SWTEST

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2023 CONFERENCE

Dynamic High Wattage Wafer Test, a Novel Approach to Keep DUT Temperature Constant

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Agenda

- Background: High Wattage Dissipation
  - Final test vs. Wafer test
- Objectives
- The 3 Evaluation Methods
- New Concept
- Key Data
- Discussion
  - Strengths and Weaknesses
- Conclusion
- Follow-on Work

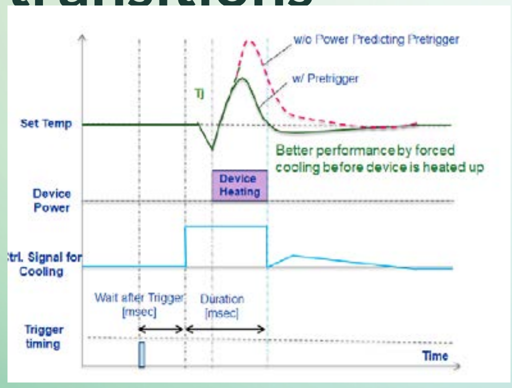
Background

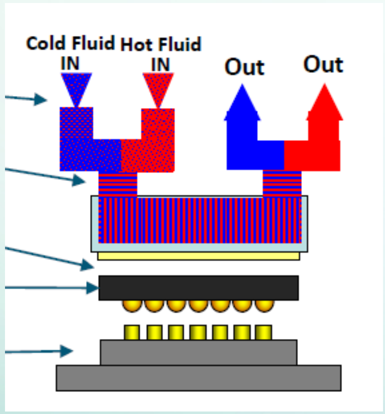
- Social Networks, Big Data and Artificial Intelligence require a huge amount of the highest performing CPUs and GPUs with multiple cores
- Looking at Advanced Packaging → stacking of chips, you need to know that your chips are good = KGD (known good die)
- Small geometry below 7 nm means high power density, which is hard to control locally when power is applied during probing
- Up to now, no wafer test provider can maintain the constant temperature of DUT while changing the load
- Keeping the chuck temperature constant has been demonstrated by various vendors, keeping the DUT temperature constant so far is impossible

Technical Background

• Final Test vs Wafer Test

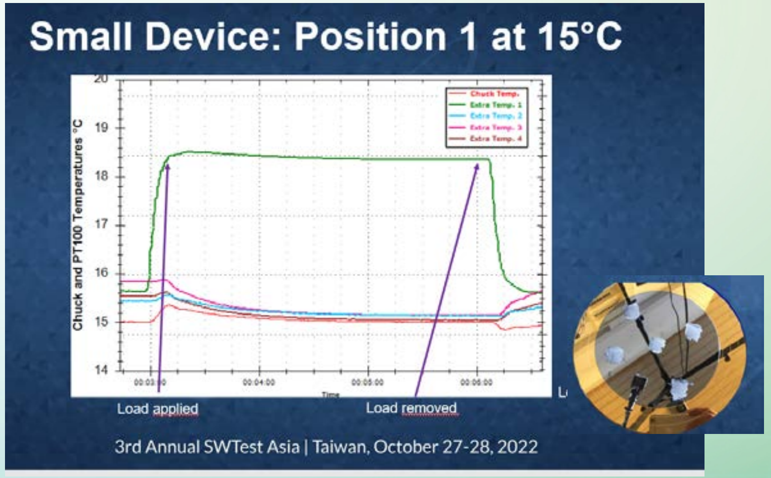
– In final test, low thermal mass of the temperature transmitter allows very fast thermal transitions





Armstrong, D. «Our Best-Known Methods for the Testing of High-Power Ics», Too Hot to Test Workshop, 2021

– In wafer test, large thermal mass prevents rapid temperature change of the chuck



Reitinger, K., «High wattage dissipation under temperature – a new method for test evaluation», SW Test Asia, 2022

Objectives

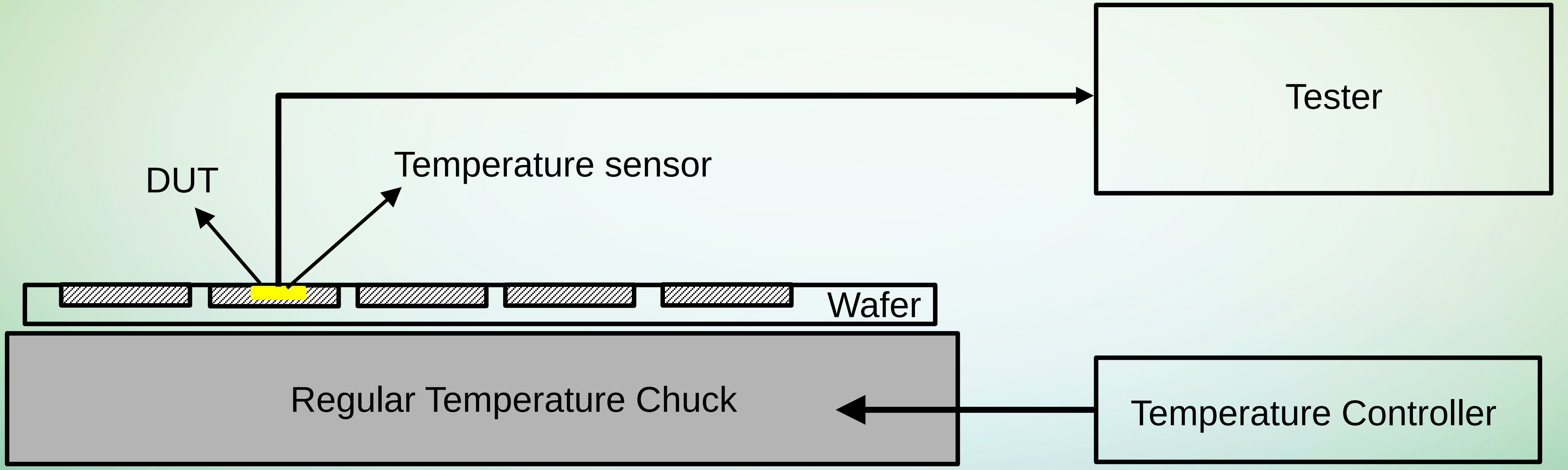
1. Solve the problem of not being able to perform CPU and GPU tests at wafer-level. This means:
   - Maintaining DUT temperature during dynamic power test in wafer test, not just final test
   - Having the temperature tolerance bandwidth as low as possible
   - Dissipating high wattage (more than 500W) at low temperatures (below -40°C) with high temperature accuracy (below 5°C vs 30-50°C now)

