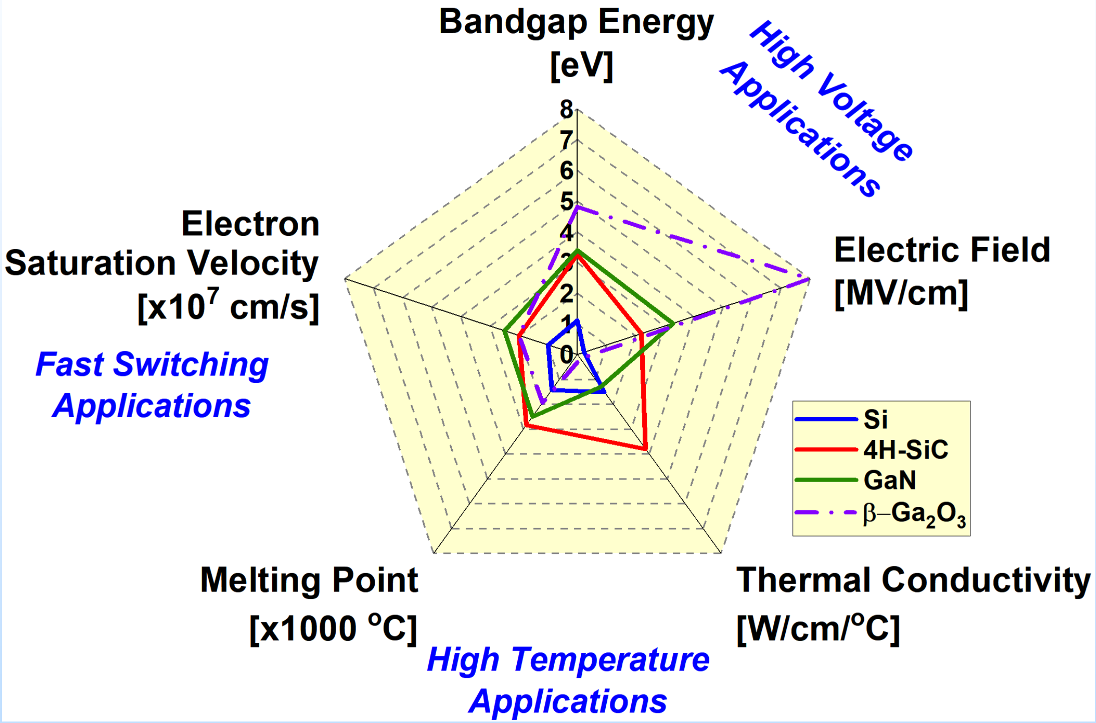

Image courtesy of Jean-Marie Lauenstein, NASA

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- **Preliminary Testing at MSU FRIB**
- **17 & 20 MeV Kr**
- **35.4 MeV/(mg/cm2) [Si]**
- **29.6 MeV/(mg/cm2) [Si]**
- **2 Samples Available**
- **Delidded**
- **Parylene coated**
- **Unspecified Max voltage**
  - **<600V**

Ion	Linac Energy [MeV/u]	Linac Charge State	Cu Foil Width [µm]	Min Flux [pps/cm^2]	Max Flux [pps/cm^2]	Energy at 70mm Air [MeV/u]	Surface LET in Si at 70mm Air [MeV/(mg/cm^2)]	Range in Si [µm]
^{16}O	40	7	10	1.00E+02	1.00E+07	38.4	0.8*	1920
	30	7	10	1.00E+02	1.00E+07	28.0	1.0	1090
	20	7	10	1.00E+02	1.00E+07	17.1	1.5	471
^{40}Ar	20	11	10	1.00E+02	5.00E+06	14.2	7.9	214
	15	11	10	1.00E+02	5.00E+06	7.4	11.5	87
^{86}Kr	25	19	5	1.00E+02	1.00E+06	17.9	23.1	217
	20	19	5	1.00E+02	1.00E+06	11.4	29.6	123
	17	19	5	1.00E+02	1.00E+06	7.0	35.4	73
^{129}Xe	25	28	5	1.00E+02	5.00E+05	14.9	50.5	144
	20	28	5	1.00E+02	5.00E+05	8.0	62.6	76
^{169}Tm	20.3	27	5	1.00E+02	5.00E+05	8.6	75.0	90
^{209}Bi	20.3	36	5	1.00E+02	2.00E+05	8.4	93.2	91

