SW Test Workshop
Semiconductor Wafer Test Workshop

SWTW 2016

High Voltage, High Temperature, High Current... ...and sometimes all come together at the same time!

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Overview

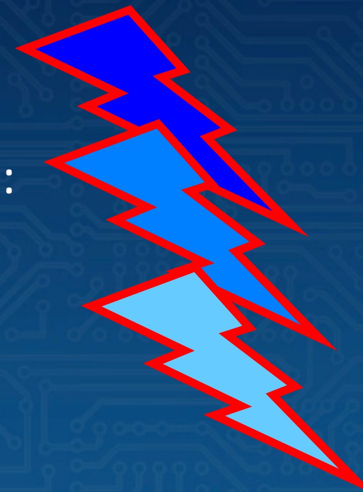
- High Power Devices - Challenges for Wafer Test
- ...some Physics

- High Voltage + High Temperature: "Why's that?"
- Lab Test: Full Wafer HV – HT contactor

- Production Test: SiC, GaN and more...
- "Hot-Cold Air Stream" High Voltage Probe Card

High Voltage on Wafer – Challenges

- **HV Flashovers**
  - If test voltage exceeds insulation strength of atmosphere:



- **known as "arcing", "sparks", "flashovers"**
  - can have unwanted effects for the device under test ...

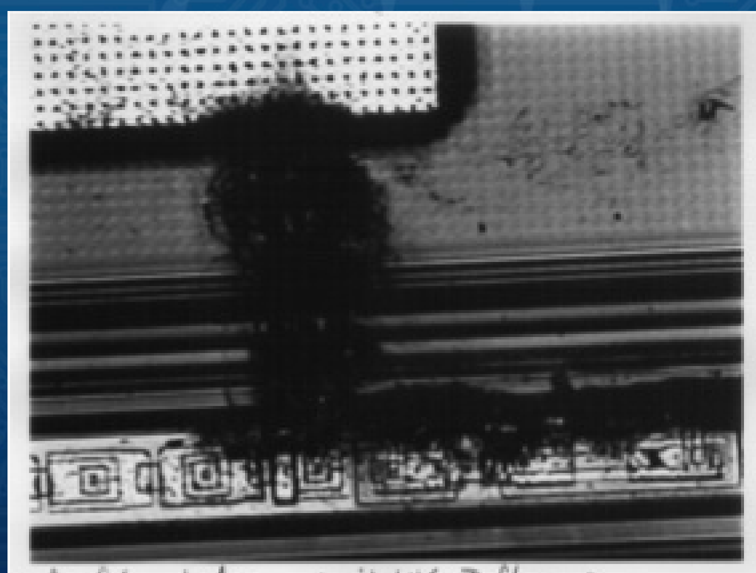
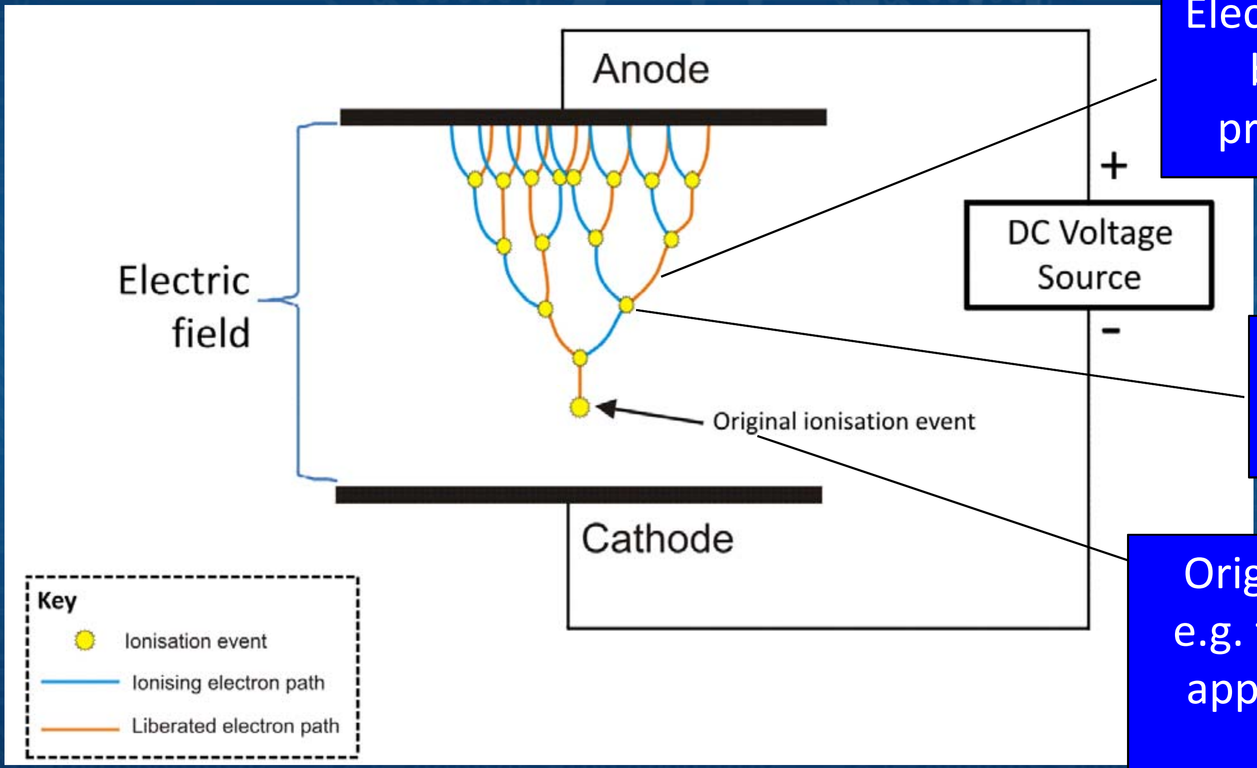


Fig. 1: Damage on wafer surface (IGBT) due to flashover between source-pad and dicing frame structure

High Voltage – some Physics...

