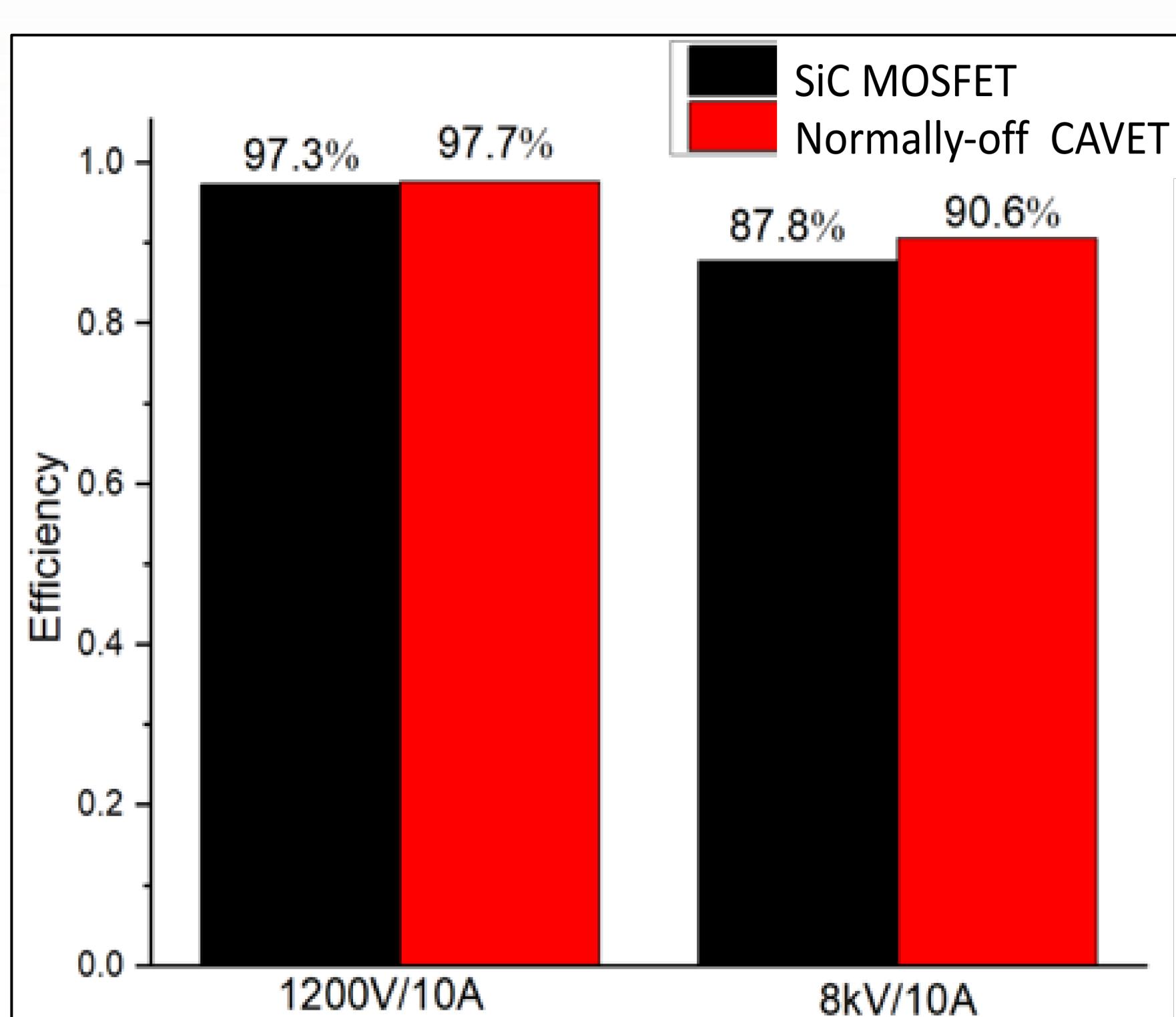


20 kV Gallium Nitride Electromagnetic Pulse Arrestor for Grid Reliability

Foundry Manufacturing of Medium-Voltage Vertical GaN PiN Diodes

Problem Statement

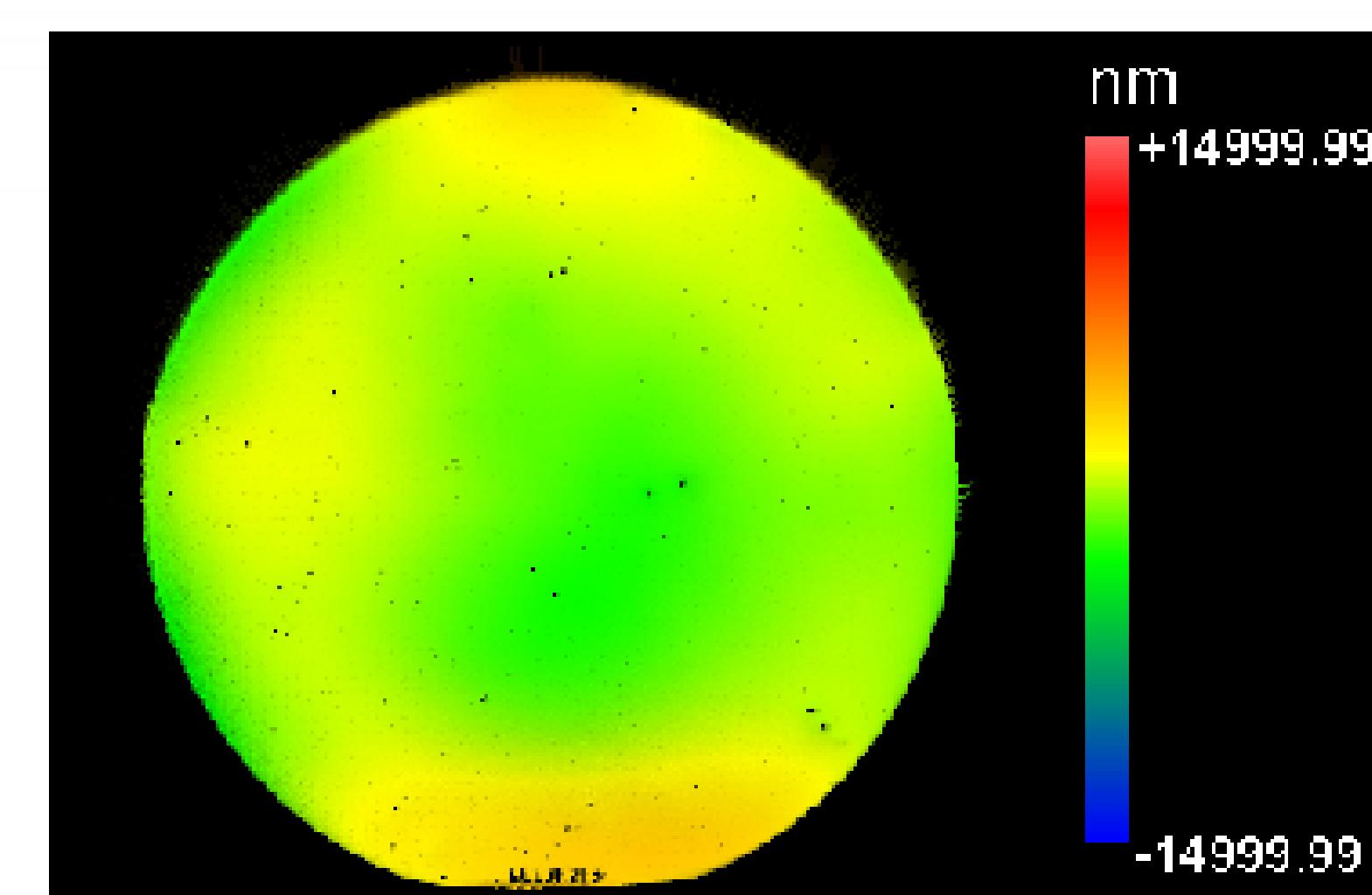
- Significant needs exist for medium-voltage (~1-100 kV) devices for key energy efficiency applications
 - Transportation electrification (EVs, aviation, rail, marine)
 - Smart grid (solid-state transformers, integration of renewables and storage, HVDC transmission)



- Vertical GaN may offer efficiency improvements relative to SiC in the medium-voltage regime
- But manufacturing process including yield and reliability evaluation is immature