Evaluation Methods

- Method 1) A temperature device (diode) inside the DUT is used to monitor the temperature during test
- Method 2) A Jig including a temperature sensor and a heater is placed into a prober in the place where the probe card used to be
- Method 3) A Jig including a temperature sensor and a heater is placed directly on a chuck with wafer

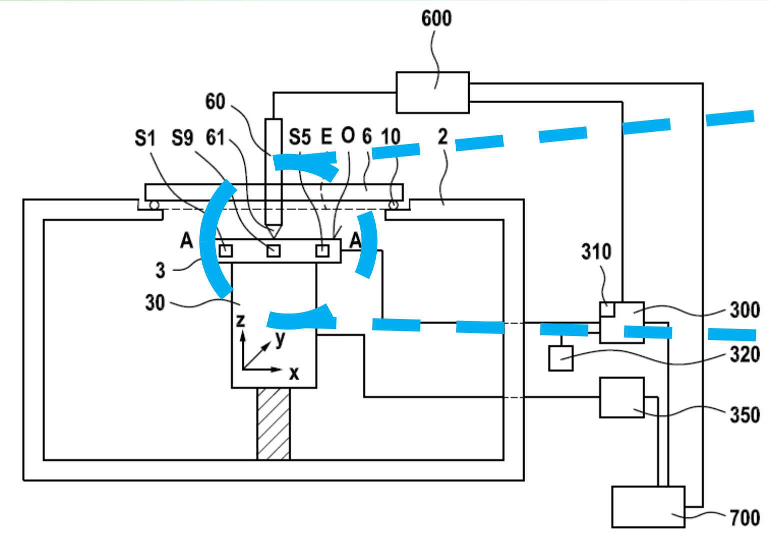
Method 1

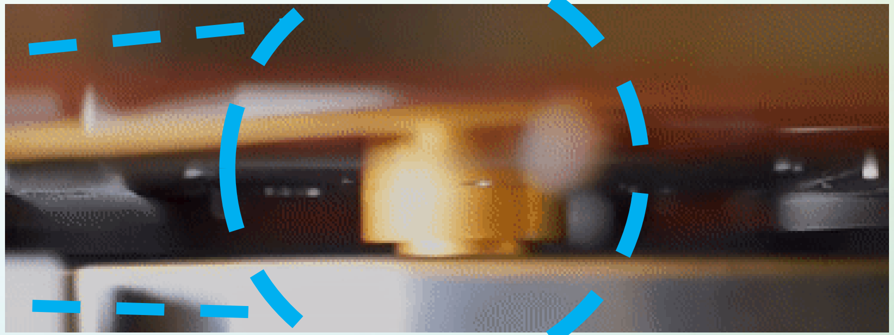
A temperature device (diode) inside the DUT is used to monitor the temperature during test



Method 2

ERS's patented calibration tool, ProbeSense™*, with integrated heater is placed into a prober in the place where the probe card used to be (see below)

