POSTER #4

New approaches to protect probe cards during high-power short circuit test

Georg Franz, Alvaro Rosa
T.I.P.S. Messtechnik GmbH

TECHNICAL INNOVATION – PHYSICAL SOLUTIONS

Test requirements

SiC power devices

For silicon carbide power devices operating in the kilovolt and kiloampere range, reliability is crucial.

Short circuit test

Device robustness against short current spikes outside the safe operating area is required.

This can be tested in the short circuit condition where the device must withstand very high currents for a defined, short duration.

Known Good Die

Module yield

For high power applications, several dies are assembled into a power module.

Overall yield requires that each single die is tested at wafer level and after singulation (dicing).

KGD test setup

The short circuit test poses some special requirements on the probe hardware, like short current paths to keep inductance low.

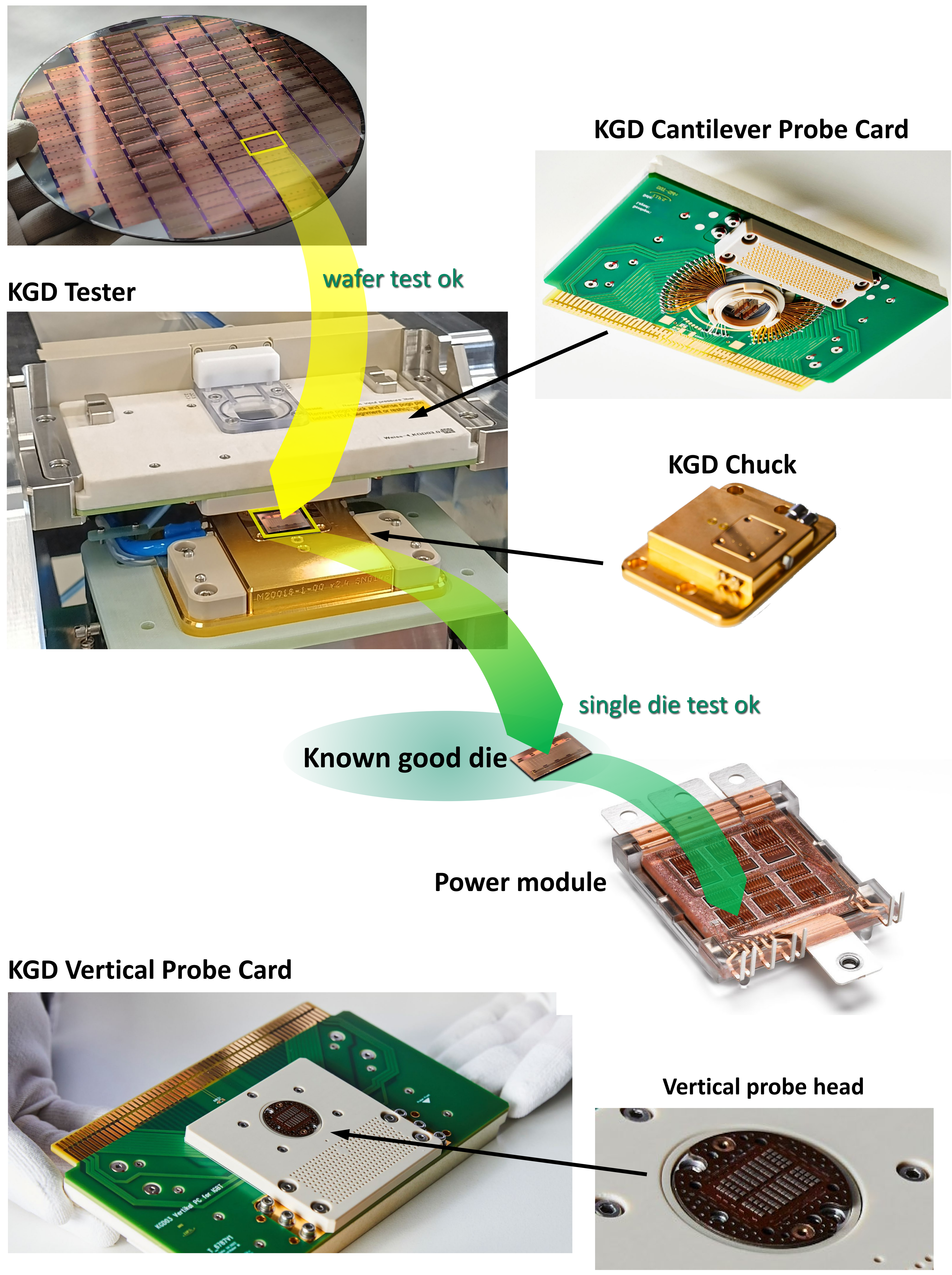
Power density

Device shrinkage

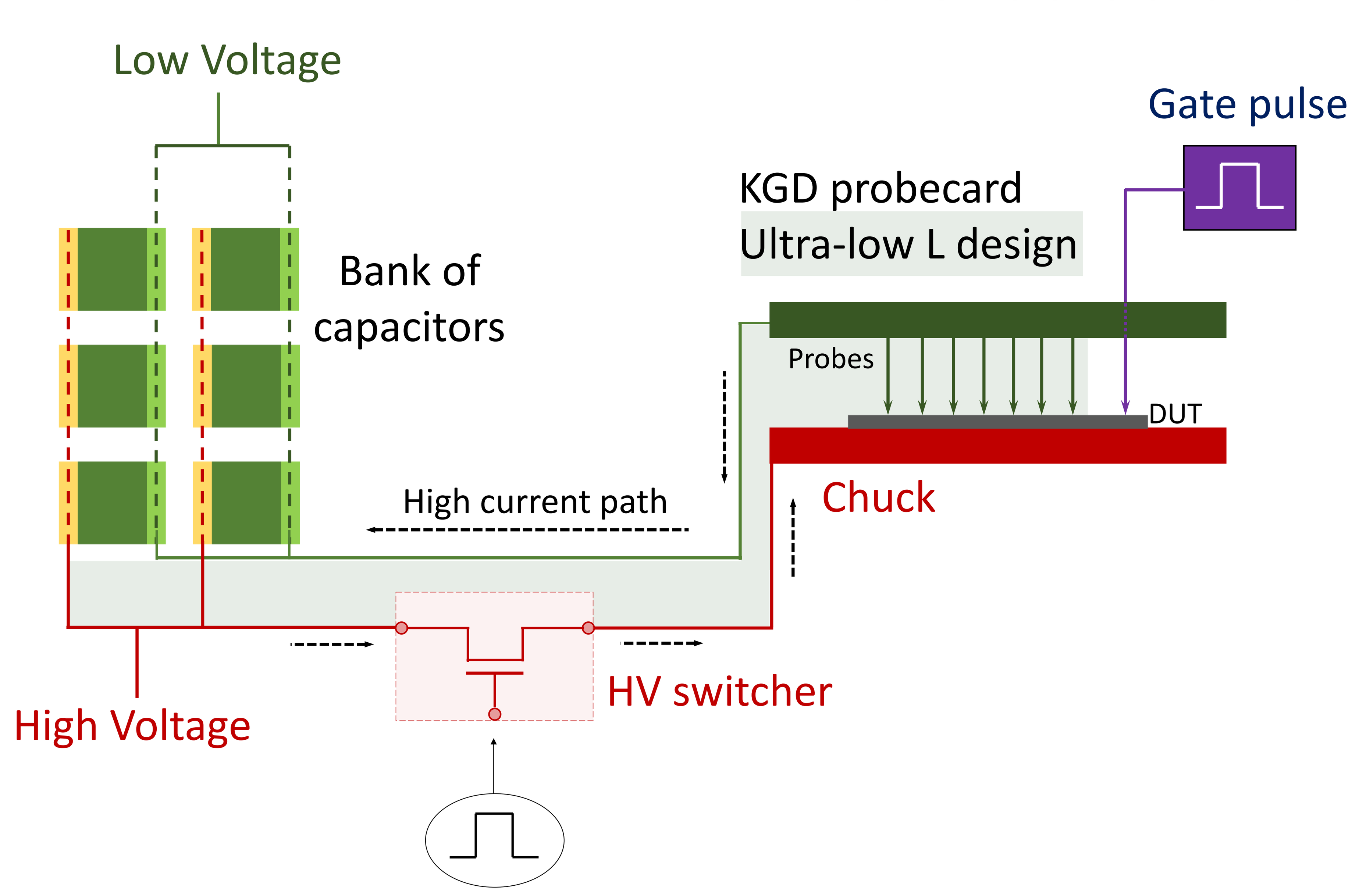
The main drivers are cost and power efficiency, leading to smaller dies with higher current densities. With smaller dies at same current the cantilever probes become the limit.

Vertical probe technology

Vertical probes can overcome that limit as they can fill the full pad opening area, achieving a higher total current density per chip.



