High Power Probe Cards

for engineering and production test – A survey.

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High Power Probe Cards

1. *Overview*
2. *Power devices – Test requirements*
3. *High Voltage Probe Cards*
4. *High Temperature HV Probe Cards*
5. *High Current Probe Cards*
6. *Conclusion*

Power devices – Test requirements

Power devices

- *Applications*
- *Device types*
- *Rated Voltage*
- *Rated Current*

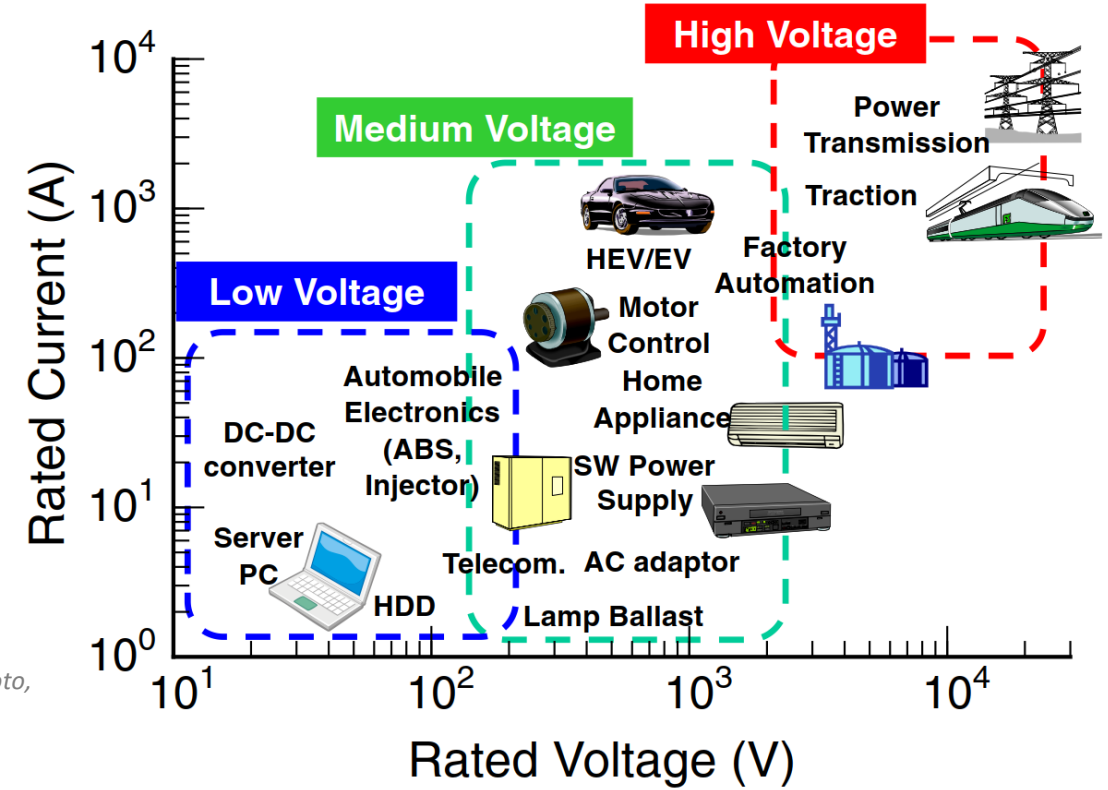


image source: Tsunenobu Kimoto, Japanese Journal of Applied Physics 54, 040103, 2015

Power devices – Test requirements

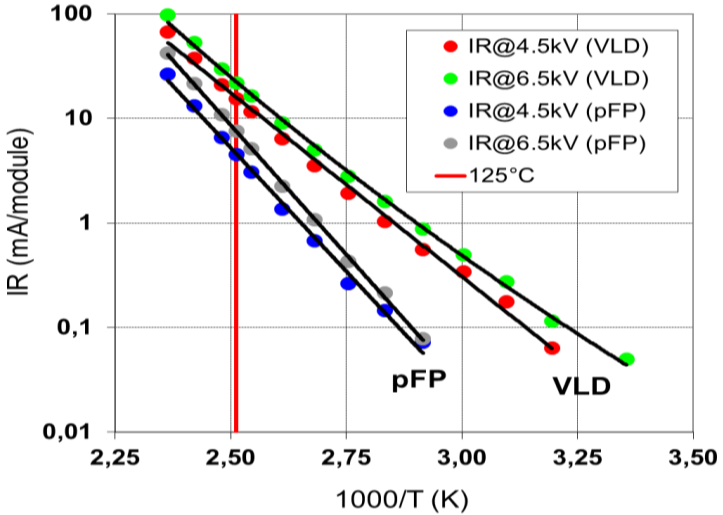
Typical production test requirements

- *Reverse Voltage (Breakdown Voltage)* *-> Up to several **kV***
- *Forward Current (On-state resistance)* *-> Up to several **kA***
- *Reverse Current (Leakage Current at high reverse voltage)*
- *Dynamic switch test (max power dissipation)* *-> Up to several **kA / kV***

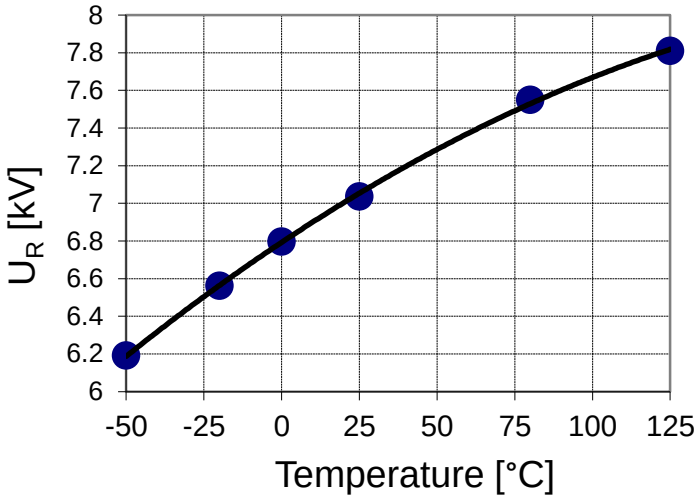
Power devices – Test requirements

Typical engineering test requirements

Reverse current I_R for IGBTs with different termination structures as a function of temperature – at different Reverse voltages.



Reverse Voltage U_R as a function of temperature.