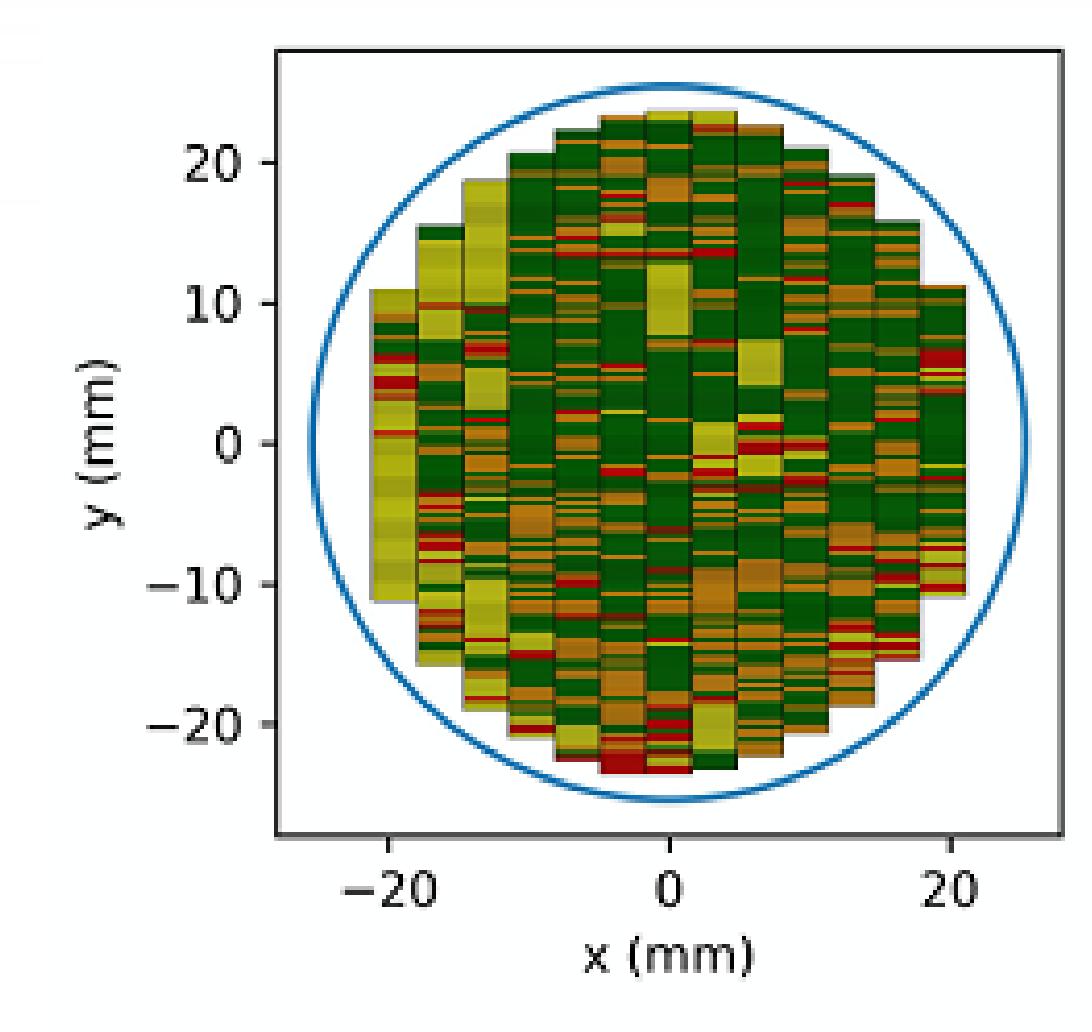
Incoming Wafer Metrology

Lot	# of wafers	Experiments
1	2	Edge termination
2	4	Vary Anode thickness Alignment to dot-core
3	4	Type I (uniform) substrates
4	4	Vary drift layer thickness
5	6	Vary anode doping and other process variations
6	4	Baseline Process w/ improved epi and high yield wafers
7	3	Baseline Process w/ improved epi and new mask
8	4	New mask, varying implant profiles
9	4	Large-area mask, Back side process demo