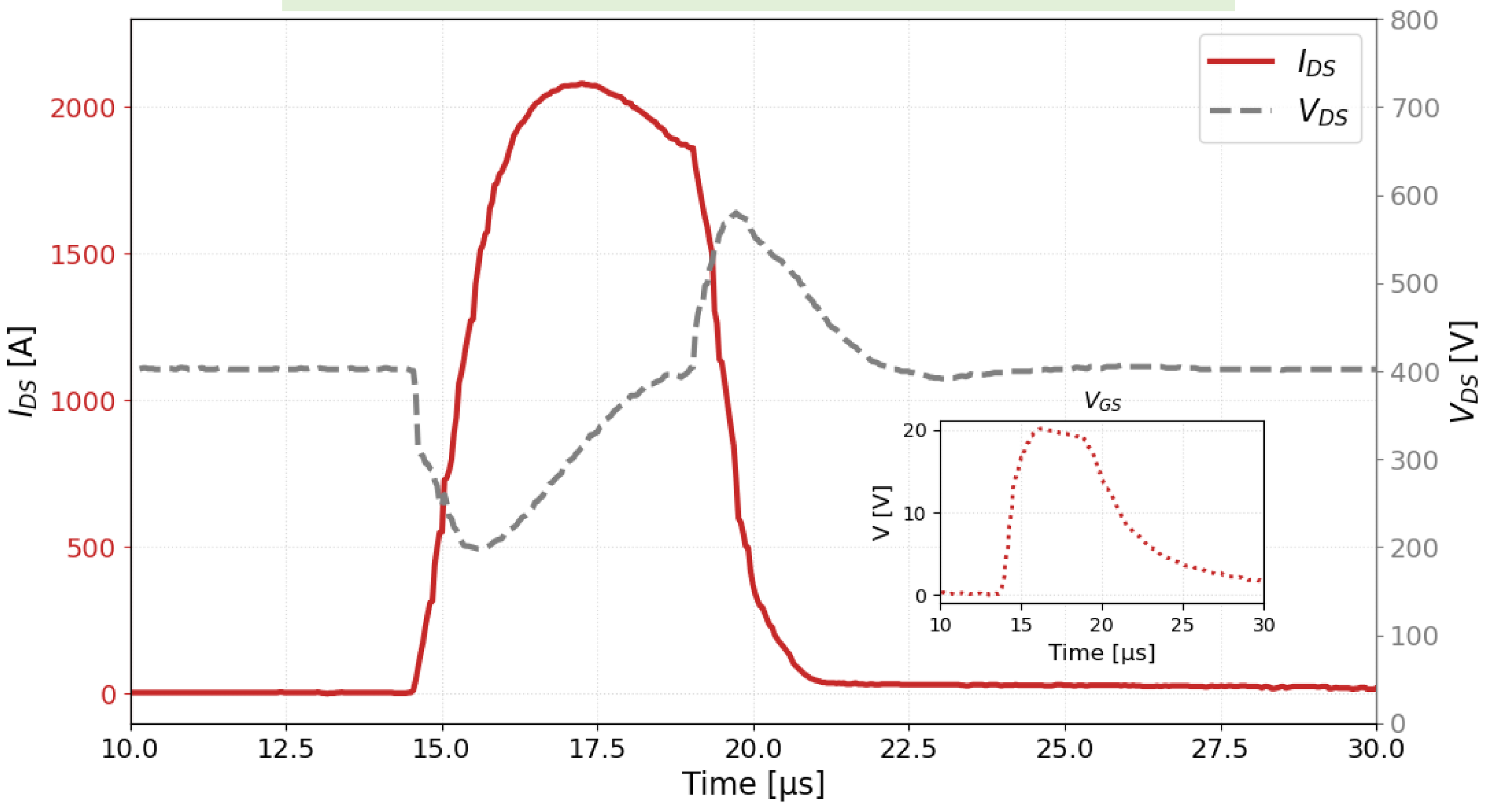
Scheme of a Short Circuit test setup



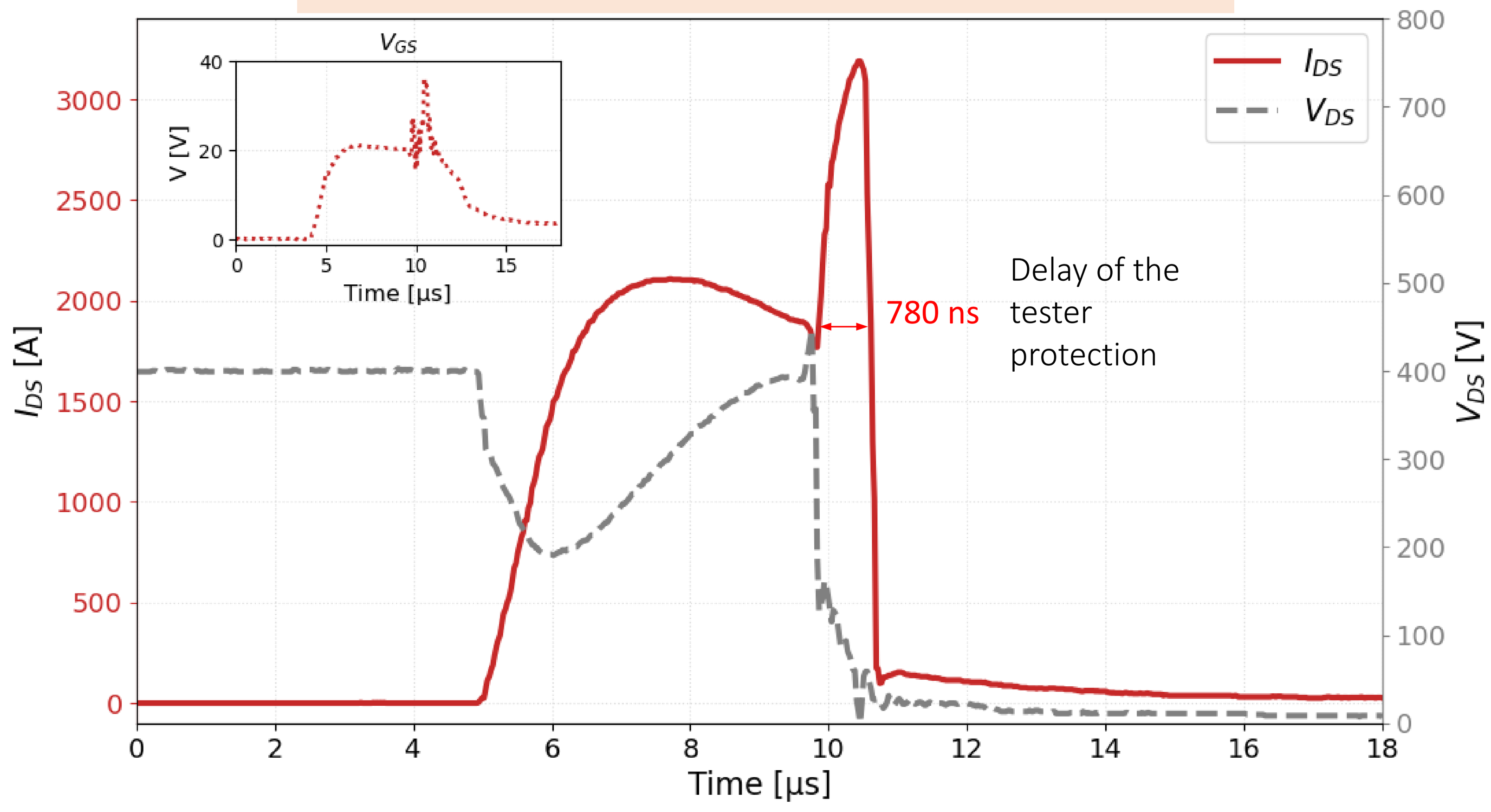
- Total inductance of the power loop of ~50nH for high switching speeds.
- Short pulse in the µs range applied to the gate of the DUT.
- High voltage of ~2/3 times the breakdown voltage V_{BV}.
- Tester with capacitors to provide the high current of the pulse: ~10 times the nominal current of the DUT.
- A switcher in the tester, to stop the test in case of failure of the DUT’s gate (a slightly longer pulse than that of the gate can be applied).
- Some testers integrate a protection on the HV switcher to stop the test in case of overcurrent due to failure.