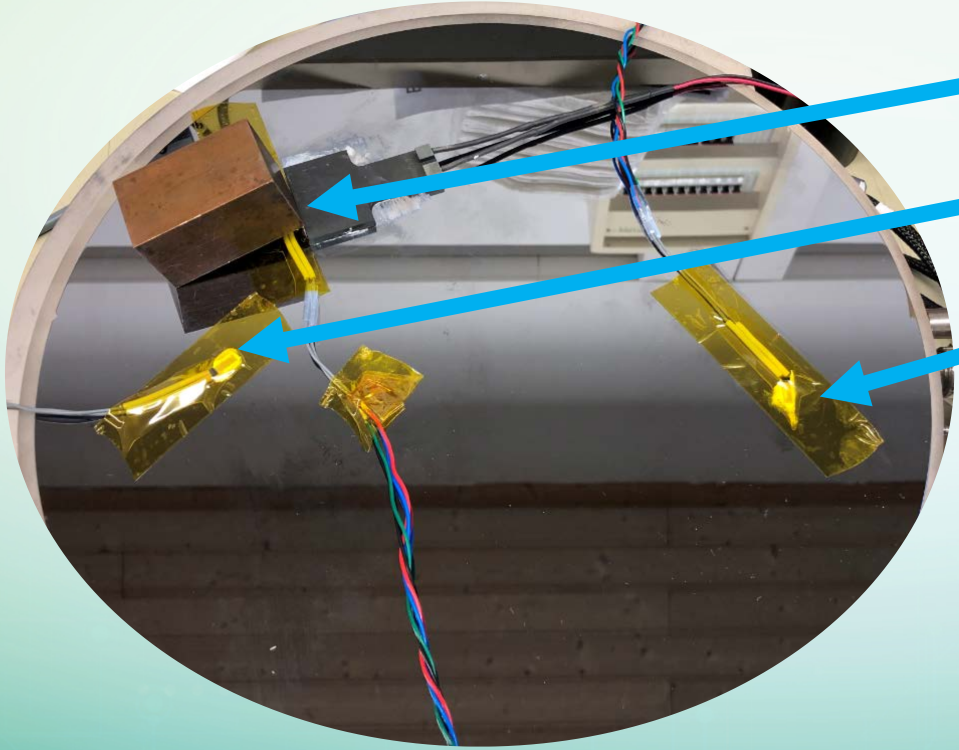




*Presented at SWTS 2022 by Bengt Haunerland

Method 3

A Jig including a temperature sensor and a heater is placed directly on a chuck with wafer



Jig

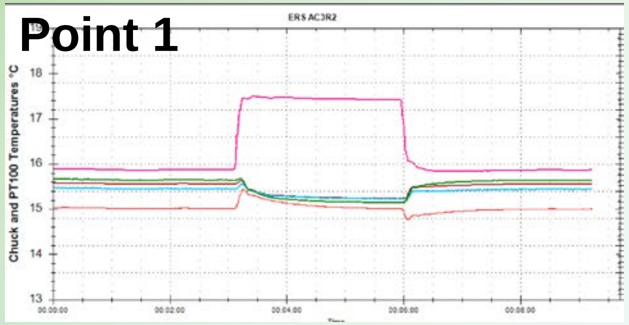
Sensor #1

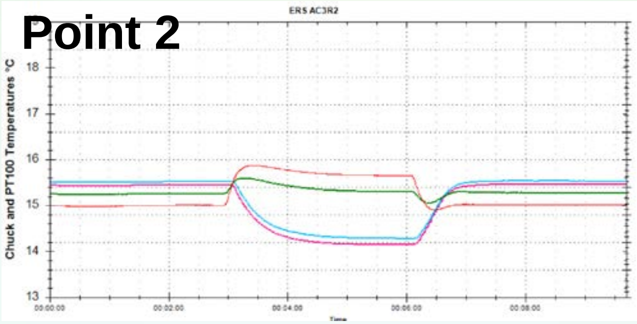
Sensor #2

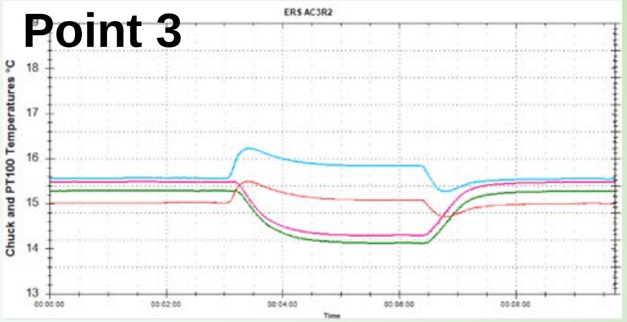
Status Quo

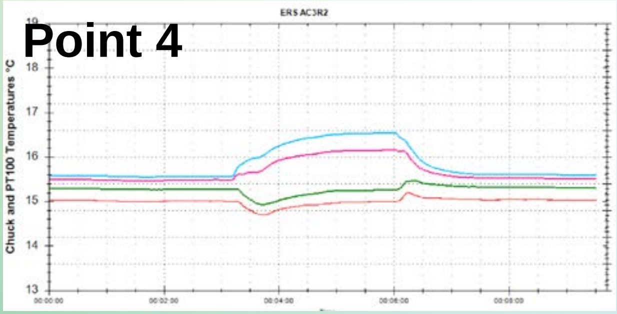
(shown on SWTWS 2021 by KR)