Power devices – Test requirements

Wafer Tests

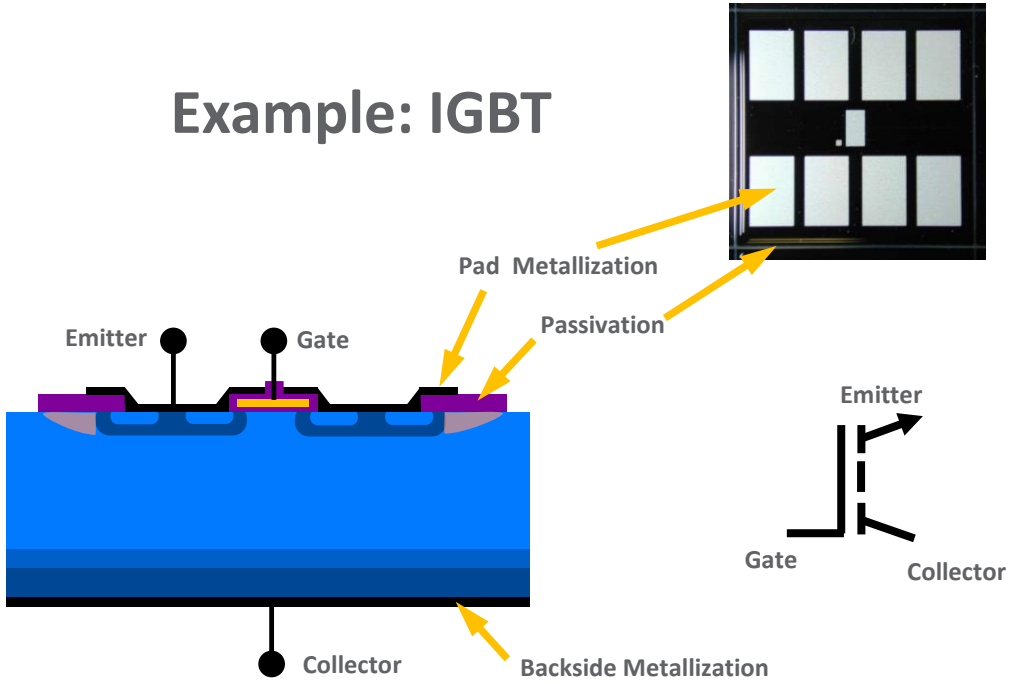
- *Production:* Reverse Voltage -> High Voltage
- *Production:* Reverse Current -> High Voltage
- *Production:* Forward Current -> High Current
- *Production:* Dynamic Switch -> High Current & High Voltage
- *Engineering:* Reverse Voltage -> High Voltage & High Temperature
- *Engineering:* Reverse Current -> High Voltage & High Temperature
- *Engineering:* Dynamic Switch -> High Current & High Voltage & High Temperature

Power devices – Test requirements

Typical power devices

- *Diodes*
- *Mosfet*
- *IGBT*

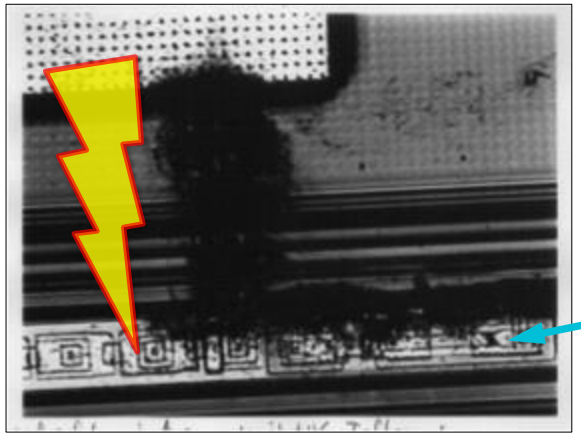
Example: IGBT



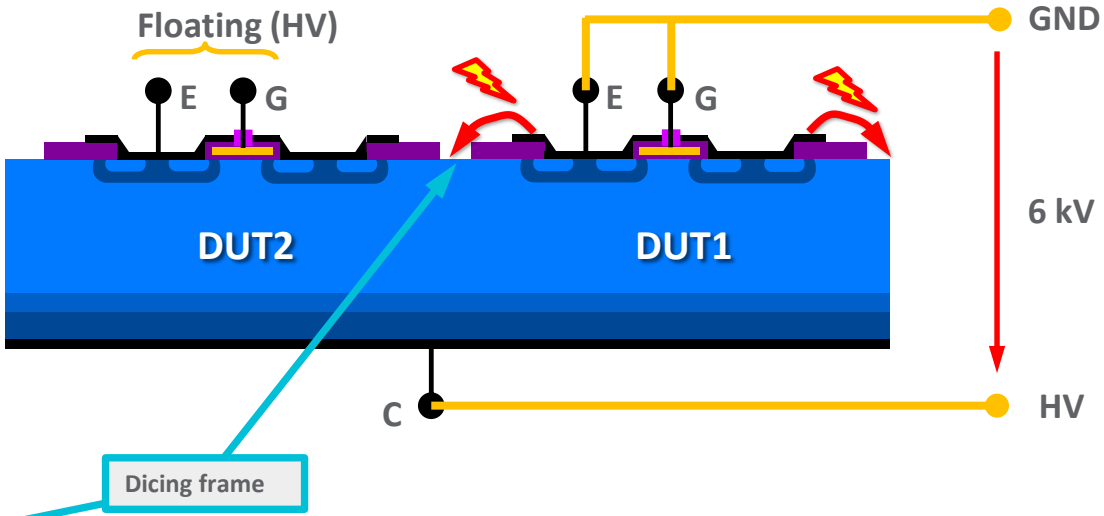
Power devices – Test requirements

High Voltage test – Flash-over risk

- *Test voltage higher than insulation strength of ambient air*
- *High discharge current*
- *Device damage*



