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KEYSIGHT

Community of
On-Wafer Test &
Reliability
Experts

A Cutting-edge, Fully Integrated On-wafer Solution for Production Control of High Voltage GaN Devices

CUG008

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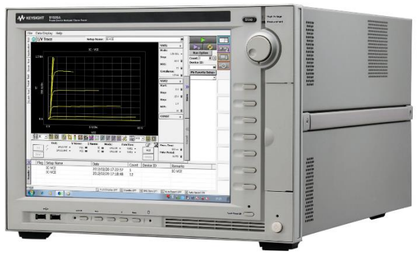
March 17, 2025

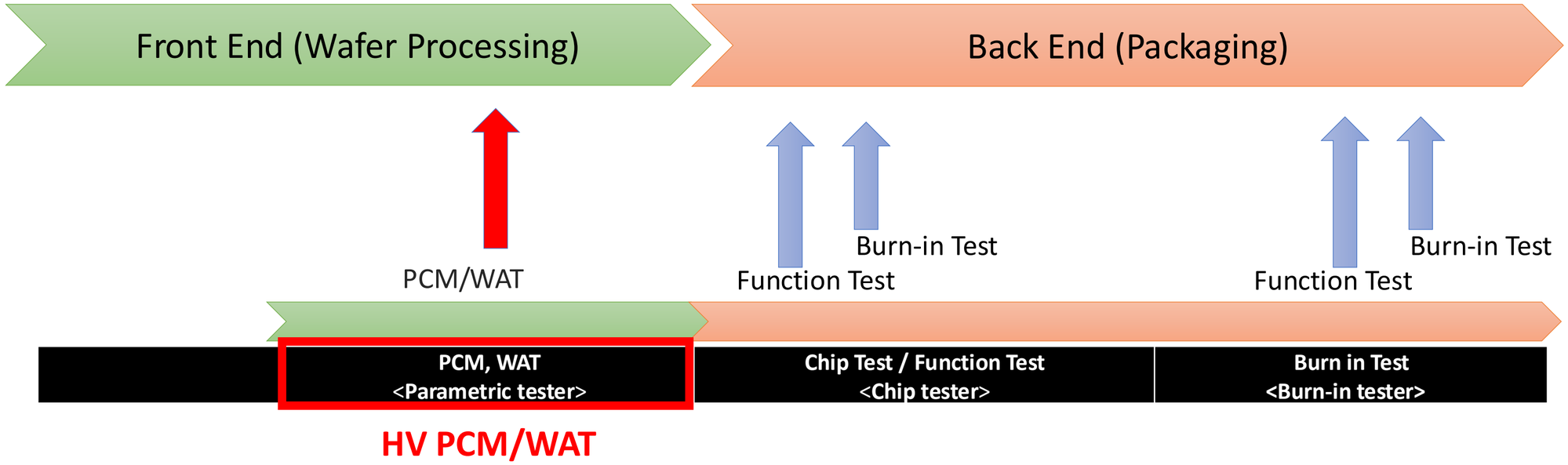
Keysight 4881HV High Voltage Wafer Test System

Atsuhiko Nakamoto

Keysight Parametric Test Solutions

	R&D	Production
Logic, Memory	B1500A Semiconductor Device Parameter Analyzer 	4080 Series Parametric Test Systems 
Power	B1505A Power Device Analyzer / Curve Tracer 	?

Demand of High voltage PCM test items



Increasing the needs of wafer process parameter monitoring

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Keysight 4881HV High Voltage Wafer Test System

High-voltage parametric tests up to 3 kV, HV and LV in one-pass tests

Key Features

- 3 kV flexibly on any 29 pins
- 1kV capacitance measurement
- SEMI S2 compliance
- SPECS/SPECS-FA

3kV Probe Card I/F

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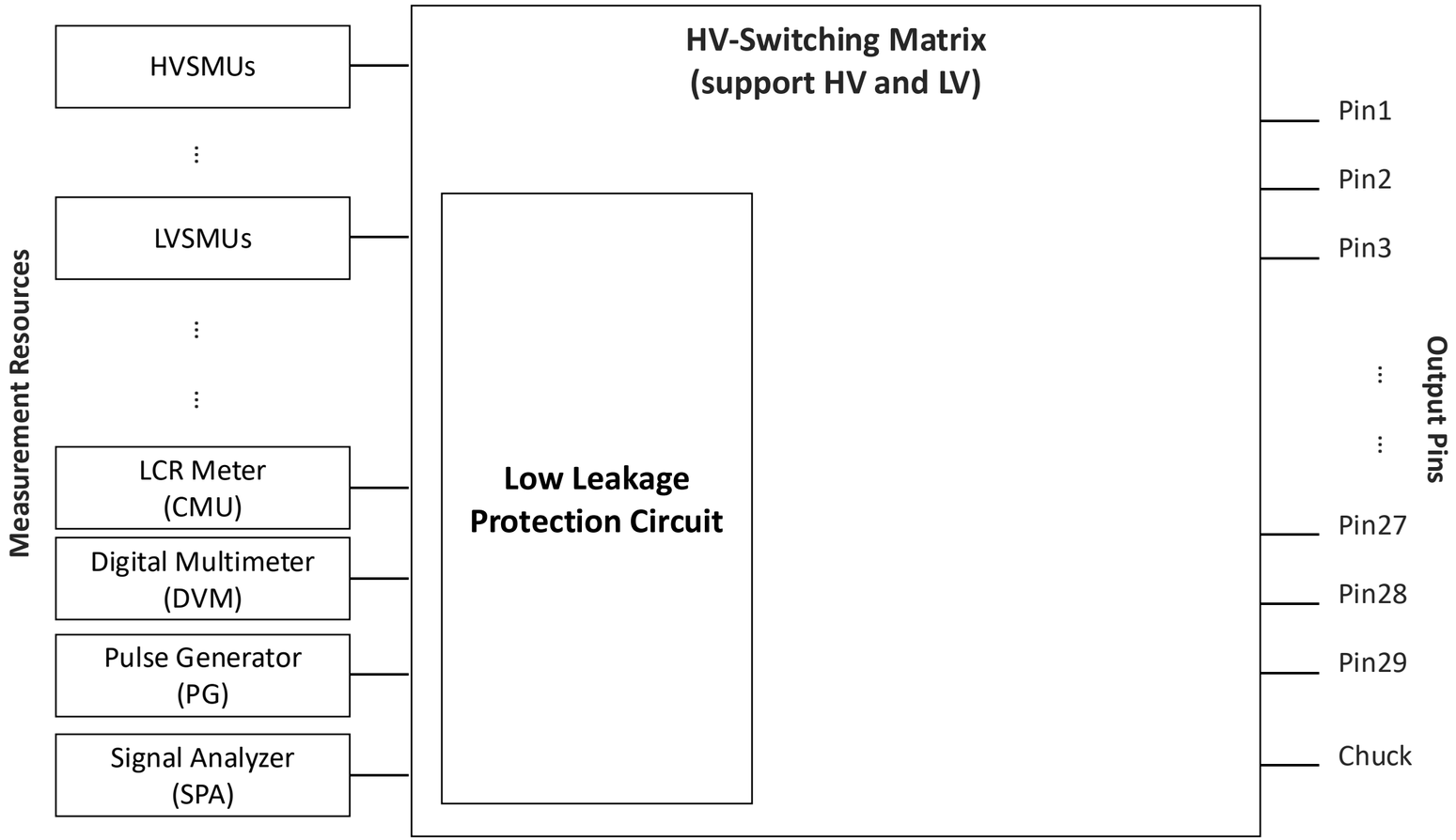
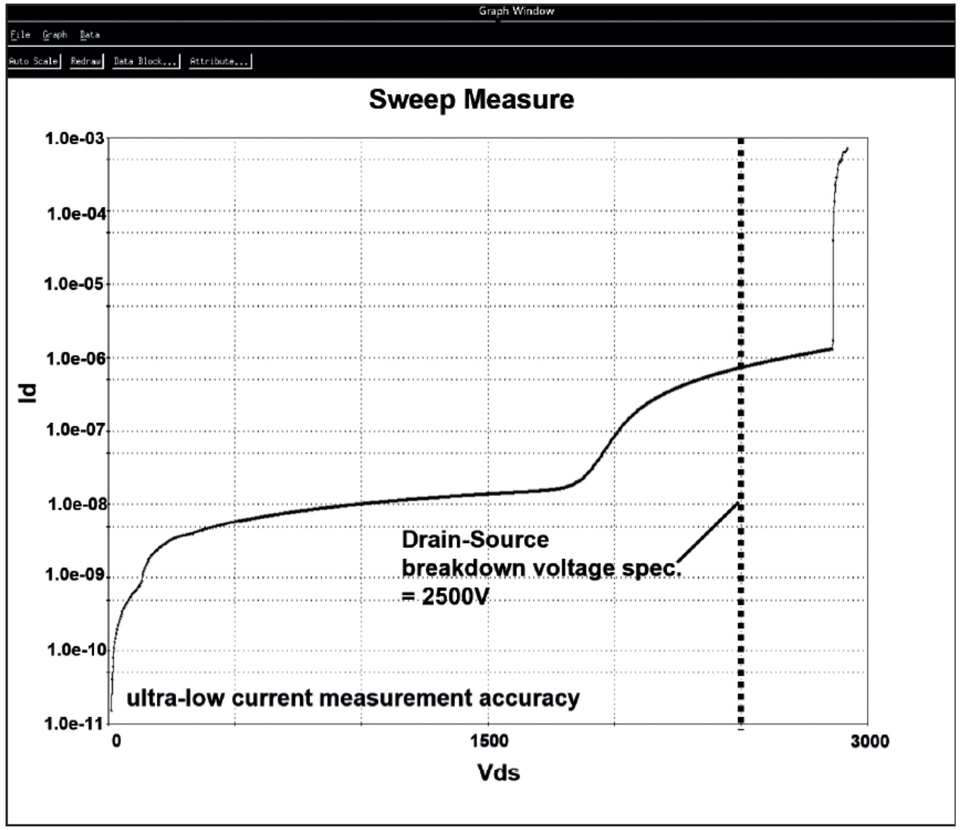
HV-Switching Matrix

- Reliable HV-Switching Matrix
- Protection circuits and equipment control from surges.

