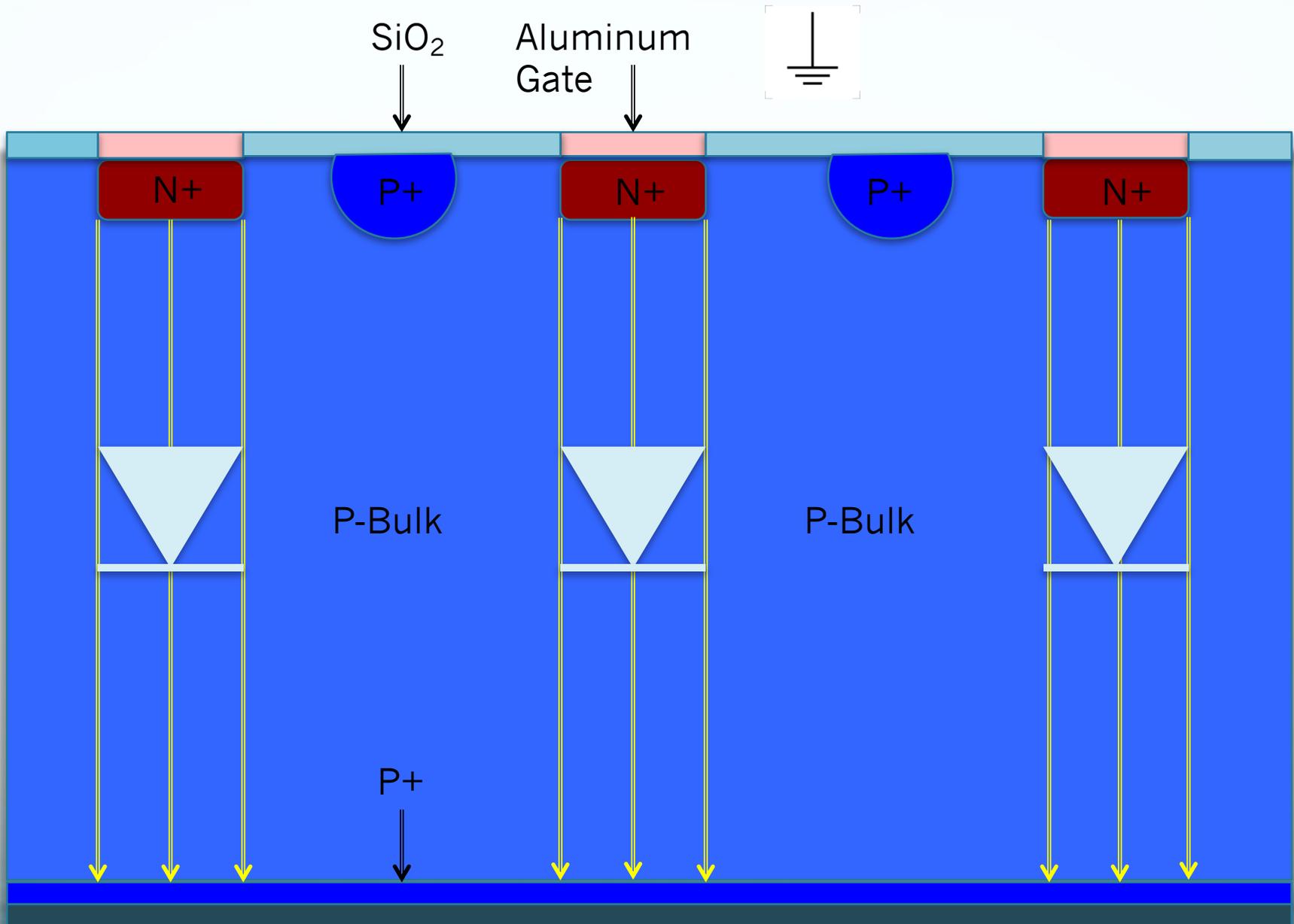


# Enhanced Semiconductor Pre-Irradiation Wafer Testing For HL-LHC Upgrade

Josh Everts

# Underlying Principles

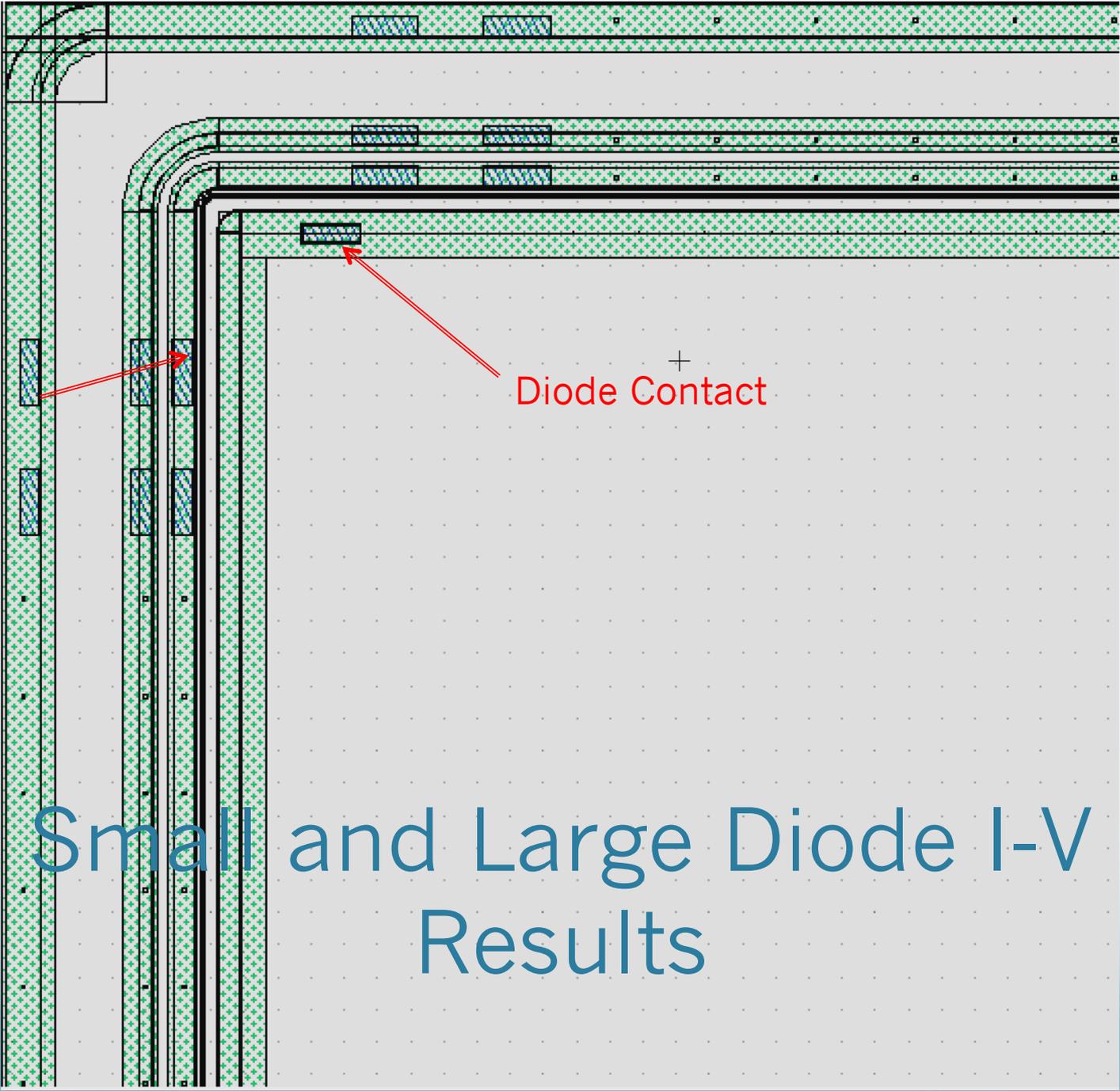
- Particles pass through the detector and collide with atoms in the silicon
- This collision ‘knocks out’ electrons from atoms
- These electrons traverse an electric field created by an applied potential (bias potential) inside the silicon wafer
- Finally, the electrons travel to outside circuitry, through amplifiers and shapers, to generate a signal for analysis



Aluminum Back Contact  $V < -170 \text{ V}$

# Advanced Semiconductor Manufacturing Process and Production Goals

- Silicon On Insulator (SOI) technology enables a thinner wafer without breakage or damage to machinery
- First time the company has produced embedded polysilicon resistors. Goal is to create uniform resistances
- Demonstrate uniformity across wafers and structures.