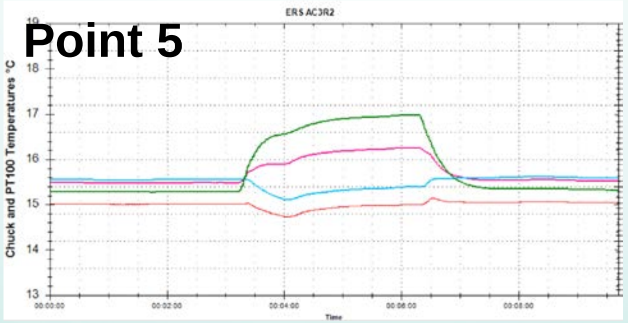
Data of 9 Points, Sensors in the Chuck

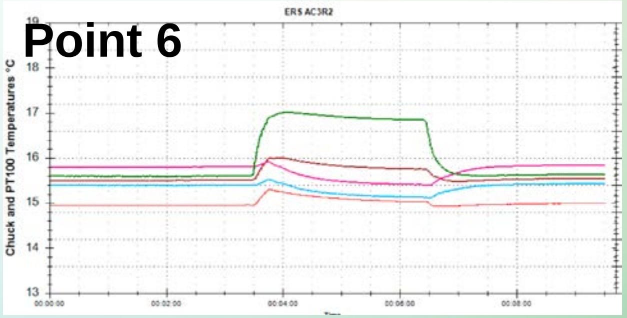


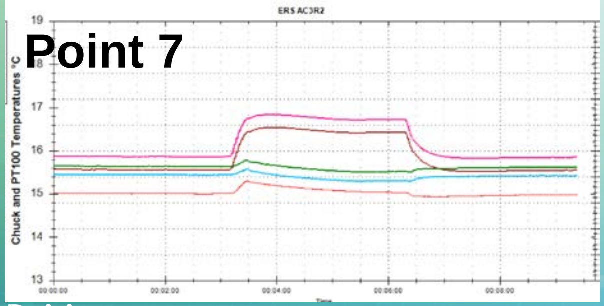


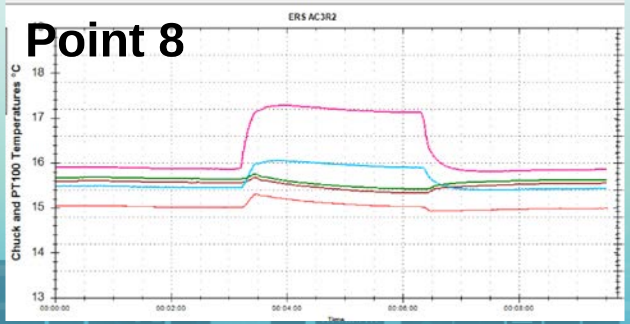


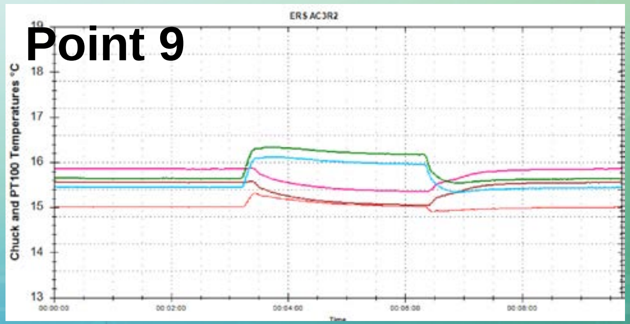






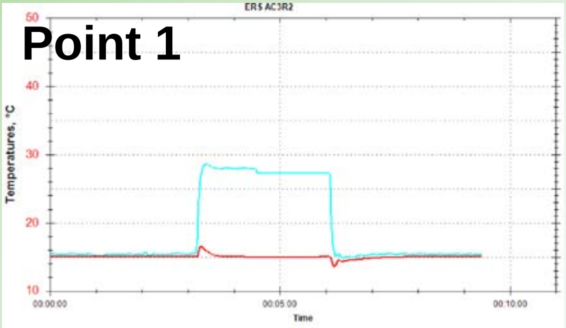