- **Flashover Mechanism: Avalanche Ionization of Gas Molecules, "Arc Discharge"**



Electrons, mean free path between collisions: pressure, temperature

Gas molecules: ionization energy

Original ionization event: e.g. from cosmic radiation, approx. 1 event / second in one cm^3

Fig. 2: Visualisation of a Townsend Avalanche *)

*) picture source: Wikipedia

...more Physics !

- **Physics of "Gas Discharges"**
  - first described by Friedrich Paschen in his PhD thesis in 1889: 1)

"Breakdown voltage between two electrodes in a gas is a function of gap distance and pressure" (Paschen's law).

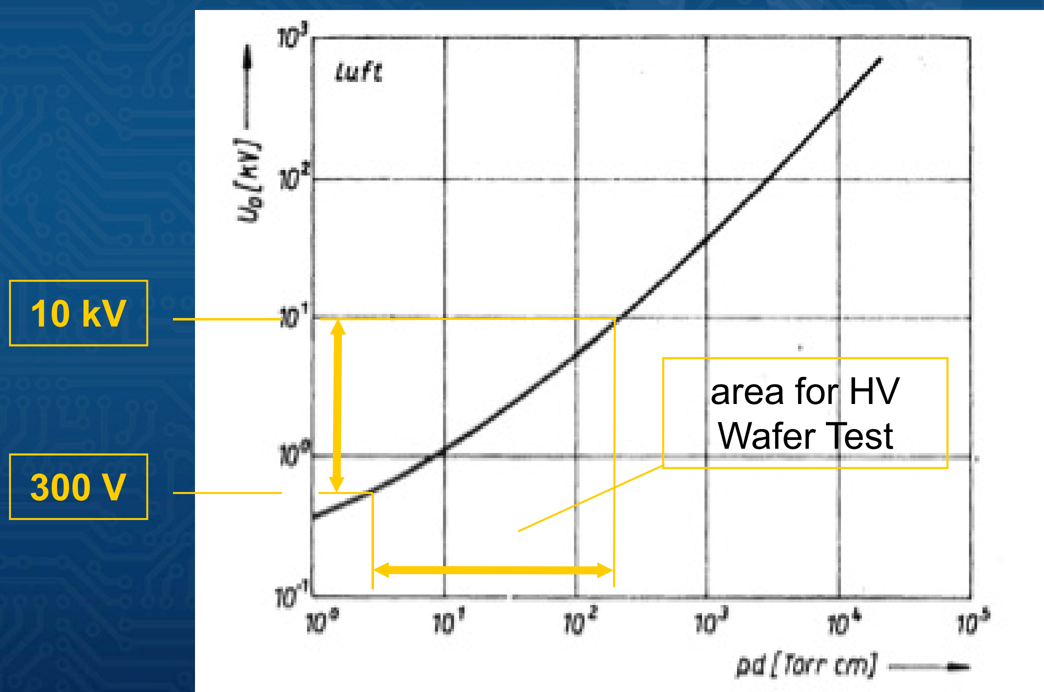
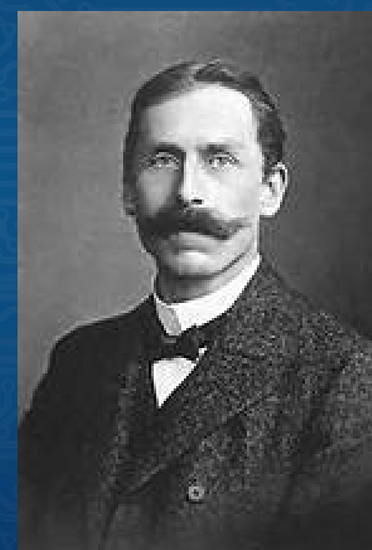


Fig. 3: Paschen Curve for air 2)



Friedrich Paschen *)

*) picture source: Wikipedia

High Voltage and Temperature...

- **Ideal Gas: Molecule density is temperature dependent**
  - the higher the temperature, the lower the molecule density - and the higher the mean-free path for a given pressure e.g. atmospheric pressure
  - increased mean-free-path length leads to lower flashover voltage
  - mathematical description by the "Ideal Gas Law": $pV = nRT$
- **Thus: Increasing pressure -> increased arcing voltage**
- **Increasing temperature -> decreasing arcing voltage**
  - rules of thumb:
    - ***Doubling (absolute) pressure will double arcing voltage .***
    - ***Increasing test temperature from room temperature 23 °C to 150 °C will decrease arcing voltage by 33 % - or require pressure increased by 50 % (absolute) to compensate for.***

Case 1: Hot Temp and High Voltage Lab Test... "Why's that?"