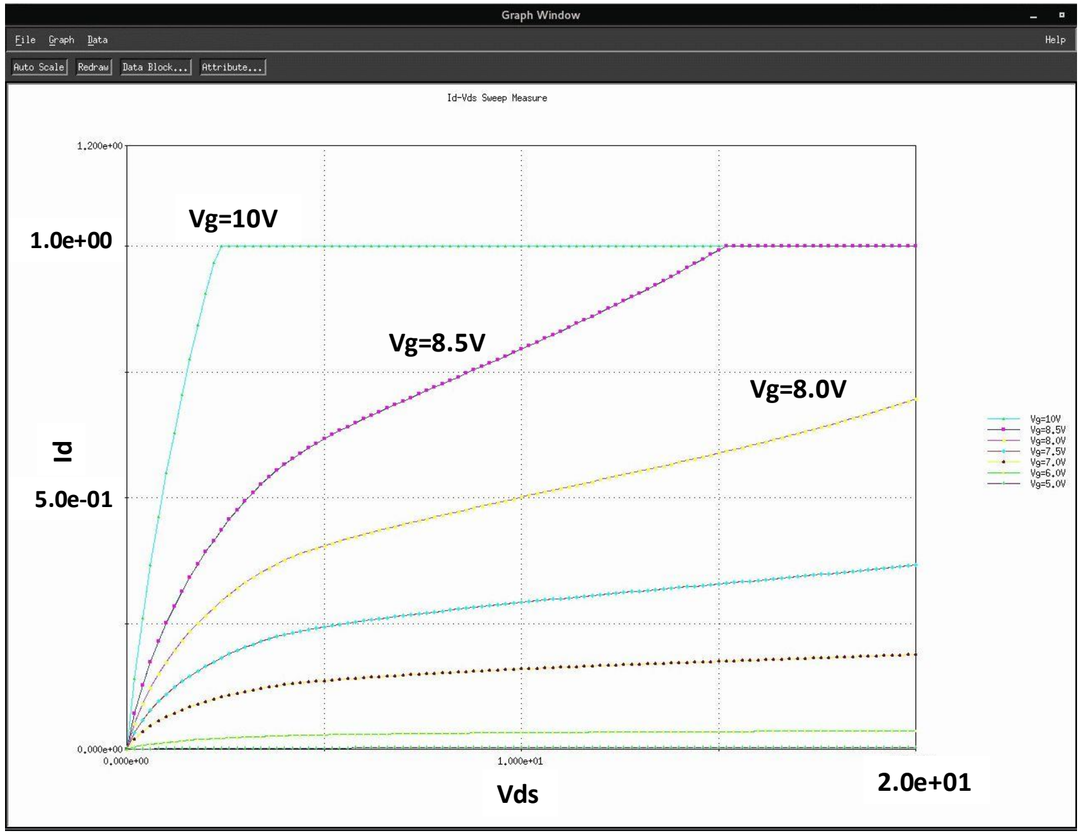


4881HV Measurement example

- High-voltage MOSFET (Vdss spec = 2500V)



- Output characteristics MOSFET Vds-Id



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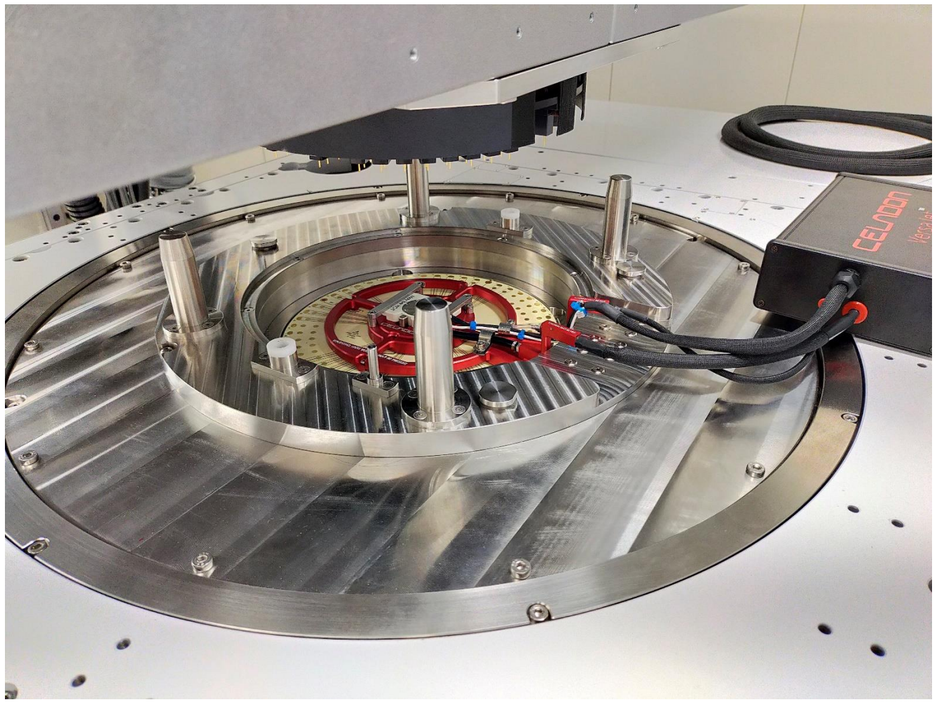
Integrated Interlock system and control



- Mutual interlock system
- Remote control of Celadon VersaJet

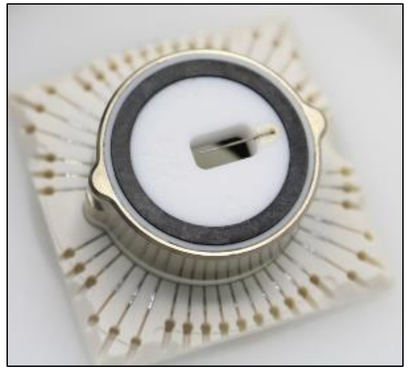
Celadon VersaJet Purpose and Use

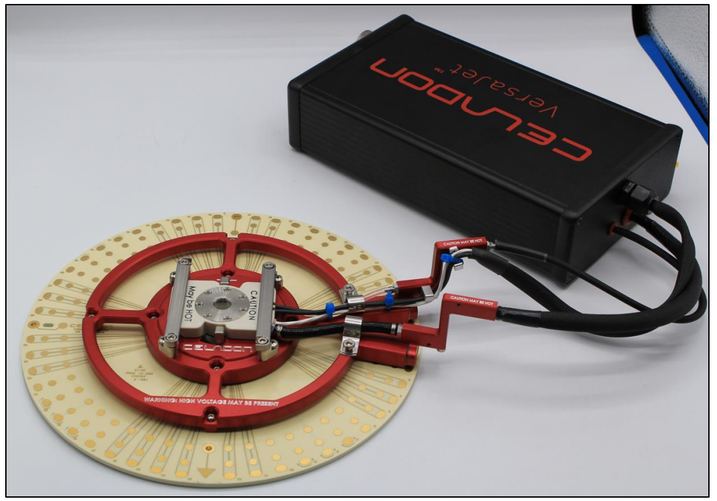
Dalton Roehl

The Celadon VersaJet

The VersaJet is an Arc Suppression system that increases the breakdown voltage due to surface flashover on a device.

- Supplies 30-35PSI of Arc Suppression Environment
- 12 channels at 3,000V channel-channel Isolation
- 32 channels at 1,000V channel-channel Isolation
- 25-200C Operational Temperature
- Replaceable VC20EHV Probe Core
- Quiet operation ~70dB 1m away
- Highly customizable for specific test equipment or requirements
- Remote control through ModBusTCP commands
- Interlock for Safe Testing