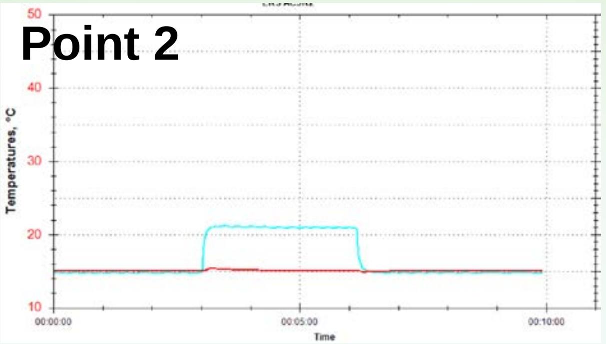


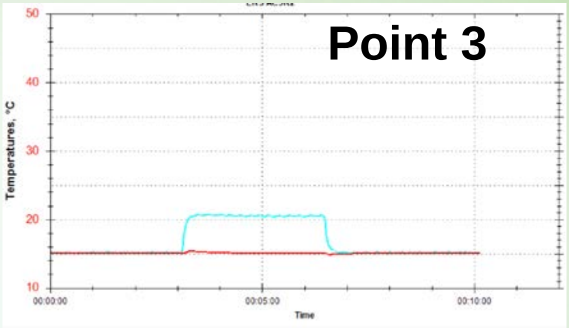


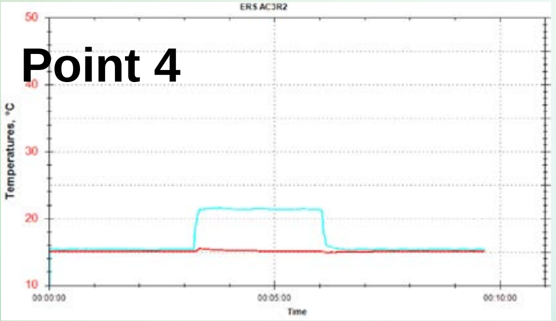
Status Quo

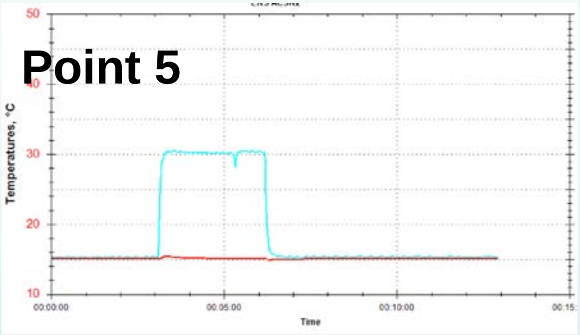
Data of 9 Points, Extra Sensor

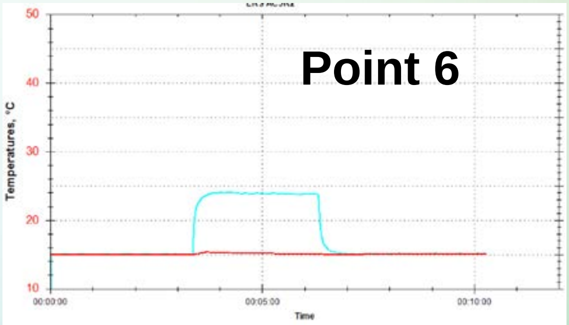