- **Characterization of Temperature Dependence of Avalanche Breakdown in IGBT Termination Structures**
  - needed during development of "VLD (variation of lateral doping) termination structure" – Infineon Technologies

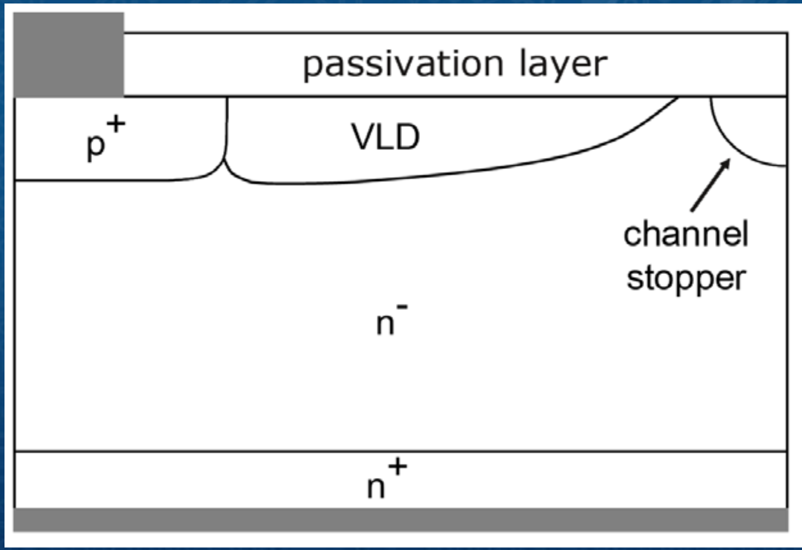


Fig. 4: Schematic cross section of VLD termination structure [3)]

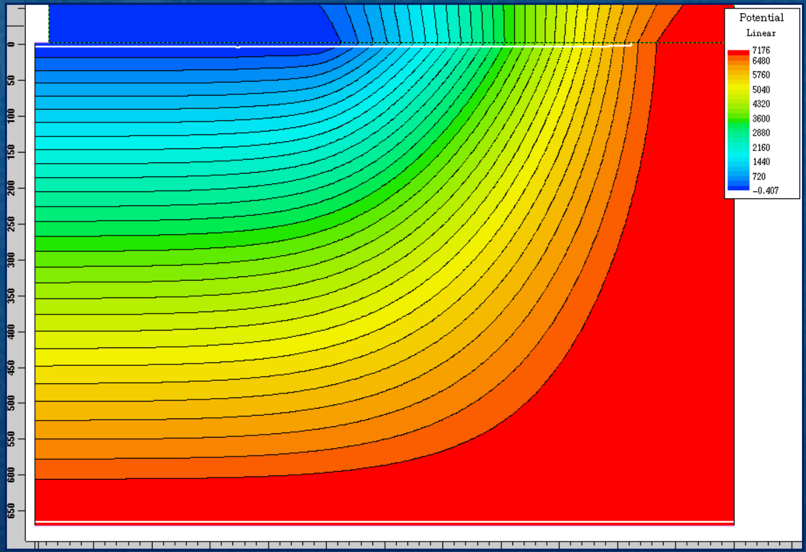


Fig. 5: Simulation of electric field in termination structure at U = 7200 V

New chip design - HV verification

- **Measurement task: HV blocking capabilities of different chip design versions over temperature**

