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High Power Wafertest – How to keep the temperature under control

ERS

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CTO

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Agenda

1. Introduction of different high power scenarios
2. Background – Market outlook and motivation
3. Thermal challenges for each scenario
4. Possible solutions for each scenario
5. Summary
6. Outlook

“High Power“ – one term for different test scenarios

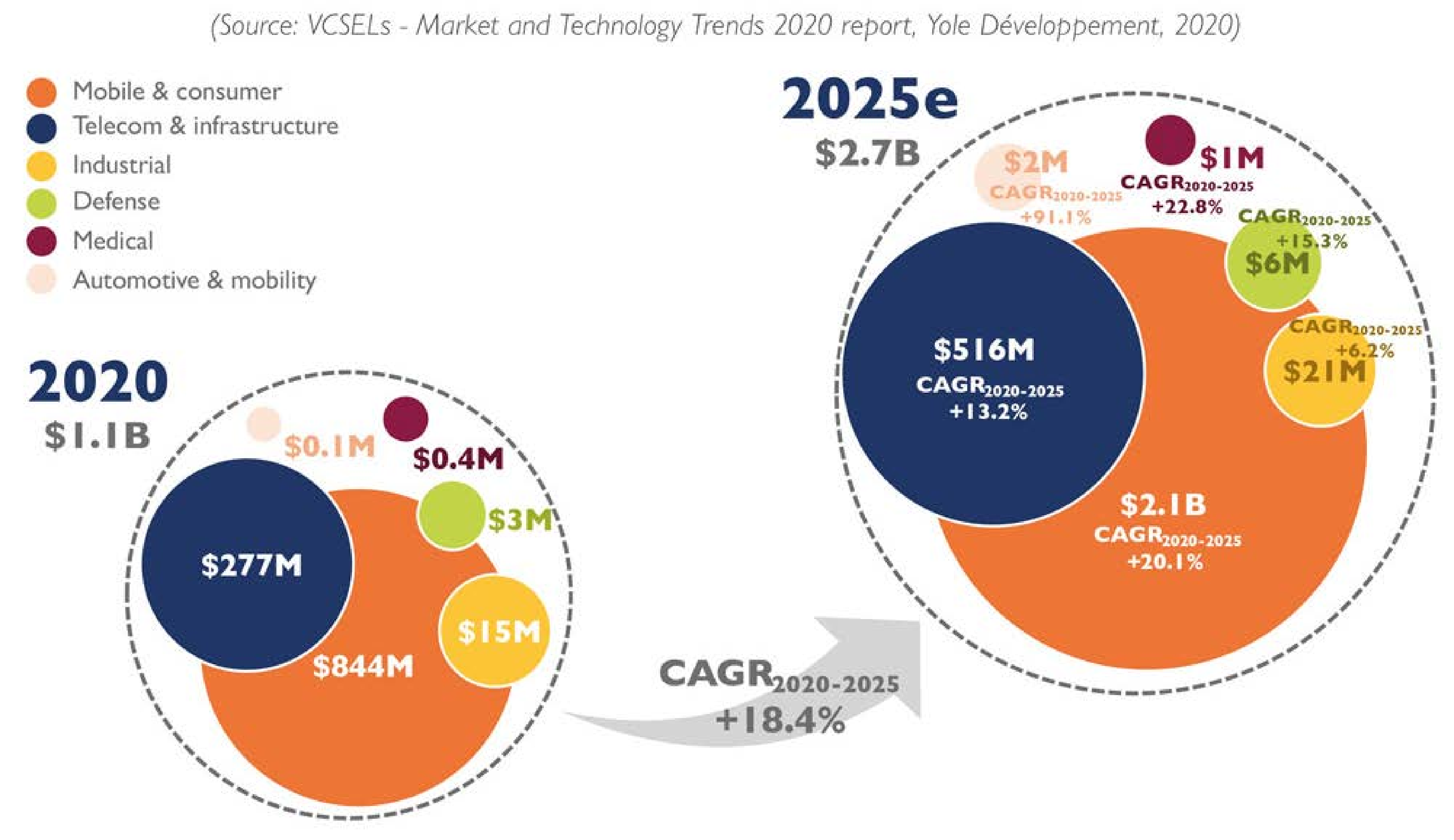
1. High voltage/High current/Short pulse test **(HV/HC)**