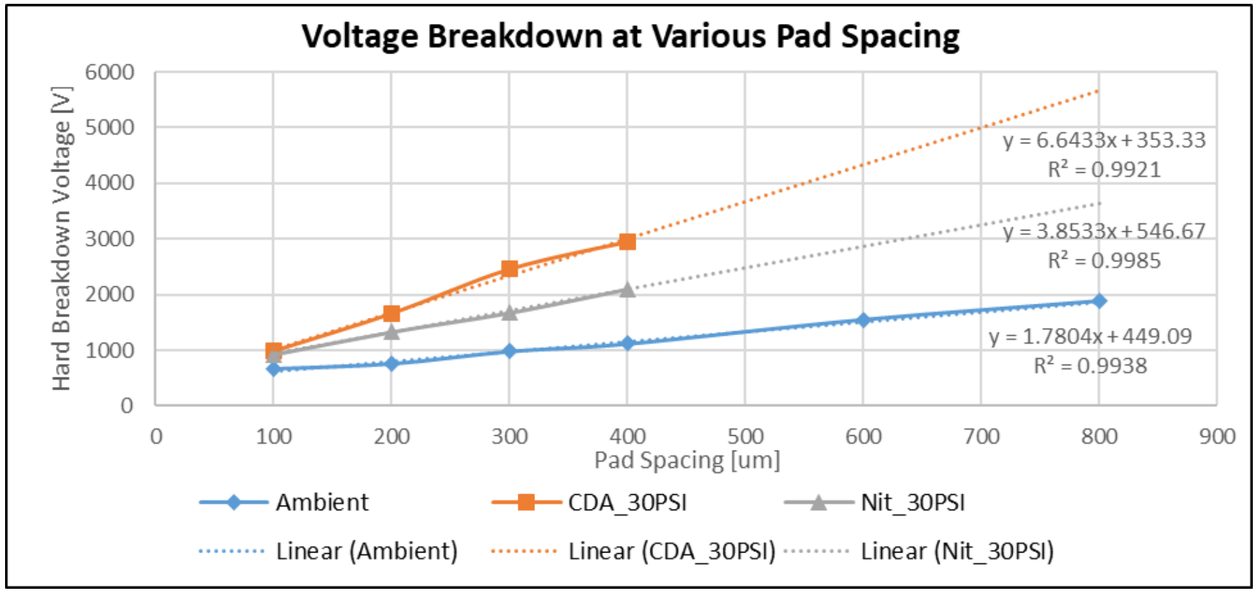


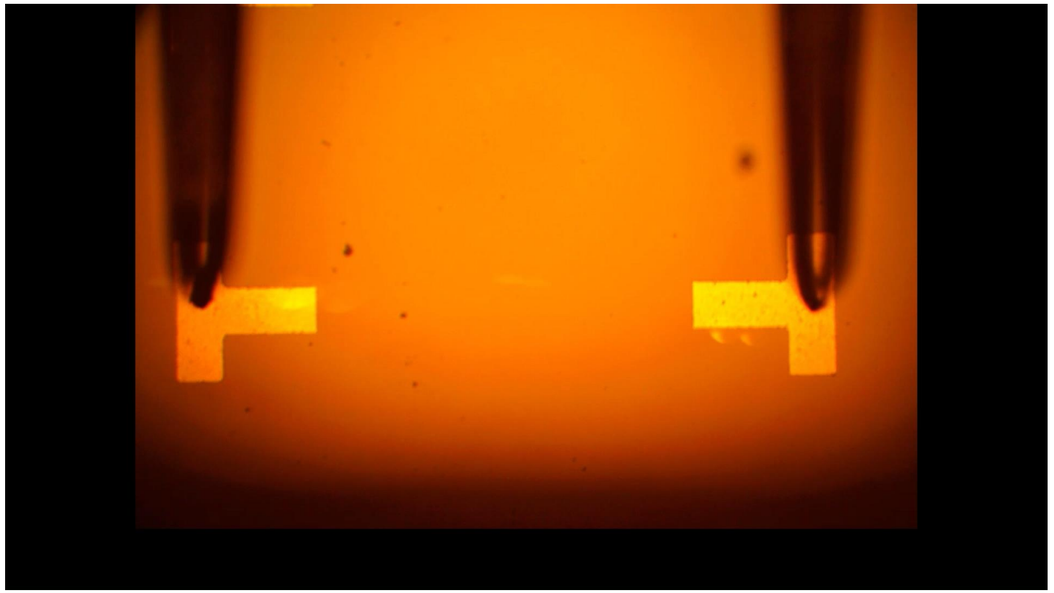


Easy and Clean On Wafer Arc Suppression!

Paschen's Law: Breakdown Voltage = Distance*Pressure

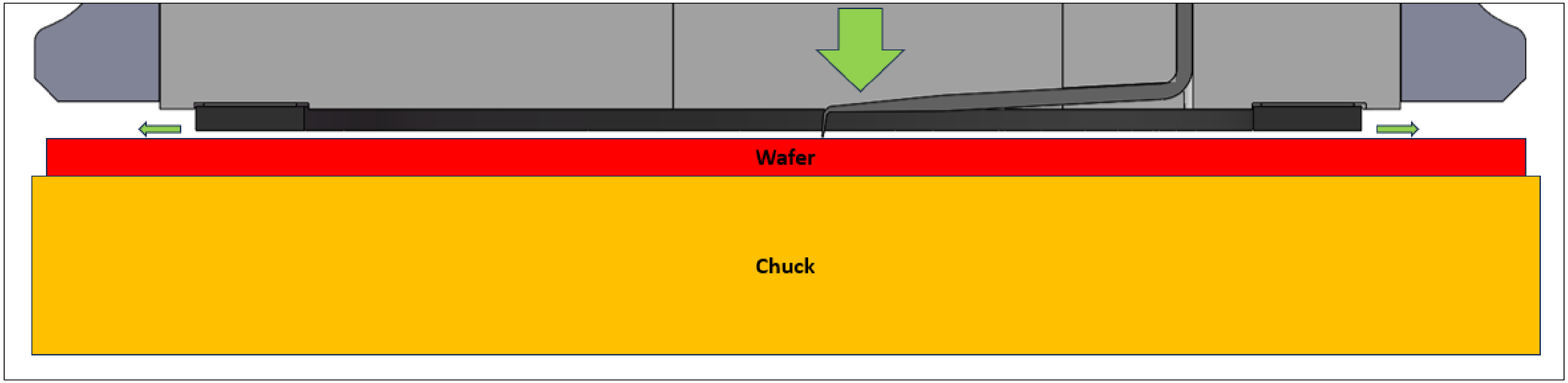
- The VersaJet takes a supply of air through the Control Unit and Heater to apply directly to a "Pressure Bubble" above the device.
- By creating the Pressure Bubble above the device, a higher breakdown voltage can be applied before the arc occurs.





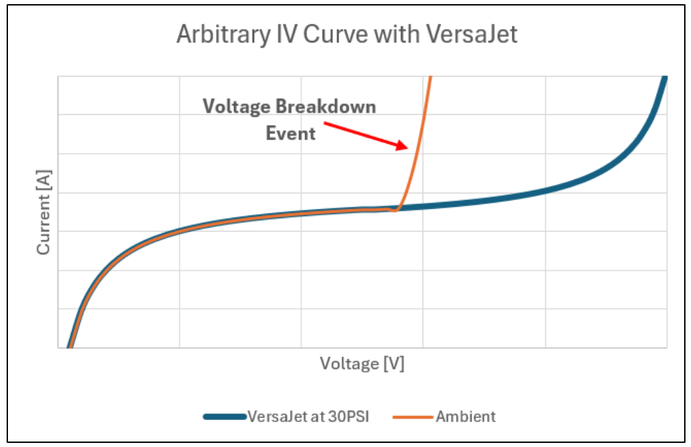
VersaJet – How it Works

- While probing, a very thin 50µm annular gap is made between the VC20EHV and the wafer surface.
- CDA supply and a thin gap creates a “Pressure Bubble” locally above the Device without contacting the wafer.
- This creates a stable probing environment over a large temperature range 25-200C by heating the CDA prior to the probe card.

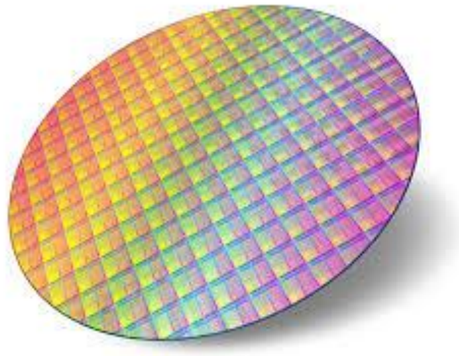


VersaJet - Importance

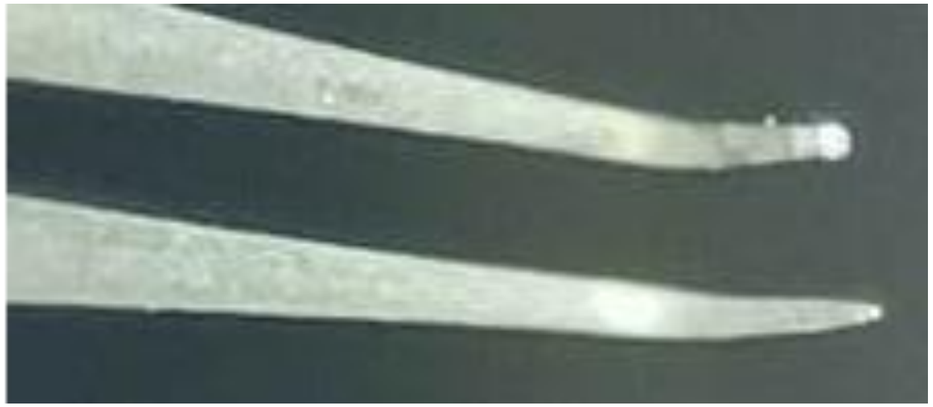
Characterizing more of an IV Curve prior to breakdown.



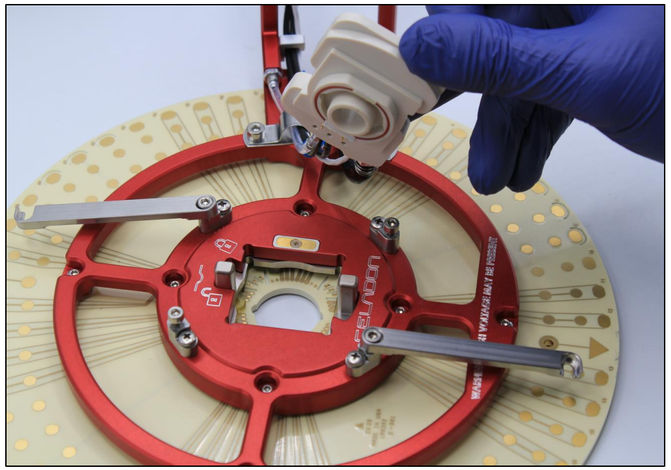
No need for Fluorinert or other expensive and unknown fluids to contact your wafer.

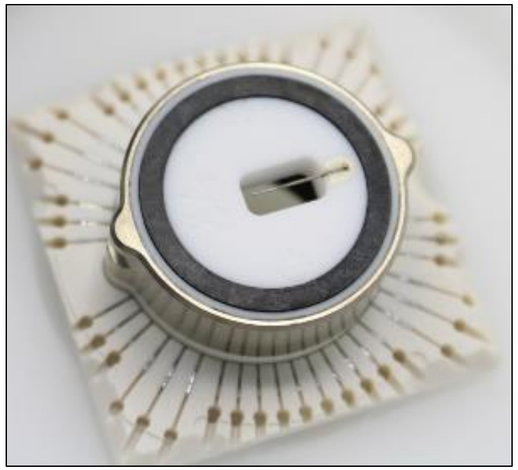


Unexpected fails can damage test equipment or adjacent devices.



TheVC20EHV probe core can be swapped easily if there is damage or a different device layout.