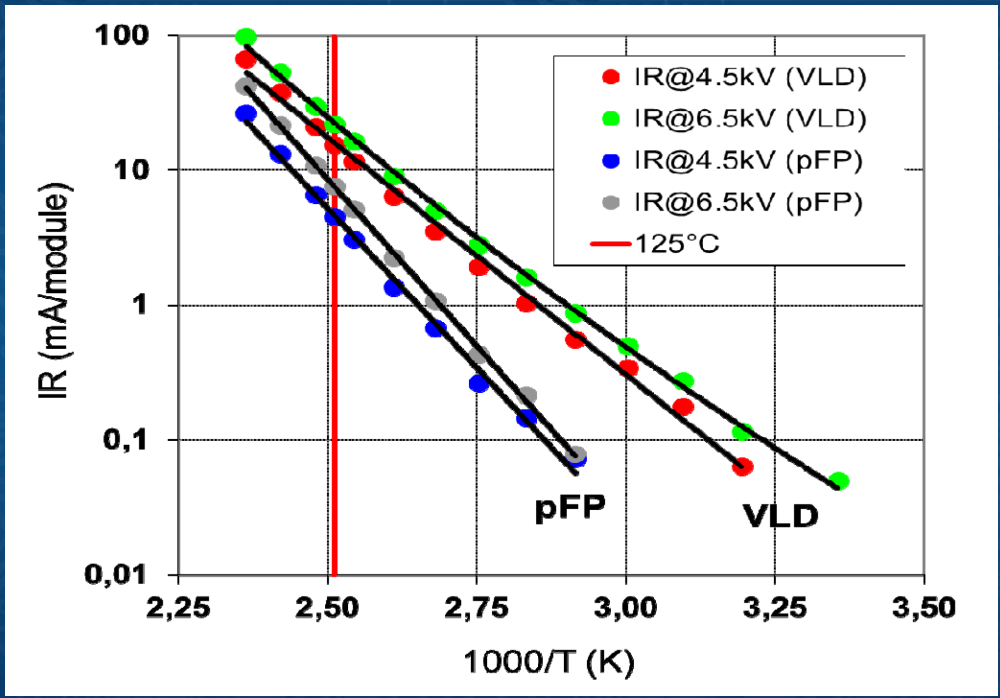
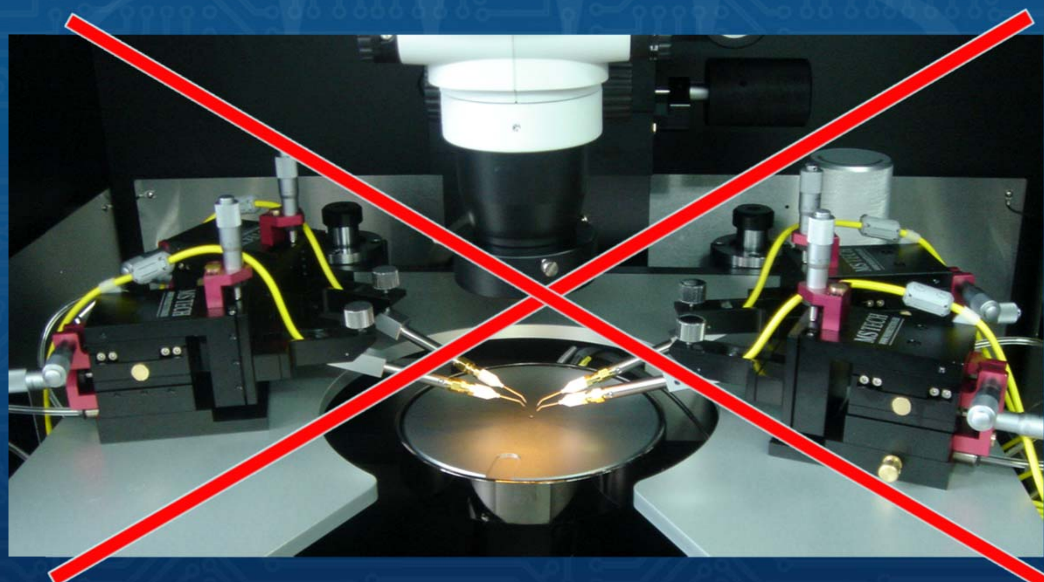


Fig. 6: Leakage current for IGBTs with different termination structures as a function of temperature [3)]

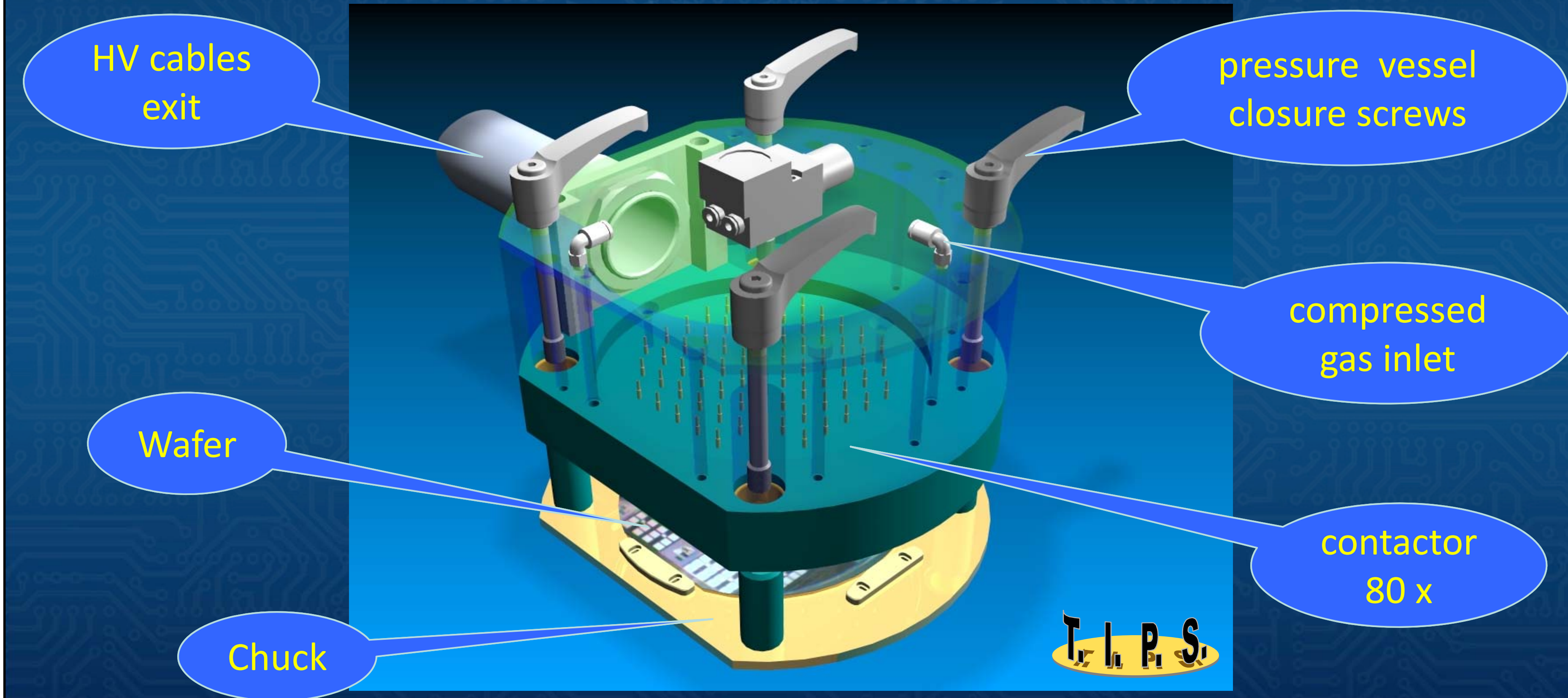
HV chip design verification

- **High numbers of measurements to be done for good statistical significance**
  - "Classic" laboratory characterization approach with manipulator probes is extremely time consuming due to complicated chip preparation required – wouldn't meet timelines requested...