Short Circuit (SC) test failure in high-power devices

SHORT CIRCUIT TEST PASSED

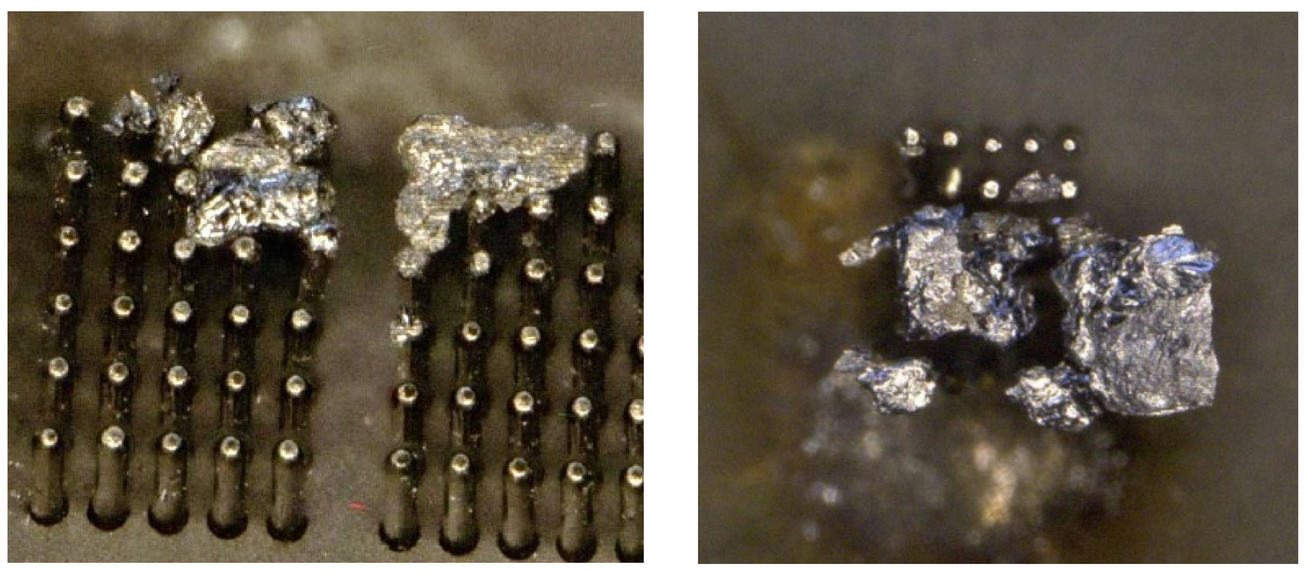


SHORT CIRCUIT TEST FAILED



Short circuit tests on a SiC module. The drain current saturates at more than 2kA and surpasses 3kA after failure. The V_{DS} test voltage is 400V and varies during turn-on and turn-off due to the inductive peaks $V_L = L*di/dt$. When the DUT fails, the voltage drops and the tester protection stops the test in ~780ns.

When a catastrophic failure occurs…

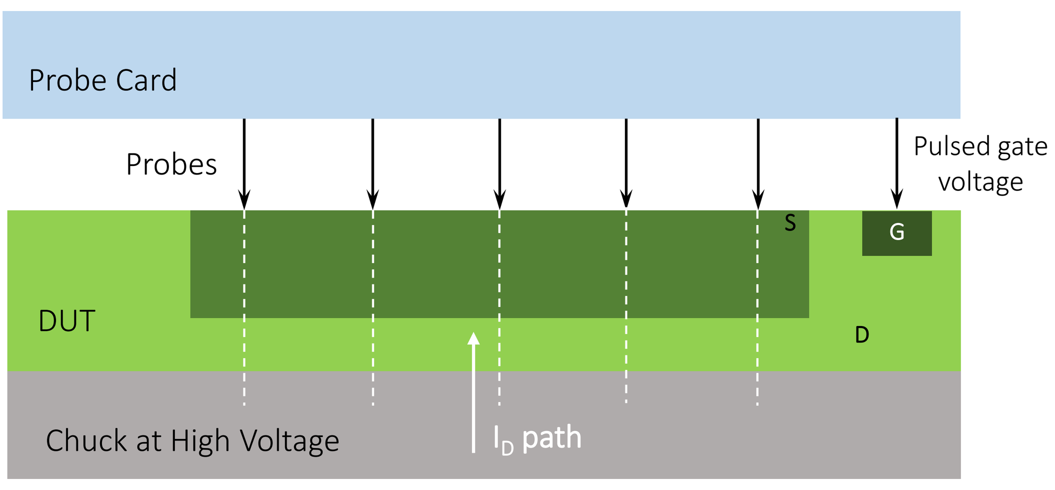


Metal contamination fused to vertical probes

When a device fails during an SC test, a high current flows through the melting DUT, ejecting melted metal across the needles and reducing their service life.

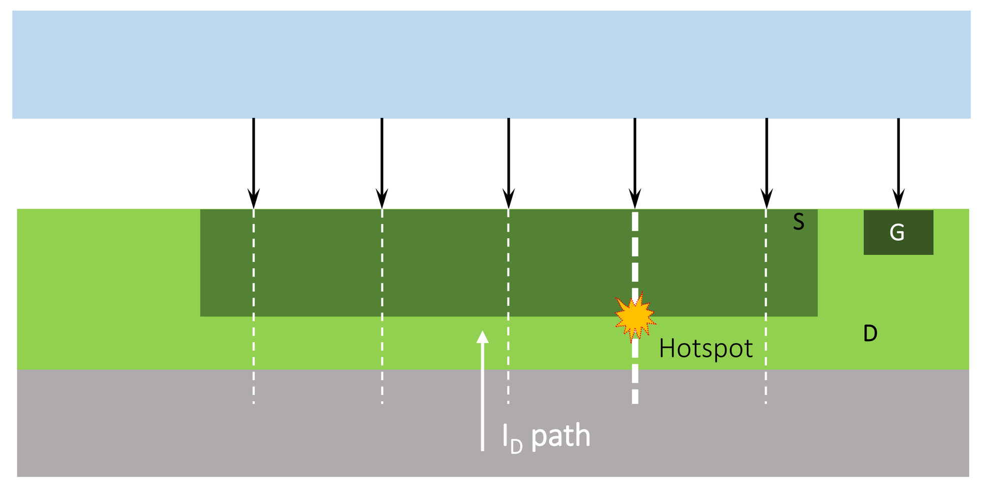
The fastest tester protections can stop the test in 780 ns after the failure. In high-power devices, this reaction time is not enough to protect the probes. Thus, a faster protection is needed (τ < 100ns).