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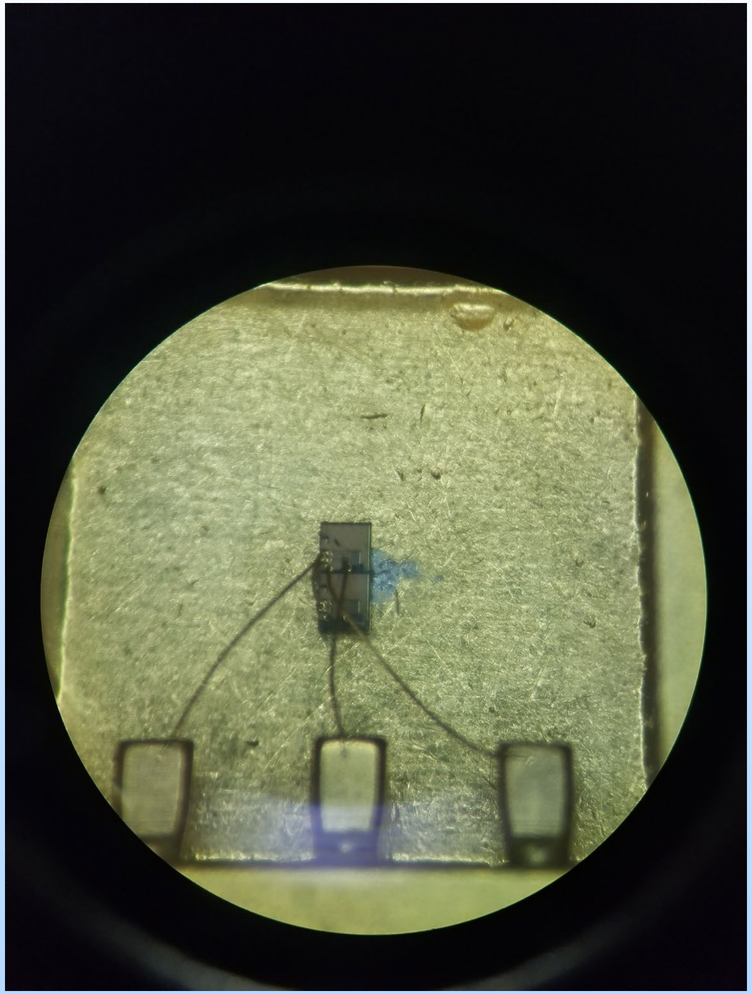

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