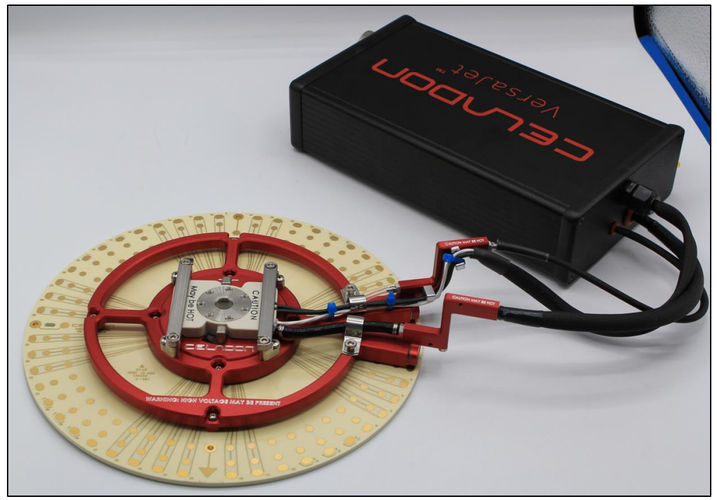




VersaJet - Customization

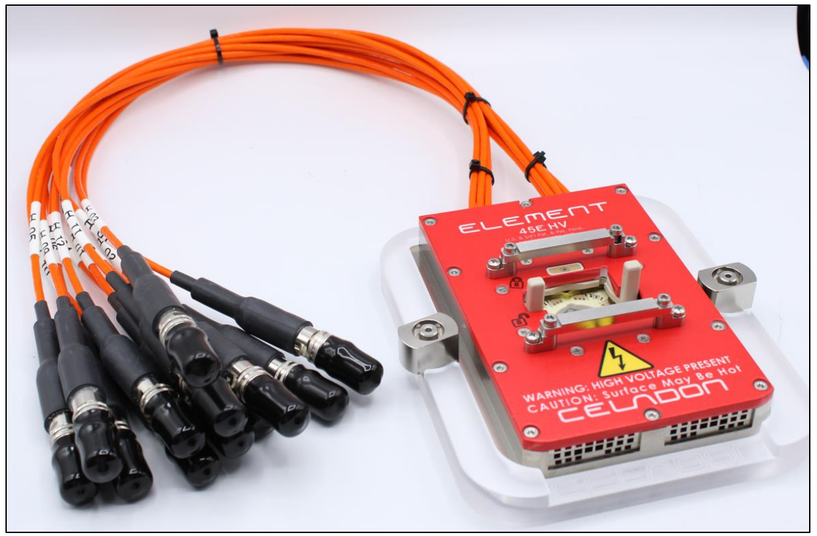
- The VersaJet can be configured to various Test Systems requiring specific connections.
- The VersaJet can be optimized for High Voltage and/or High Current applications.
- Complete Lab to Fab solution.

Keysight 4881HV

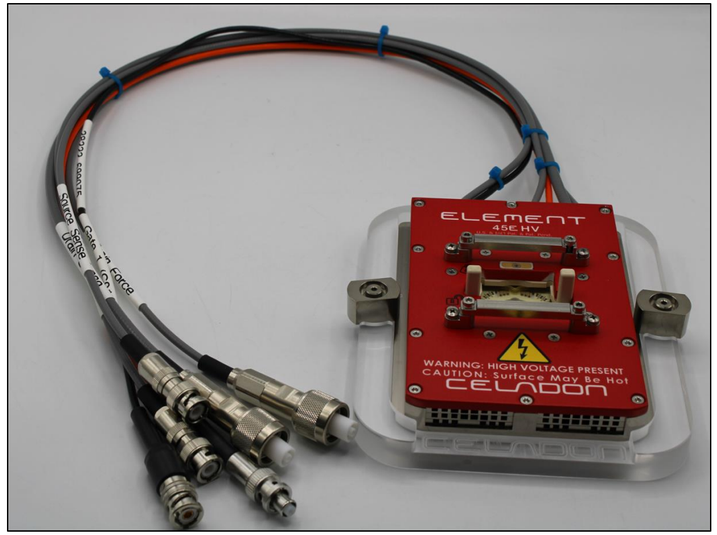


AMCAD Pulser

Keithley 2657A



Keysight B1505A



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THANKS

For Your Attention

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Robust Solutions for Breakdown Testing on Medium-Current Devices

CUG009

長洛國際股份有限公司
CHAIN-LOGIC INTERNATIONAL CORP.

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March 17, 2025

What is the difference between medium-power and high-power testing?

Special considerations for Medium-Power Breakdown Test

Probe Card design strategies

Test results

Conclusions

Methods needed to Manage High Currents during High Power tests are well understood

To maintain ~1A (rms) per pin, multiple probe pins per pad are designed into the VC20EHV high power probe cards. Other considerations are

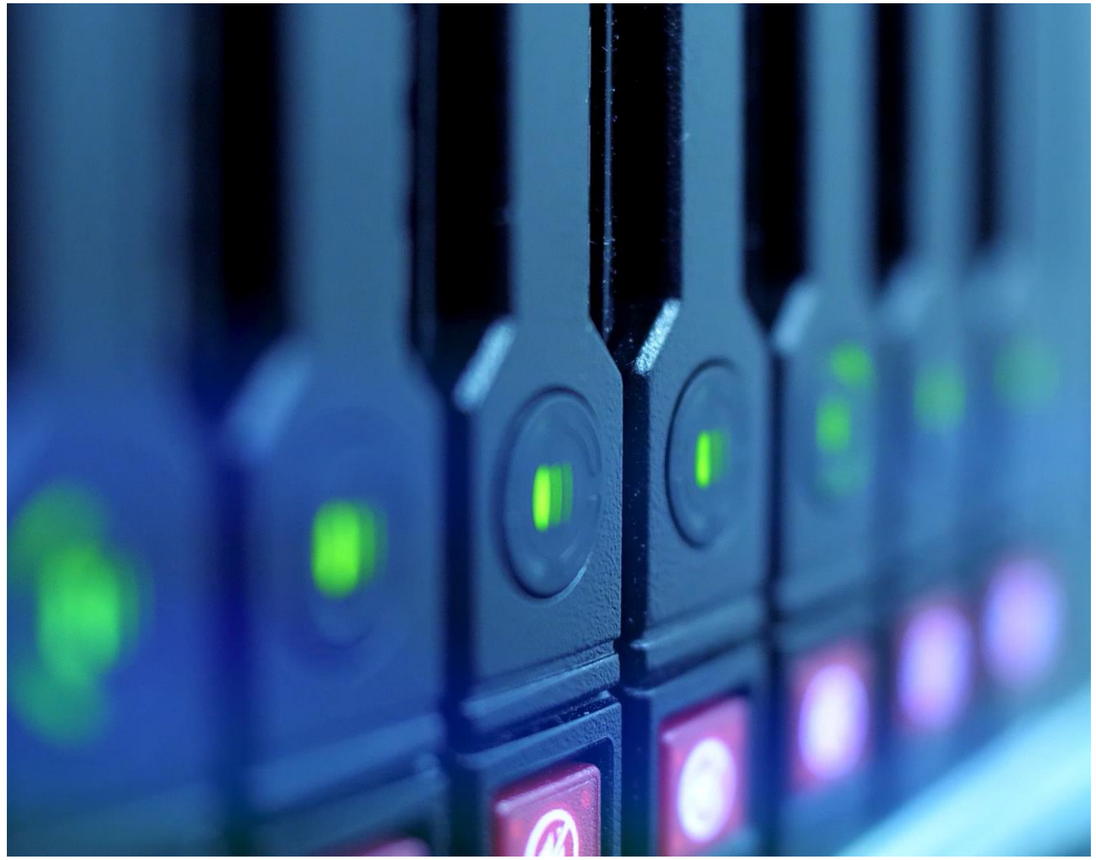
- Dedicated high current and high voltage channels
- Dedicated high current probe cards and dedicated high voltage probe cards

Note that

- High voltage means >1000V
- High current means > 1A (either DC or rms pulsed)
- Special guardrails are in place to protect the tester and probe cards from damage during these tests

“Medium Power” has a broader definition, >50 to 500V depending on application

- Most tests are with currents <250 mA
- Standard VC20E probe cards can be used for most of these tests.



Celadon has worked on a wide variety of different projects supporting High Power testing, for example:

Customized probe card for on-wafer testing of AlGaN/GaN power transistors

R. Venegas[1], K. Armendariz[2], N. Ronchi[1]

[1]imec, [2]Celadon Systems Inc.

September 2015

Customized probe cards

Our solution employs a CELADON VC20 VersaCore™ with multiple needles mounted on a 45E probe card adaptor.

- High current measurements
- Low leakage (for breakdown measurements) less than 5fA's
- Easy to swap between different probe card cores using Celadon's insertion tool
- High temperatures (ceramic core) up to 200C

Conclusions

In this presentation we have demonstrated how the CELADON VC20 VersaCore™ and the 45E probe card holder are successfully used for testing GaN power devices for switching applications.
In particular, we have shown:

- On-wafer high voltage and high current measurements
- Versatility of the interchangeable cores to match the device layout
- Smooth shape of the measured waveforms
- Reliable measurements of fast high-current pulses
- Limited spikes
- Easy to use and reproducible measurement setup

But Medium-Power Breakdown Tests have their own unique set of challenges:

- But during breakdown testing (GOI, HCI, etc.), currents can far exceed the per pin current load capability at breakdown.

- PSMC is using Celadon's VC20E probe card for Gate Oxide Integrity testing (GOI)
  - Device breakdown occurs during these tests.
  - This breakdown causes a large increase in current flow through the DUT and probe card. The currents can be high enough to burn the probe pins.

- This poses an issue for throughput and increases cost of test.

Test Parameters: GOI

This test is done by applying a voltage through the Gate with all other connections Grounded.

Voltage step is applied to the DUT 1V-130V with 1V step. Current through the DUT is measured.

Below are some examples of GOI TDDB Testing for reference:

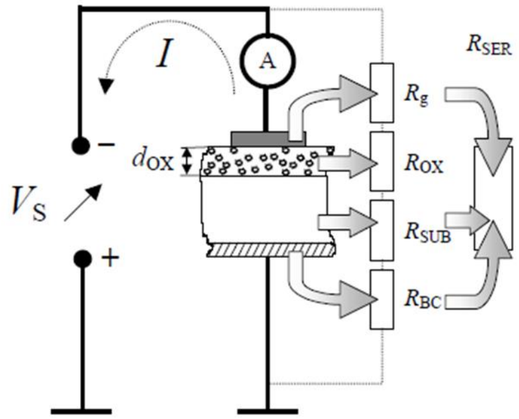


Fig.1. Common electrical circuit for GOI evaluation. Silicon oxide film resistance (R_{OX}) and each part of series resistance (R_{SER}) are shown separately: R_g – resistance of poly-Si gate, R_{SUB} wafer substrate resistance, R_{BC} – wafer backside contact resistance.