Normal short circuit test condition



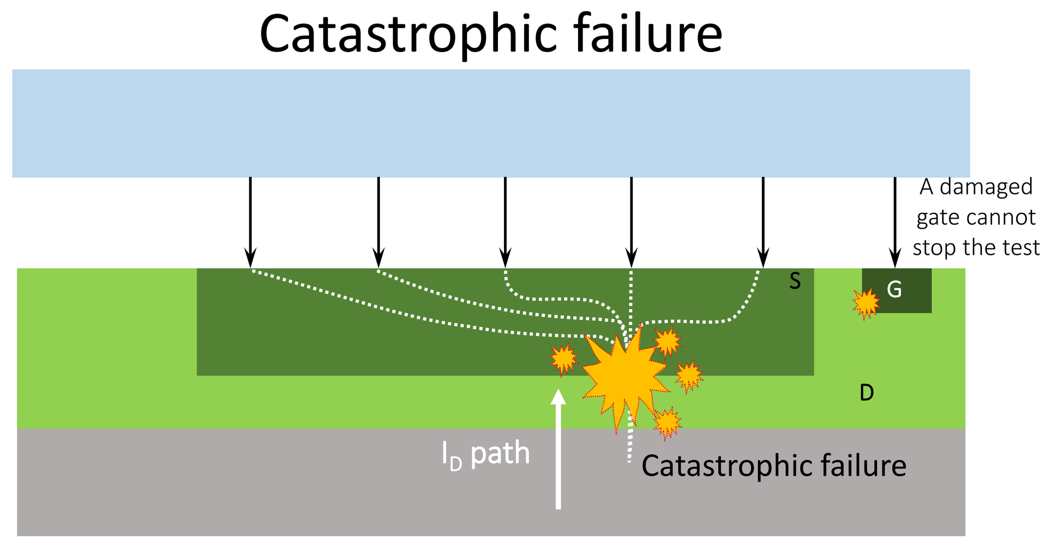
A high voltage is applied to the drain, and a pulse in the µs range is applied to the gate. The current ID is left free to increase.

Failure initiates



If the device is defective or the SC test time is long, a hotspot will form, and the current at that point will exponentially increase until total failure in short, in 50-100ns. (Thermal runaway).

Catastrophic failure



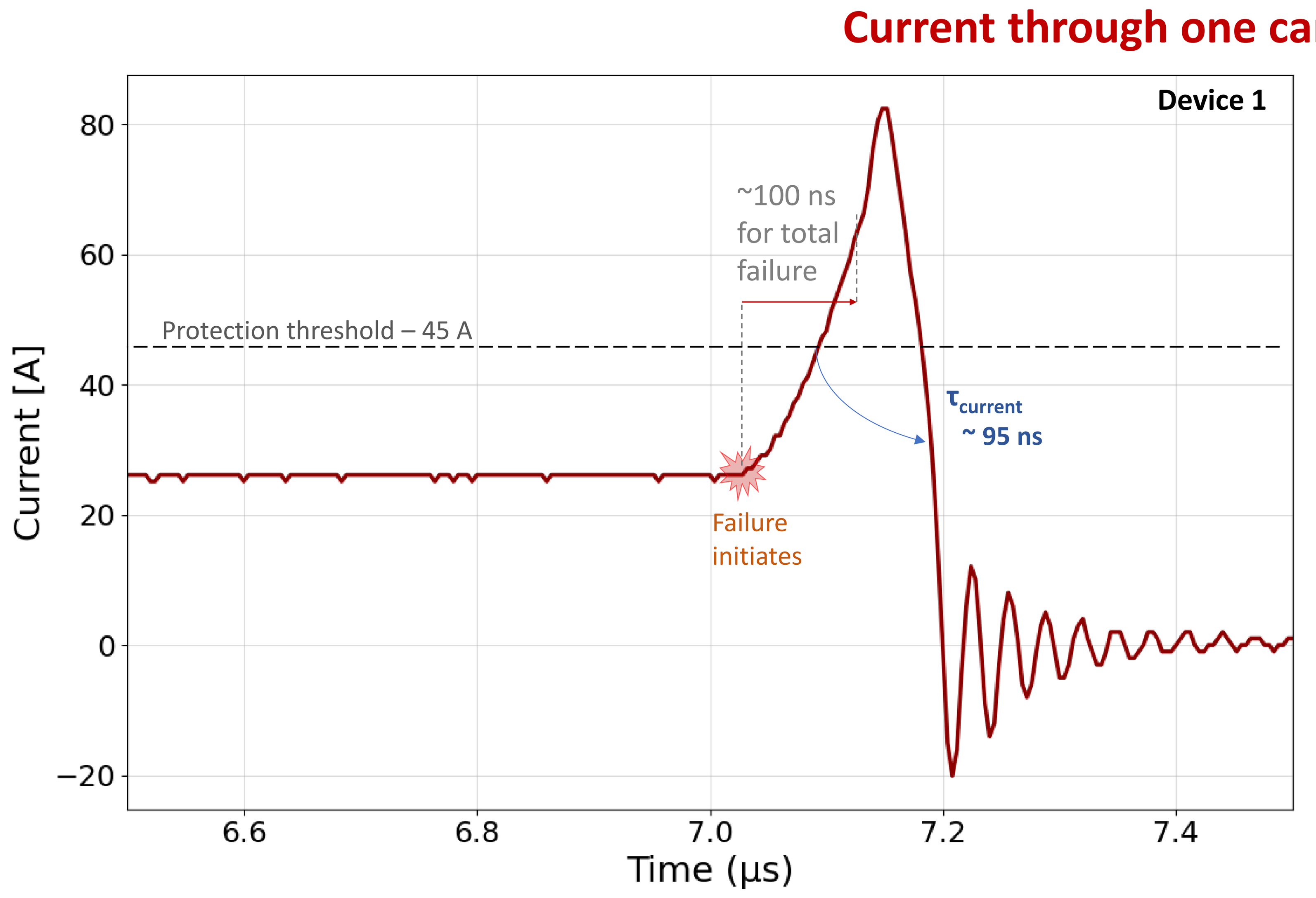
After the SC failure, the high current heats the die, increasing the failure area and so the current, leading to liquid metal ejection. An external switcher is needed to stop the test.