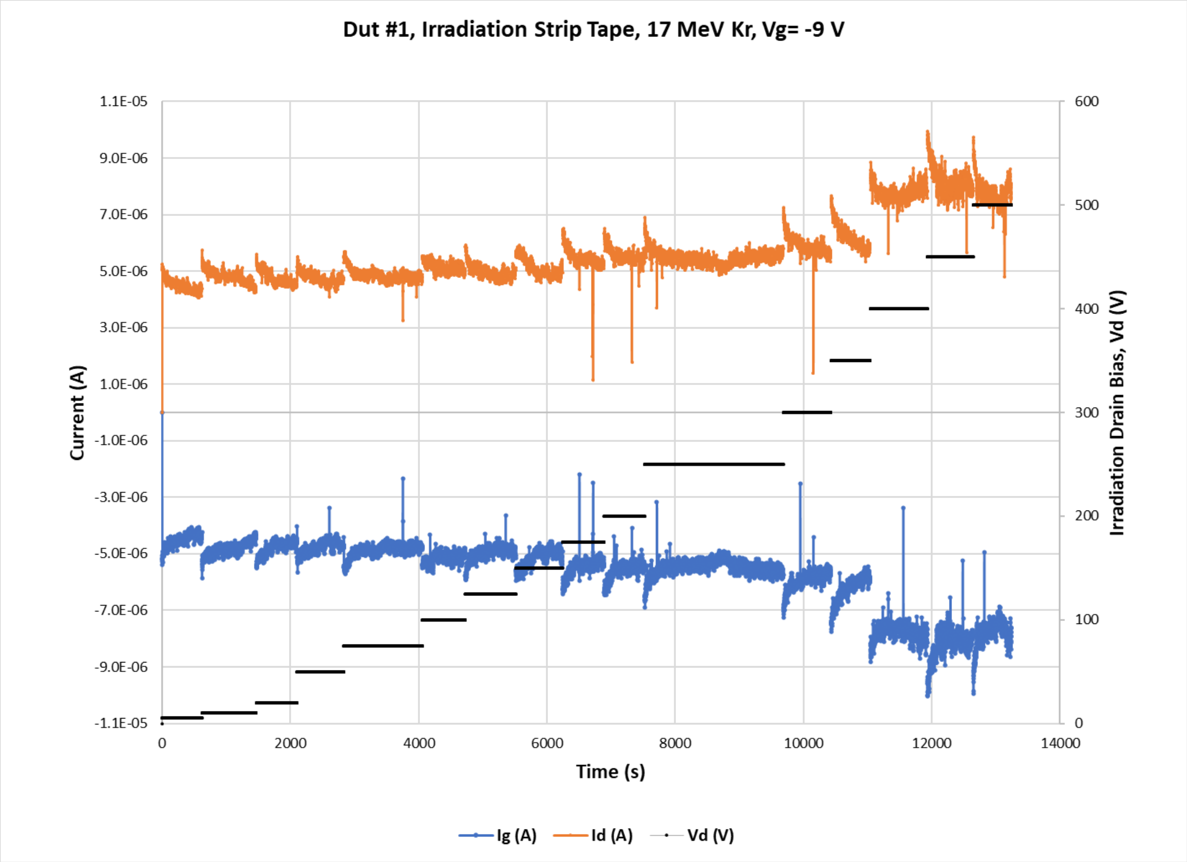
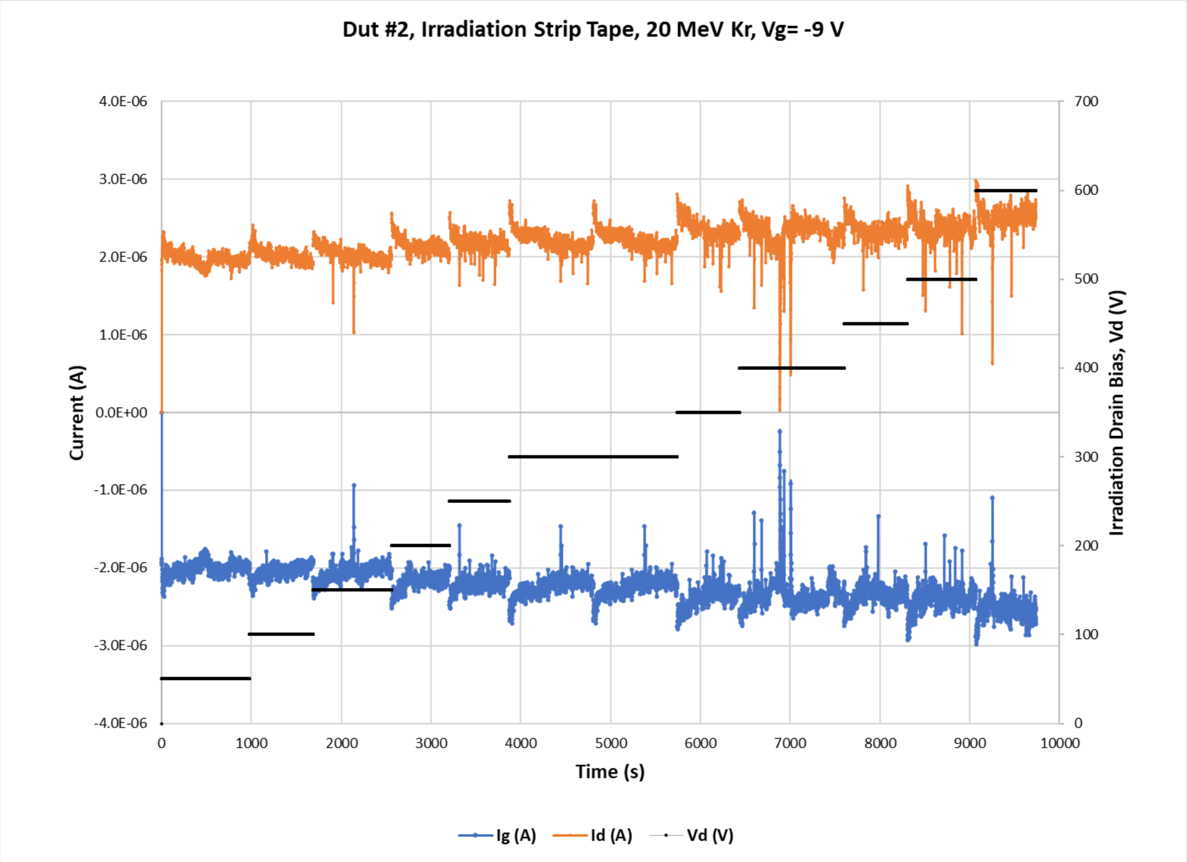
AFRL β-Ga_2O_3