2. Low voltage/High current per device/Single or low number of parallel DUT short screening test **(Hi-Wattage)**

3. Low voltage/Low current per device/High number of parallel DUT/Full wafer contact **(FWC)**

One common challenge:
Accurate temperature regulation of DUT

Market Outlook

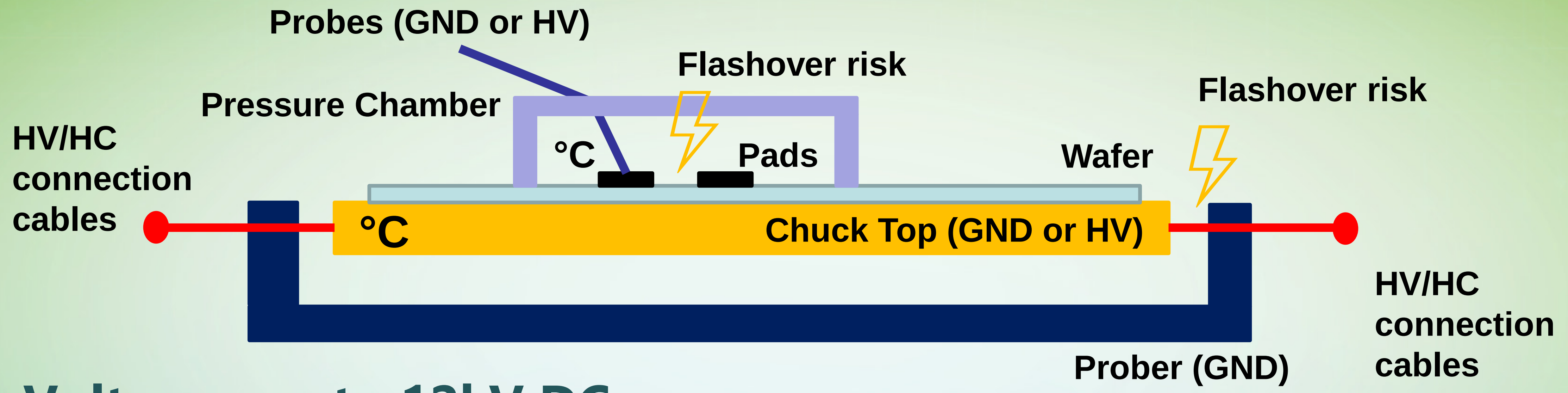


VCSEL

Motivation

- **Major topics such as renewable energies, cloud computing, big data and electromobility would be inconceivable without them**
- **As with all semiconductor devices there is a trend to test early: means wafer probing**
- **As a thermal chuck manufacturer, we are focusing on temperature maintainance and accuracy under these special conditions**

Typical HV – HC Test Set-up



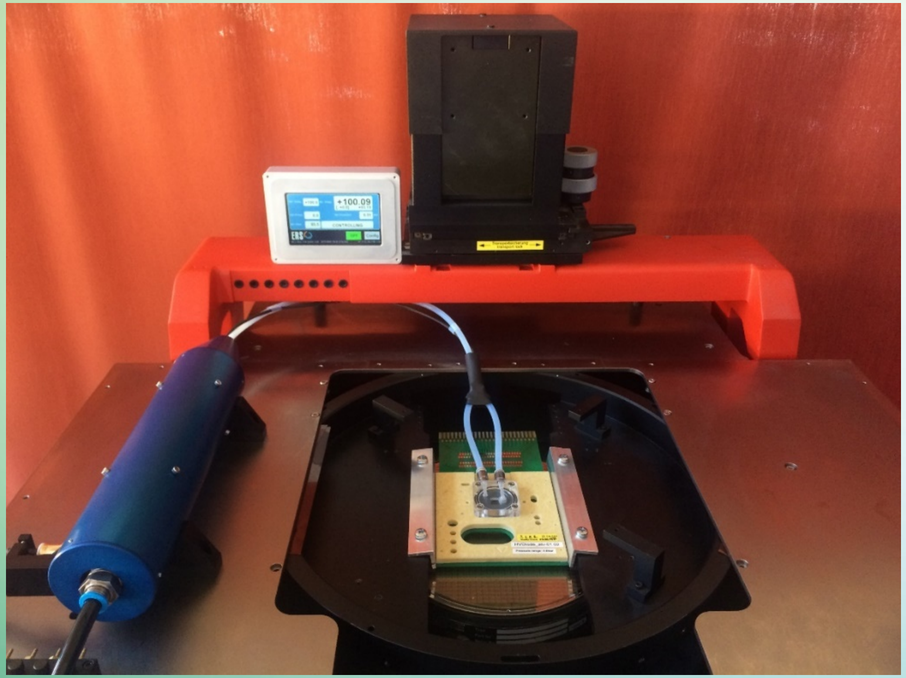
- Voltages up to 12kV DC
- Current up to 600A
- Pulsed tests
- Spark suppression techniques are used (low conducting gases, pressurized chambers)
- Products: IGBT, MOSFET, HV Diodes,

HV – HC Test Thermal Challenges

- CDA pressurized probe cards cause huge temperature offset at high temperature test
- Flashover risk at chuck and surrounding
- Wafer backside contact
- Very high temperature required for new materials (SiC, GaN)
- High voltage isolation layers needed, bad thermal conductivity

Solution for Temperature Offset Caused by CDA Pressurized Probe Cards

- **ATCM (Air Temperature Control Module)**



- Controls Temperature, Flow and Pressure of the CDA
- Usable up to +300°C
- Connected to chuck temperature controller with automatic offset algorithm