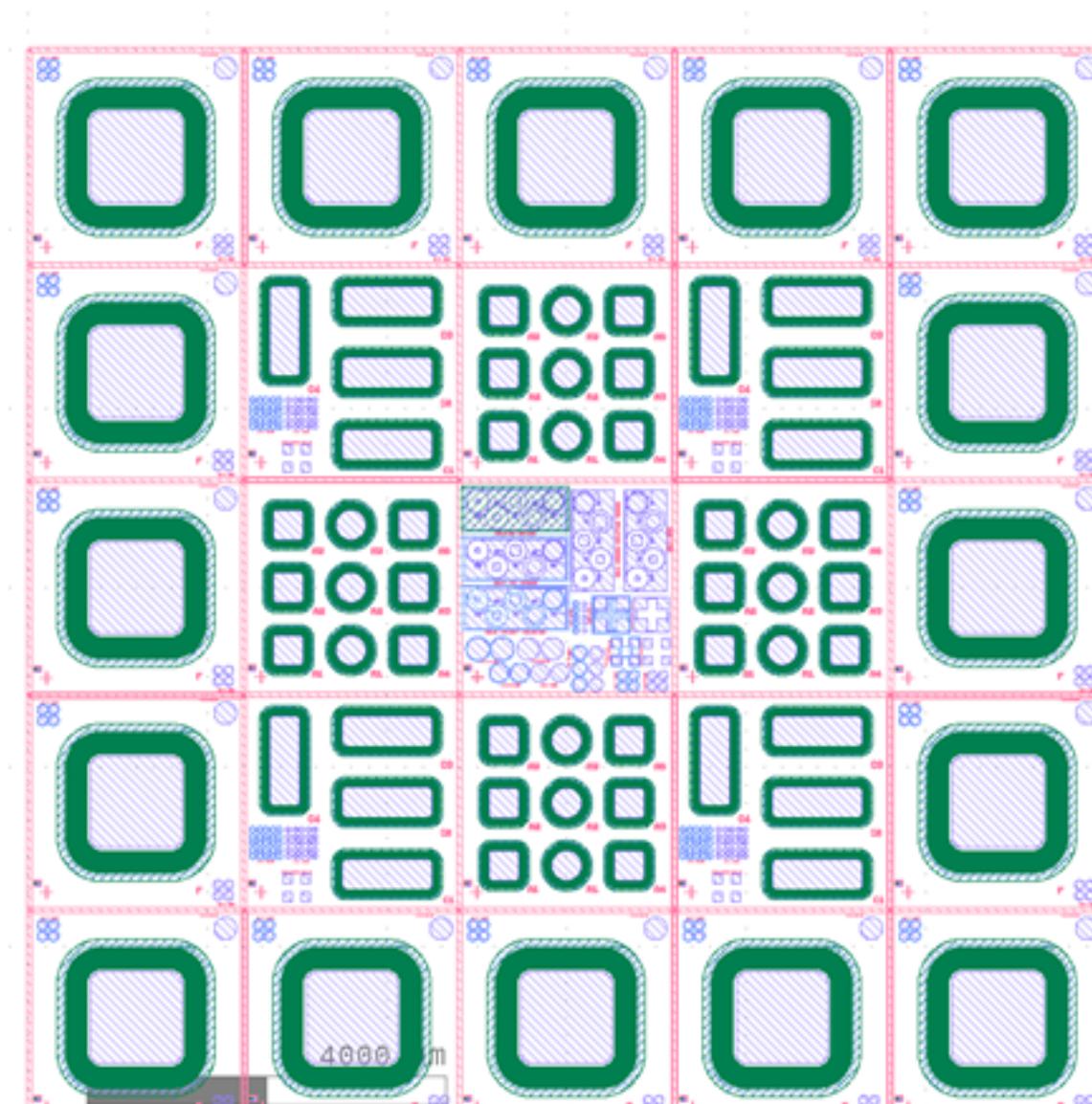
Raw optical profilometry data

- Epitaxial growth done at Sandia by MOCVD and wafers delivered to NRL for characterization and processing
- >35 wafers delivered
- >26,000 devices processed to date