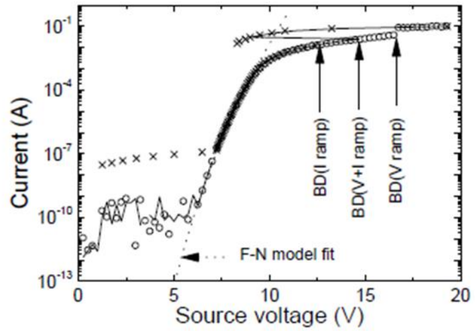
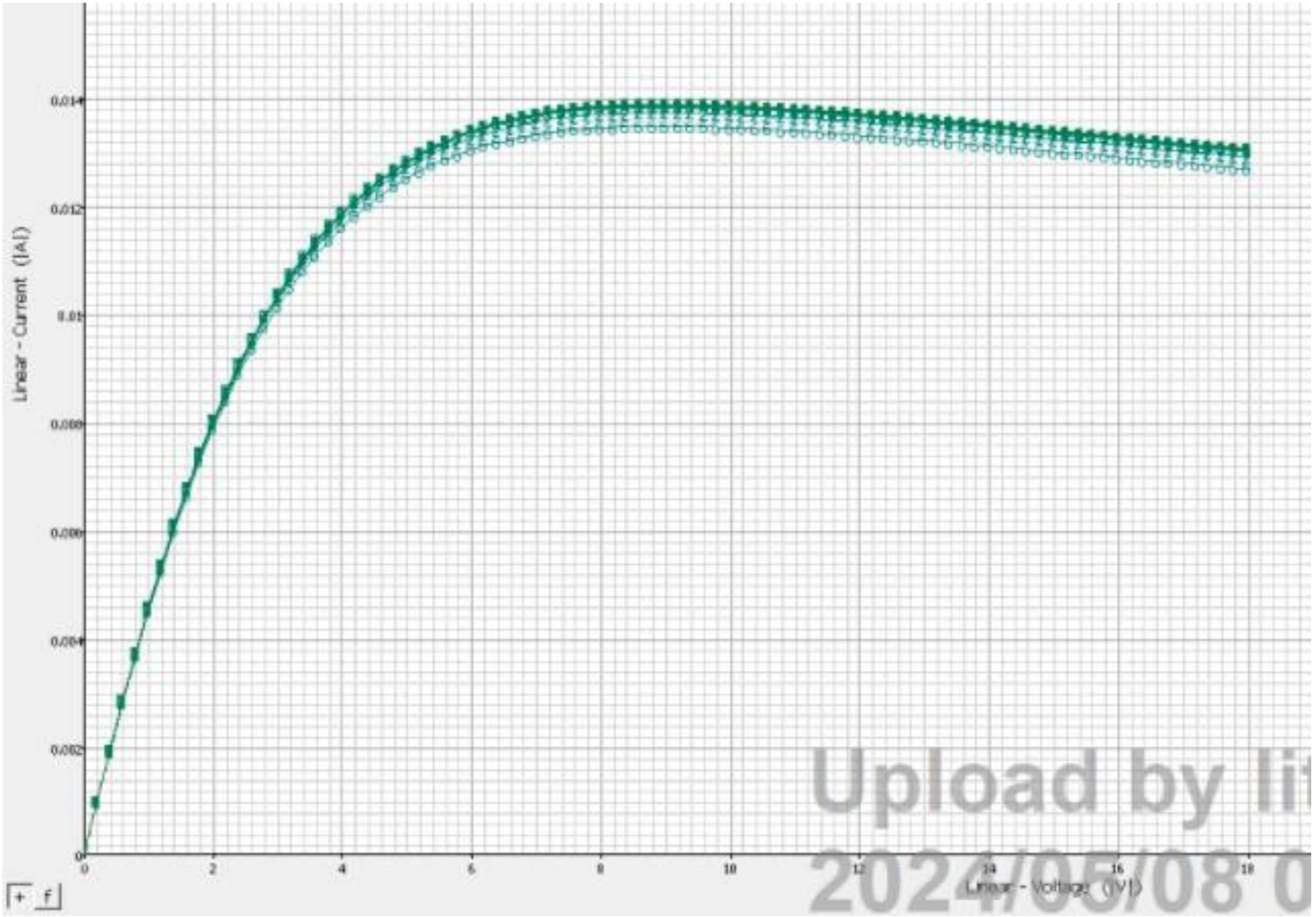
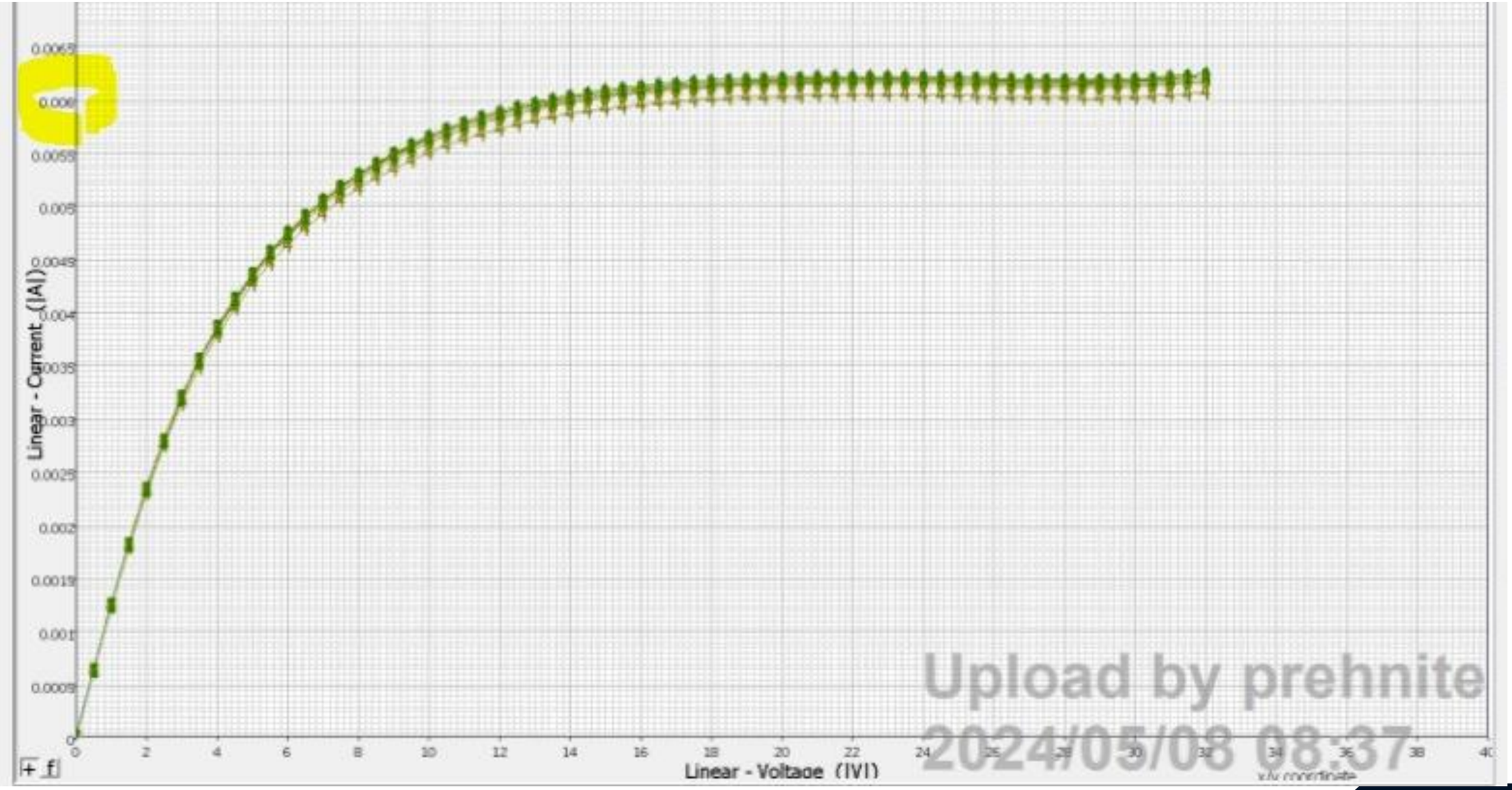


Fig.3. Voltage-ramp (open circles), current-ramp (crosses) and V+I ramp (solid line) TZDB measurement sequences. Rectangular gate, area S_g=10mm^2, oxide thickness d_{OX}=8nm. Arrows indicate oxide film breakdown events for each sequence.

18V Device at 10mA



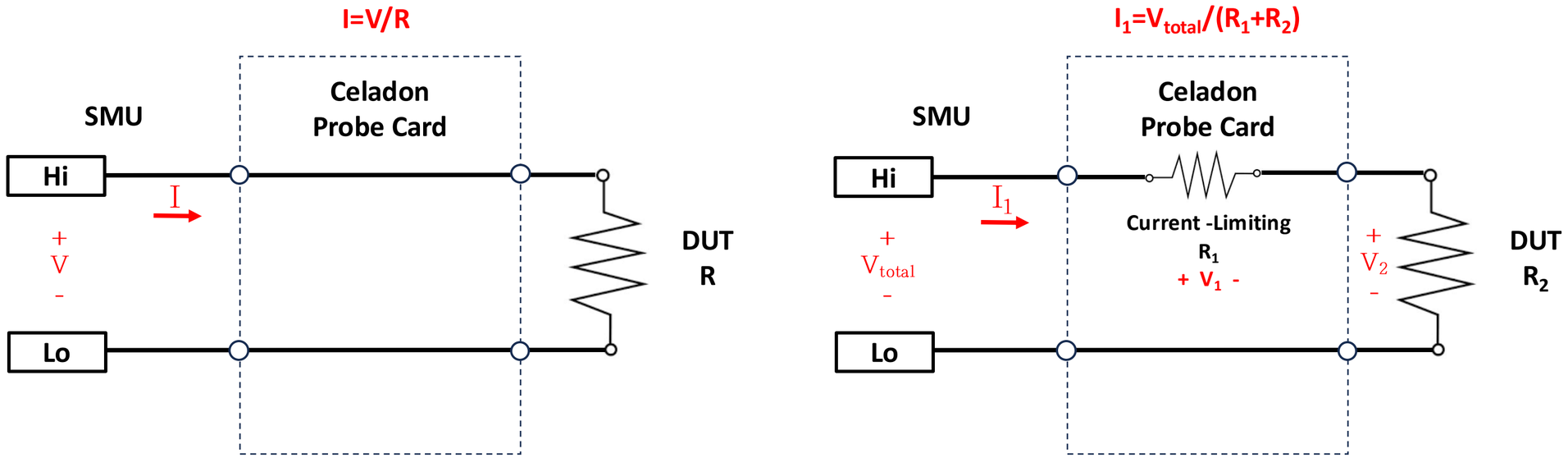
32V Device at 6mA



Suggested Solution to Preventing Burnt Pins

- Add a current limiting Resistor in series to the Gate connection of the probe card (between the tester and the probe card needle).
- If/when the device breaks down the test circuit will maintain a resistance to decrease the current spike.