HV/HC Test - ATCM Performance

w/o ATCM

Chuck Temperature (°C)	CDA airflow (l/min)	DUT Temperature (°C)	Temperature Offset (°C)
60	60	50	-10
80	60	65	-15
100	60	80	-20
100	100	51	-49

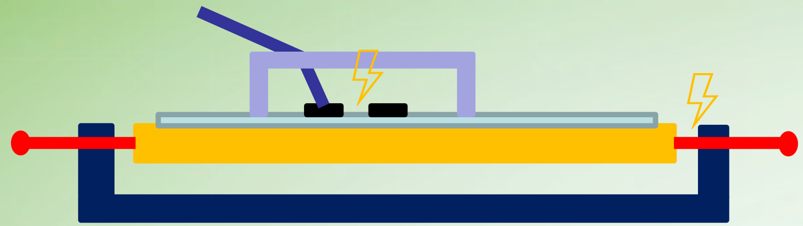
- Almost 50°C (!) offset

with ATCM

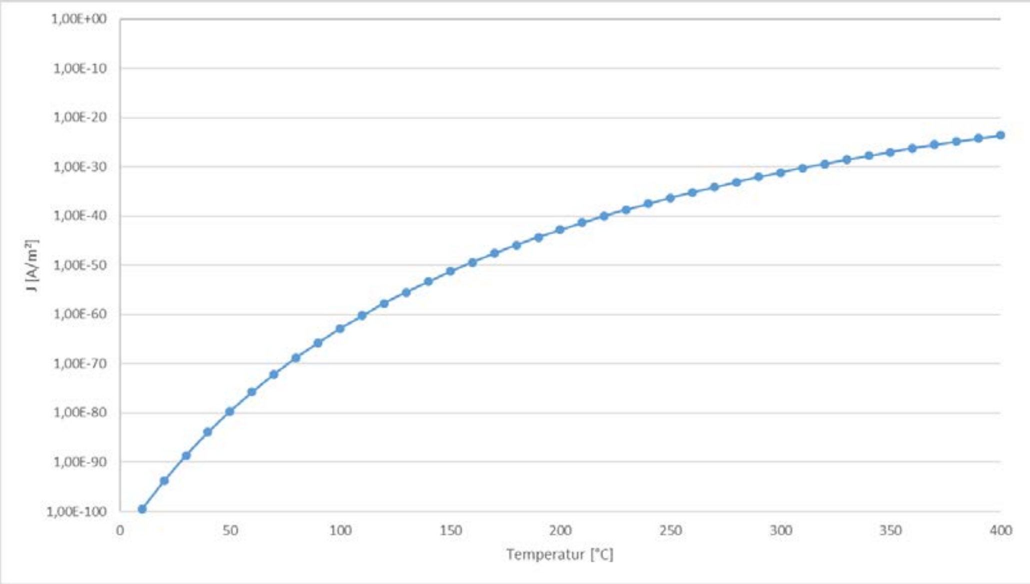
Chuck Temperature (°C)	Pressure (bar)	CDA airflow (l/min)	DUT Temperature (°C)	Temperature Offset (°C)
100	2	50	100	0
100	4	50	98,6	-1,4
100	4	75	99	-1
100	4	83	100	0
100	4	100	100,6	0,6
100	6	130	97	-3

- Offset clearly below 5°C
- Automatic adaption to even higher air flow

Flashover Risk in Dependency to Temperature



Flashover risk points



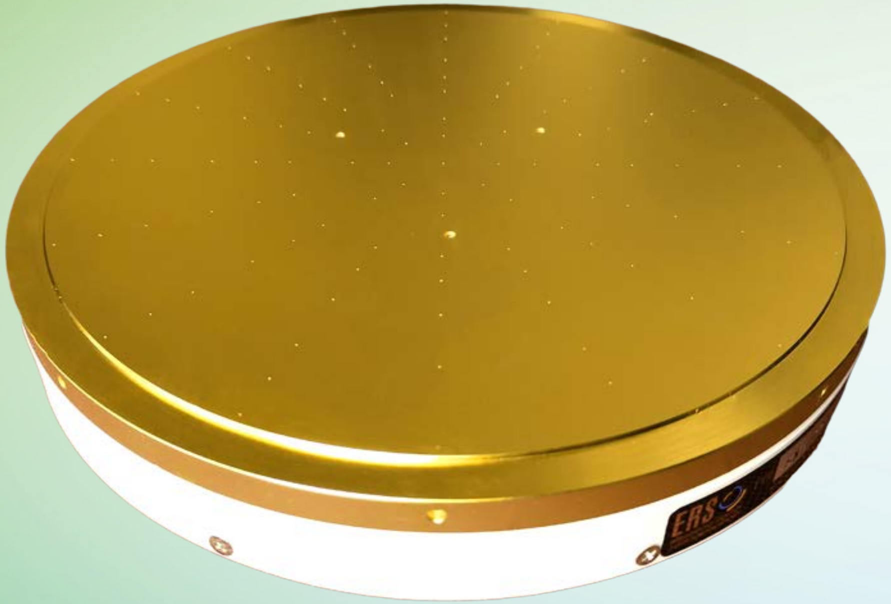
Current Density over Temperature

Gas Properties

Gas	$(E/p)_0$ $\frac{kV}{bar \cdot mm}$	c $\frac{kV}{(bar \cdot mm)^{1/2}}$
SF_6	8,80	0,27
	6,61	2,19
CO_2	3,21	5,88
Luft	1,85	3,87
	2,43	2,01
	2,44	2,12
N_2	2,44	4,85
H_2	1,01	2,42