- **Irradiation Strip Tapes**





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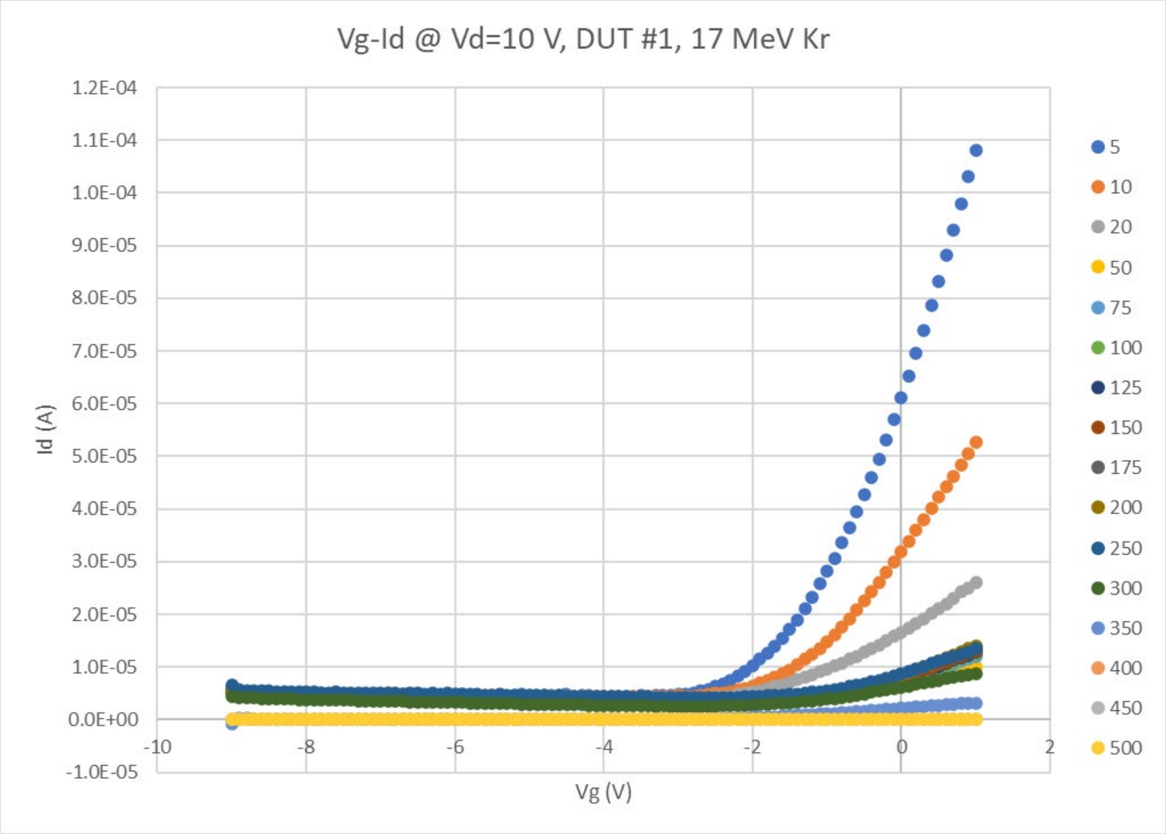
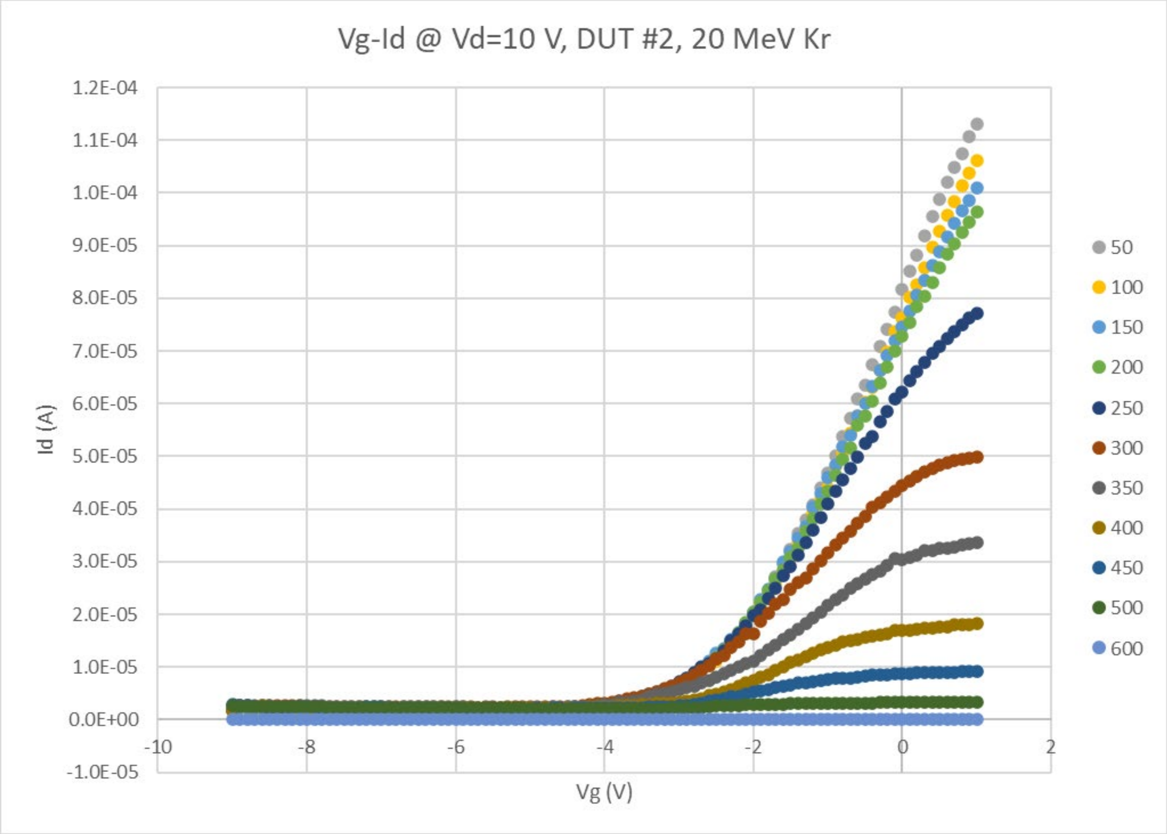
- **Vg-Id Curves**