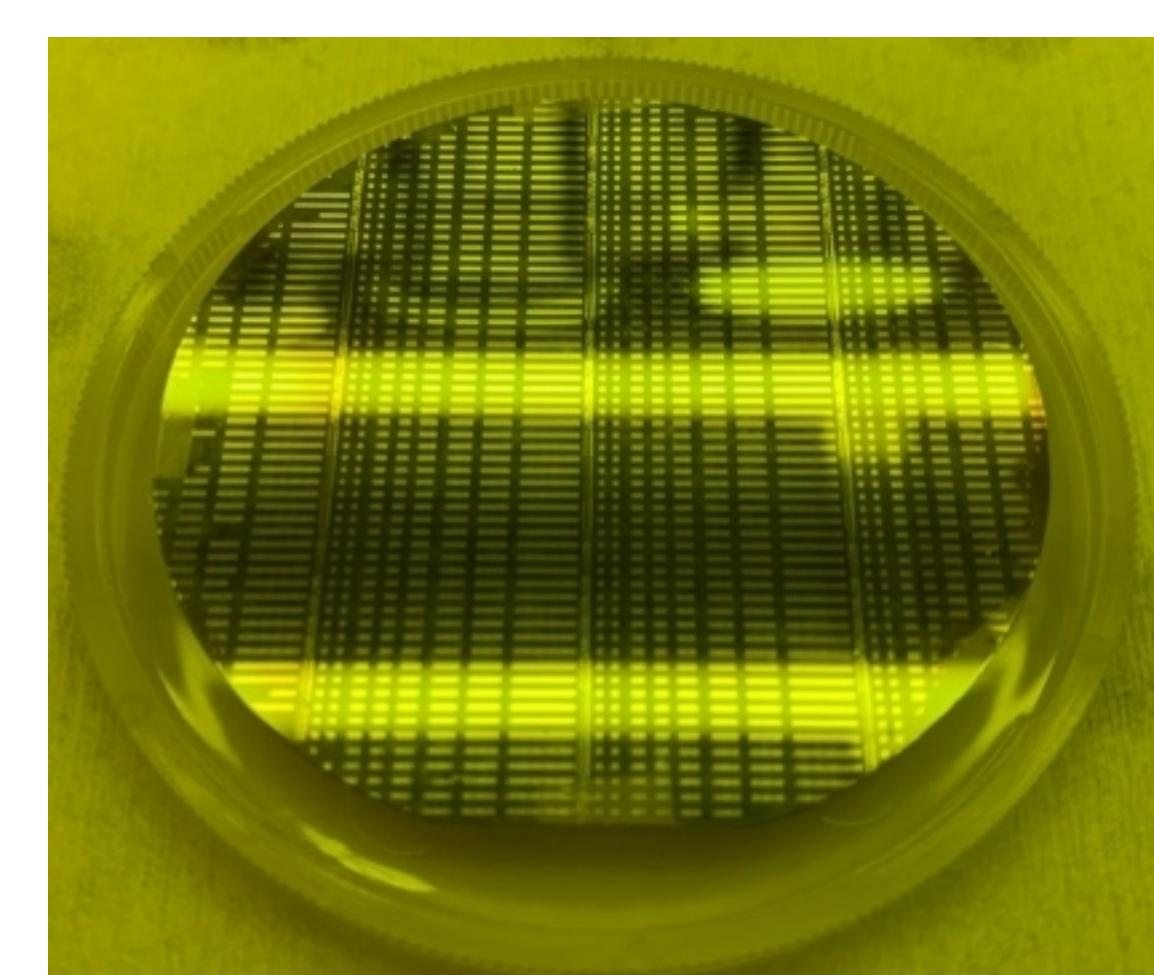


Anticipated 1 mm² device yield