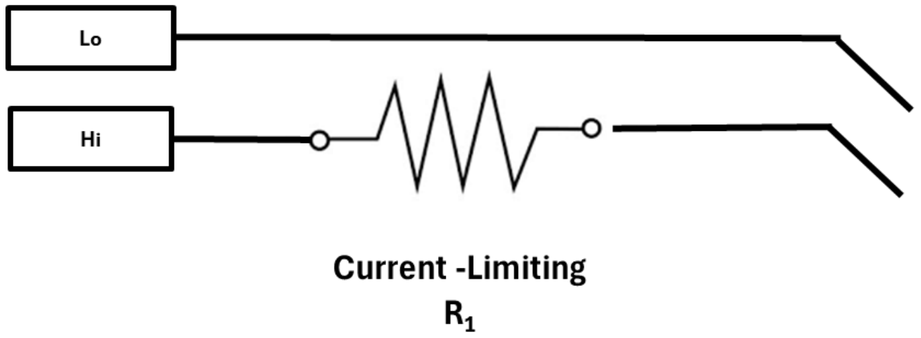
- Note: Adding a series resistance will alter the voltage and current applied to the DUT.



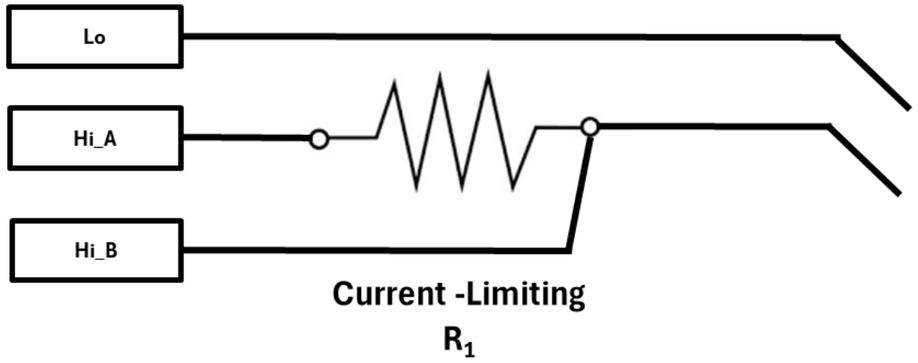
Option 1: Add resistors to the Probe Card

- A PCB can be added to the VC20E to allow an inline resistor.
- Option 1a: Resistor inline on the Hi Channel (Gate)
- Option 1b: Resistor inline on the Hi Channel (Gate), but with an additional channel allowing the user to bypass the resistor if needed.

Option 1a

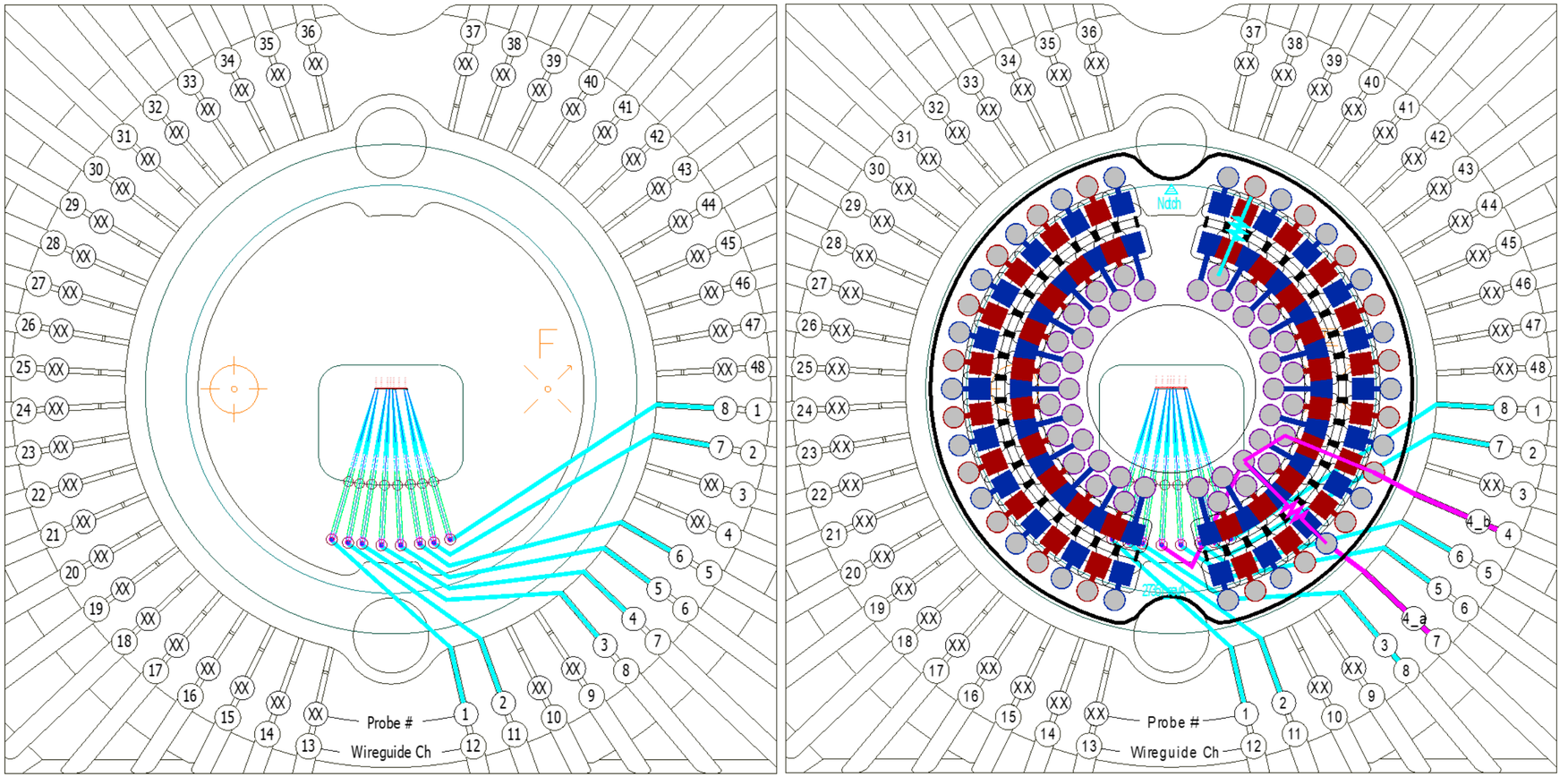


Option 1b



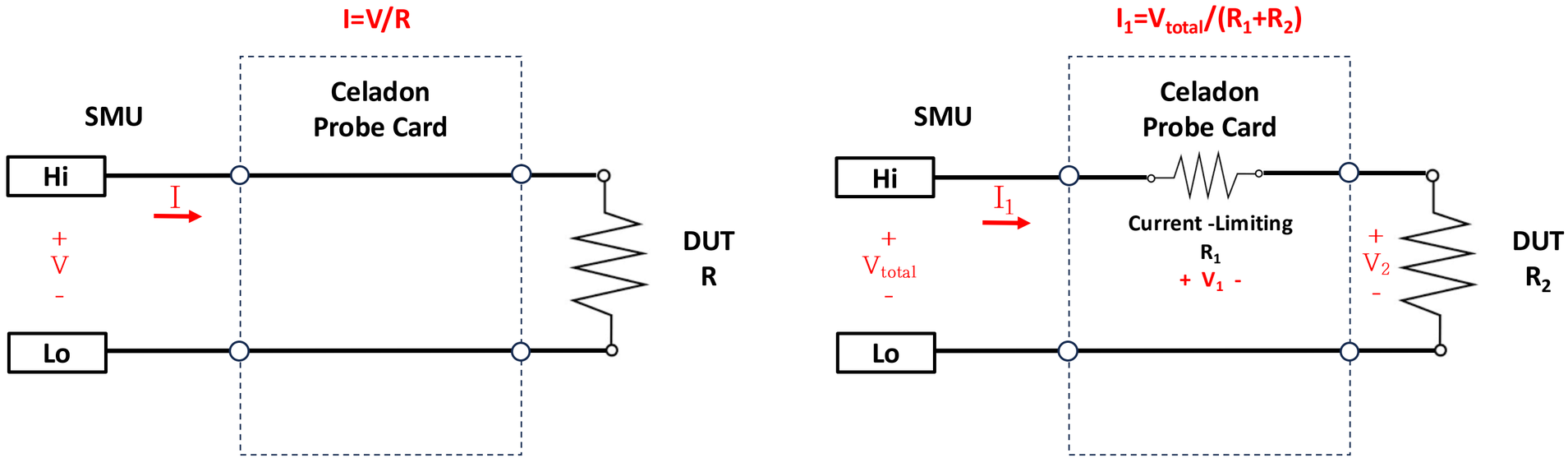
Option 1: Add Resistors to the Probe Card

- Example Probe Card configuration



Option 1 Add Resistors to the Probe Card

- Resistor value can be chosen in the 0603 Resistor package type
- Based on the basic operating conditions Celadon recommended using testing 1kΩ, 2.2kΩ, or 10kΩ resistor. For completeness, 20kΩ and 50kΩ could be tested as well.
- With the following conditions:
  - A resistor large enough to reduce the surge current below to less than 1.0A
  - A resistor small enough to allow the user to conduct their test within the Tester limits.