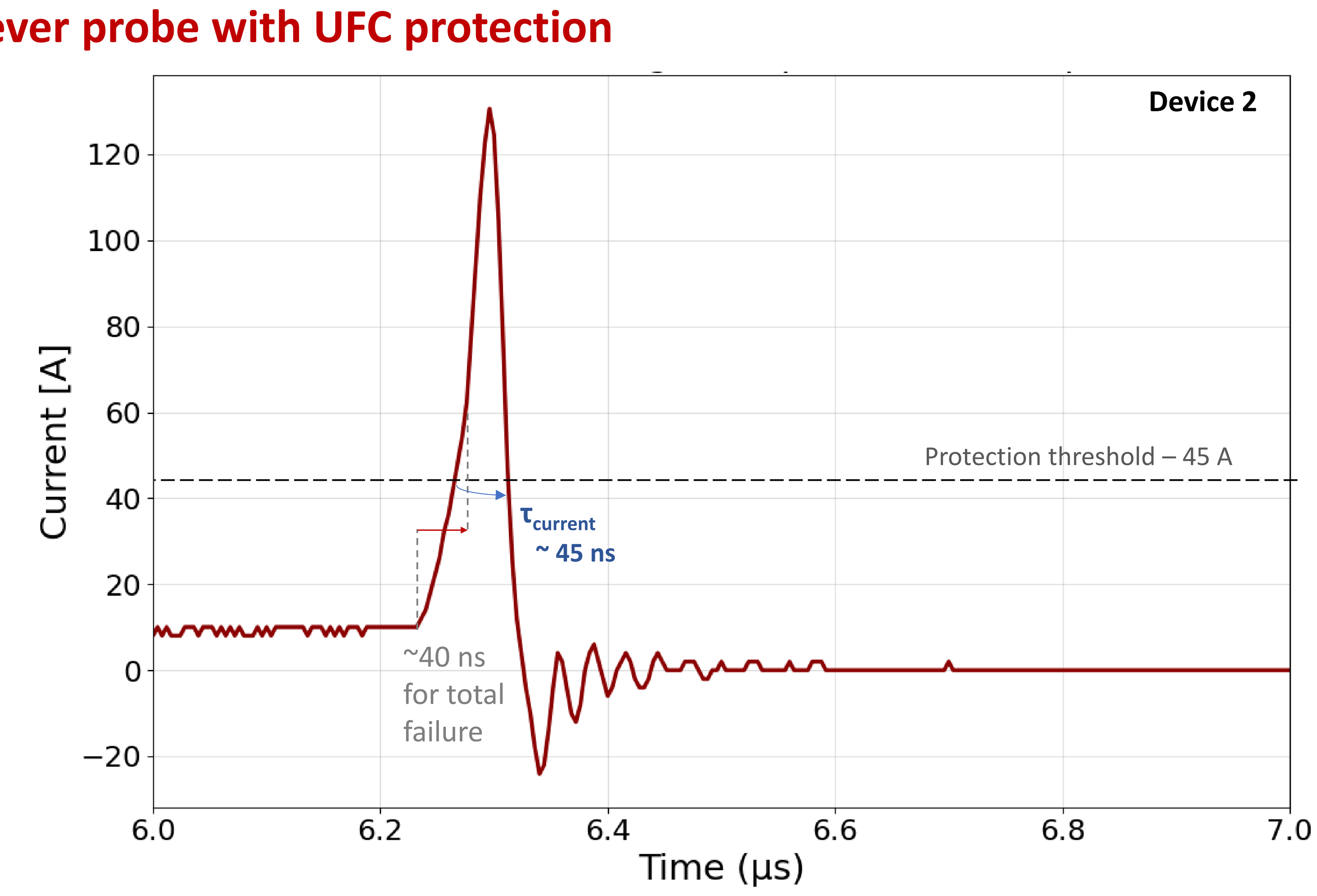
Ultra-Fast Clamp (UFC)

The UFC is a protection circuit to be integrated into the KGD interface board, operating independently of the tester protection. It was designed to reduce the energy dissipation at the DUT after failure, preventing melting and metal ejection over the probes.