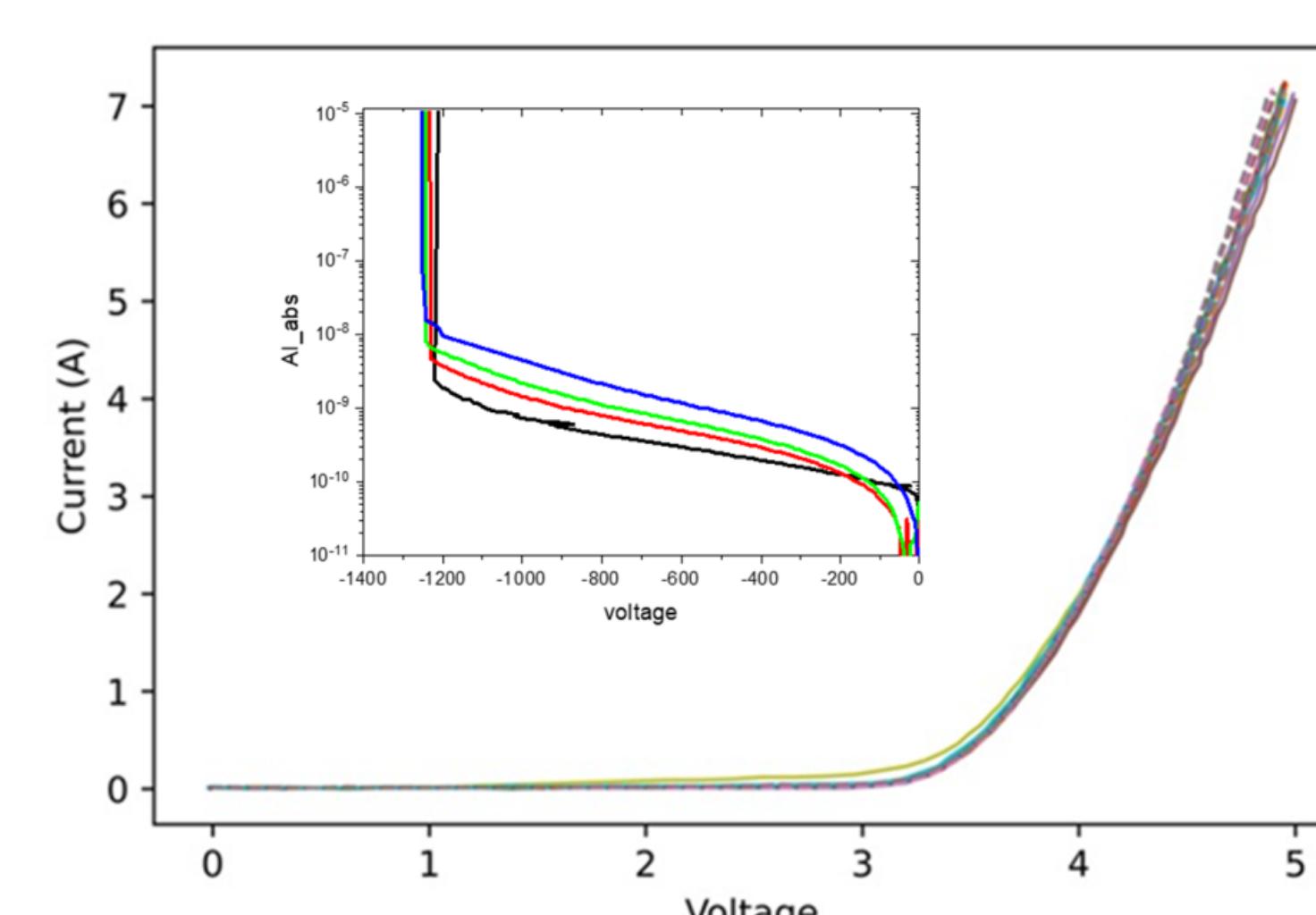
Foundry mask layout



Device Processing and Characterization