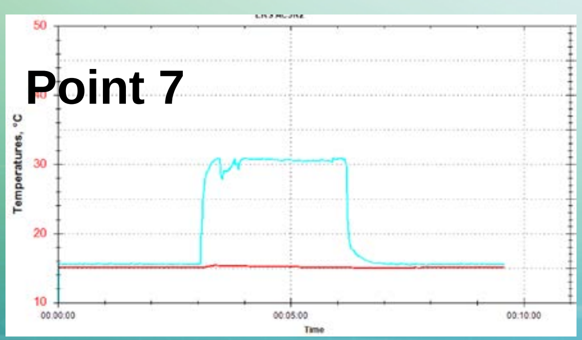


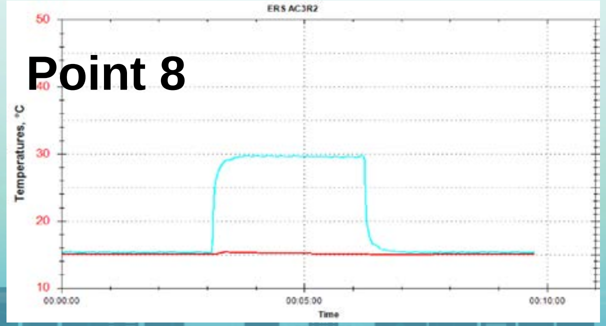


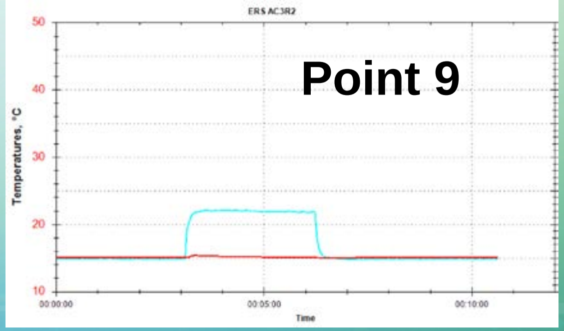






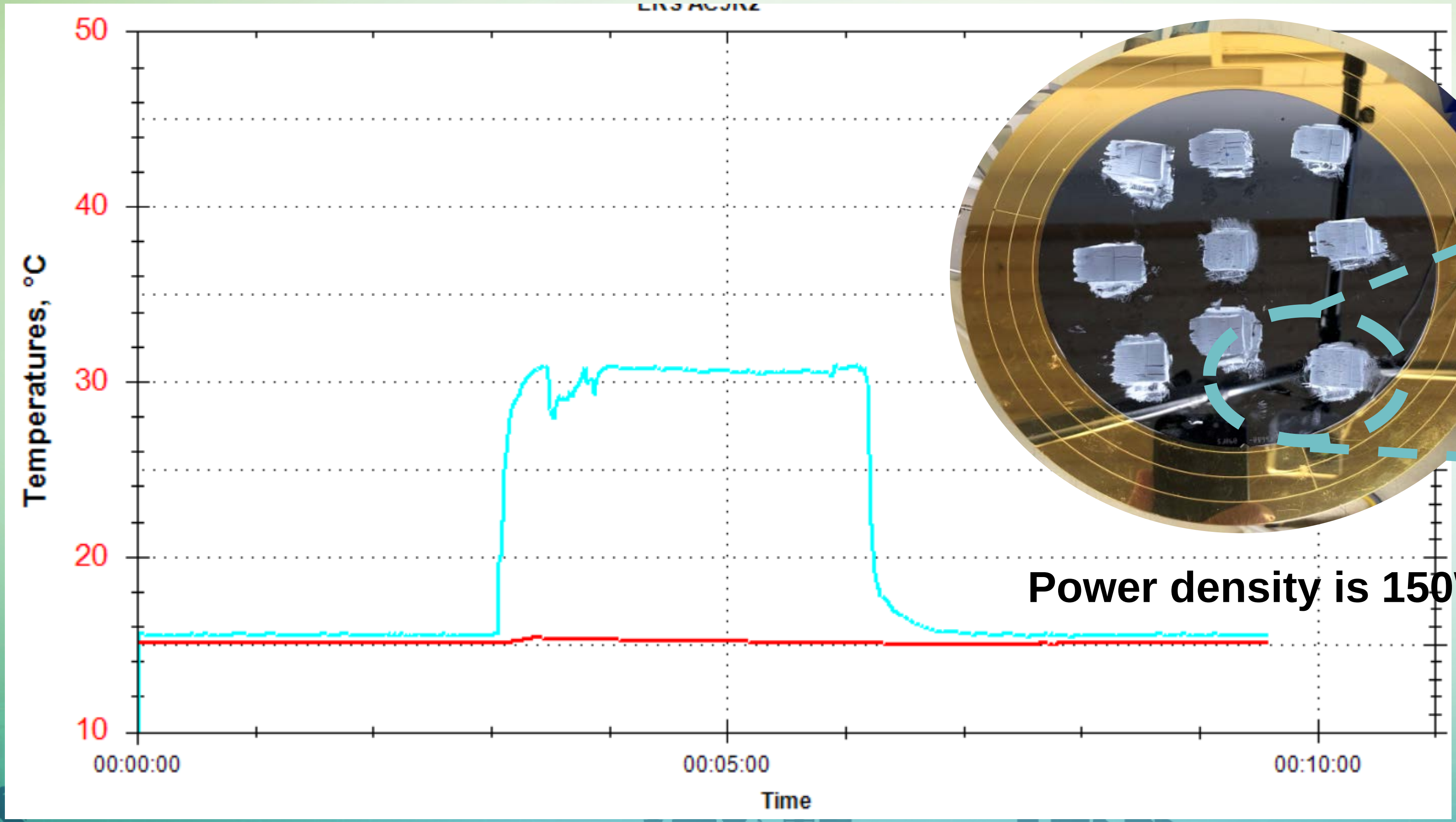


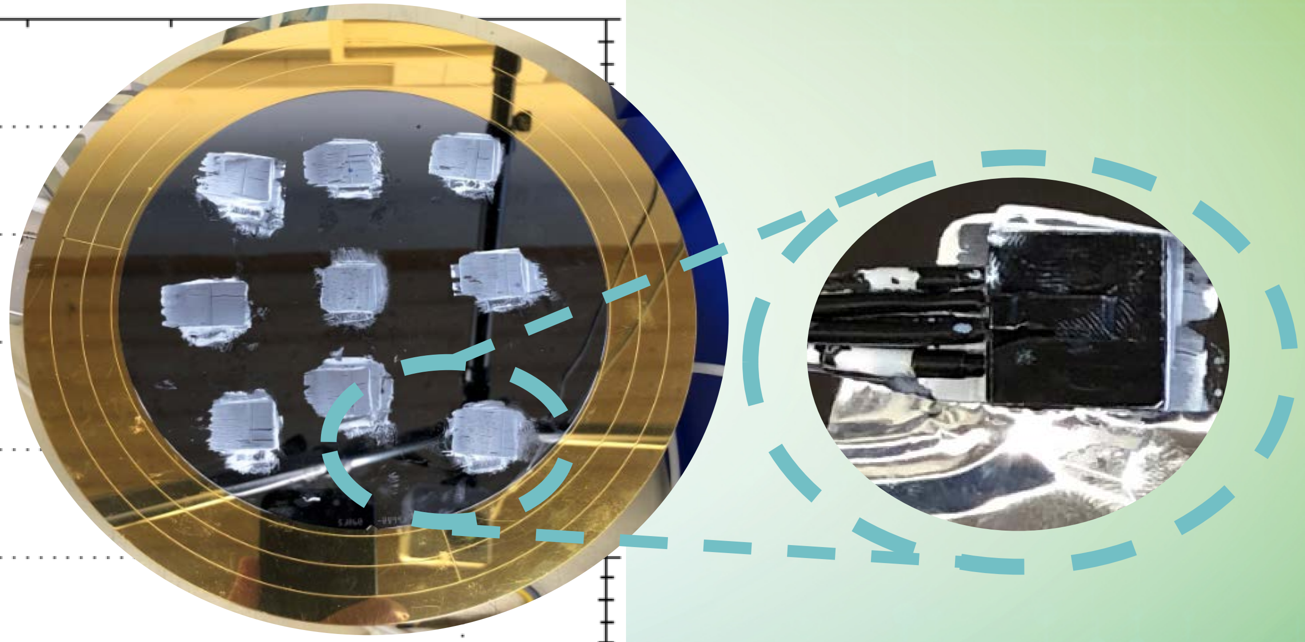




Status Quo

Heating up of the device while chuck temperature is constant