Failures during Short Circuit tests at 400V

Current through one cantilever probe with UFC protection





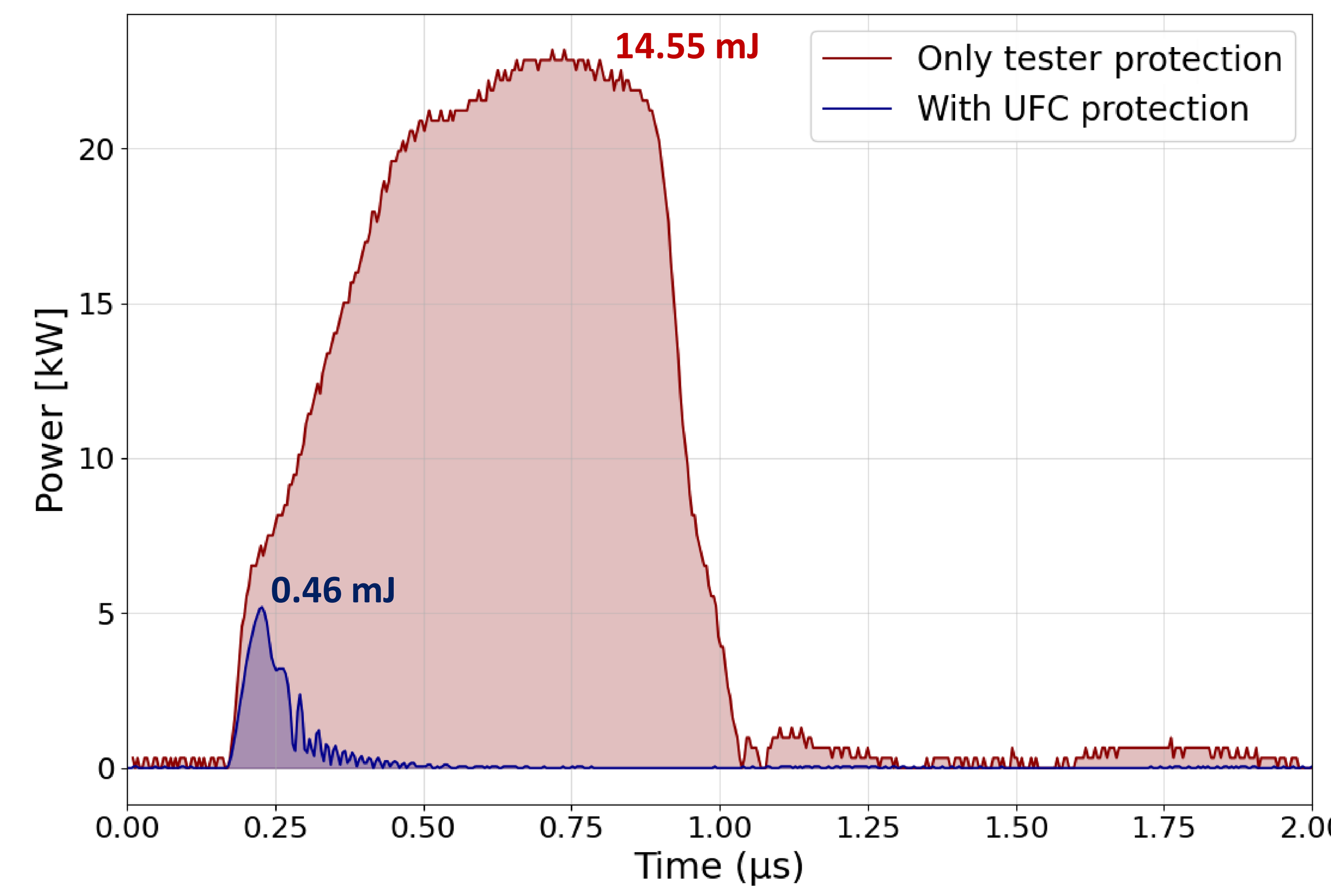
- The protection time τ is measured from the threshold point until the 63% drop of the peak current.
- If the failure occurs faster, a higher current peak will be reached, but the protection will act faster. Thus, the total energy dissipated at the DUT after failure remains very low.

Ultra-Fast Clamp (UFC)

Our newly developed protection circuit detects the initial failure and diverts the energy from the DUT extremely fast so that it does not melt, protecting the testing probes.

- When a short circuit failure occurs, it limits the peak current and **protects the DUT in 45 to 95ns**, depending on the failure speed.
- The **total energy** in the DUT after failure is **reduced 30 times** with the UFC protection, compared to a 750ns tester protection
- Prototype UFC tested up to 600V in a short circuit test, extendable up to 1.1kV for our first design.
- Next step: integration in the KGD interface board

Energy dissipated by the DUT after failure



The DUT power in the small area of failure integrated over time yields the total energy dissipated by the DUT in that area. The power plots are obtained from the current and voltage measurements after failure.

Protection by robust vertical probes

New RzBeam probes

TIPS‘ new buckling beam probes have superior material properties for high current tests, extending probe life in short circuit test conditions.

Higher conductivity

with twice the bulk conductivity of conventional palladium alloy probes, self heating is greatly reduced.

Higher hardness

improves contact performance at the probe tip, reducing the contact resistance that causes most of the tip heating.