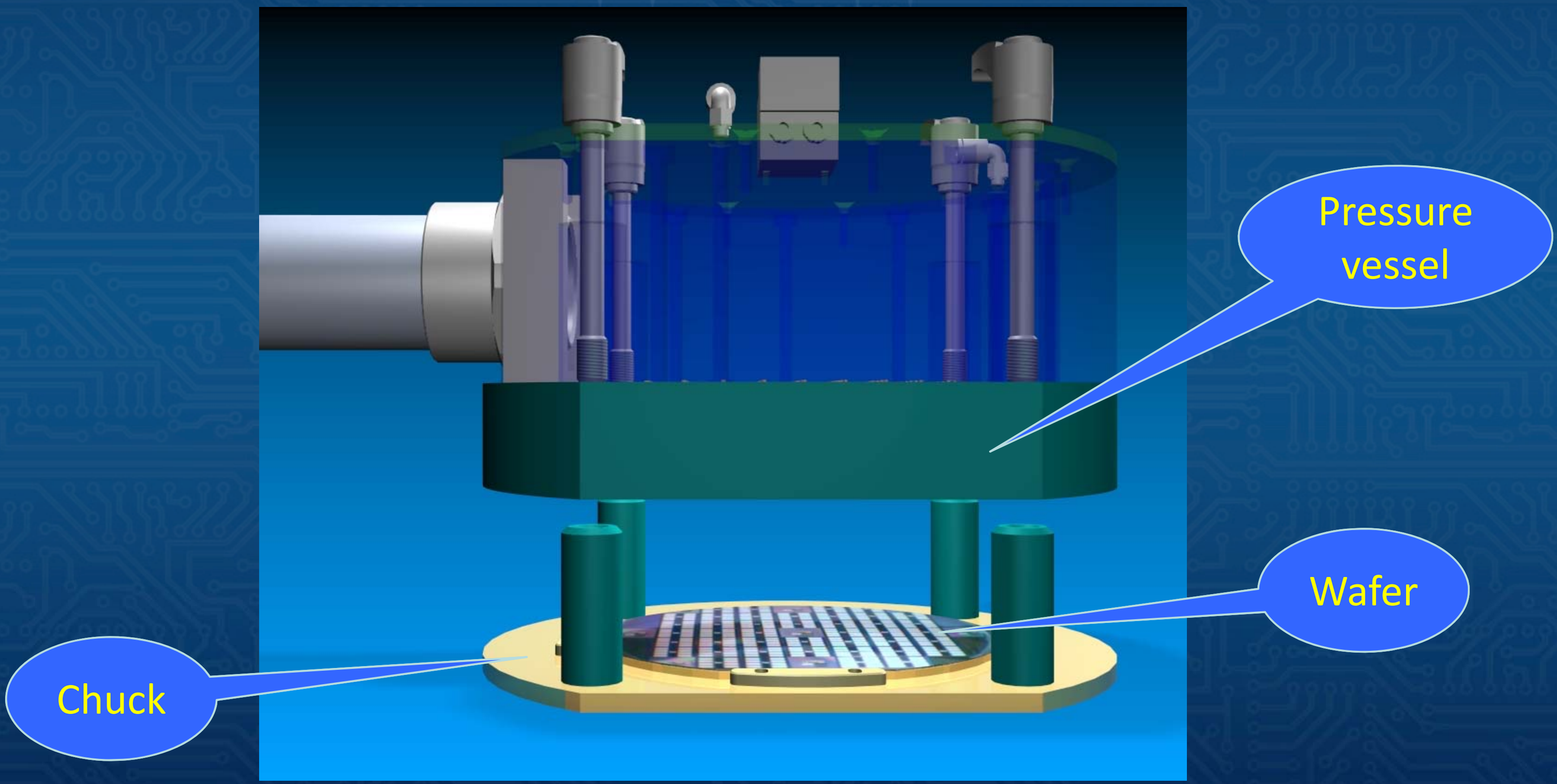
HV Full Wafer Contactor

- **6" full wafer wafer single touchdown, 80 x parallel test, 10 kV capable, - 40 °C - 175 °C, max. 4 bar pressure vessel**



HV Full Wafer Contactor (2)

- "non-gas-loss" design: instead of compressed air also use of compressed HV insulating gas (SF6) is possible



"HV – Messplatz, Villach"