Reverse voltage test



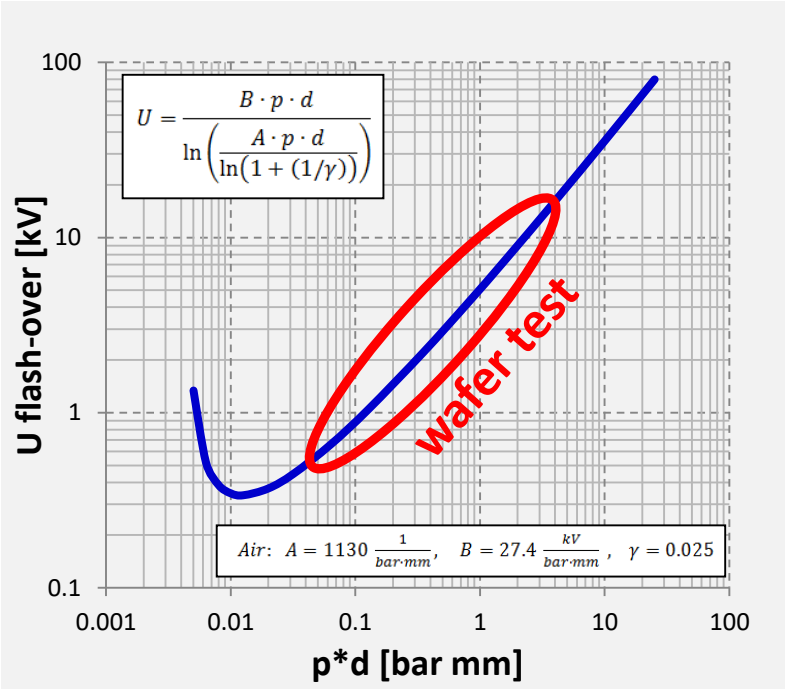
High Voltage Probe Cards

Flash-over suppression: theory

- *Empirical Paschen law*
- *For breakdown strength of air*
- *breakdown voltage increases with pressure*
- *Higher pressure -> higher test voltage*

-> Safe test voltage rises appr. linearly with pressure!

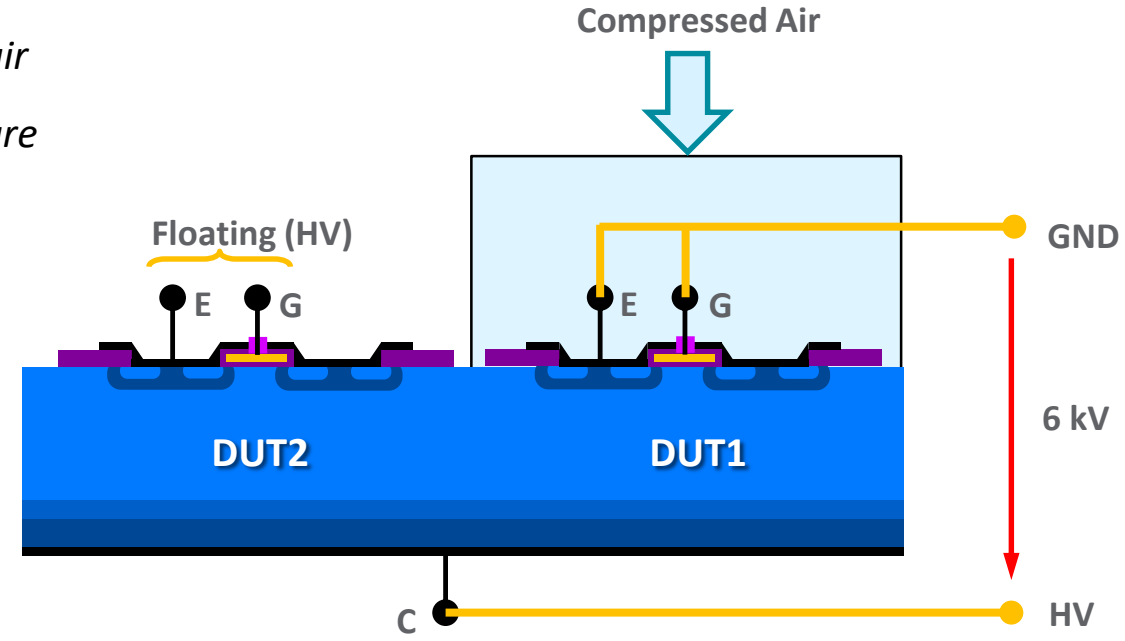
Paschen law



High Voltage Probe Cards

Flash-over suppression: principle

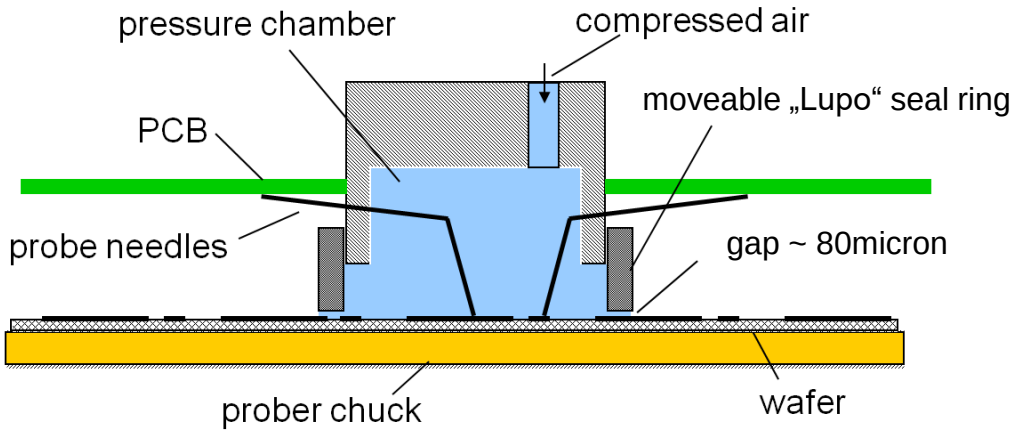
- *Increase breakdown strength of air*
- *Local application of higher pressure*
- *Chip-scale pressure chamber*