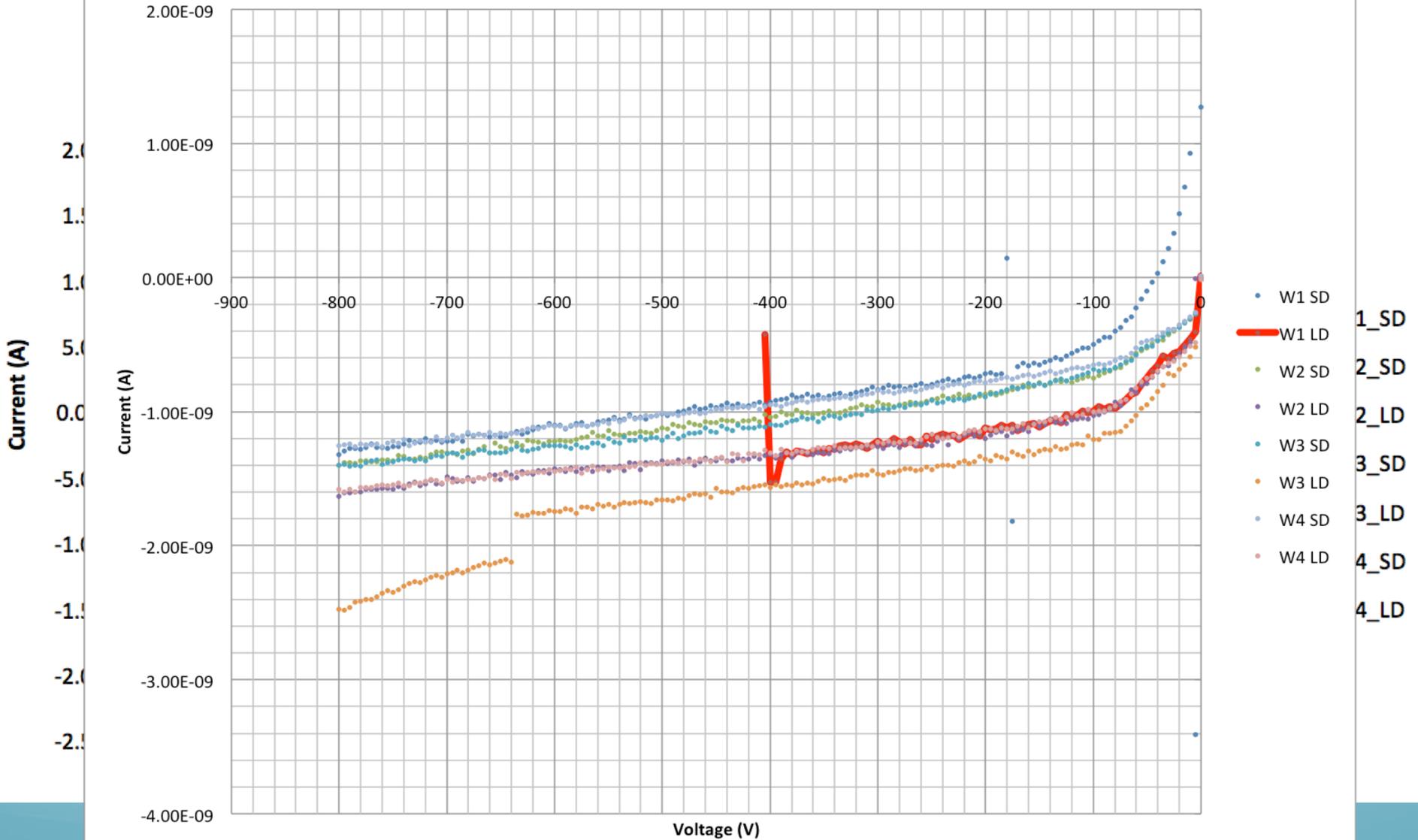


Guard Contact

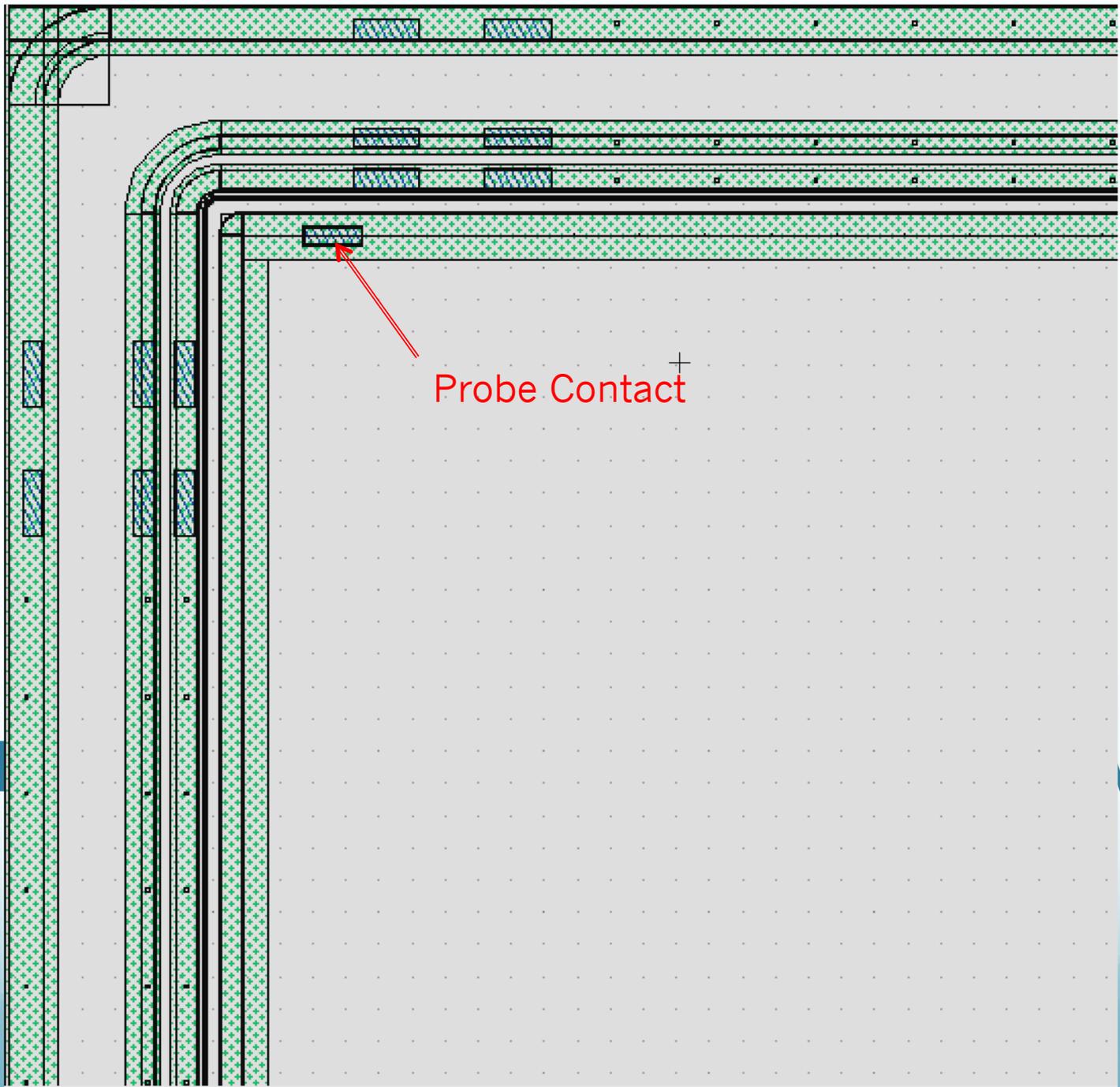
+  
Diode Contact

# Small and Large Diode I-V Results

# K Die Guard Current: Wafers 1-4 On Small and Large Diodes

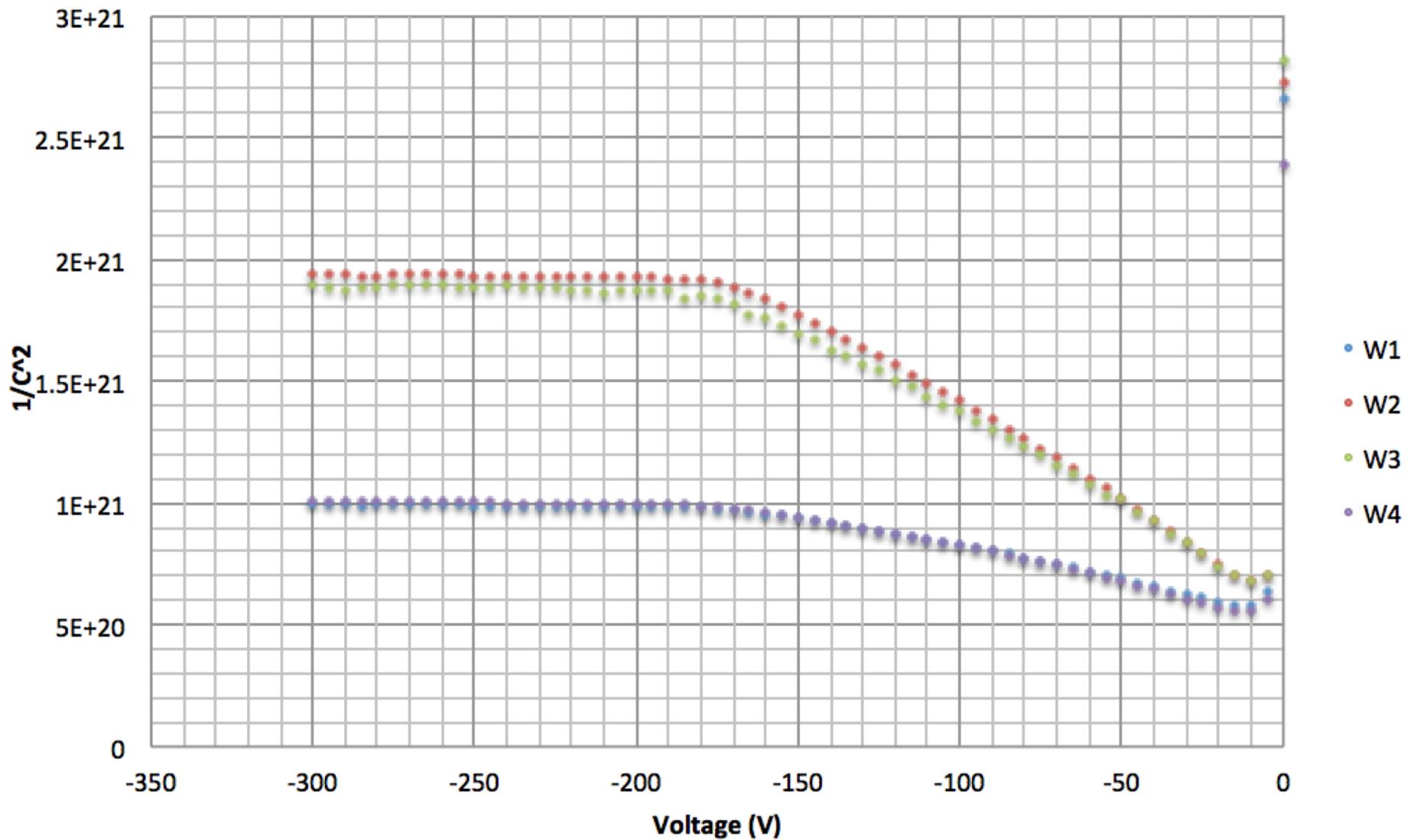


S