HV enclosure cabinet

Dr. Gerhard Schmidt

HV
full wafer
contactor

Summary – Lab Test Setup

- 6" full wafer contactor allows fast high voltage characterization of HV IGBT and diodes and greatly speeds up development for new HV chip designs.
- Full temperature range coverage from – 40 °C – 175 °C,
- lossless pressure vessel allows (restricted) use of insulating gases (e.g. SF6) for most demanding applications
- Very low parasitic current leakage (1 nA @ 10 kV)

Case 2: Production Wafer Sort

- **Device under test: one of the "exotic" SiC, GaN... specimens**
- **900 V – 20 A – 175 °C – and very narrow HV structures**
  - First proposal: use off-the- shelf TIPS High Voltage "LuPo" probe card with floating air bearing seal, supplied with compressed air at ambient temperature, hot chuck

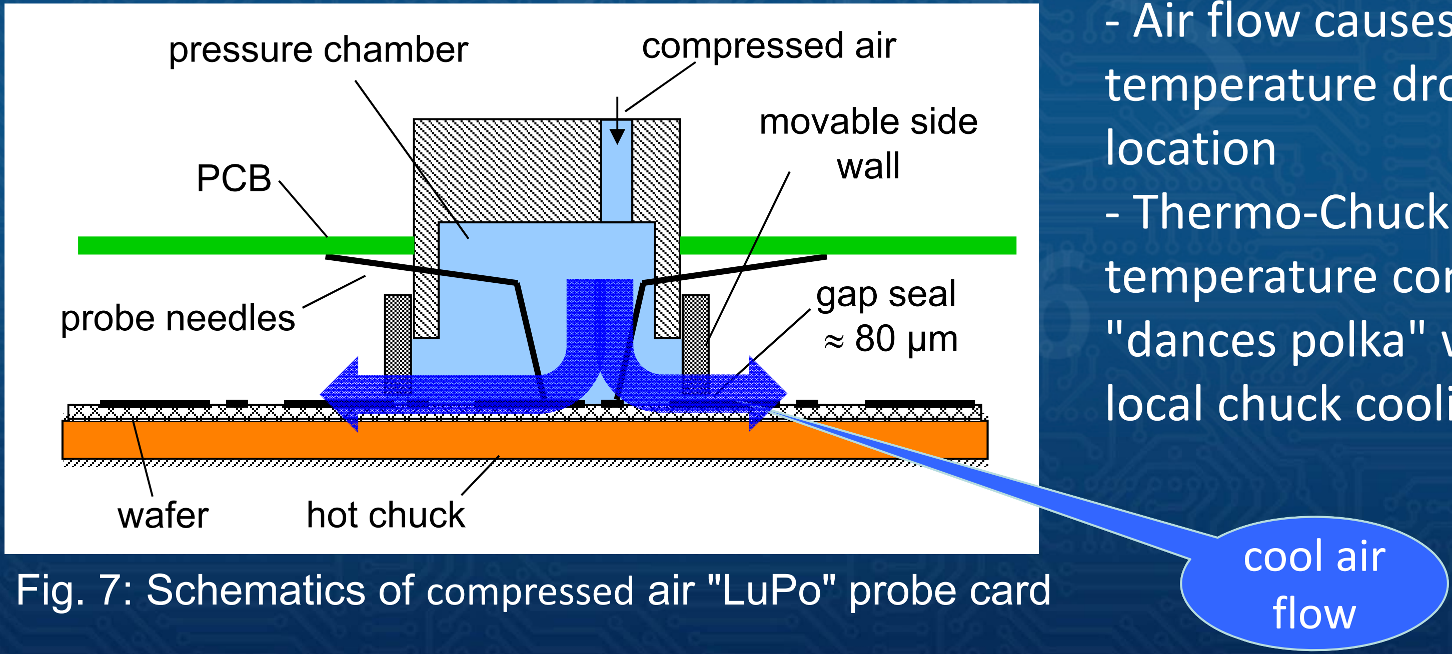


Fig. 7: Schematics of compressed air "LuPo" probe card

- Air flow causes sharp temperature drop at DUT location
- Thermo-Chuck temperature control "dances polka" when facing local chuck cooling.

Hot-Cold-Airstream Probe Card

- compressed hot air at chuck temperature to create hot compressed air test emvironment
- cold air stream to insulate probe card components from heat