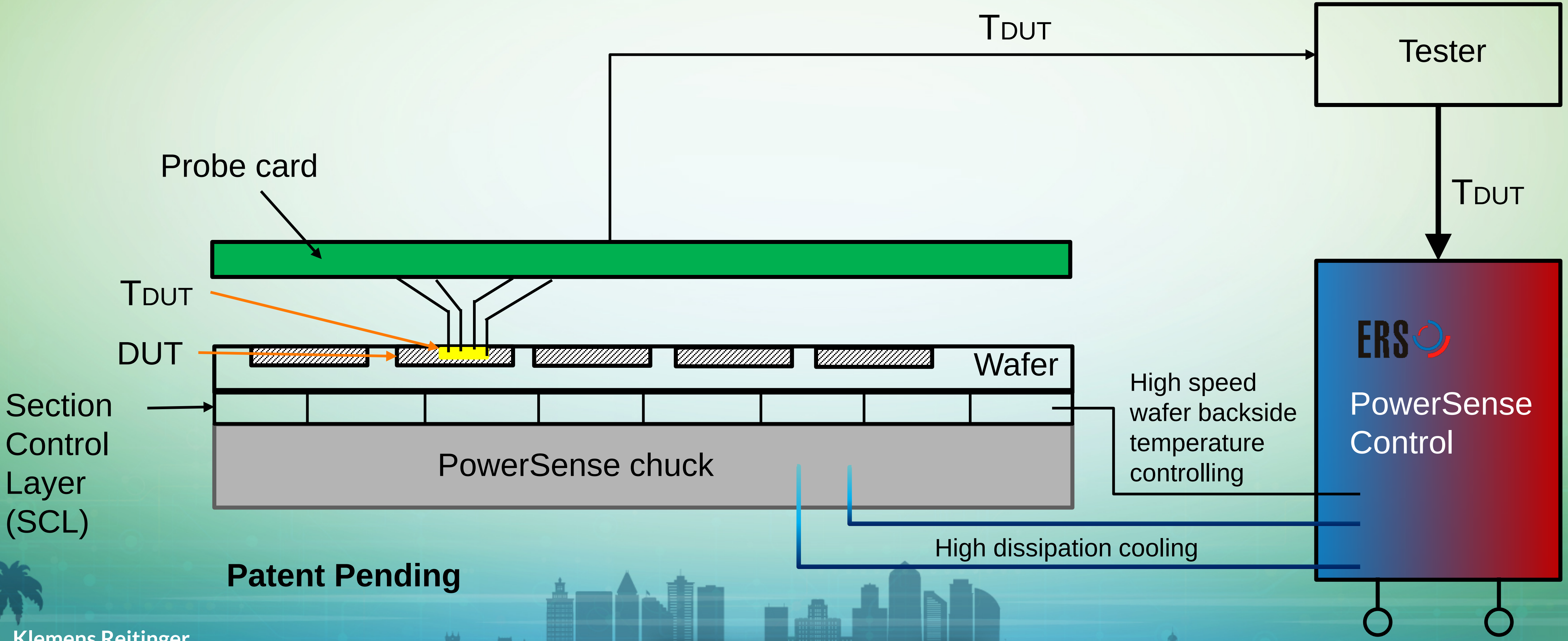




Power density is 150W on 15 mm x 15 mm

New Concept

The key of the method will be a very dynamic heating element with isolated sectional sensor and controlling capability (means individually controlling the temperature below each die)