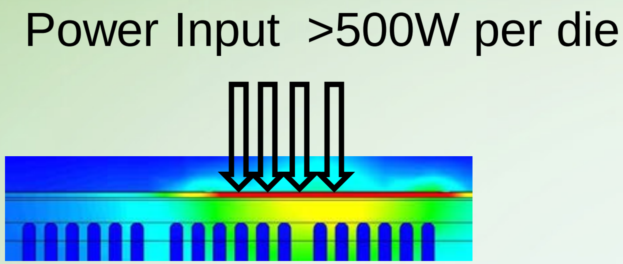
- **Flashover risk significantly raises with higher temperature**
- **Air gaps have to be sufficient**
- **Other gases than air may help – but: environmental concerns have to be taken into account**

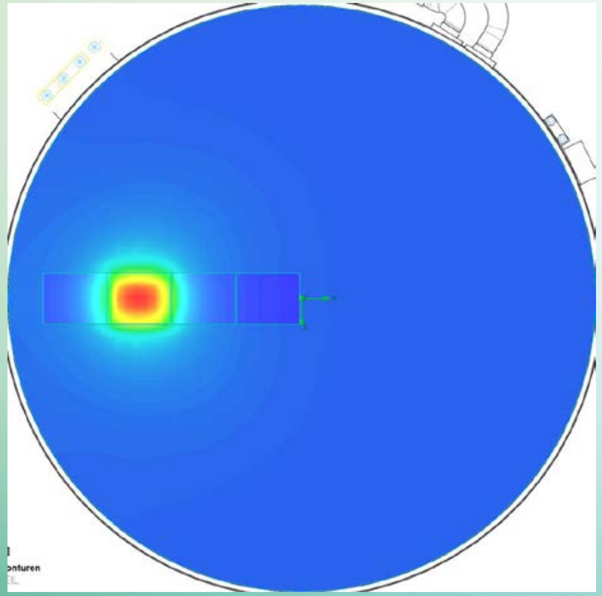
Typical HV/HC High Temperature Chuck



- Up to 12kV insulated chuck top
- Up to 3kV low leakage triaxial set up
- Thermally optimized and fully integrated insulation components
- Low resistance gold surface with special vacuum design
- Thermally designed HC connection points to the chuck top
- Ultra High Temperature configurations available for GaN, SiC, etc. wafers

Typical High Wattage Test Set up





- Single chip is tested with low voltage and high current
- A high-density power load is applied to the DUT
- High temperature rise needs to be addressed
- Temperature uniformity over the 300mm surface must be ensured under load
- Products are typically CPU, GPU

High Wattage Test Thermal Challenges

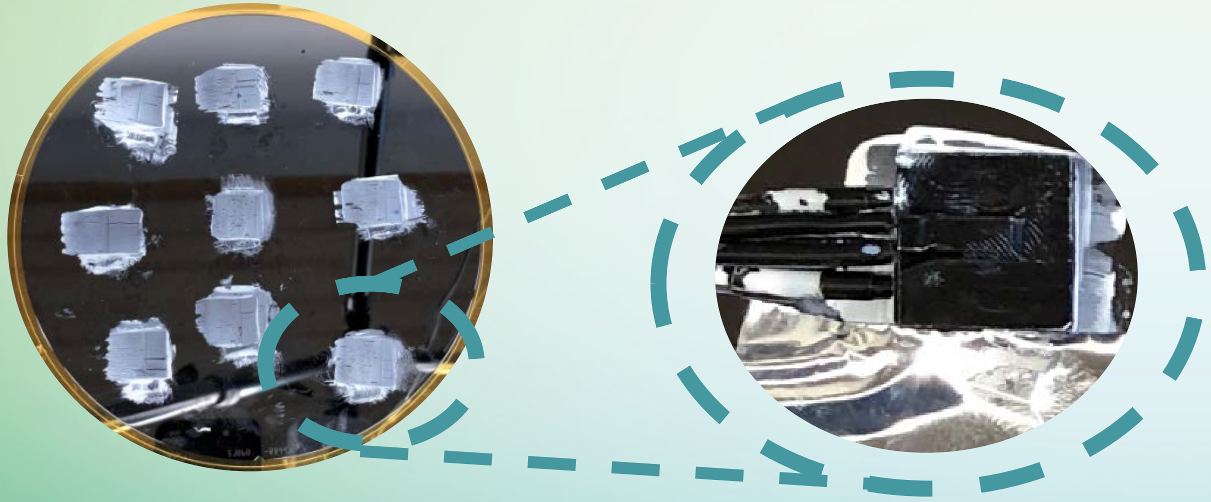
- High wattage density needs high dissipation capability from the chuck underneath the wafer
- Cutting edge devices generating high wattage to be removed by the chuck and chiller
- Thermal resistance between wafer and chuck creates a temperature offset
- Thermal conditions for the DUT needs to be the same independent of the die‘s position on the wafer