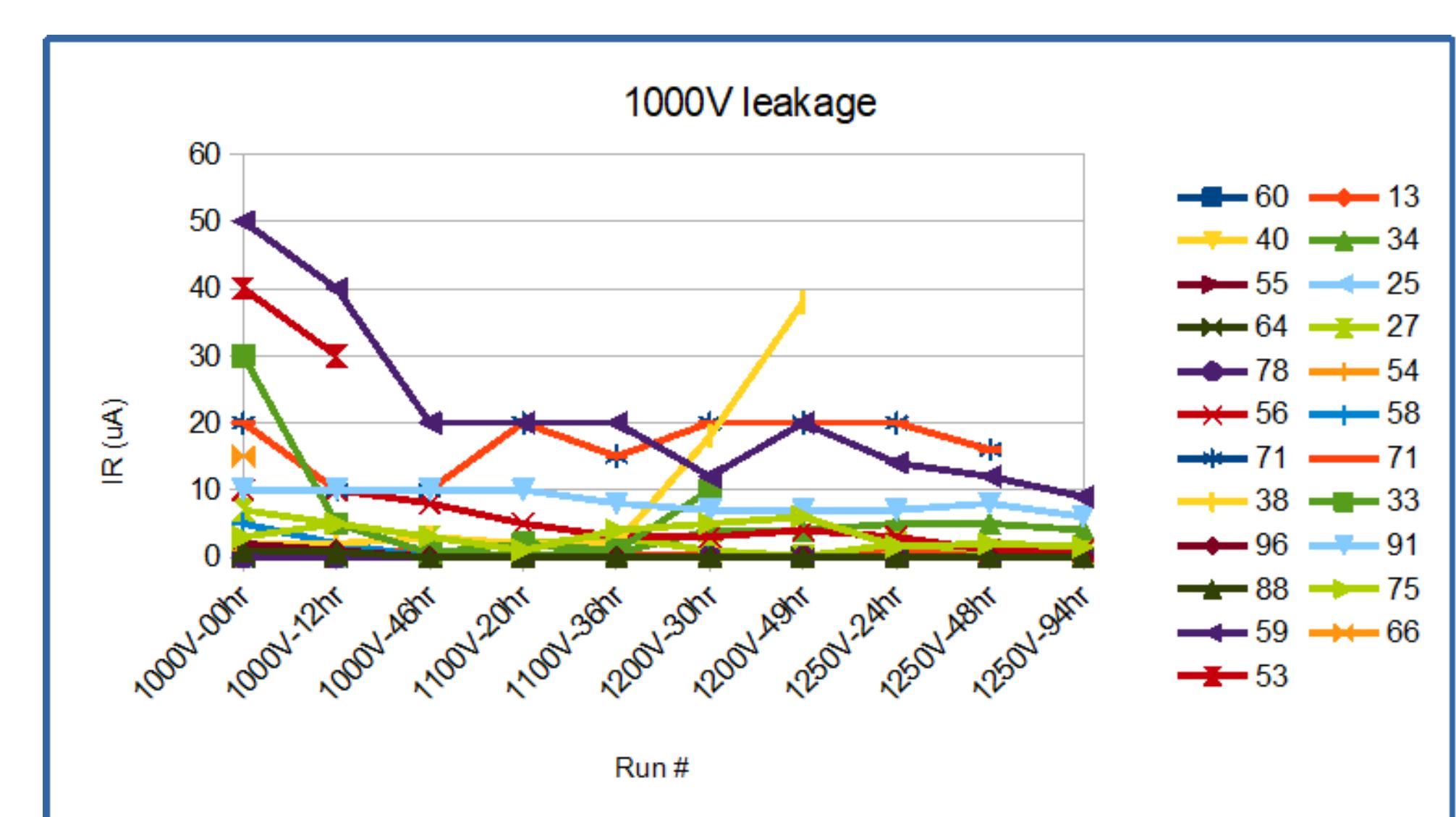


Typical foundry wafer



Forward and reverse IVs