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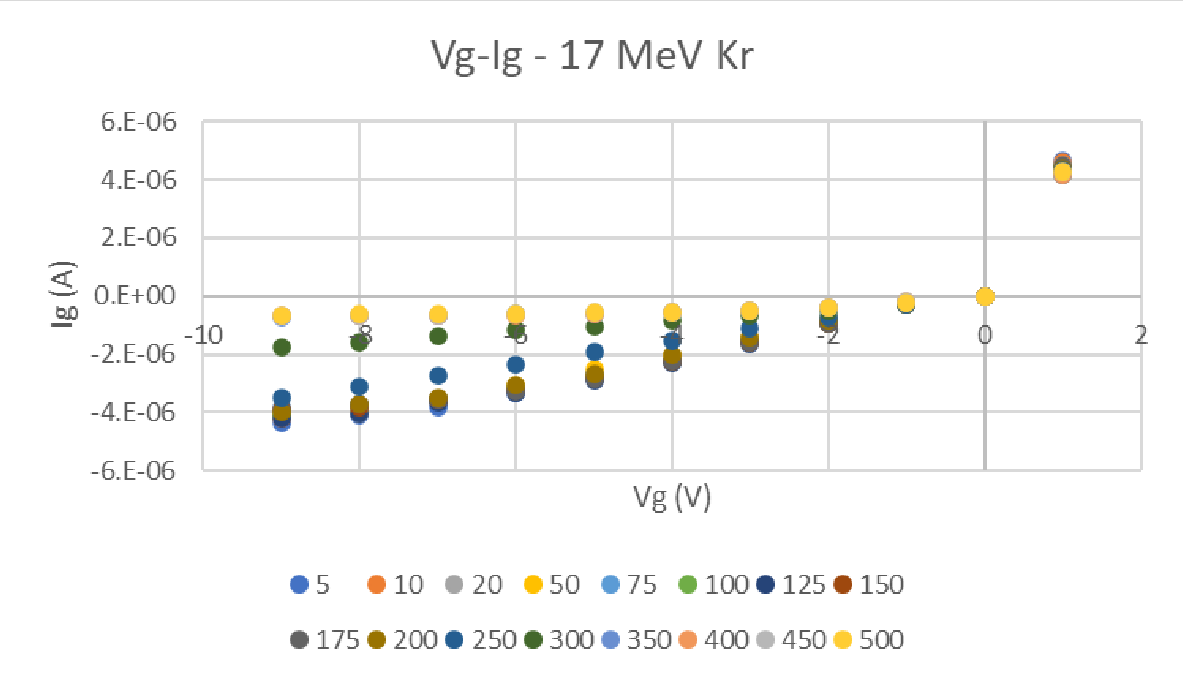
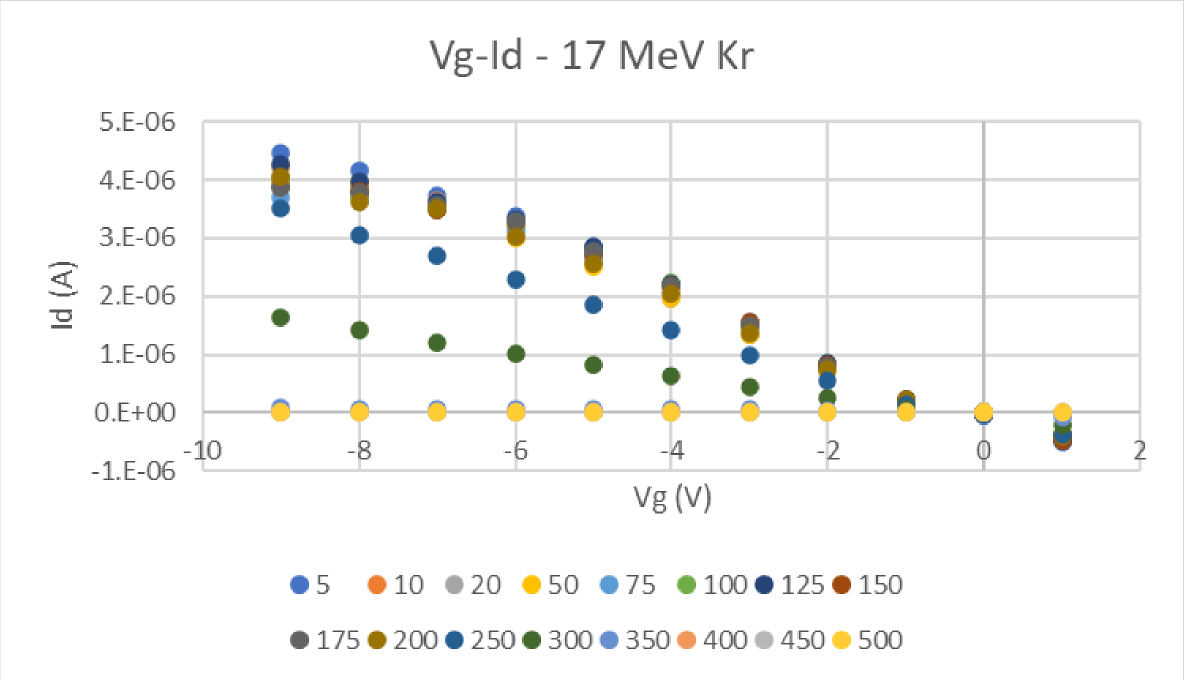
- **PIGS DUT #1**