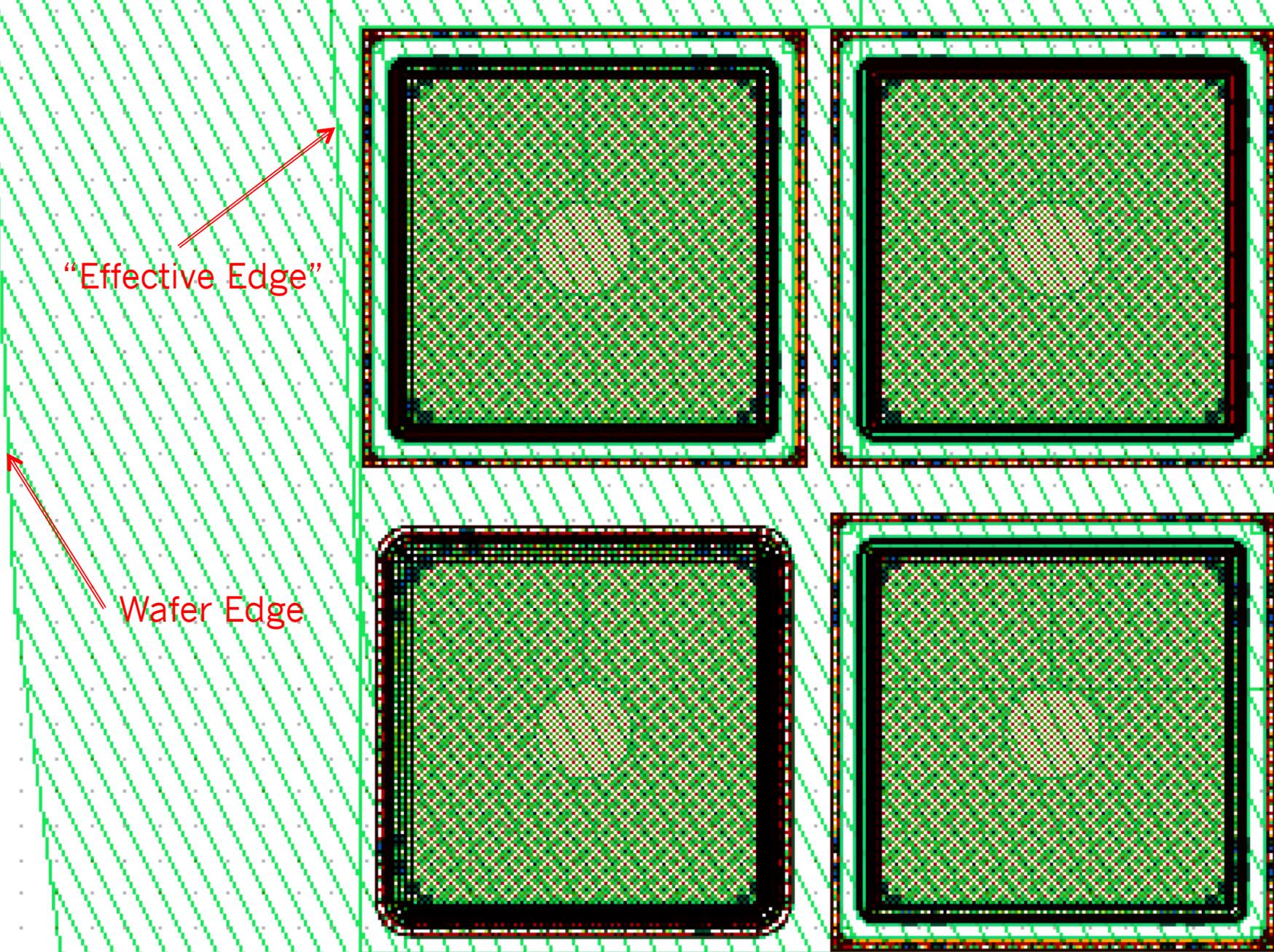
V

# 1/C^2 Large Diodes Across Wafers 1-4



# Small and Large Diode Conclusions

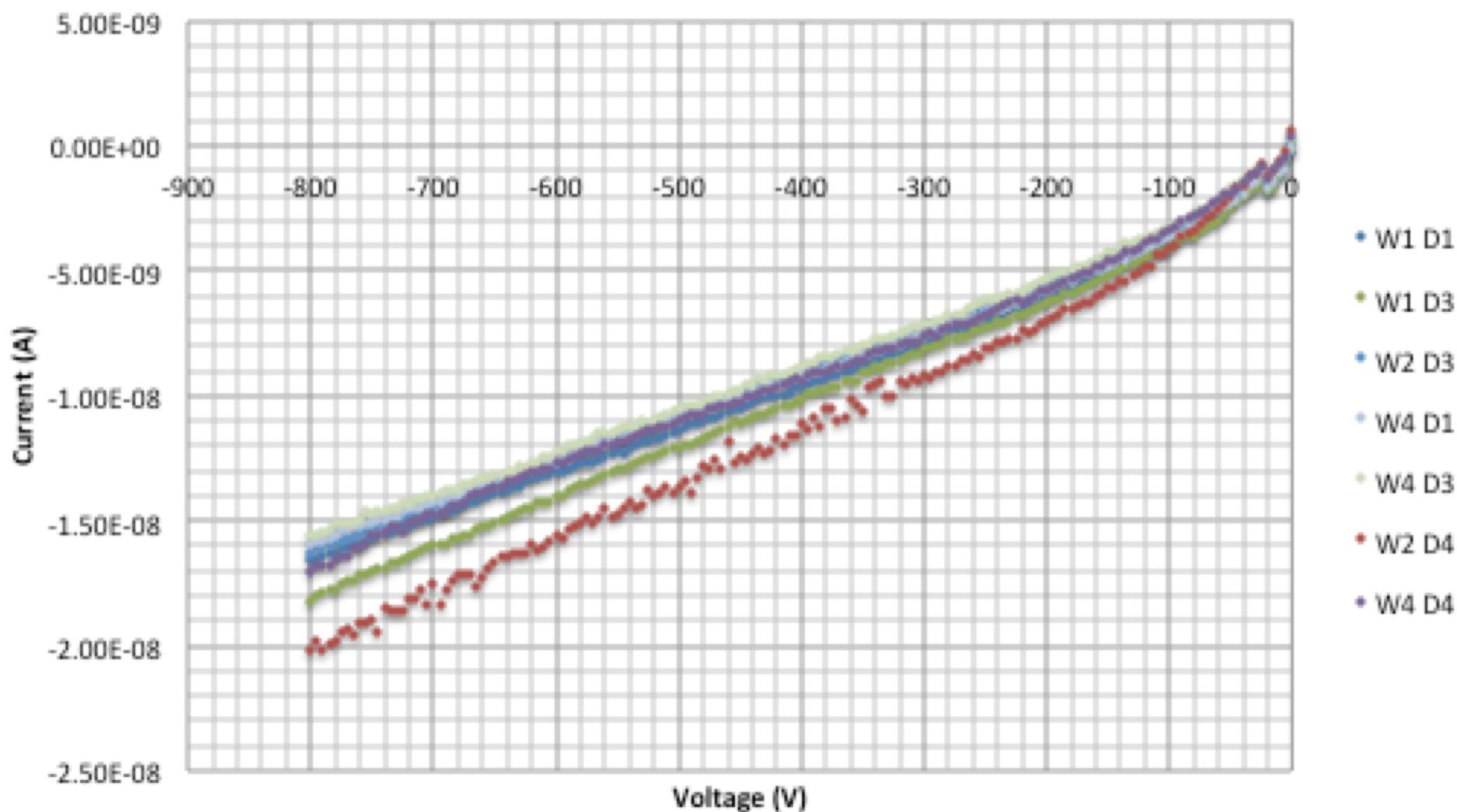
- Silicon resists breakdown across nearly all tested wafers indicating low levels of impurities