High Voltage Probe Cards

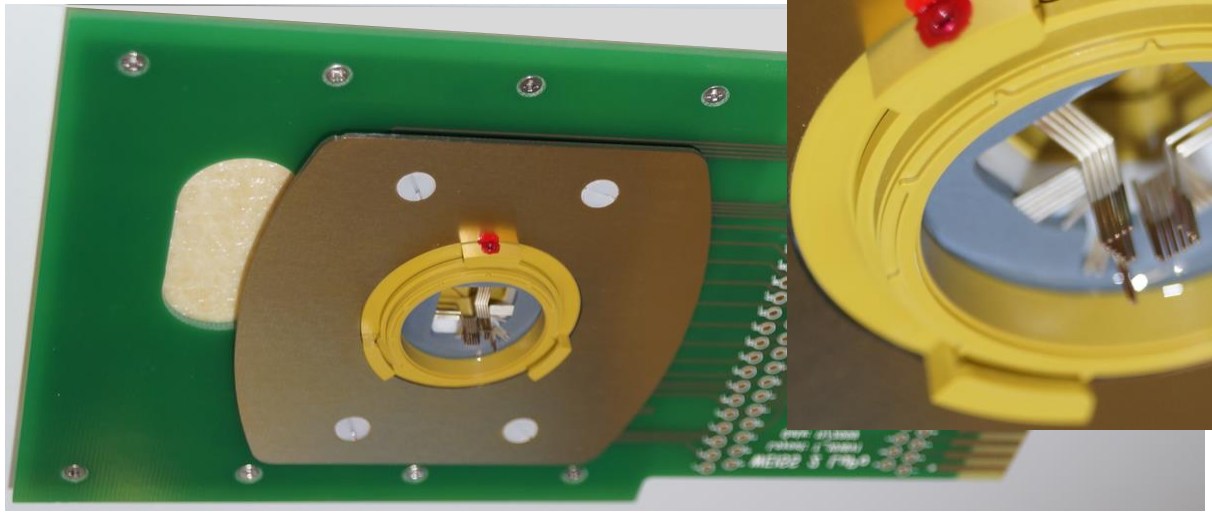
“Lupo” pressurized air chamber design

- *Non-contact seal*
- *Seal hovers above wafer*
- *Compressed Air expands in gap*
- *Air exhausts through gap*
- *Pressure constant over chamber*