Solution for High Wattage Dissipation

- Chuck system combines multi sensor sections in the chuck with new liquid heat exchanger
- Thermal controller software controls temperature independently of DUT location
- New heat exchanger inside the chuck eliminates bottleneck for powerful liquid chiller
- Modular chiller concept to adapt on dissipation and temperature range

High Wattage Dissipation

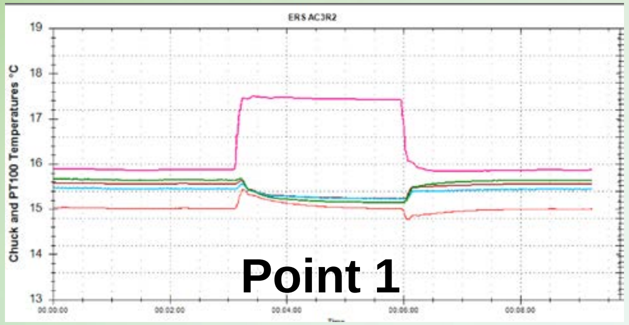
Measurement Set up

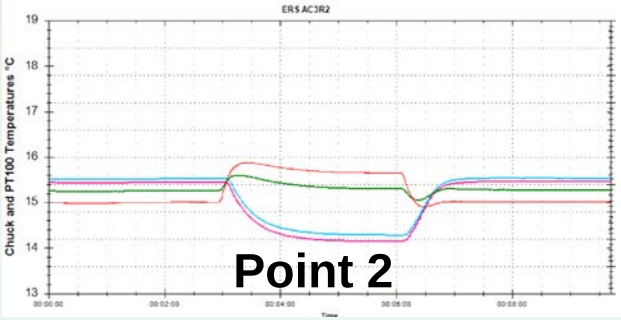


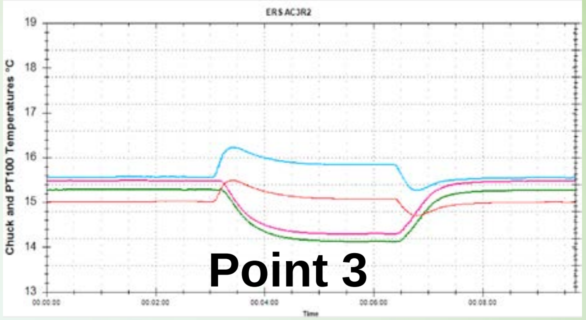
- Data taken at 9 different sections of the chuck
- Power density is 150W on 15mm x 15mm
- Chuck set point is +15°C
- Temperature is measured inside the chuck and also directly beside the DUT with extra sensor

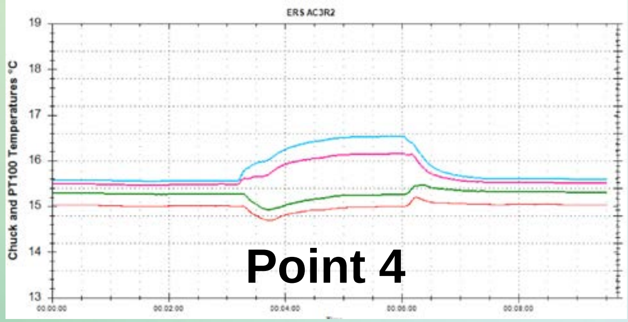
High Wattage Dissipation Data

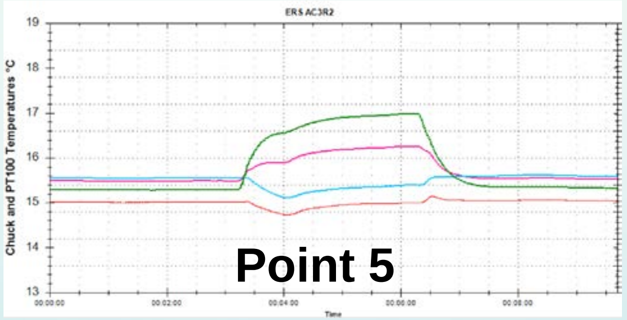
Data of 9 points, sensors inside the chuck:

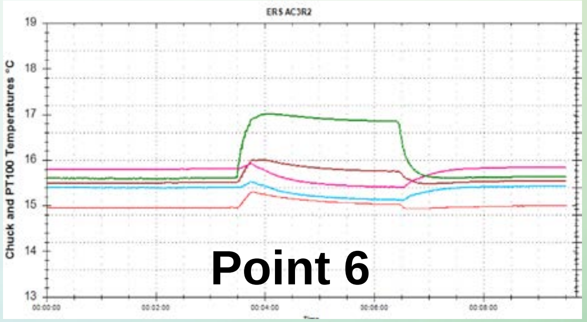


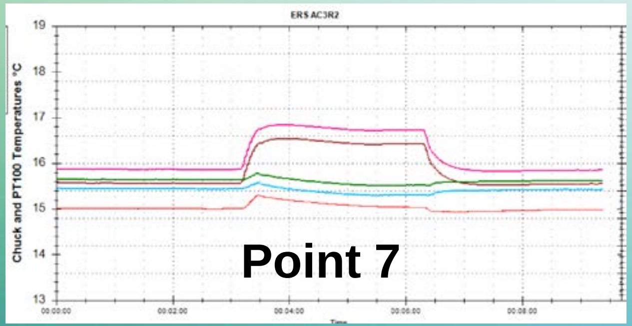


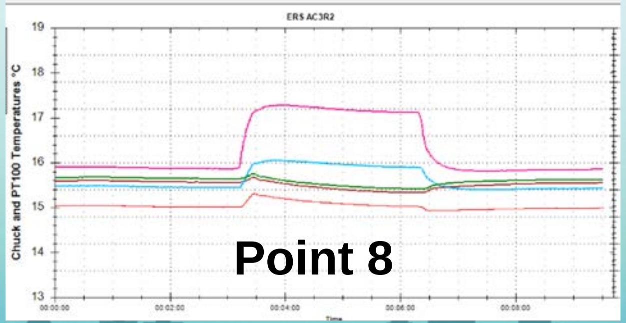


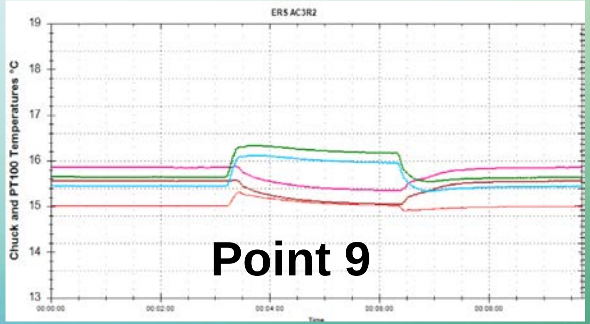






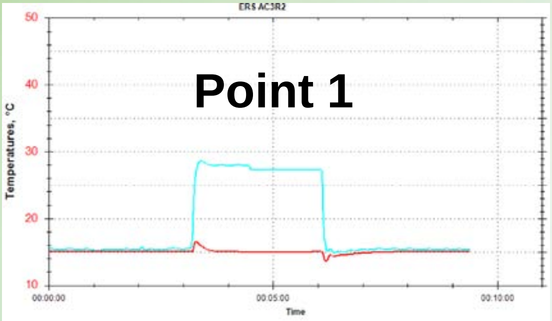


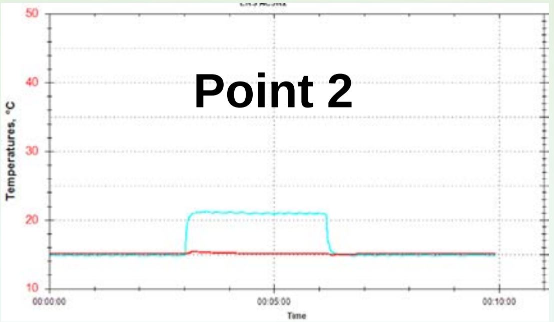


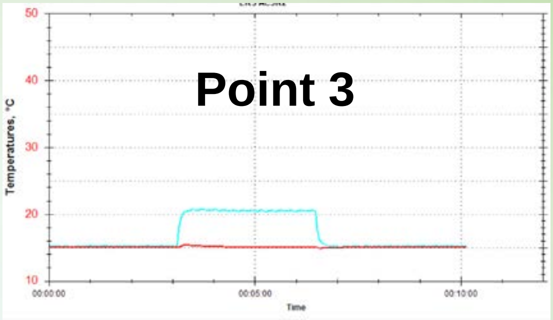


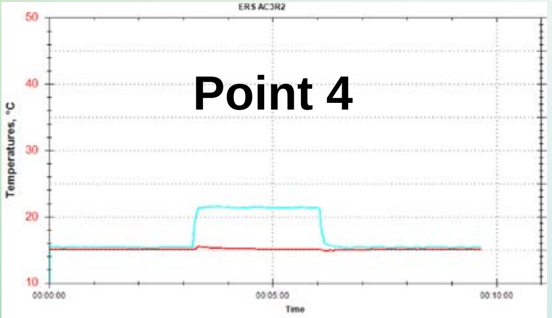
High Wattage Dissipation Data

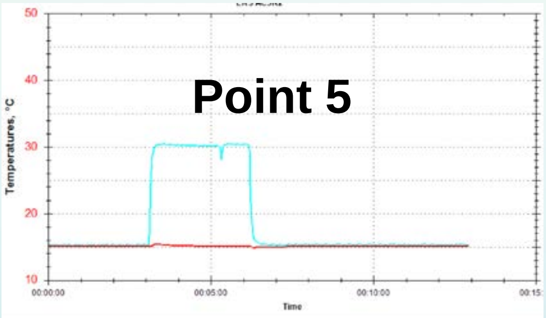
Data of 9 points, extra Sensor:

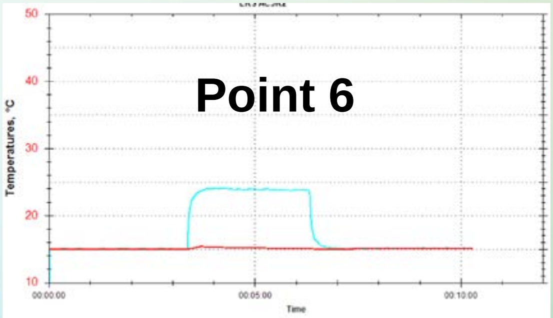


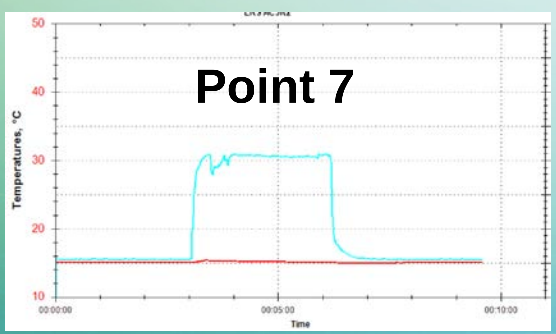


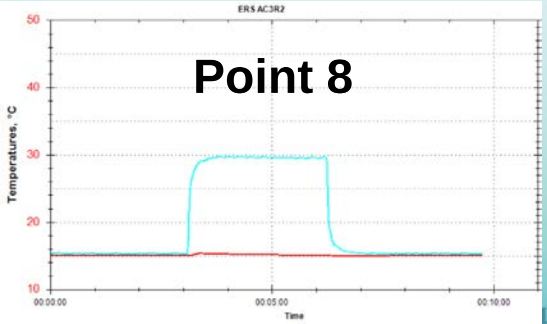


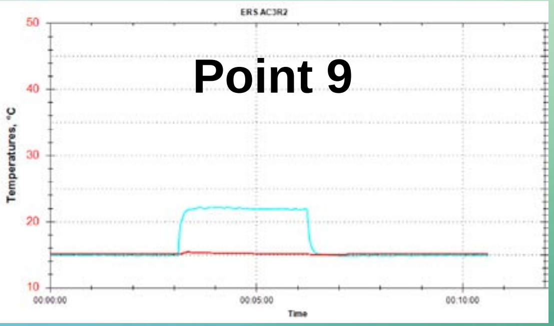












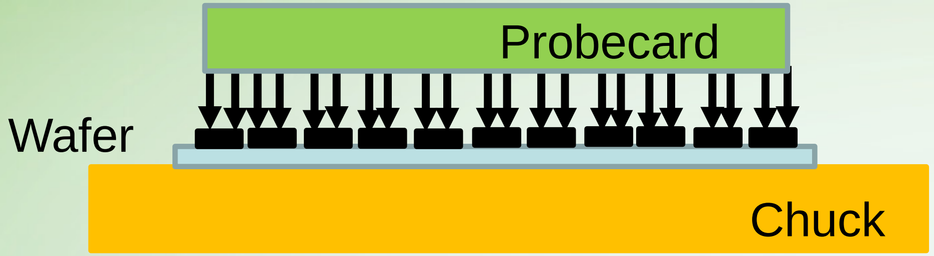
Interpretation of Data

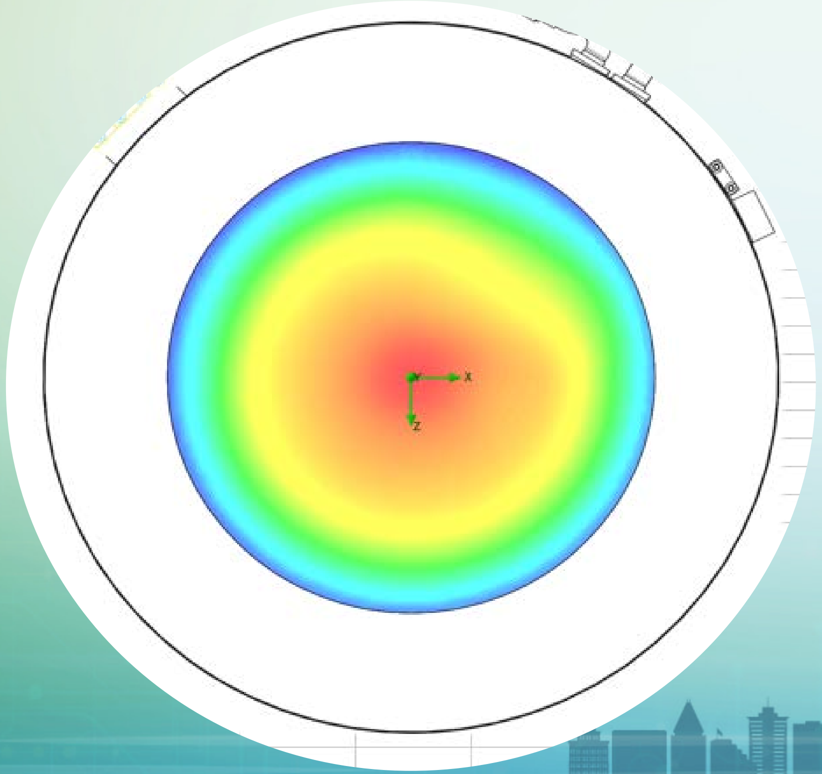
- Uniform reaction on all 9 points inside the chuck within +/-2°C
- Uniform reaction of the extra sensor (≈ DUT), however in a bigger range of about +/- 5°C
- Thermal resistance between sensor / wafer / chuck is key to the data → thermal resistance between wafer and chuck is key to real measurement
- Average thermal resistance in this case is (25°C – 15°C) / 150W = 0,07 °C / W

Summary of High Wattage Chucks

- **Solution is provided for High Wattage device testing (CPU, GPU, etc…) up to:**
  - 600W per die
  - -60°C up to +150°C temperature range
  - 300 mm
- **Data proved:**
  - Same reaction independent from location
  - Fast adaption of chuck regarding power application
  - Uniform thermal resistance between chuck and wafer

Typical Full Wafer Contact (FWC) Test Set Up





- **Massive parallel contacting of many dies on the wafer up to full wafer contact**
- **Power is generated by many low power devices (e.g. 2048 x 0,5W = 1024W thermal load)**
- **Products: DRAM, VCSEL, WLBI**

Thermal issues with FWC

- The total amount of power can get very high, challenging at low temperatures
- Even with the strongest chiller, the heat exchange capabilities of the chuck is the bottleneck
- Good thermal uniformity is hard to achieve, especially non-operating dies are hard to predict

Thermal Solution for FWC Test