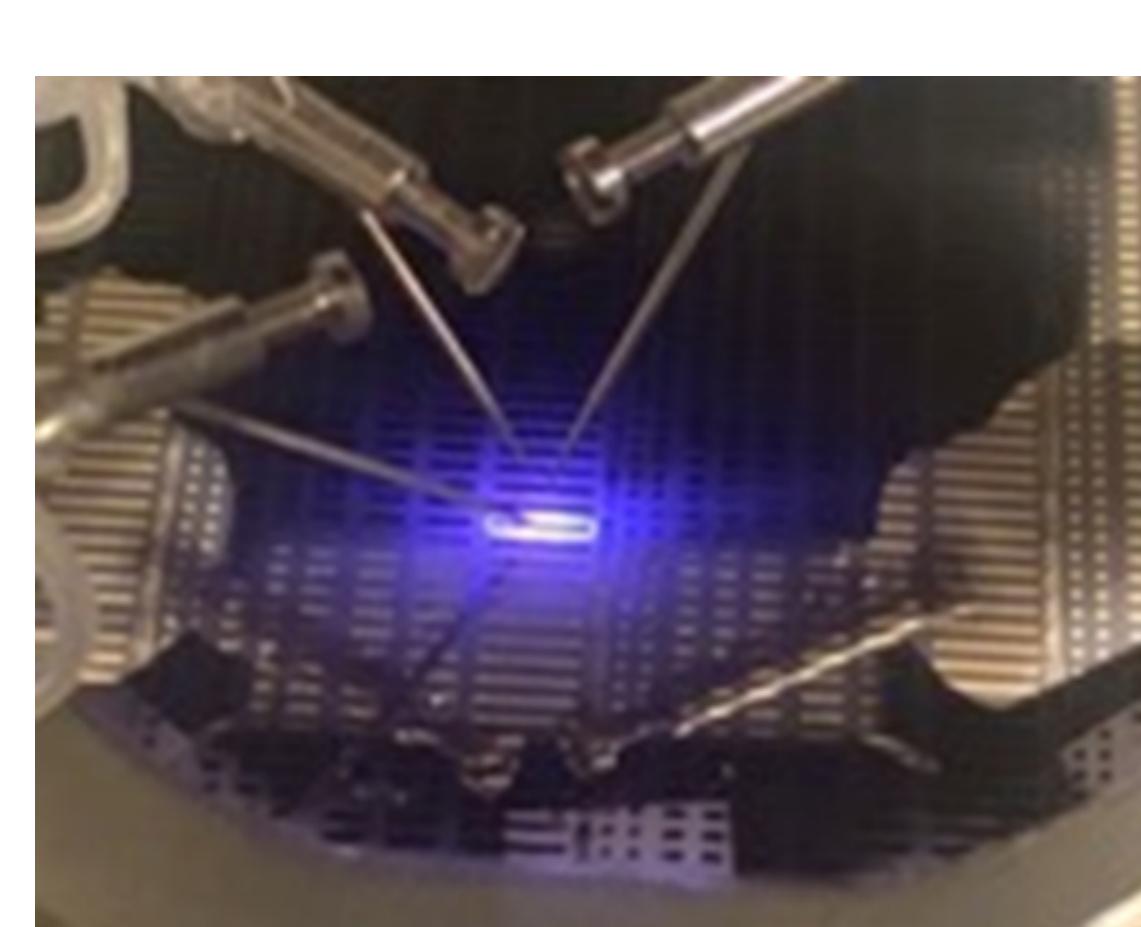
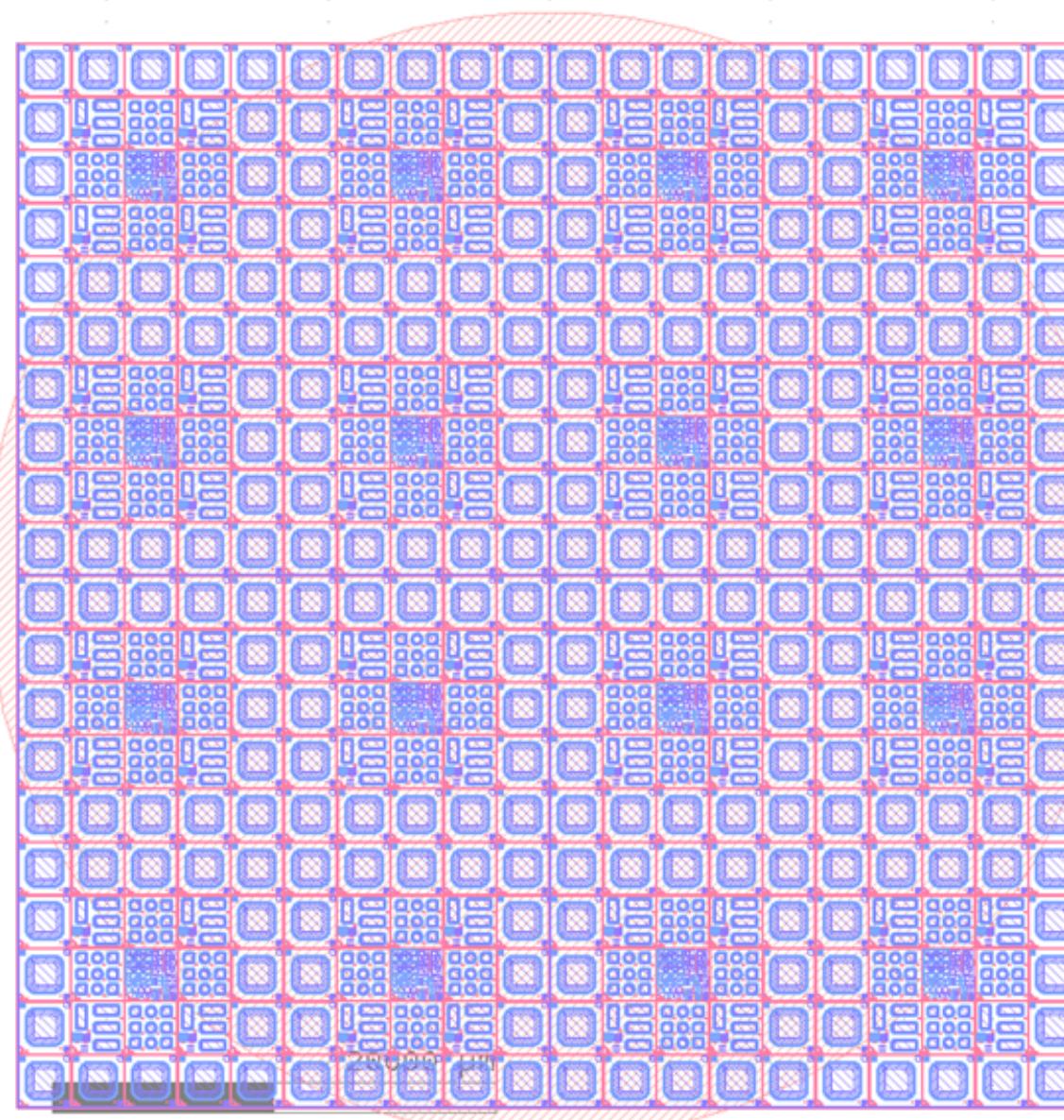
Reliability testing