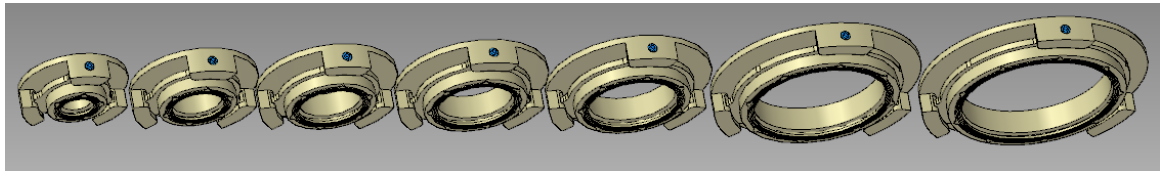


High Voltage Probe Cards

“Lupo” pressurized air chamber

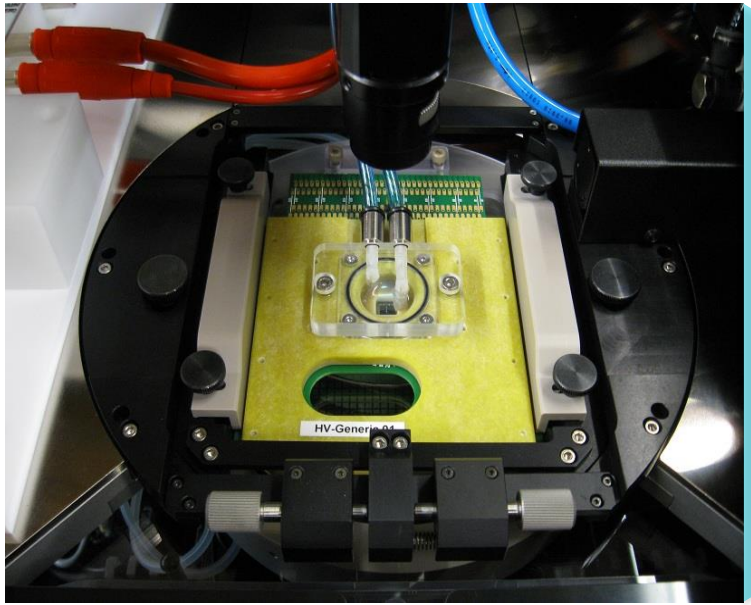


moveable „Lupo“ seal ring



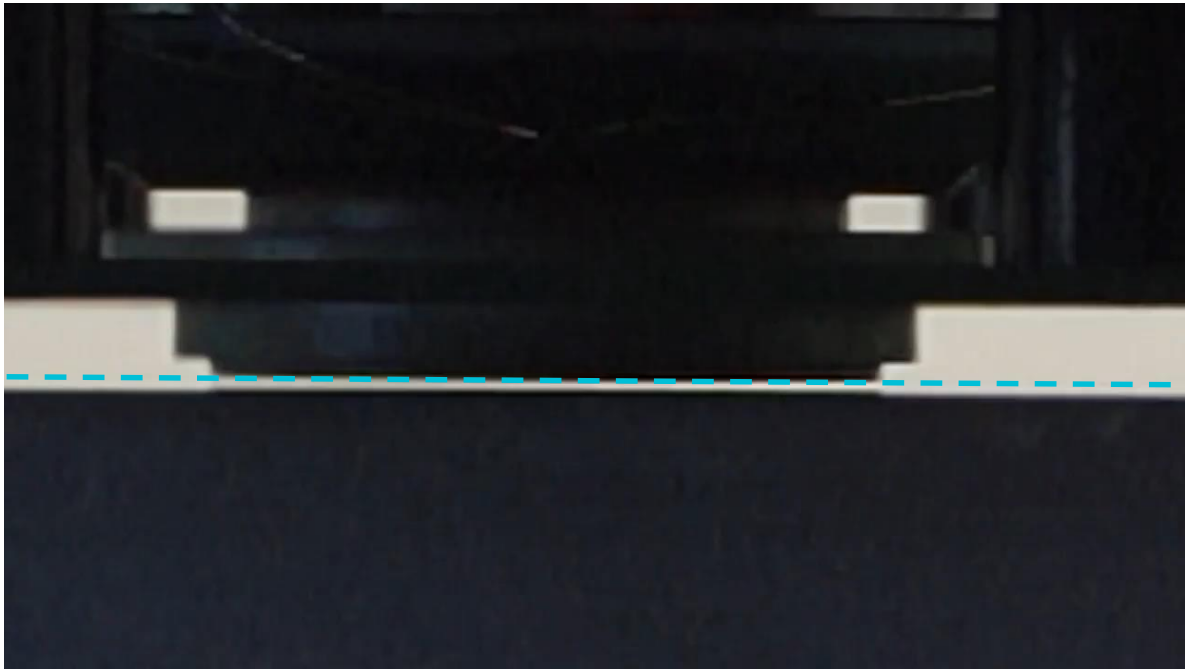
High Voltage Probe Cards

“Lupo” probe card in Tesla Prober



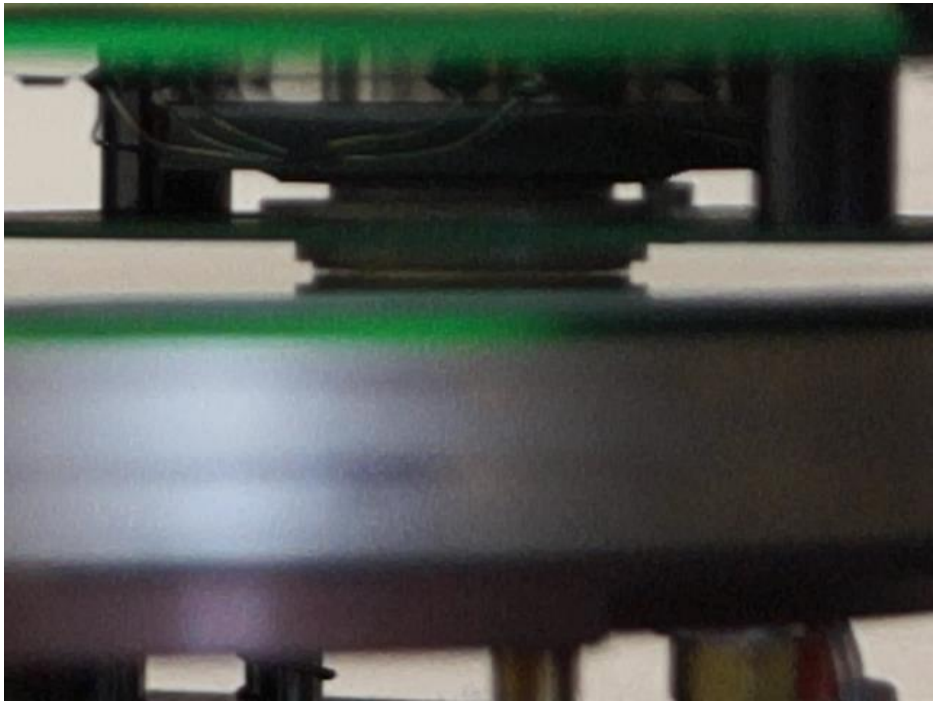
High Voltage Probe Cards

“Lupo” contactless operation



High Voltage Probe Cards

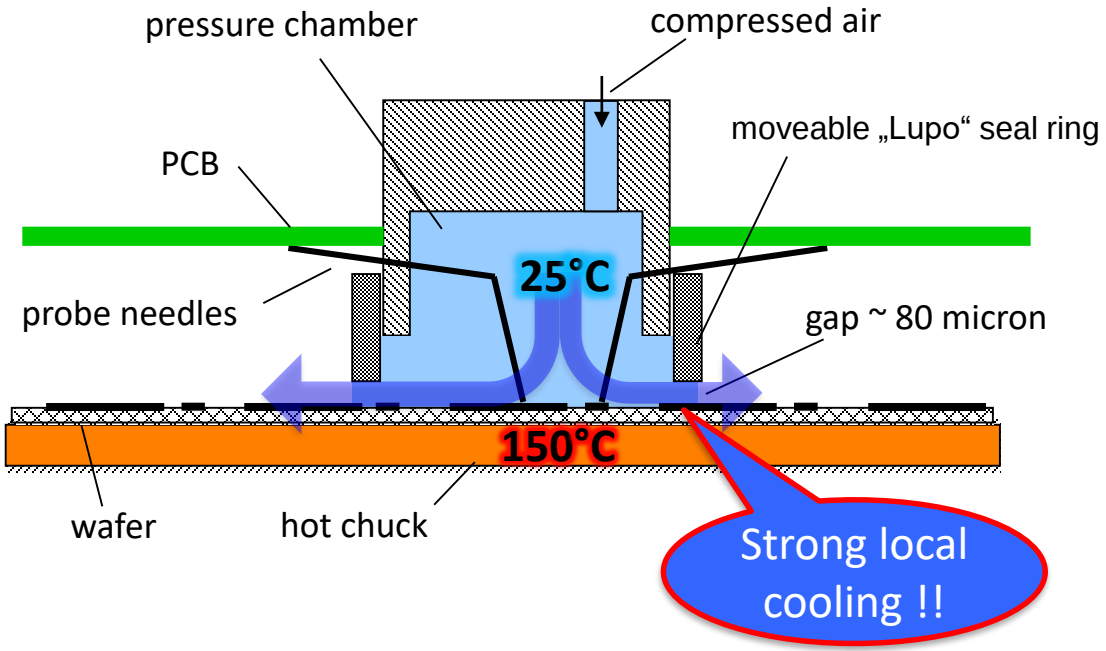
"Lupo" contactless operation



High Temperature HV Probe Crads

HV Wafer probing at higher temperatures

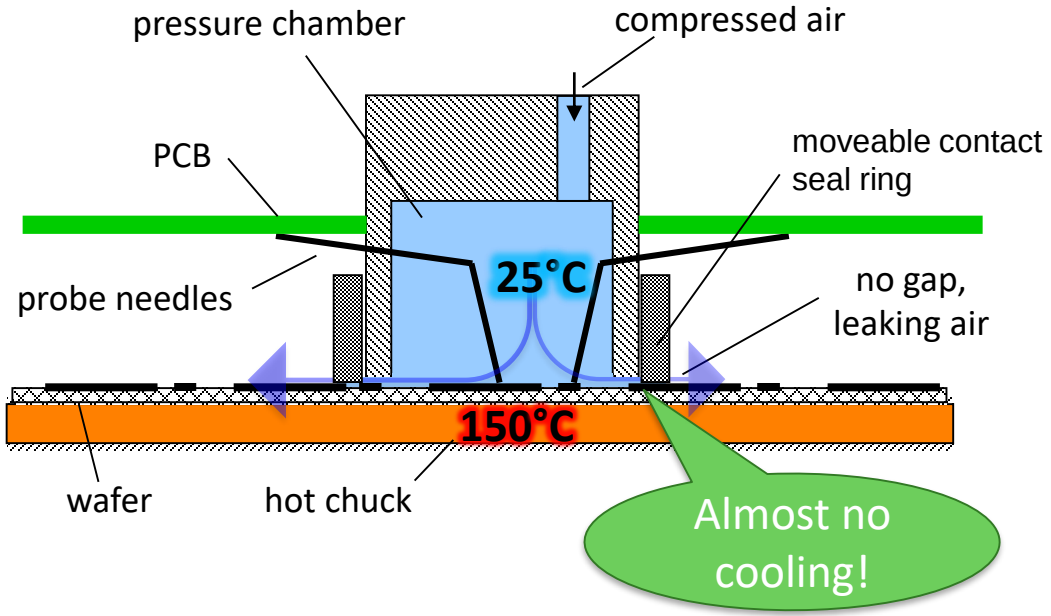
- *Hot chuck 150°C*
- *TIPS Lupo air chamber*
- *Cooling effect on wafer*
- *Local cooling can disturb Chuck temperature control*