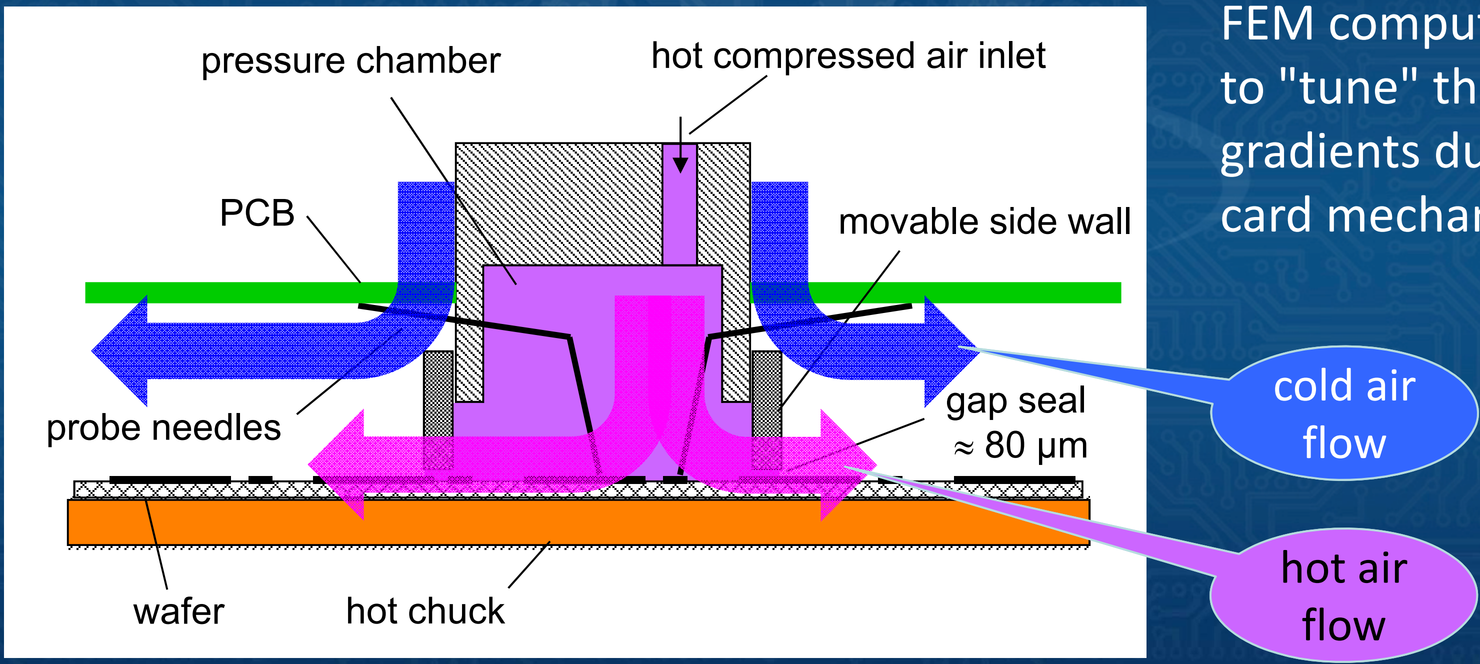
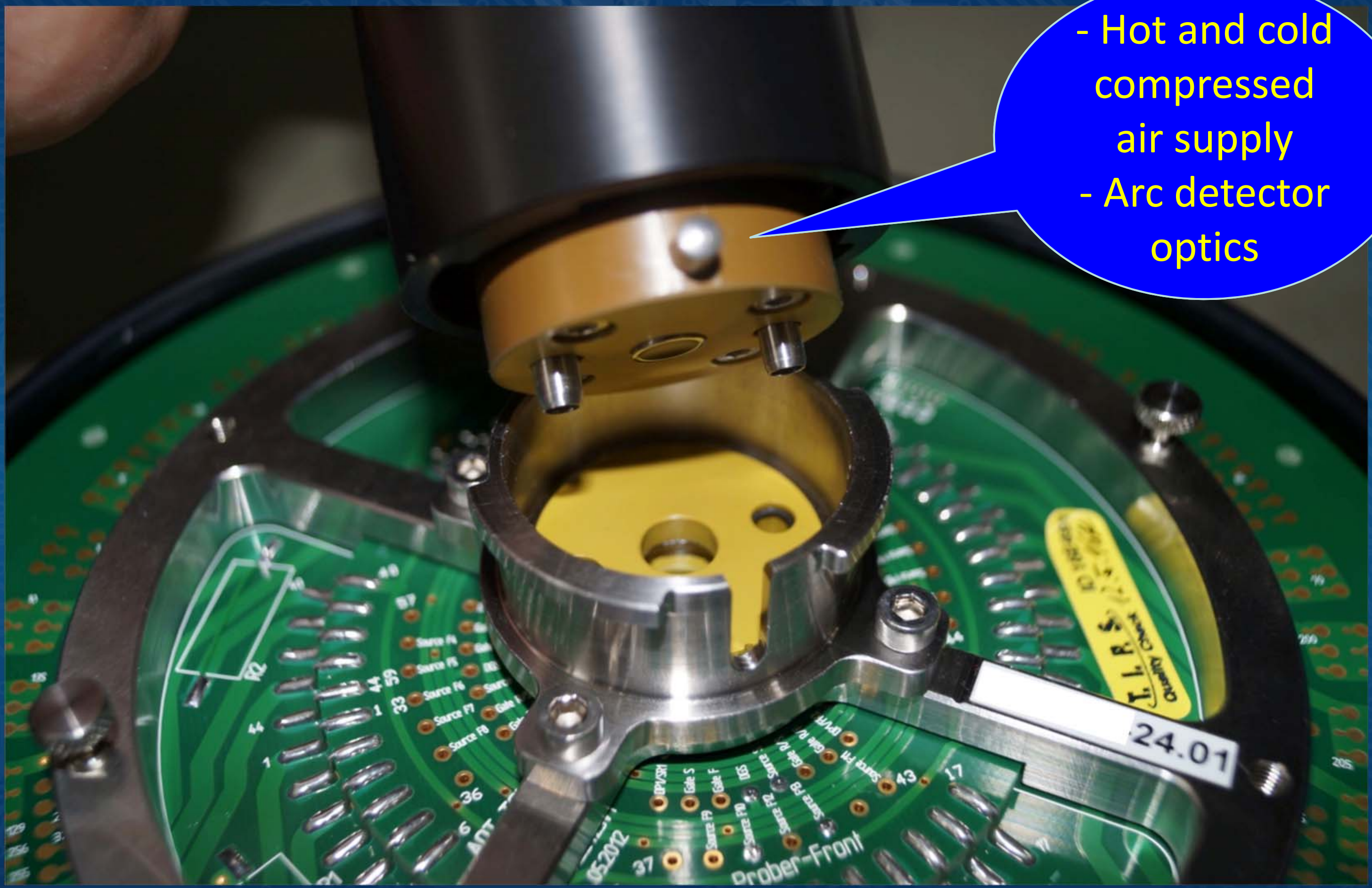