- Leakage currents are low indicating that the guard ring is providing good isolation
- C-V curve indicates full depletion at 170V-close to the expected value.



“Effective Edge”

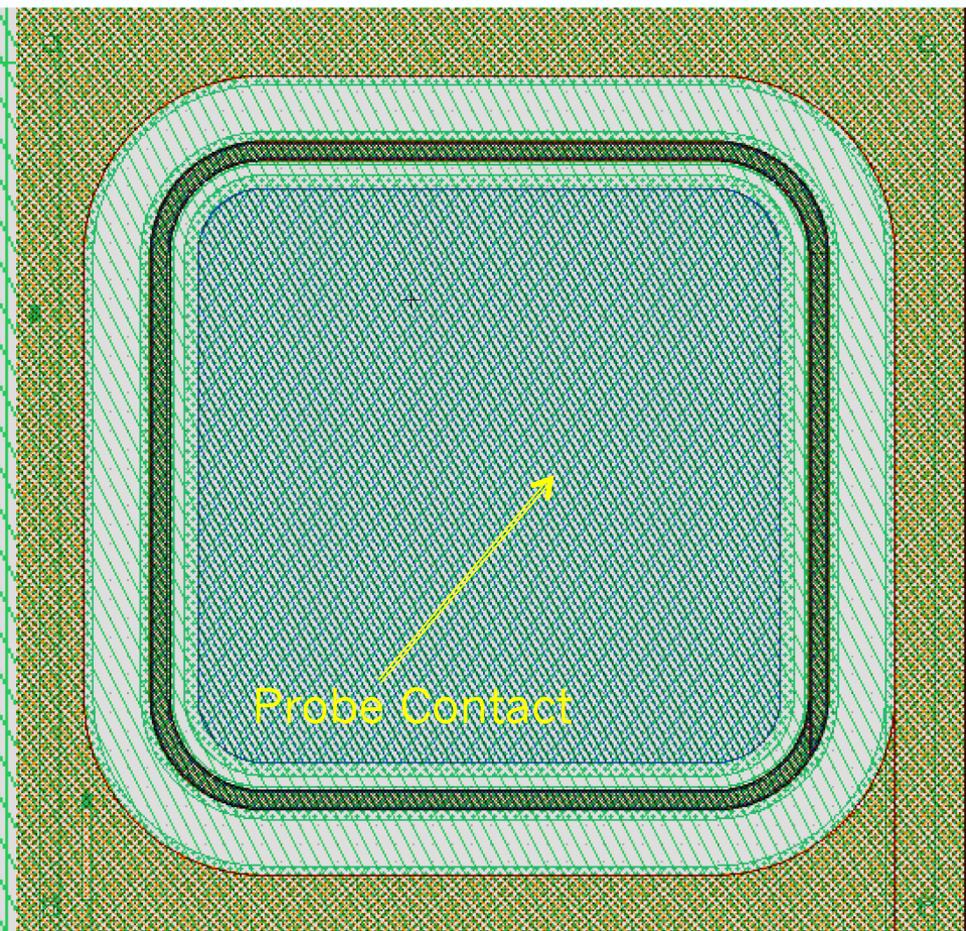
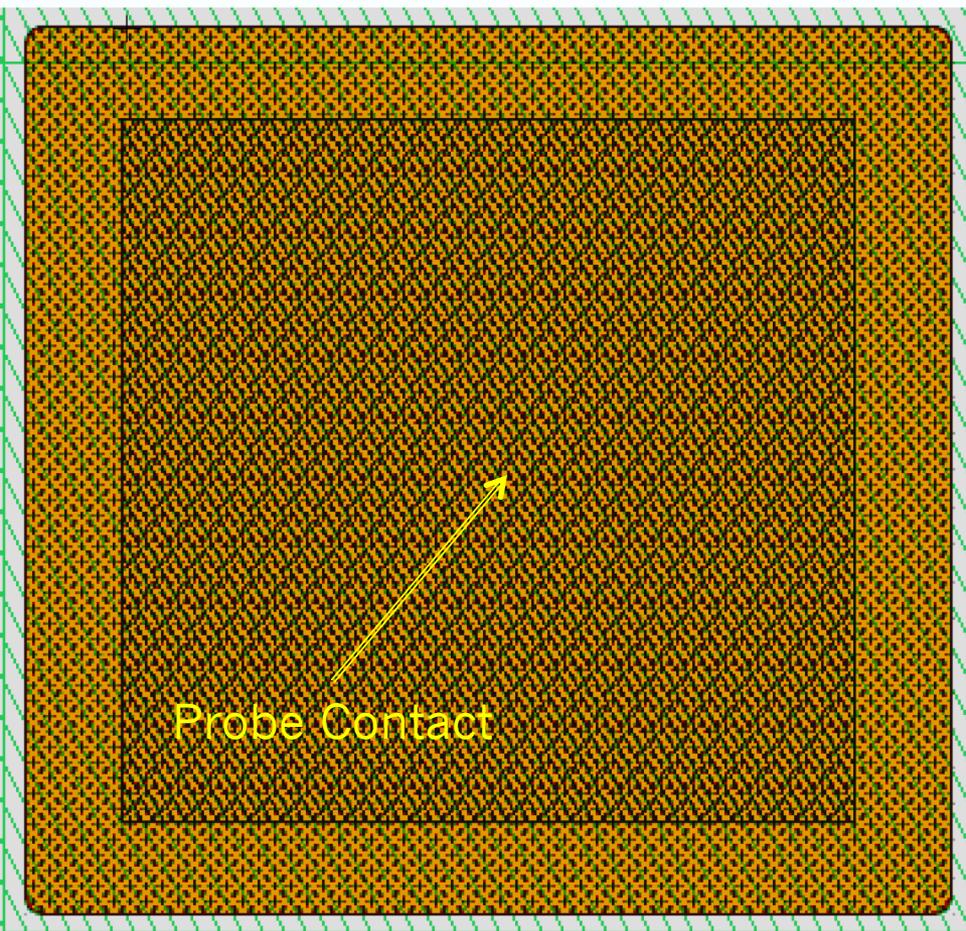
Wafer Edge