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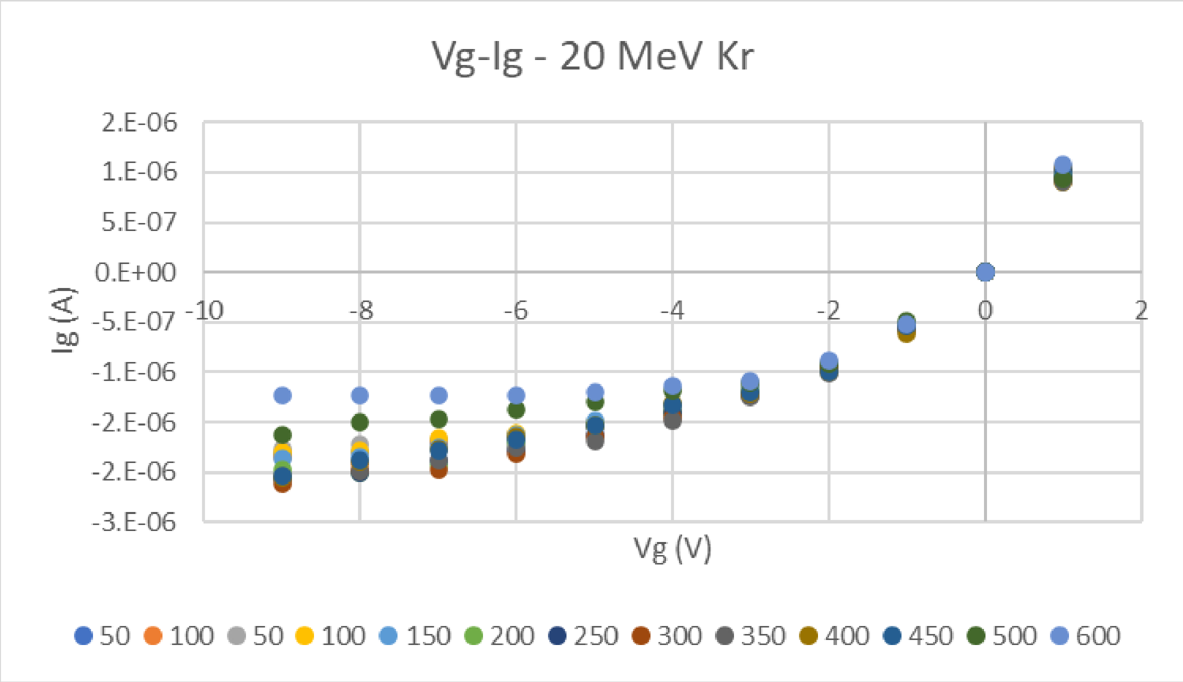
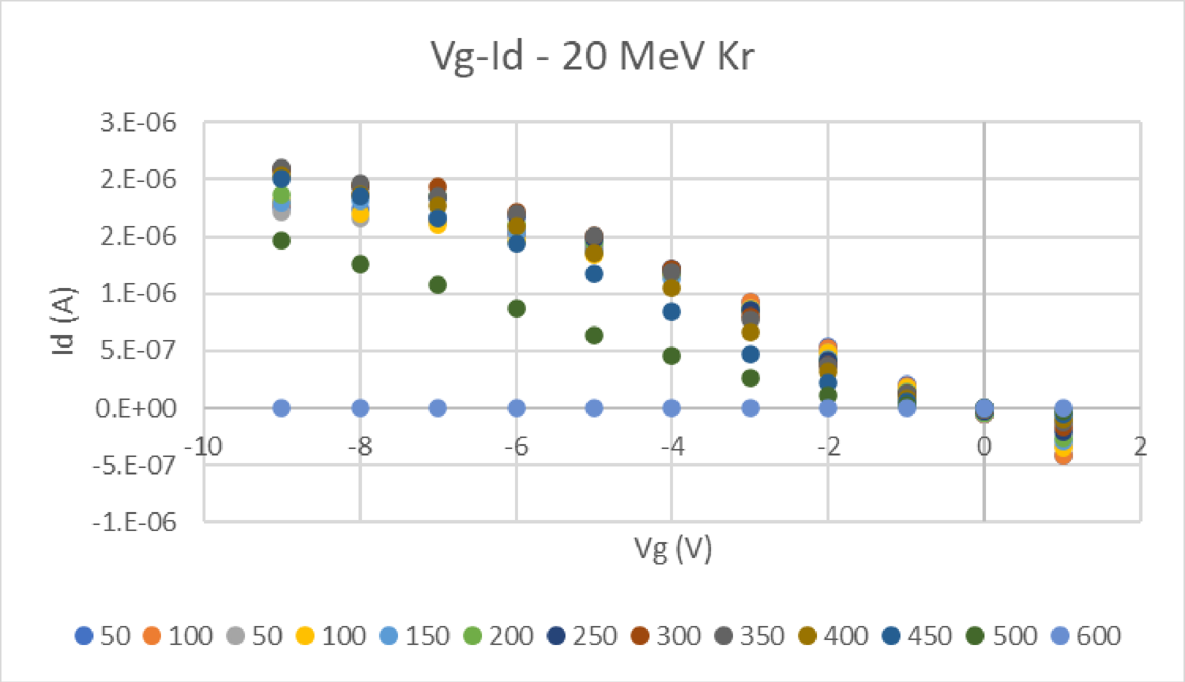
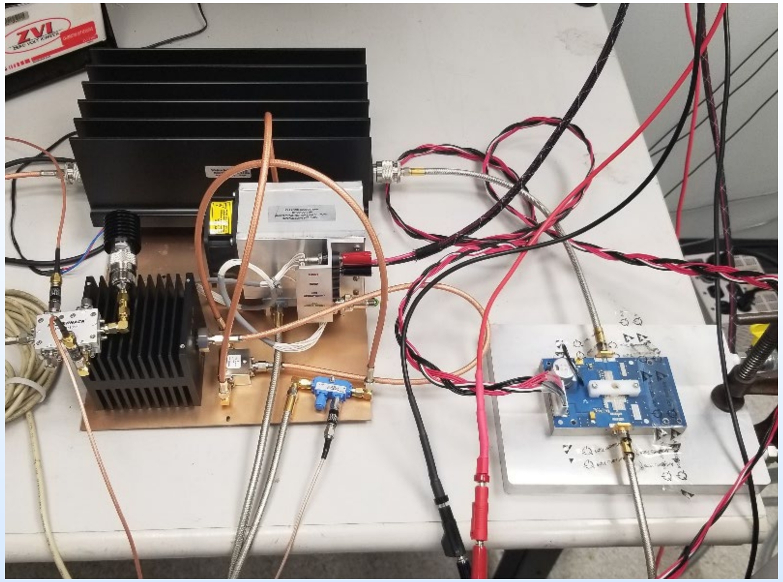
- **PIGS DUT #2**