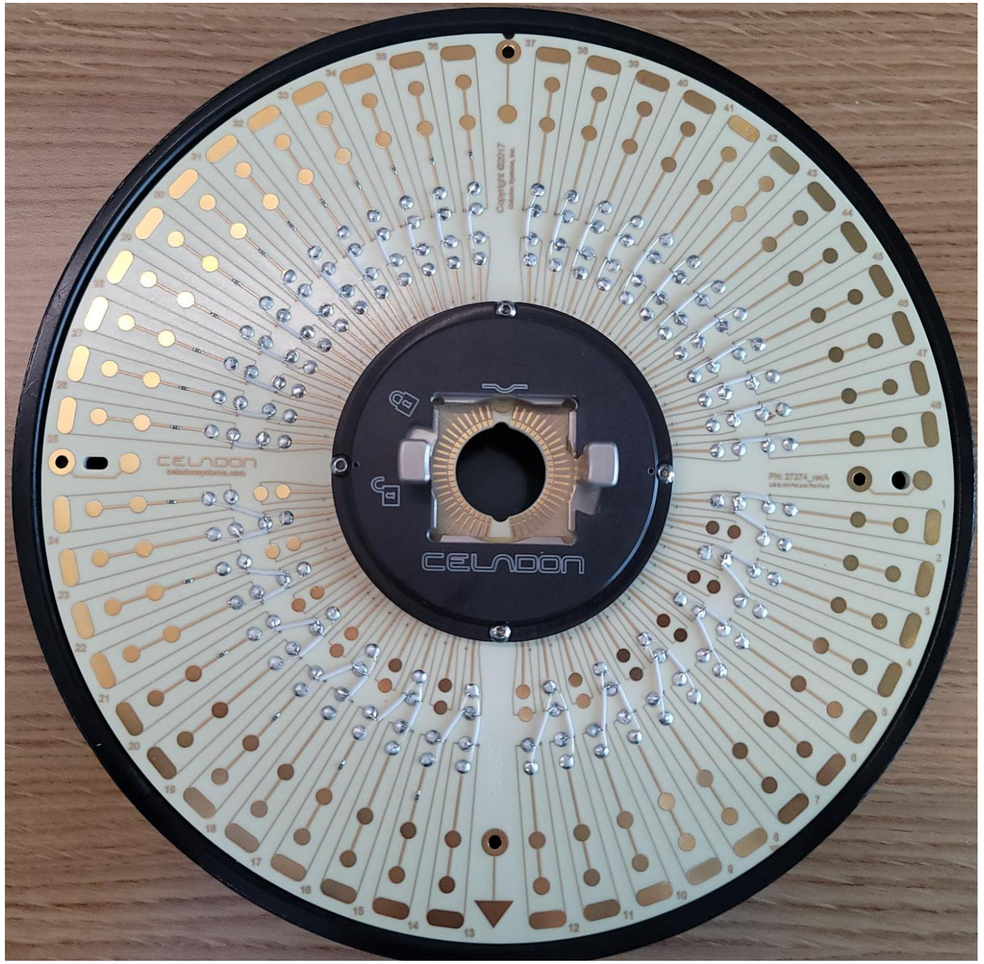


Option 2: add the Resistor to the Probe Card Interface (PCI)

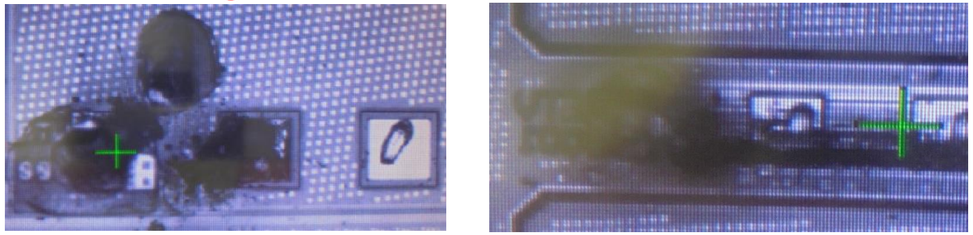
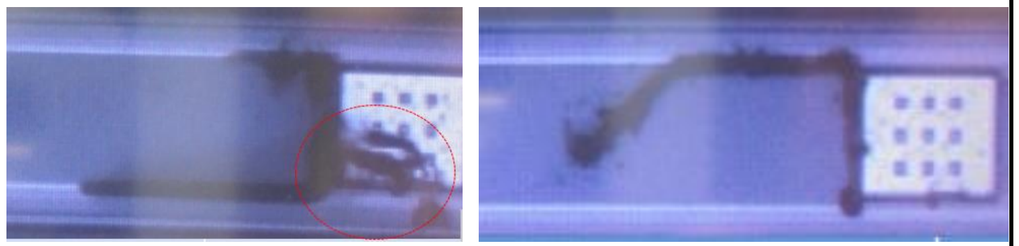
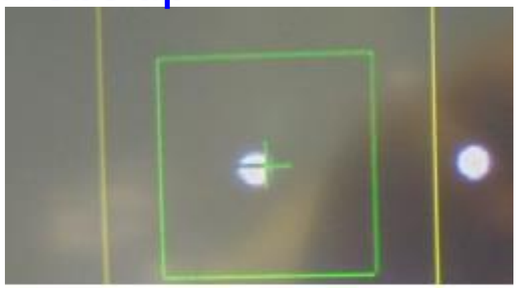
- Using a Celadon 4080 PCI, the following example configurations can be made:
- CH1-12: Hi-A and Hi-B connection on separate channels
- CH13-24: Hi-A with and Hi-B with inline resistor
- CH25-36: Inline resistor
- CH37-48: Normal connection.

- Since adding resistors to the VC20E is faster and more cost efficient, this approach was selected

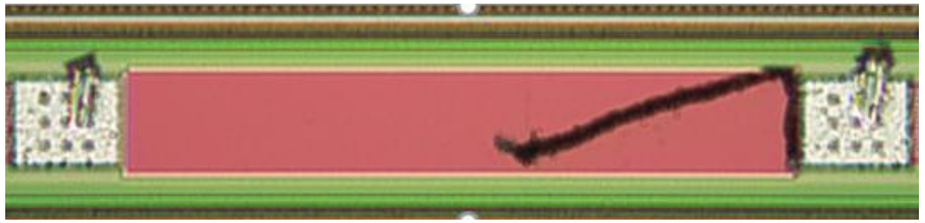
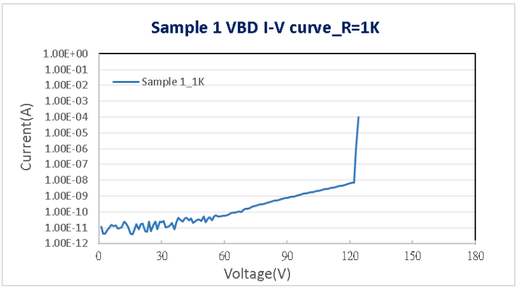
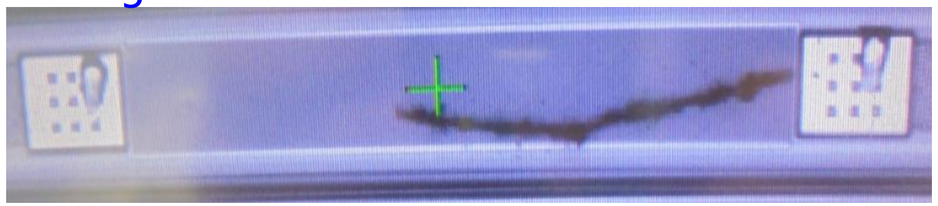
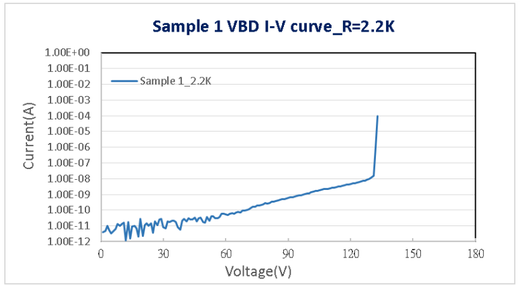
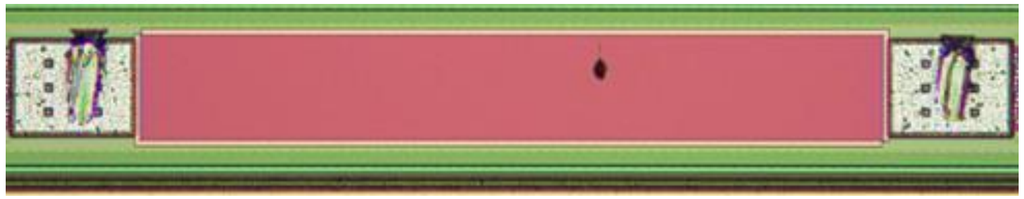
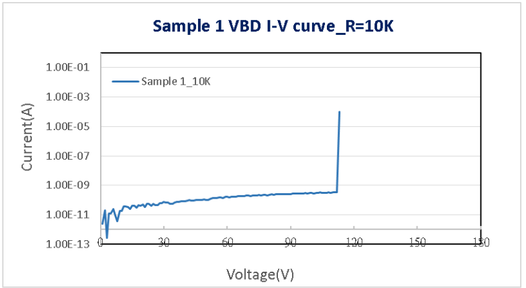
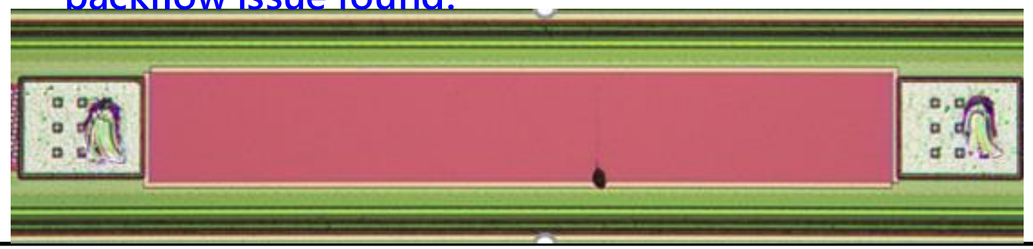
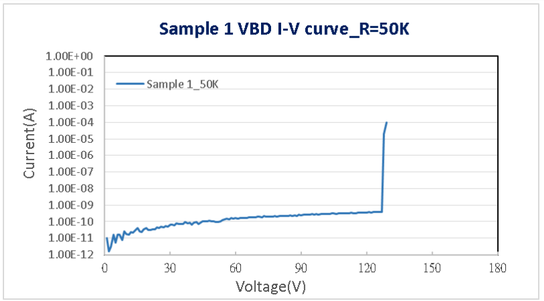
- A custom PCI can also be designed based on the most effective resistor determined by the probe card tests