## 'Normal' IV Curves Wafers 1-4 Diodes 1-4



# J Die Diode Conclusions

- I-V Curves show that a majority of diodes go into breakdown early, indicating that structures this close to the edge are prone to the effects of edge currents
- Building structures this close to the ‘effective edge’ is not viable



MOS1: Oxide Thickness: 4 microns

Capacitance: 2.16 nanoFarad (.863 nF/cm<sup>2</sup>)

MOS2: Oxide Thickness: 5 microns

Capacitance: 2.5 nanoFarad (.690 nF/cm<sup>2</sup>)

MOS3 Capacitance: 4.75 nanoFarad (21.6 nF/cm<sup>2</sup>)

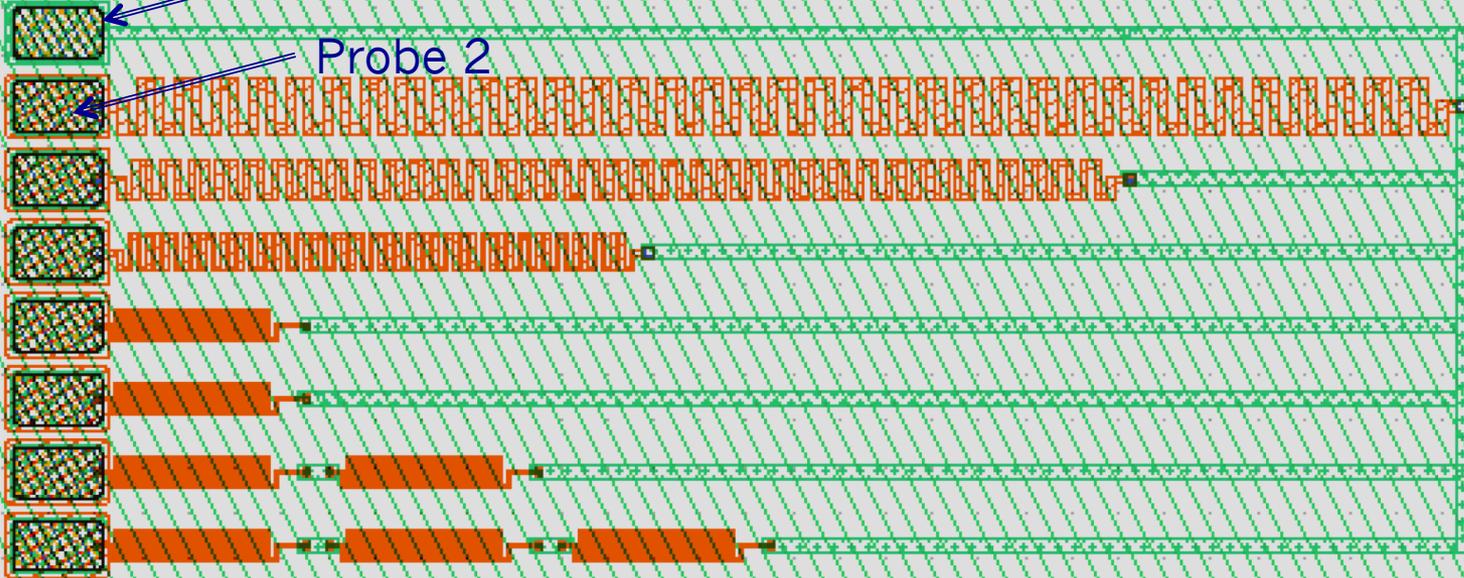
MOS3 Oxide Thickness: 0.17 microns

Expected MOS3: 5.30 nanoFarad (24 nF/cm<sup>2</sup>)  
0.10 microns

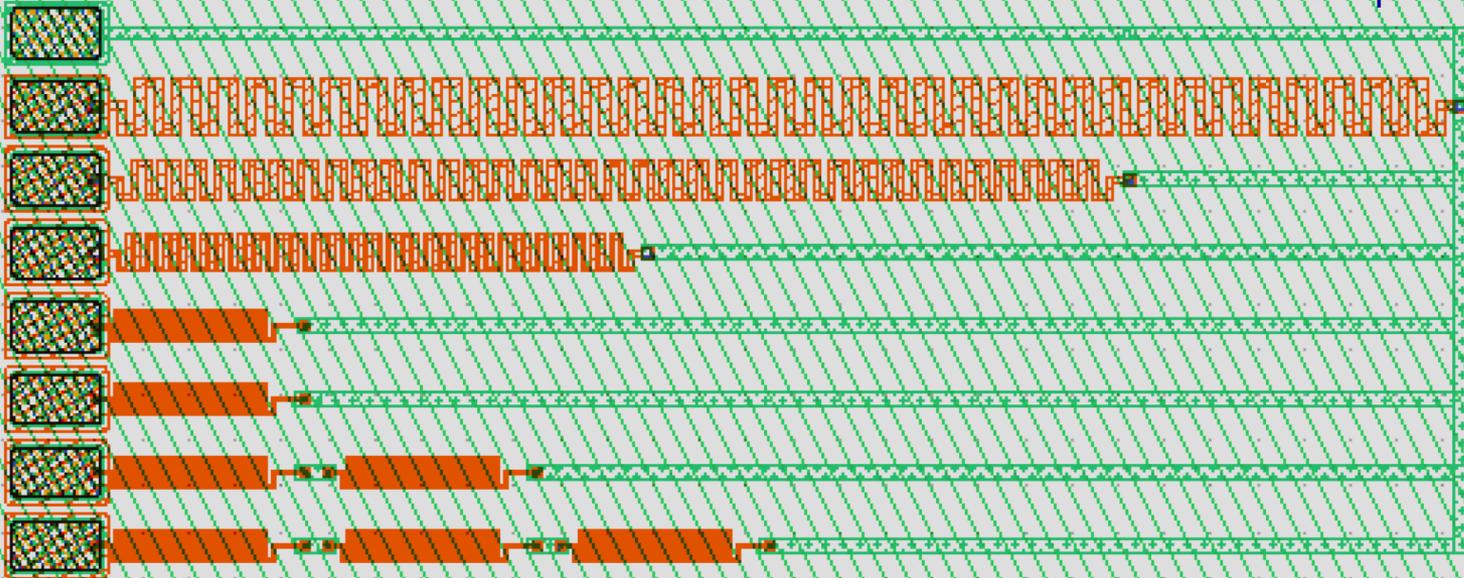
Probe 1

“Far Complex”