High Temperature HV Probe Crads

HT Engineering Probe Cards

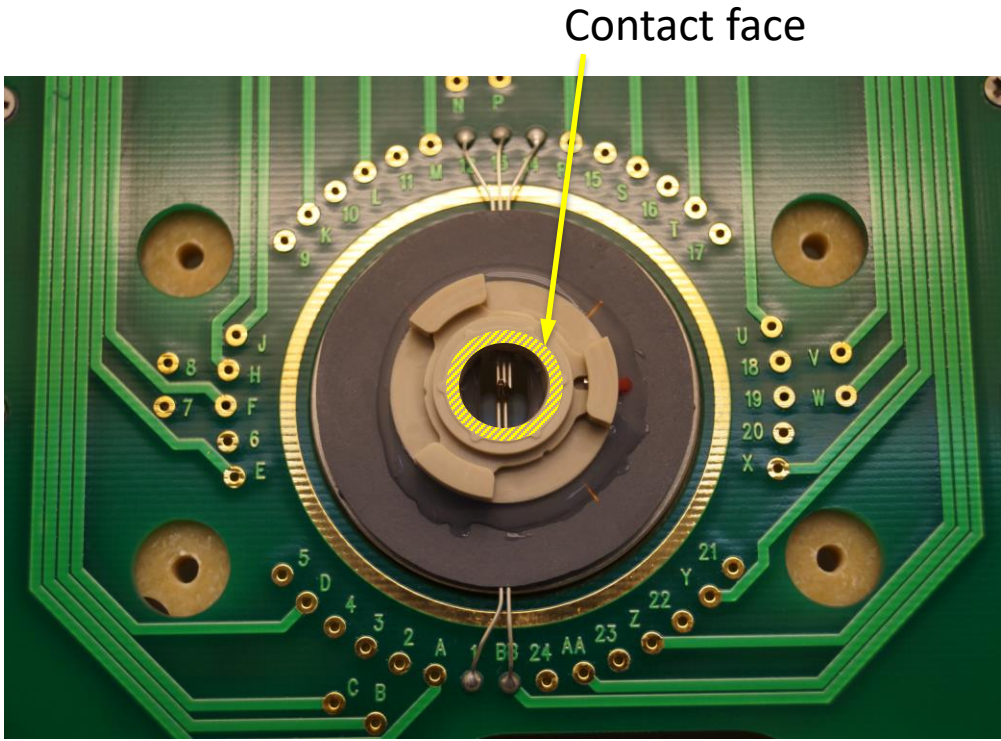
- *device characterization and development*
- *hot wafer chuck 150°C*
- *compressed air 25°*
- ***Contact*** *Lupo seal :*
  - *-> low air flow*
  - *-> low cooling*



High Temperature HV Probe Crads

HT Engineering Probe Cards

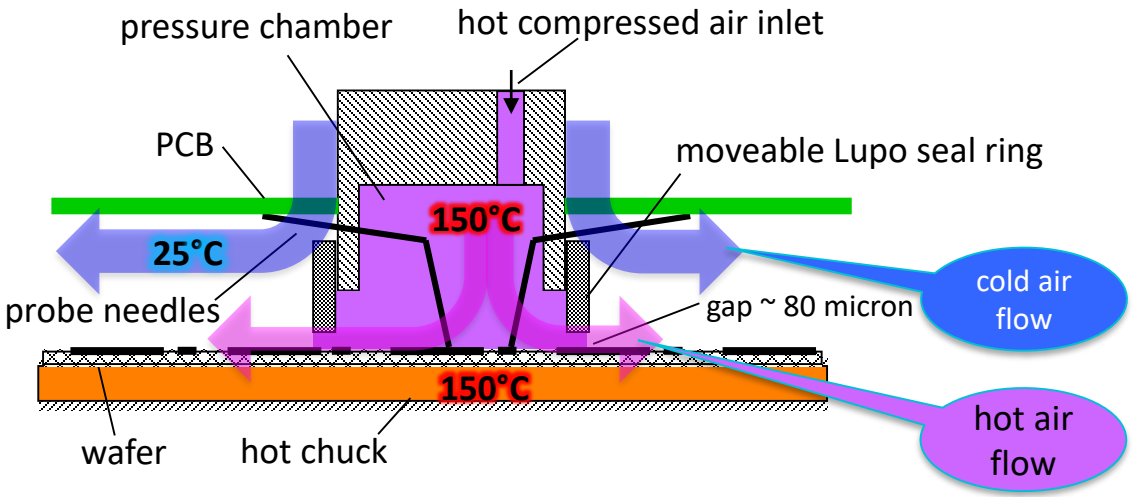
- ***Non-hovering*** *air chamber seal*
- *Large flat contact surface*
- *Seal still moveable*
- *Seal adjusts to probe wear/overtravel*