Difference Before and After adding resistor

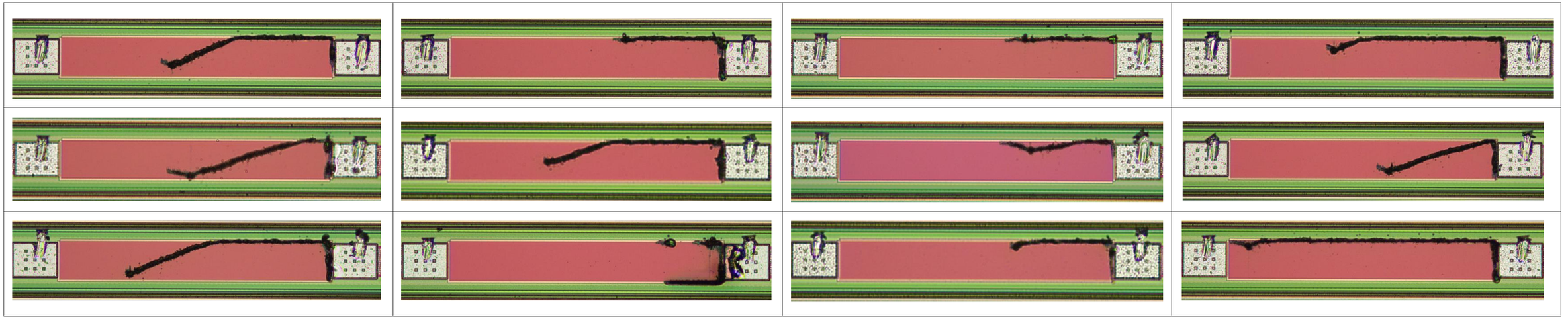
Other Vendor (w/o res)	After testkey burnout, currents backflow caused PAD damage. 	Probe tip damaged seriously 
Celadon (w/o res)	After testkey burnout, currents backflow caused PAD damage. 	Probe tip damaged slightly 
Celadon (w/1K res)	After testkey burnout, currents backflow caused damage only to the PAD edge. 	No damage on the Probe tip 

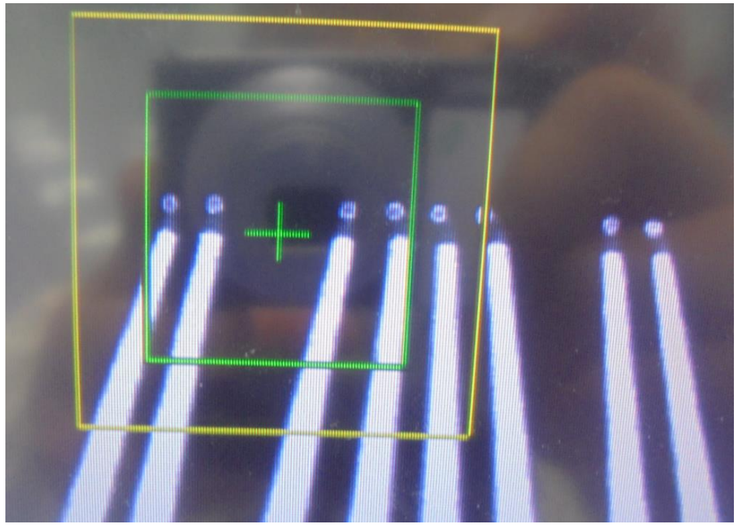
Comparison by added resistor value

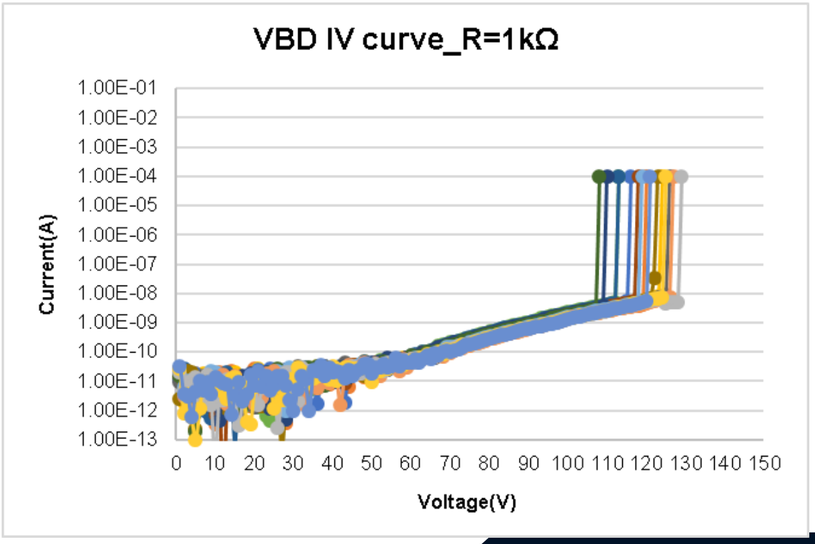
1K	After testkey burnout, currents backflow caused Damage only to the PAD edge. 	
2.2K	After testkey burnout, currents backflow but no damage on the PAD. 	
10K	After testkey burnout, no currents backflow issue found. 	
50K	After testkey burnout, no currents backflow issue found. 	

R=1kΩ

After test key burnout, currents backflow caused damage only to the PAD edge.

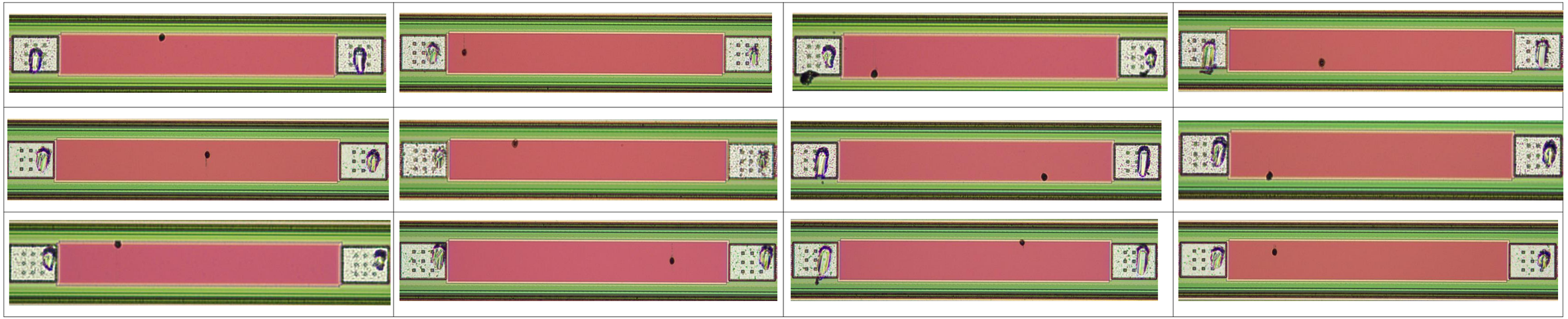


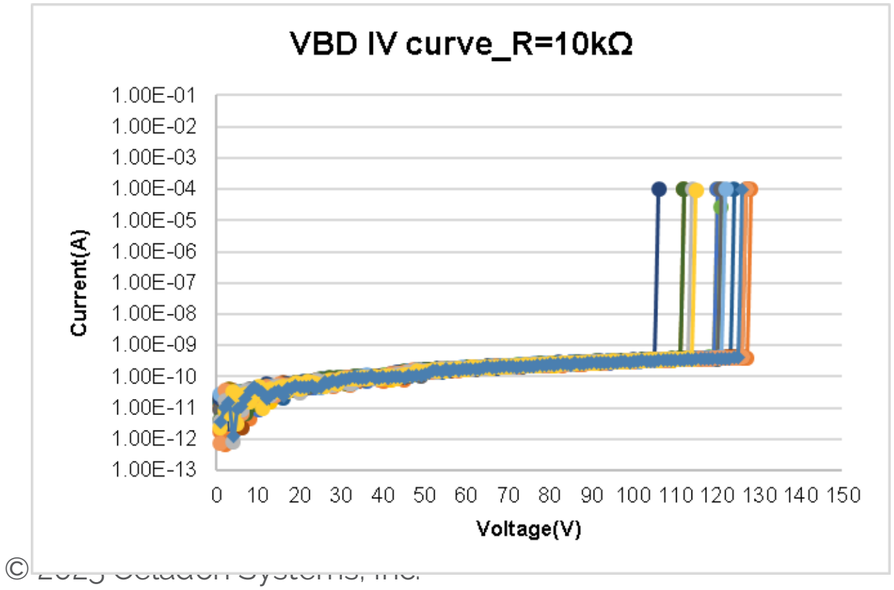


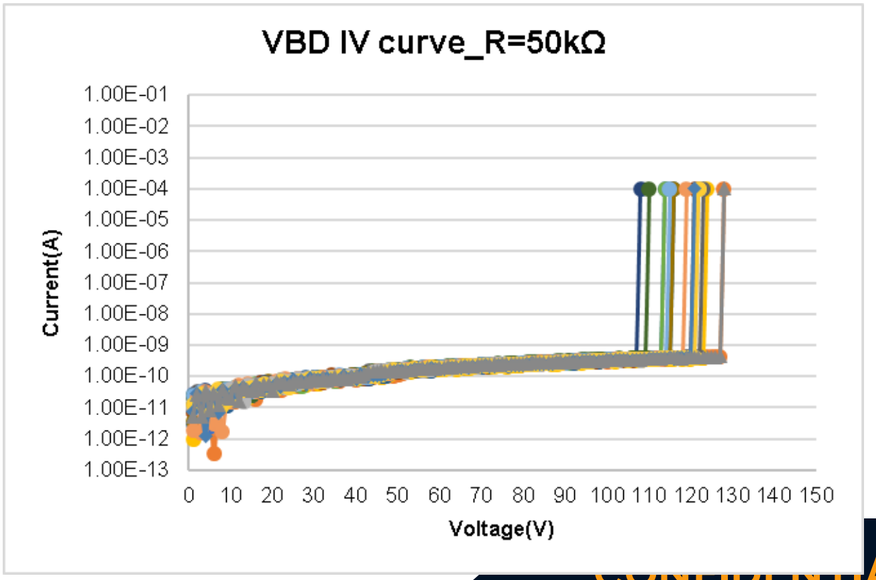


R=10k & 50kΩ

After test key burnout, no currents backflow issue found.







Summary and Conclusions

- Celadon provided four test cores to see which resistor value had the most impact while still providing the needed test results

- PSMC determined that the 10kΩ resistor provided the best results:
  - No Current backflow
  - Probe card pins were not damaged during test
  - No damage to the test pad edges or other areas around the pad
  - Good test data was obtained

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PSMC

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Experts

THANKS

For Your Attention

長洛國際股份有限公司
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