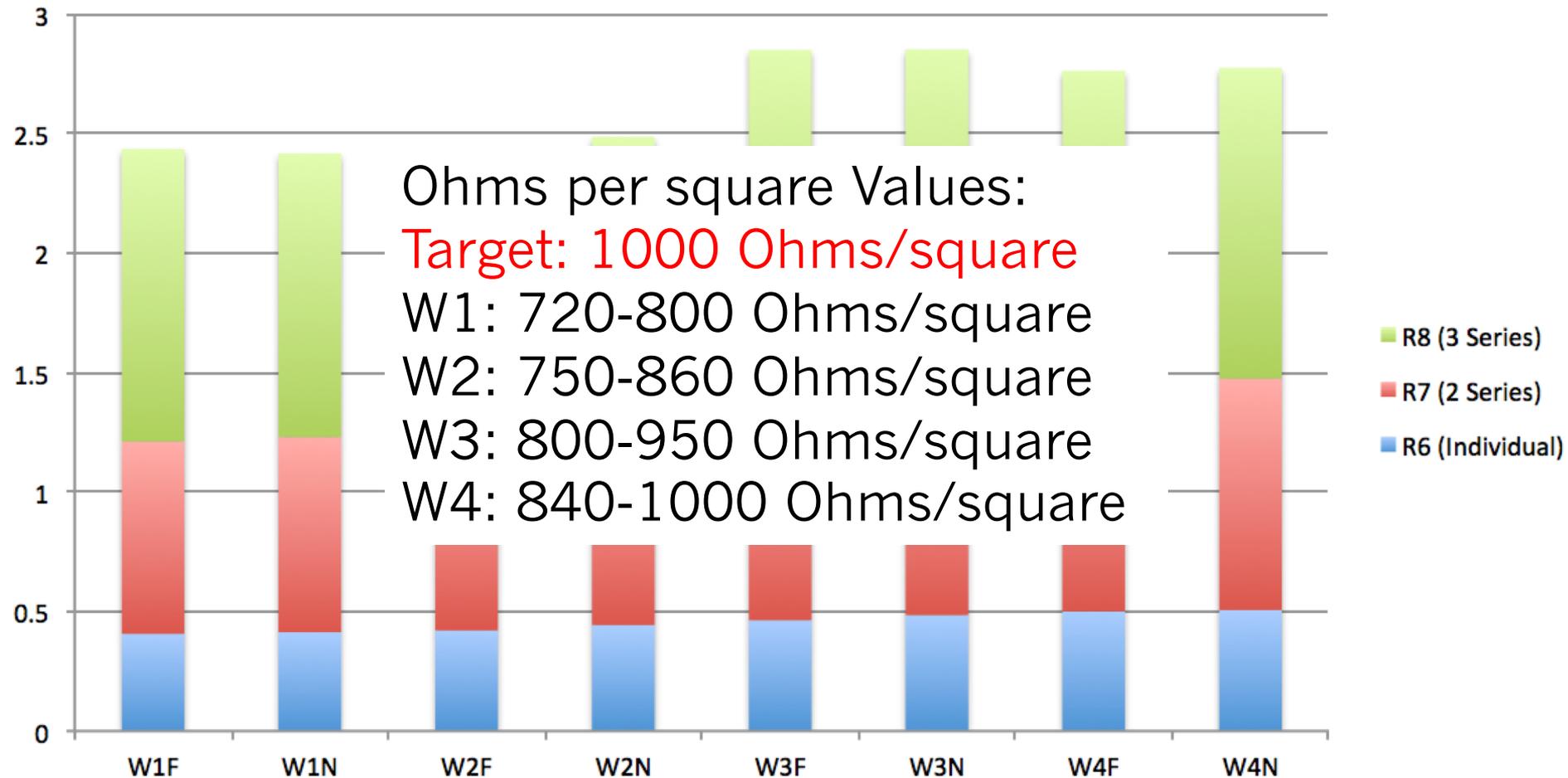
Probe 2



“Near Complex”

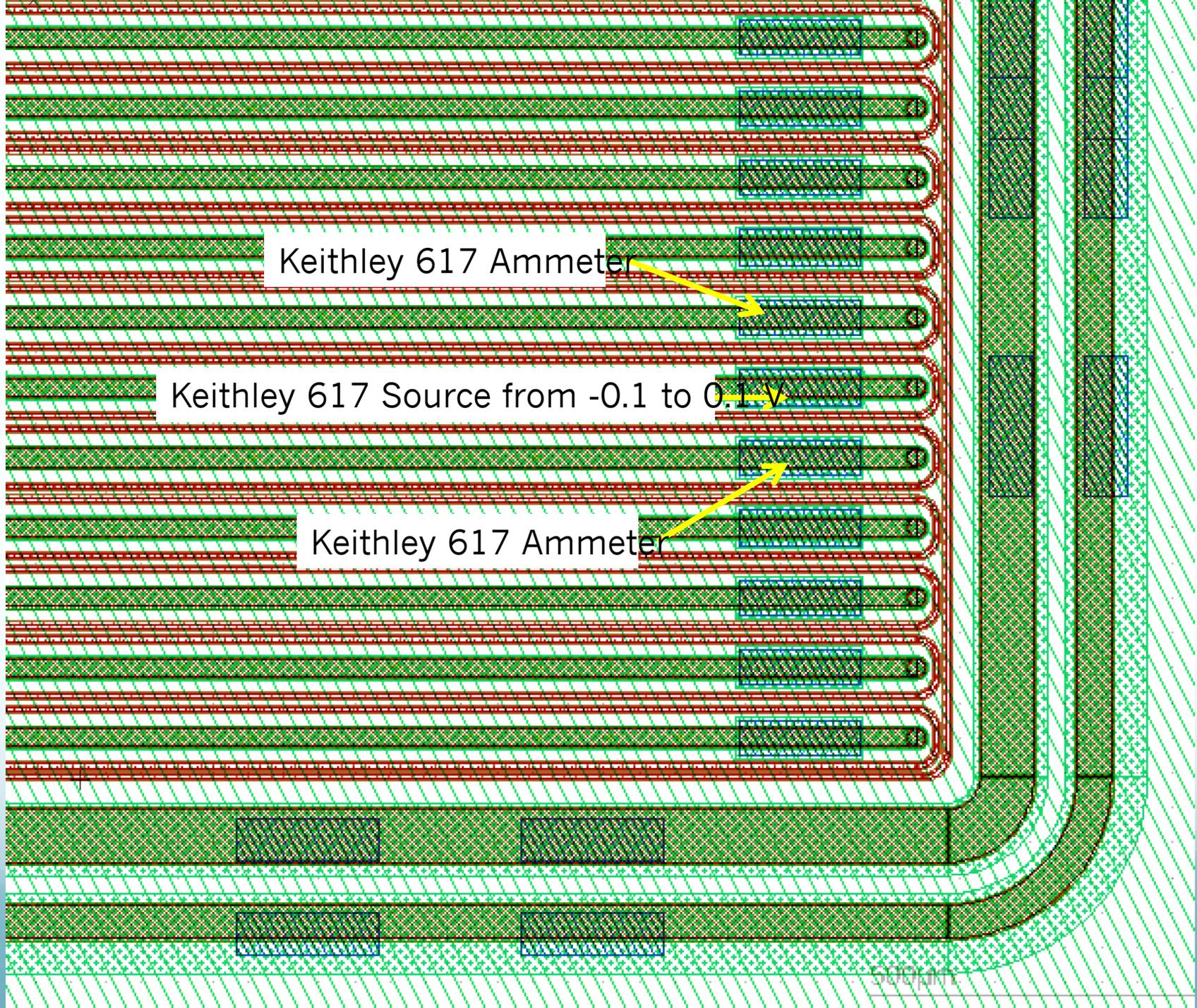


## R6-R8 Series Resistance Comparison Across Complexes



# Polysilicon Resistor Conclusions

- Overall resistances are consistent between complexes on each wafer although less than expected
- Manufacturing differences have caused large variation between resistances on different wafers, this must be fixed before further use in AC coupled strip detectors
- Series resistances are somewhat inconsistent illustrating some difficulties with manufacturing