High Temperature HV Probe Crads

HT Production Probe Cards

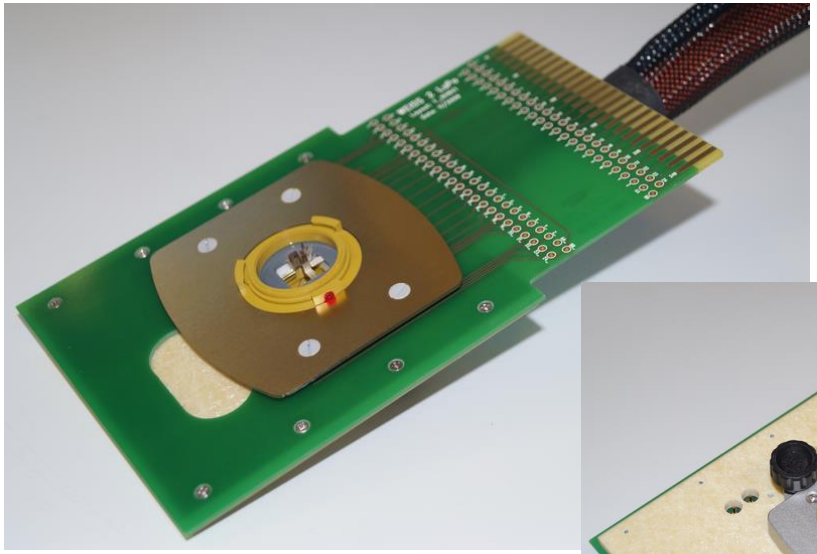
- *Hot compressed air supply*
- *dual hot-cold air stream to protect probe card*
- *reduced breakdown strength at higher temperatures*

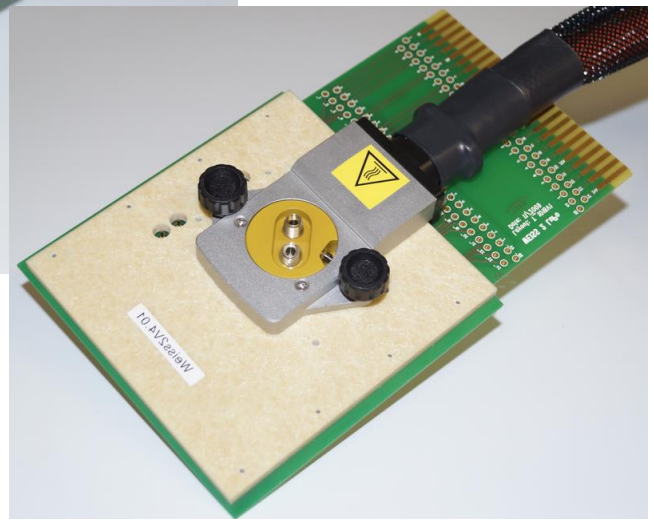


High Temperature HV Probe Crads

HT Production Probe Cards

- *production wafer sort*
- *hot wafer chuck 150°C*
- *hot compressed air 150°*
- *non-contact Lupo seal*





High Temperature HV Probe Crads

High Temperature Pressurized Air Supply

- *Electrical heater*
- *Heats cold compressed air to 150°C*
- *closed-loop temperature control*
- *temperature sensor in probe card*
- *fast settling, stable operation*
- *integrated air cooling for probe card*

High Temperature HV Probe Crads

Impact of Temperature on Breakdown Voltage

- *Breakdown strength (Paschen law) for 25°C*
- *Hot air has lower density*
  -> pressure must be increased to get same breakdown strength
  -> compensation factor is ratio of absolute temperatures

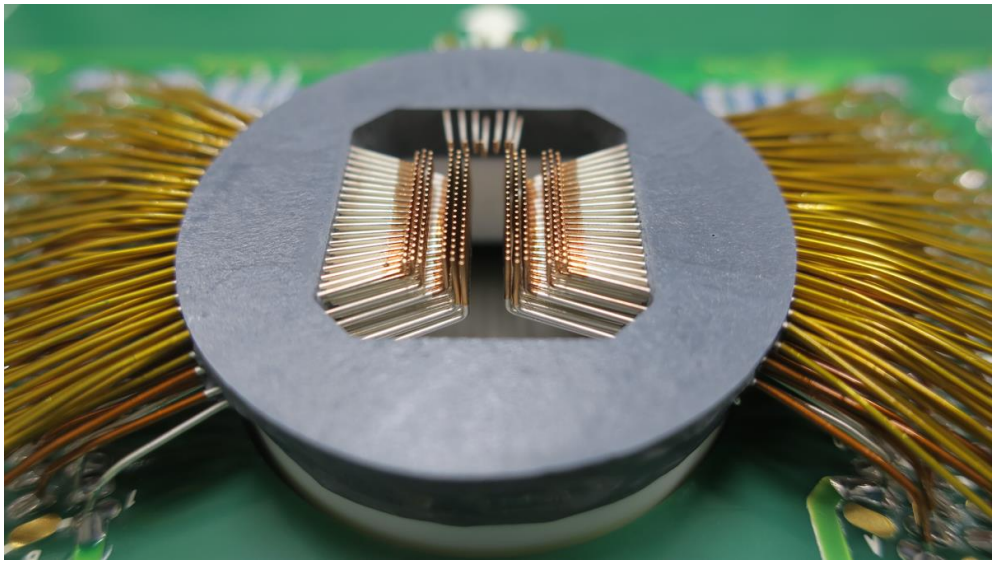
At 150°C -> 33% higher pressure needed!

- *Hot air stream: blows up to 600 W into prober prober thermal management!*

High Current Probe Cards

High current test

- *Forward current test*
- *Up to 1200 Ampere on a single die!*
- *Pulsed currents 5A/probe for 200µs*
- *Limiting: Probe tip heating*
- *Copper-Beryllium probes*