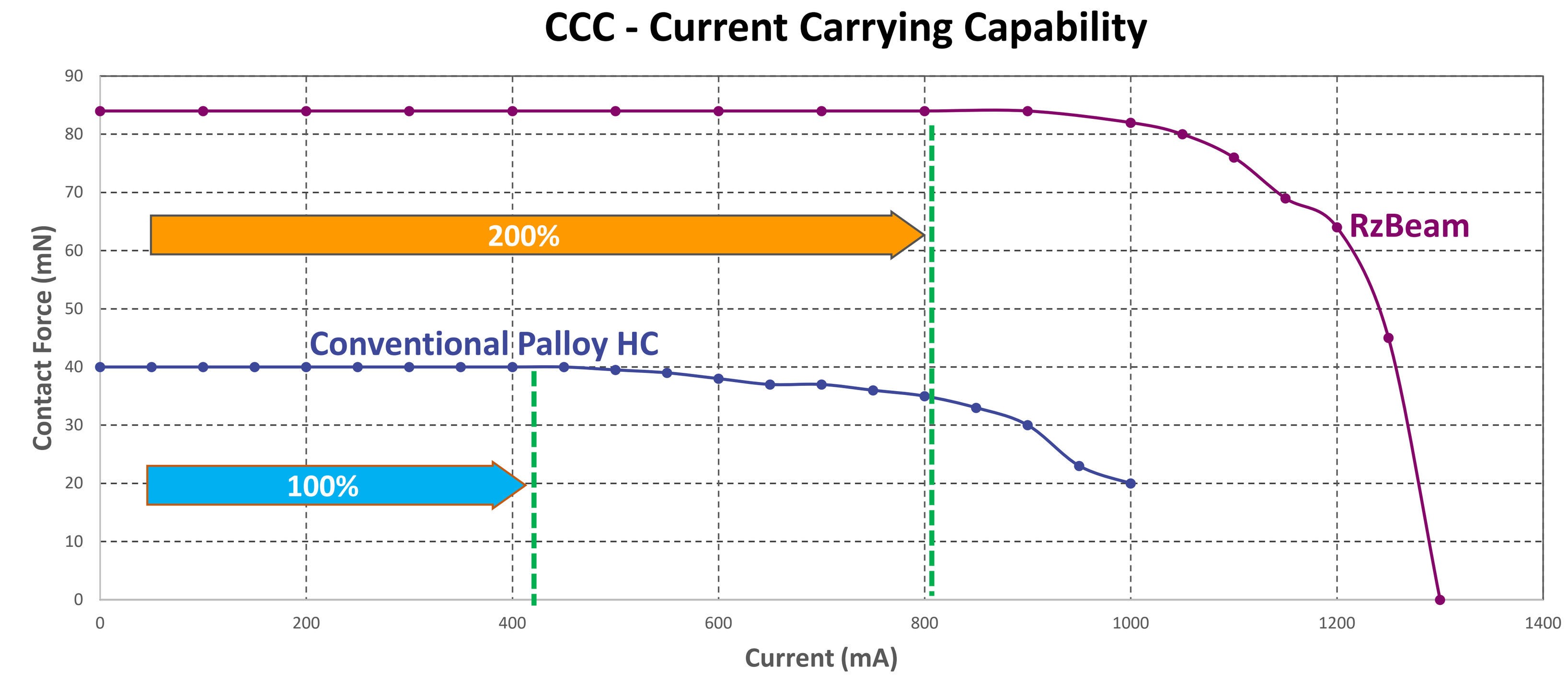
Higher melting point

of the probes allow higher current at the same cooling conditions. It also prevents welding of tip to pad, and molten debris does not stick to the probe tips. This can significantly increase probe card life in SC test.

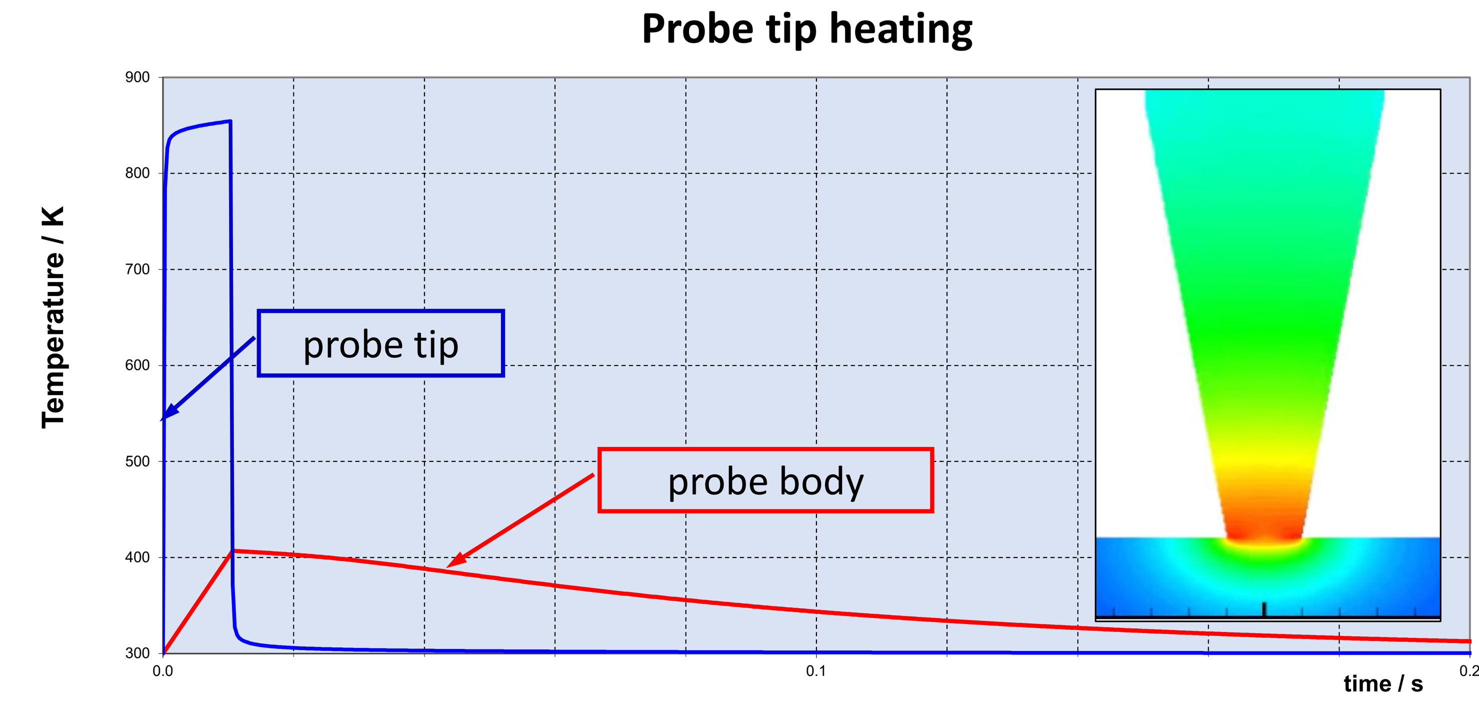
Higher pulse current limit

dynamic thermomechanical simulation shows that tip heating is dominant. The RzBeam material properties reduce the slope of the temperature rise so even higher test currents can be used.

CCC - Current Carrying Capability



Probe tip heating



Conclusions

Challenges for probe protection

- Short-circuit test failures in high-power devices develop in 50-100ns, causing DUT melting and probe contamination, reducing the service life of the probecard.
- The fastest tester protections can react in ~750ns, which is not fast enough to effectively protect the probecard.

Results and Performance

- Ultra Fast Clamp protection was successfully tested, capable of detecting the failure and diverting the energy from the DUT within 45-95ns, reducing the post-failure energy dissipated in the DUT by 30x compared with the fastest tester protection.
- Robust RzBeam probes further improve reliability by reducing the contact resistance, increased heat conductivity, and reducing molten-metal adhesion.

Next steps

- Integration of the UFC protection on the KGD, to protect the probecard independently from the tester protection.
- Development of a new design to extend the maximum voltage operability beyond the current 1100V limit.

Contact

For additional information, please contact:

Georg FRANZ
Senior R&D - T.I.P.S. Messtechnik GmbH
g.franz@tips.co.at
+43 4242 319 720 19

Alvaro ROSA
Electronics R&D - T.I.P.S. Messtechnik GmbH
alvaro.rosa@tips.co.at
+43 4242 319 720 63