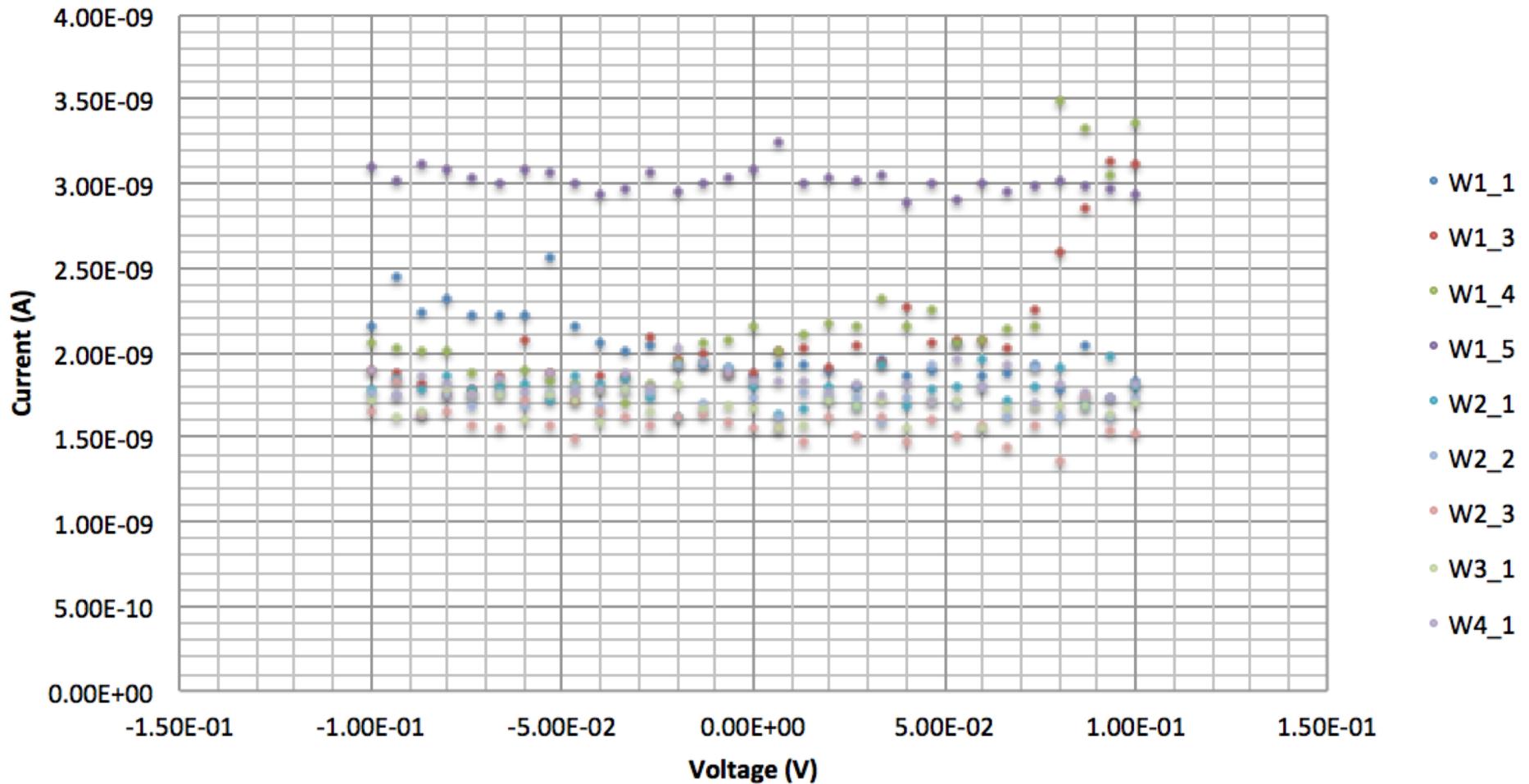


Keithley 617 Ammeter

Keithley 617 Source from -0.1 to 0.1 V

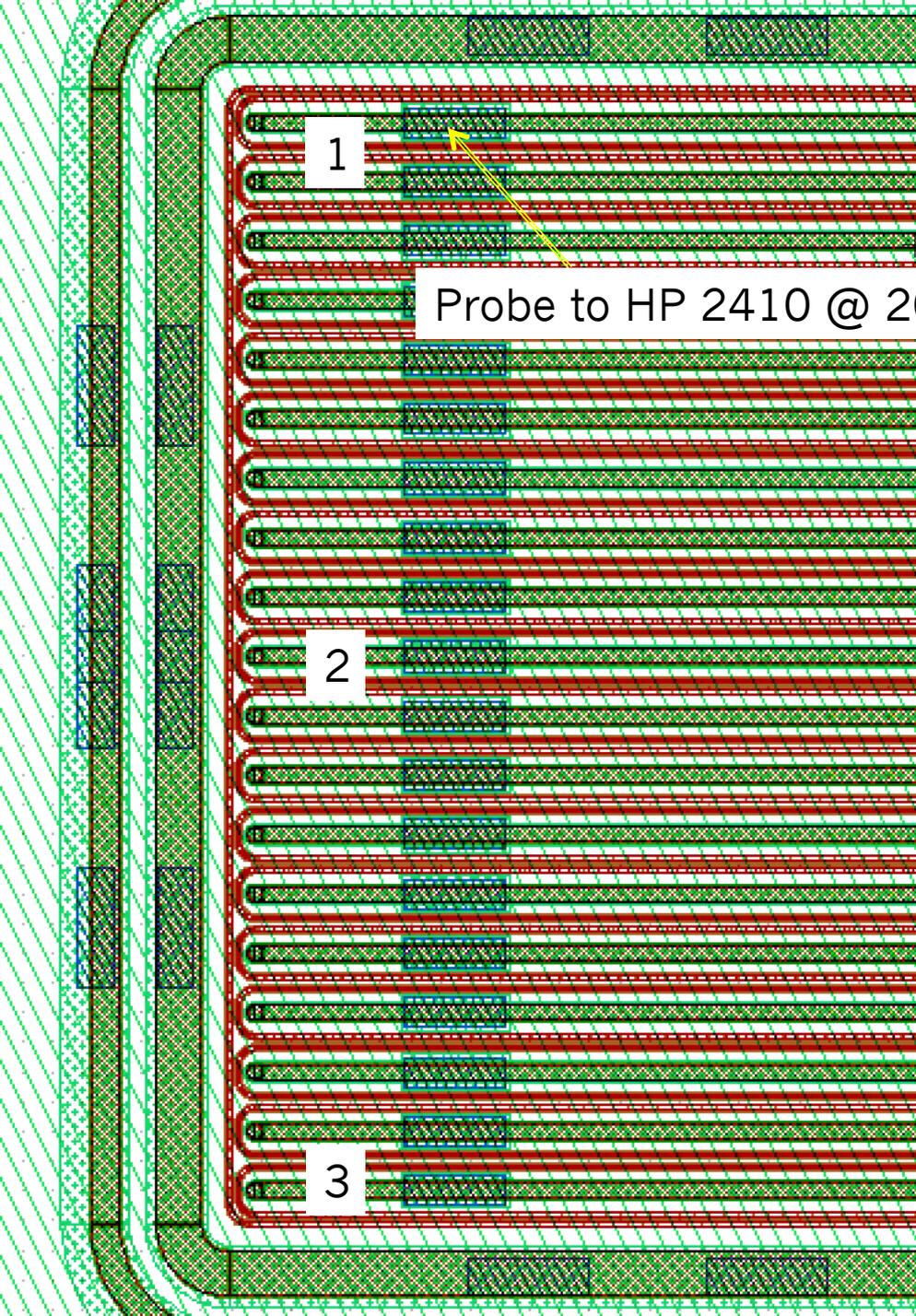
Keithley 617 Ammeter

## Interstrip Resistances SSD-DC Wafers 1-4

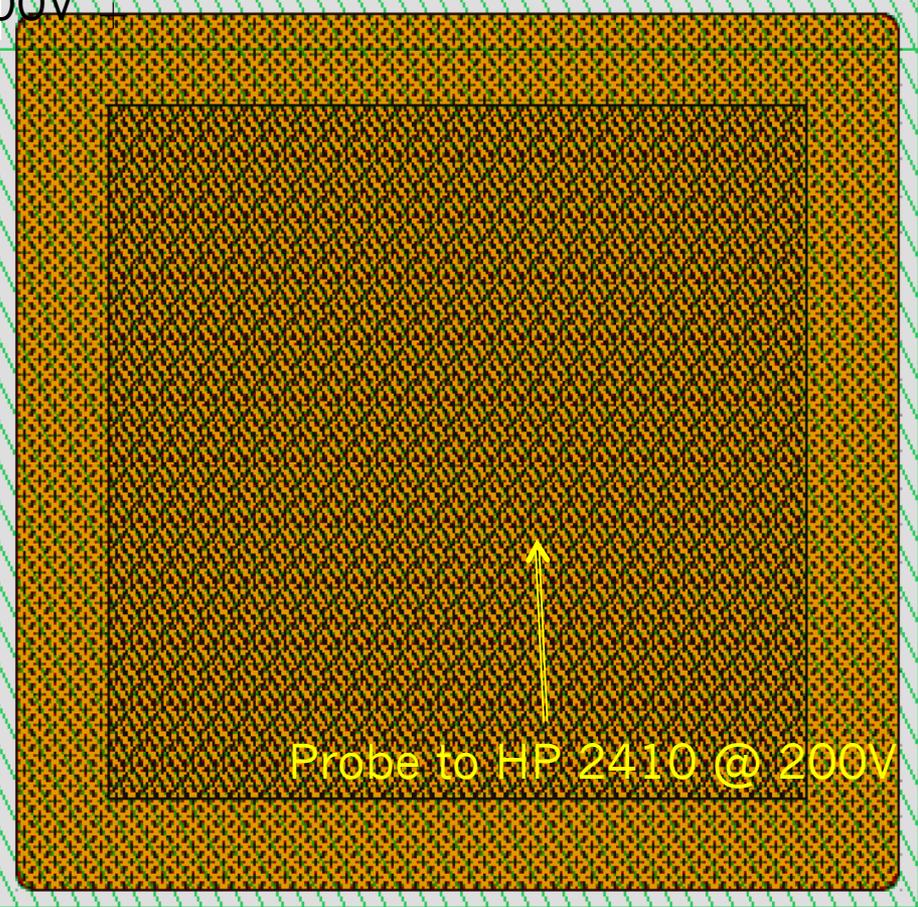


# Interstrip Resistance Conclusions

- P-stops are working correctly as resistances are  $>1$  gigaOhm for wafers 2-4 and around 0.5 gigaOhm for wafer 1
- Further testing with a more accurate setup (lower humidity, measuring voltage drop with a current source) is required for truly accurate measurements

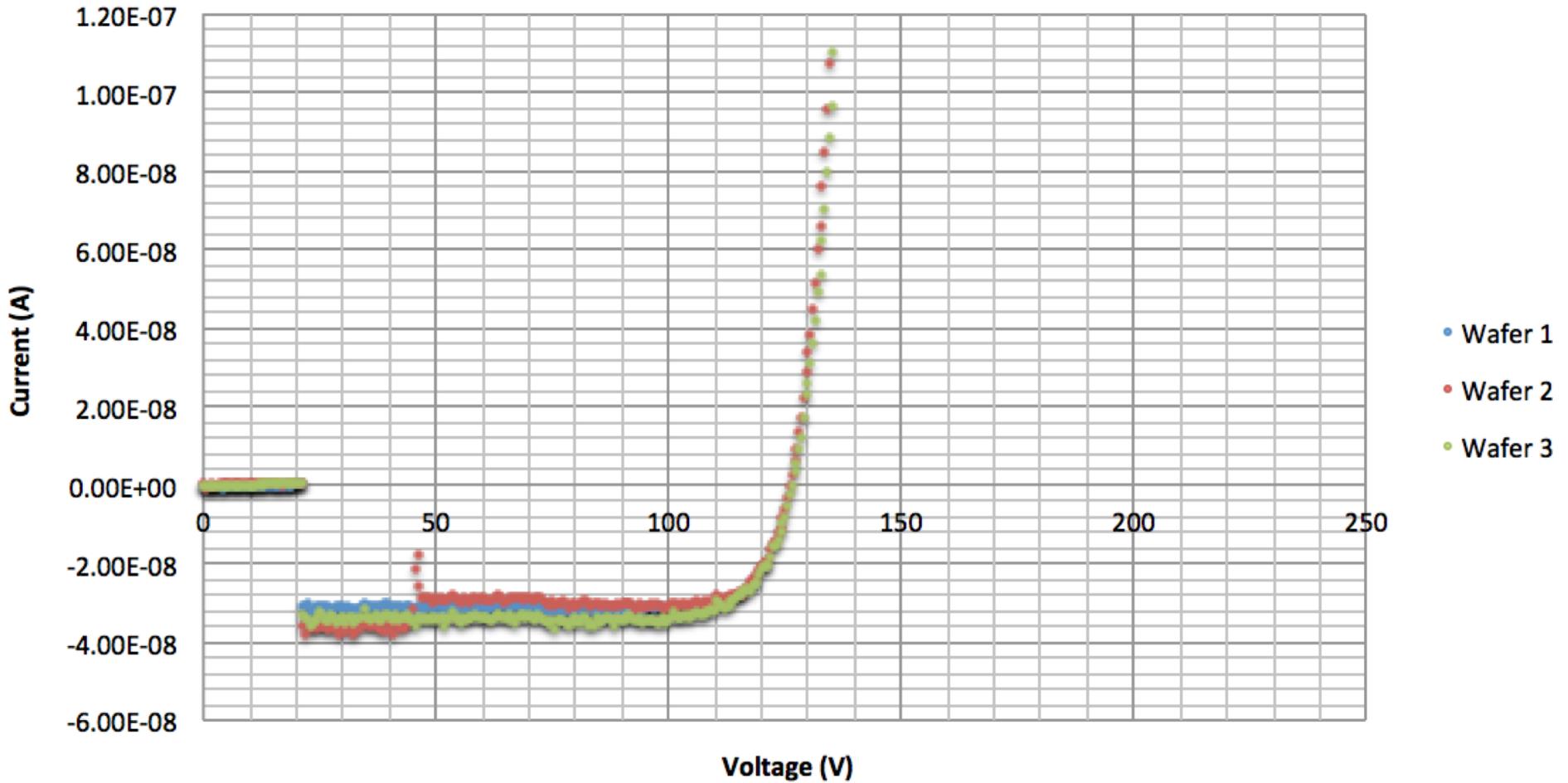


Probe to HP 2410 @ 200V



Probe to HP 2410 @ 200V

# MOS3 W1-W3 Leakage Current



# Breakdown Voltage Conclusions

- Breakdowns are expected with this test but the oxide layer held up surprisingly well, especially in the strip detector.
- This, and the higher breakdown voltages suggest a high uniformity of oxide thickness and good resistivity

# Summary

- Small and Large Diodes are well constructed and underlying bulk silicon is high quality
- J-Die Diodes suffer from early breakdown, especially near the edge of the wafer. In general, detector pixels/strips must be further from the edge to avoid these effects
- Polysilicon Resistors function well, however ohms/square values don't match up with each other or expected values.
- P-stops and guard rings function well
- Oxide Capacitances are at expected values, along with leakage currents

# Thank you for listening!

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