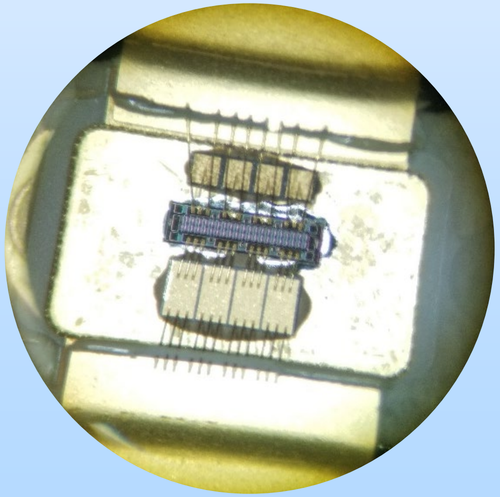




RF GaN HEMTs – Aerospace Corporation

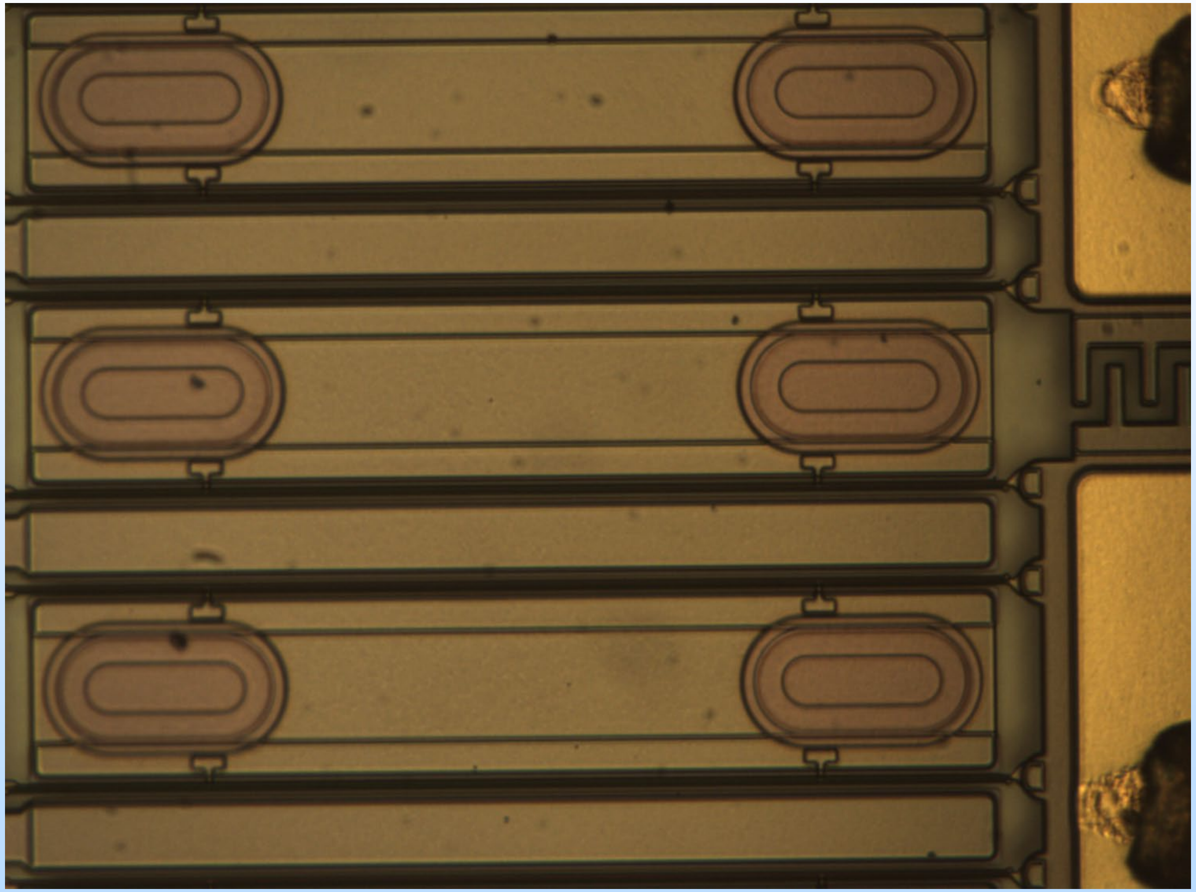
- 2 different RF test setups for comparison
- Lower power devices from Aerospace
- REAG Power Device Test board adapted for DC mode testing
- Awaiting Beamtime