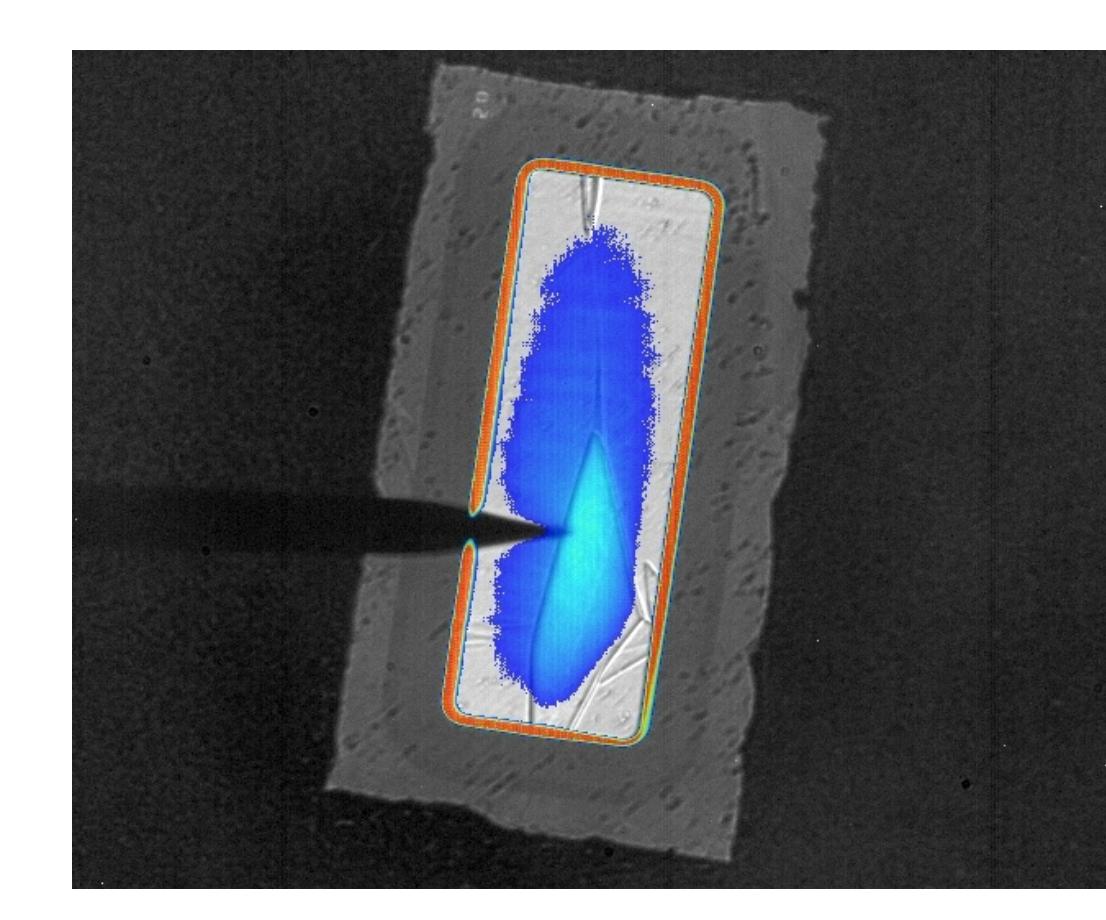
Breakdown (V) I_c (A/cm²) R_{on} (Ω·cm²) N_d (cm⁻³)

187	6.54e-03	2.71	2.60e+16
359	6.54e-03	2.53	2.55e+16
437	6.42e-03	2.37	2.54e+16
744	6.28e-05	2.35	2.54e+16
210	6.41e-05	2.29	2.55e+16
729	4.51e-05	2.23	2.47e+16
703	3.34e-05	2.22	2.56e+16
744	2.31e-05	2.19	2.56e+16
759	6.22e-04	2.13	2.57e+16
640	1.99e-05	2.19	2.58e+16
765	5.51e-05	2.18	2.56e+16
764	5.45e-05	2.17	2.43e+16
760	7.16e-05	2.27	2.44e+16
755	4.32e-05	2.21	2.42e+16
760	5.67e-05	2.21	2.34e+16
358	4.11e-03	2.63	2.81e+16
760	4.64e-05	2.99	2.81e+16

Correlation of measured electrical parameters



Wafer under test



Failure analysis

- Most work to date on 1.2 kV devices
- 3.3 kV device work started