Fig. 8: Schematics of Hot-Cold-Airstream "LuPo" probe card

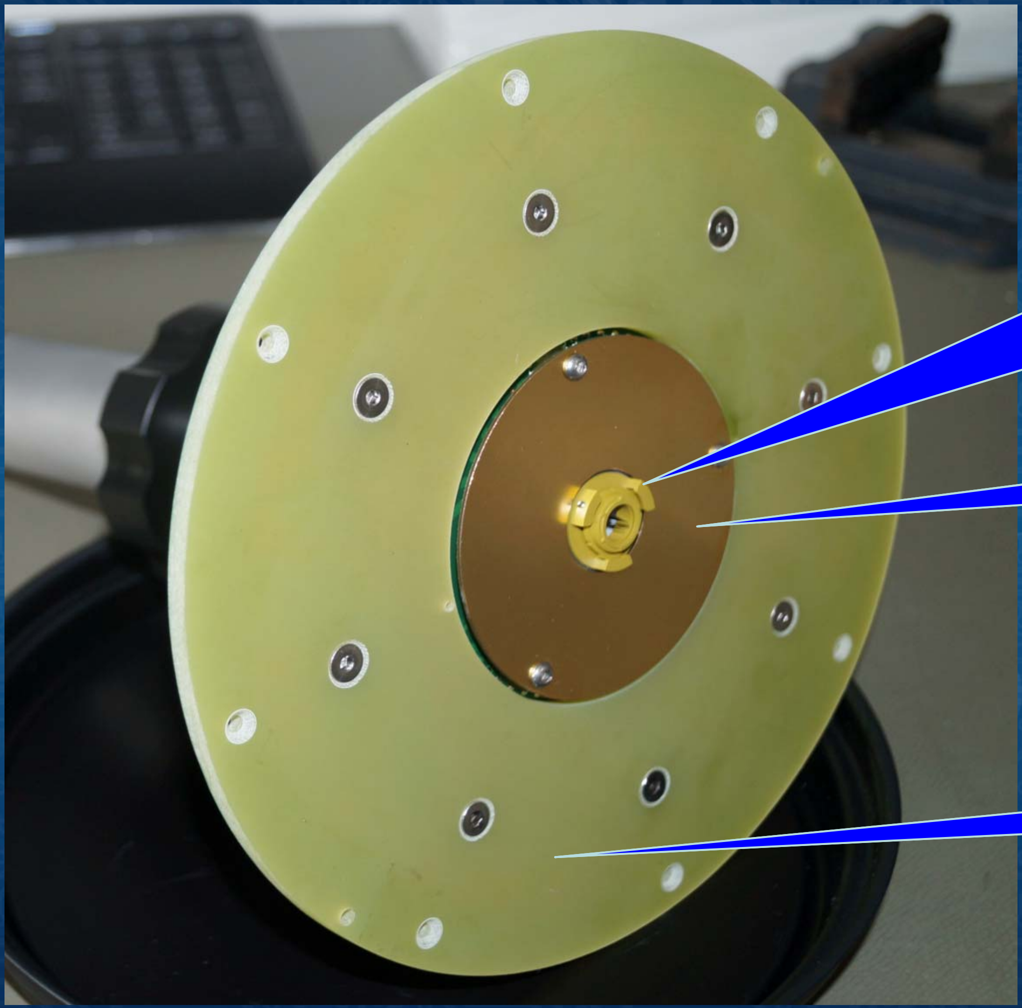
FEM computation used to "tune" thermal gradients during probe card mechanical design

Hot-Cold-Airstream Probe Card (2)



- Hot and cold compressed air supply
- Arc detector optics

Hot-Cold-Airstream Probe Card (3)



Conclusion

- High Voltage – High Current – High Temperature wafer probing is feasible – but with "hard constraints" imposed by physics
- For production test: It's like having a hot air gun inside your prober – So if you can avoid it...
- If you can't avoid it...
  ....at least be careful not to burn your fingers! ☺

Thank you for your attention!

Acknowledgements

- unnamed customers willing to try out new things...
- our design and manufacturing team at T.I.P.S.

References

1) **"Ueber die zum Funkenübergang in Luft, Wasserstoff und Kohlensäure bei verschiedenen Drucken erforderliche Potentialdifferenz"**, F. Paschen, Annalen der Physik, vol. 273, no. 5, pp. 69 – 96, 1889

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3) **6.5kV IGBT and FWD with Trench and VLD Technology for reduced Losses and high dynamic Ruggedness**, Thomas Duetemeyer1), Josef-Georg Bauer2), Elmar Falck2), Carsten Schaeffer3), G. Schmidt3), Burkhard Stemmer1), PCIM Europe 2008 Conference Proceedings, ISBN: 978-3-89838-605-0