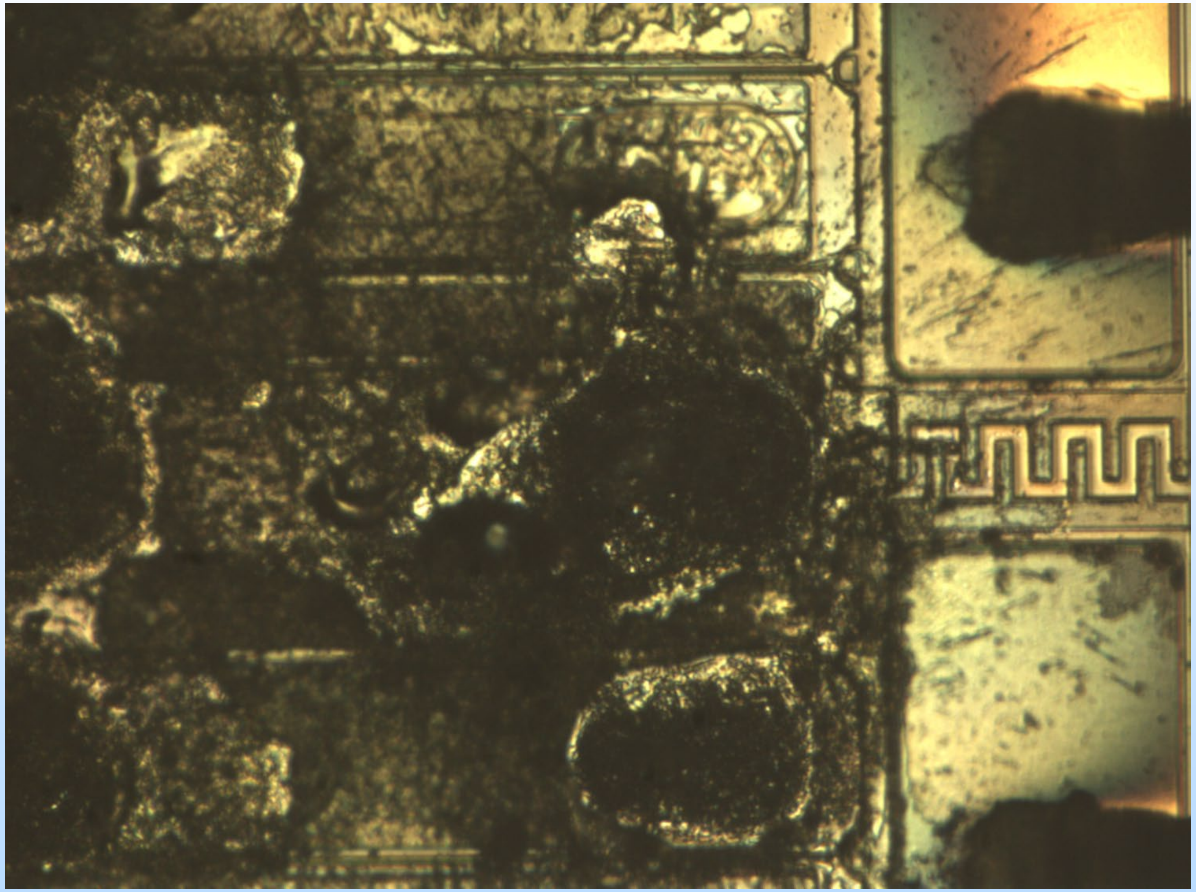




Part #	Drain Voltage	Power In	Power Out	Gate Voltage	Frequency Range	
					Min	Max
CGHV59350F	50V	46 dBm	302 W	-3V (OFF)	5.2	5.9
CGHV59070F	50V	35.5 dBm	90 W	-2.8V (OFF)	4.4	5.9
CGHV40200PP	50V	38 dBm	250W	-3V (OFF)	1.7	1.9
CGHV35150F	50V	39 dBm	170W	-3V (OFF)	2.9	3.5

CGHV59350F – Laser Induced SEE with NRL





80x Objective

RF GaN HEMTs – APL IMAP

- 16 hours at TAMU 6/12-6/13
- Qorvo parts
- RF and DC mode testing

- **What did we see?**

LogiSiC SiC Diodes

- **1200 V JBS SiC Diodes**
  - SBIR deliverable
- **Goal: Improved SEB tolerance**

Challenges

- **LogiSiC is now owned by SC Devices**
- **3.8-4 mm epoxy coating**
  - Chemical removal solution
- **Parylene-C coating complete**
- **First round testing planned for 6/24**

NEPP WBG Community Updates

- RADECS Short Course 2023 on SEE in WBG Devices
- JEDEC - TM 1082
  - Presented at January meeting
  - Incorporated comments for submission at May meeting
- SRHEC – Test and Evaluation Working Group
  - nSEE subgroup
- SBIR Topic Z1.06
  - Phase II awarded
- VU LuSTR Project wrapping up this year

Questions???

Feel free to reach out to me at:

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