- **New Heat Exchanger can allow very high power dissipation (up to 5kW)**
- **Special chuck design to deal with very high mechanical load**
- **Modular chiller concept to adapt to different applications**

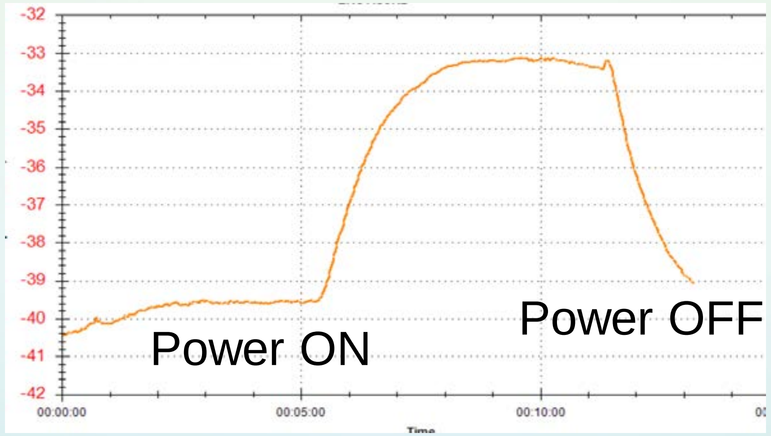
Test Set up for FWC Test

- **300mm heating device (up to 3kW) applied to a 300mm liquid chuck**
- **Temperature performance with different loadings and at different temperatures are performed**

Data from FWC Test

- **2,5kW applied at different temperatures**
- **Heat exchanger behaviour shown at different temperatures:**

+20°C



- 40°C

- 60°C

→ 2,5kW dissipation for -40°C chuck temperature possible

Summary

- All 3 „High Power“ scenarios come with thermal challenges
- Very different approaches are needed to solve the challenges
- Temperature offset of CDA pressurized probcards – can be adressed with ATCM
- Temperature uniformity at high wattage test – can be adressed with the special high wattage chuck
- Very High power dissipation at FWC – can be adressed with new heat exchanger and strong chiller, even at very low temperatures

Outlook

- **Work to be done:**
  - HV/HC Chucks:
    - > 400°C solution required
    - Lower leakage at elevated temperatures and voltages required
  - High Wattage Chucks:
    - Better control of the DUT required
    - Faster response time required
  - FWC Chucks
    - High power dissipation at elevated temperatures required
    - Better temperature uniformity required

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Thank you!

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