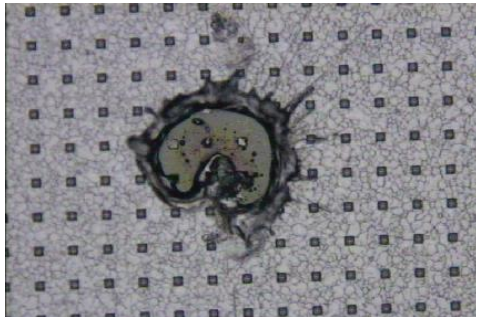


IGBT, 1200 Ampere, 250 probes

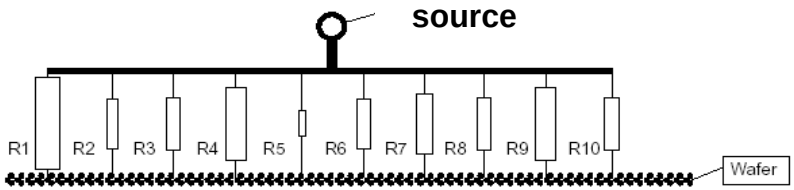
High Current Probe Cards

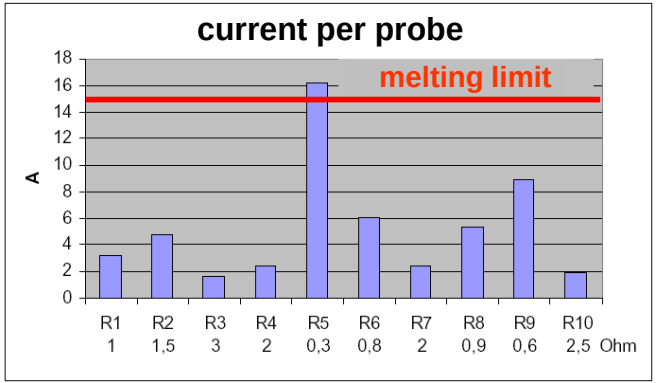
Challenges in high current testing

- *Strong probe tip heating*
- *Heating depends on CRES*
- *Non-uniform current distribution*
- *Probe / tip overheating*
- *Pad melting!*



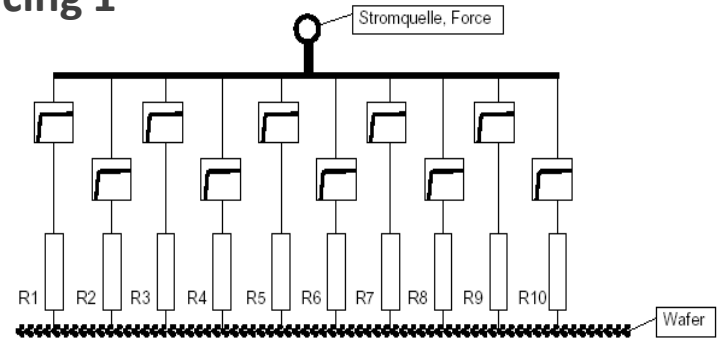
CRES per probe

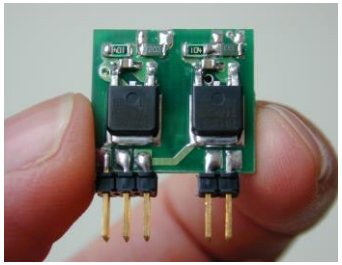




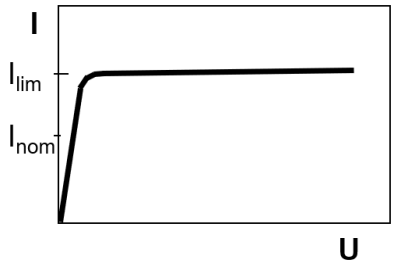
High Current Probe Cards

Probe current balancing 1





"SmartClamp" module



Electrical characteristics of "SmartClamp" module

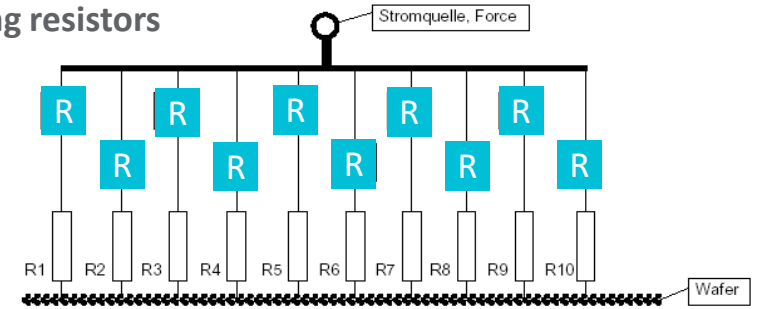
"SmartClamps“ integrated on probe card

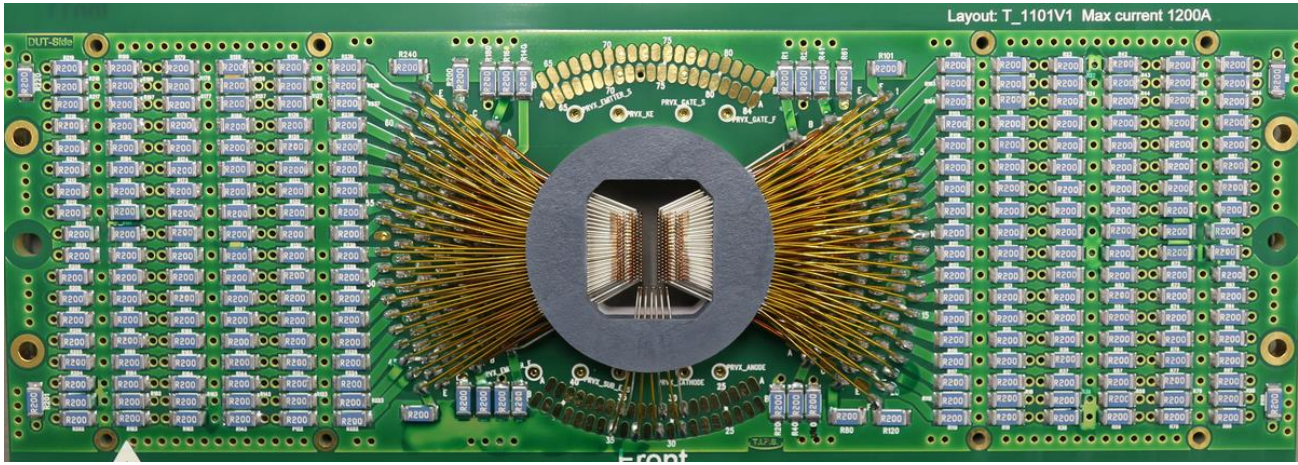
High Current Probe Cards

Probe current balancing 2

- *For high pin counts / currents*
- *Resistors have value in range of CRES*

Balancing resistors





Conclusion

- *High power testing is feasible, limits pushed to 10kV / 1000A and beyond*
- *Trend to ever higher temperatures (125…150…175…200°C)*
- *Trend to production wafer sort at high temperatures*
  -> hot air testing is feasible but very costly
- *Full coverage of test requirements is difficult to achieve, especially at higher temperatures*
  -> physics are imposing the limits
- *We recommend to use “engineering” probe cards for highest temperature / voltage requirements*

Thank You!

For questions, please contact:

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