Patent Pending

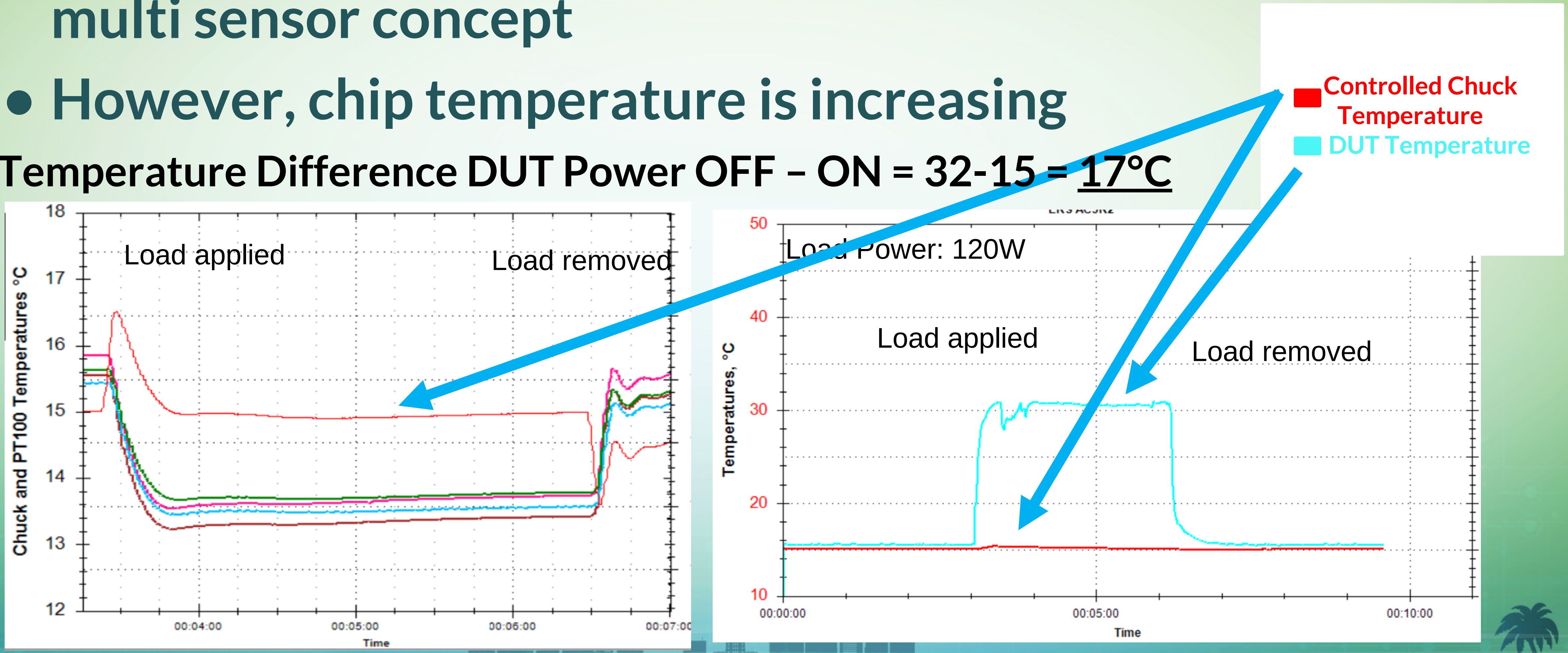
Key Data

1. Sensor in chuck
2. Sensor on chuck
3. Sensor in SCL
4. Sensor in the DUT

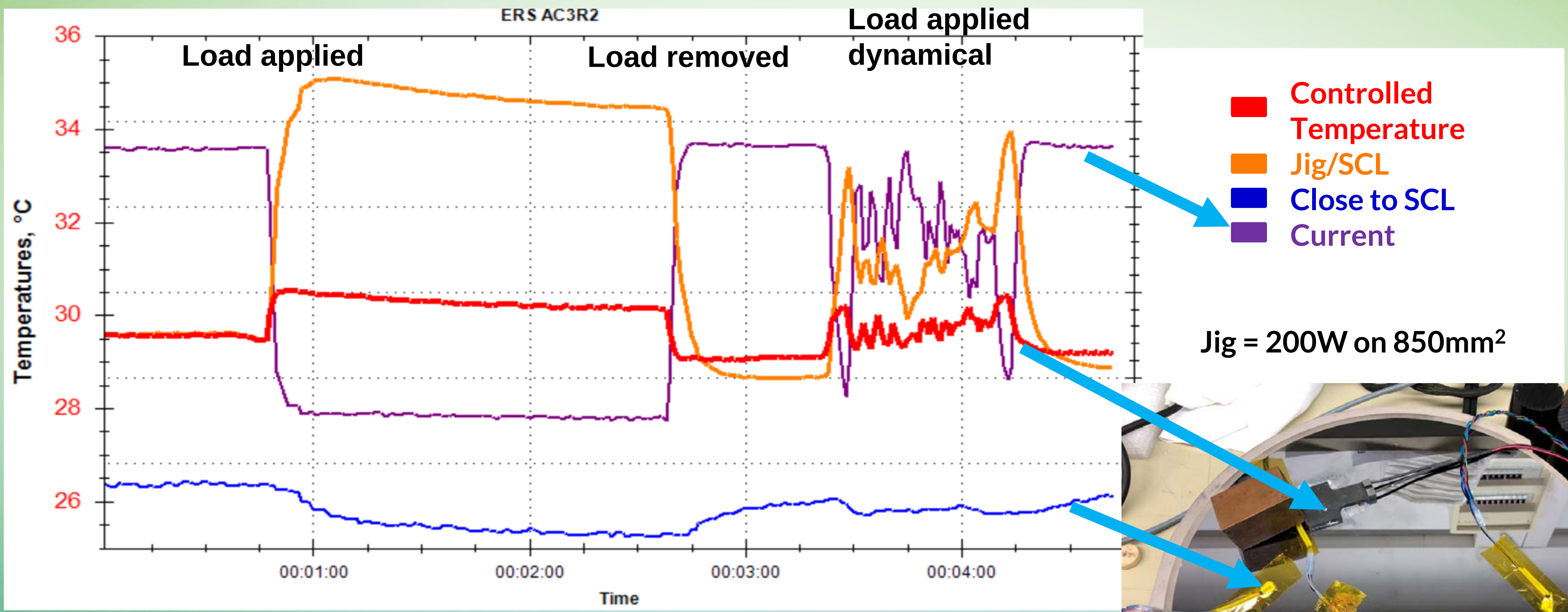
Temperature Controlled by Chuck only

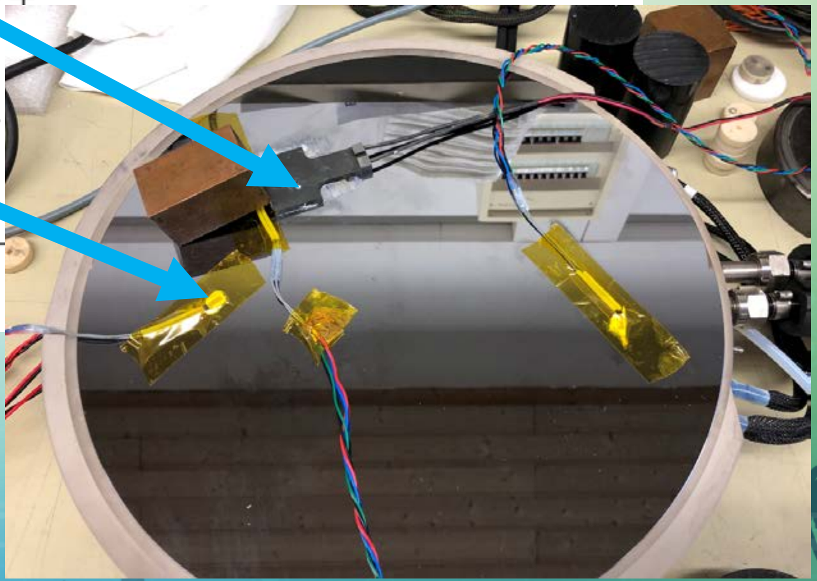
- Chuck temperature is controlled at constant temperature by multi sensor concept
- However, chip temperature is increasing

Temperature Difference DUT Power OFF – ON = 32-15 = <u>17°C</u>



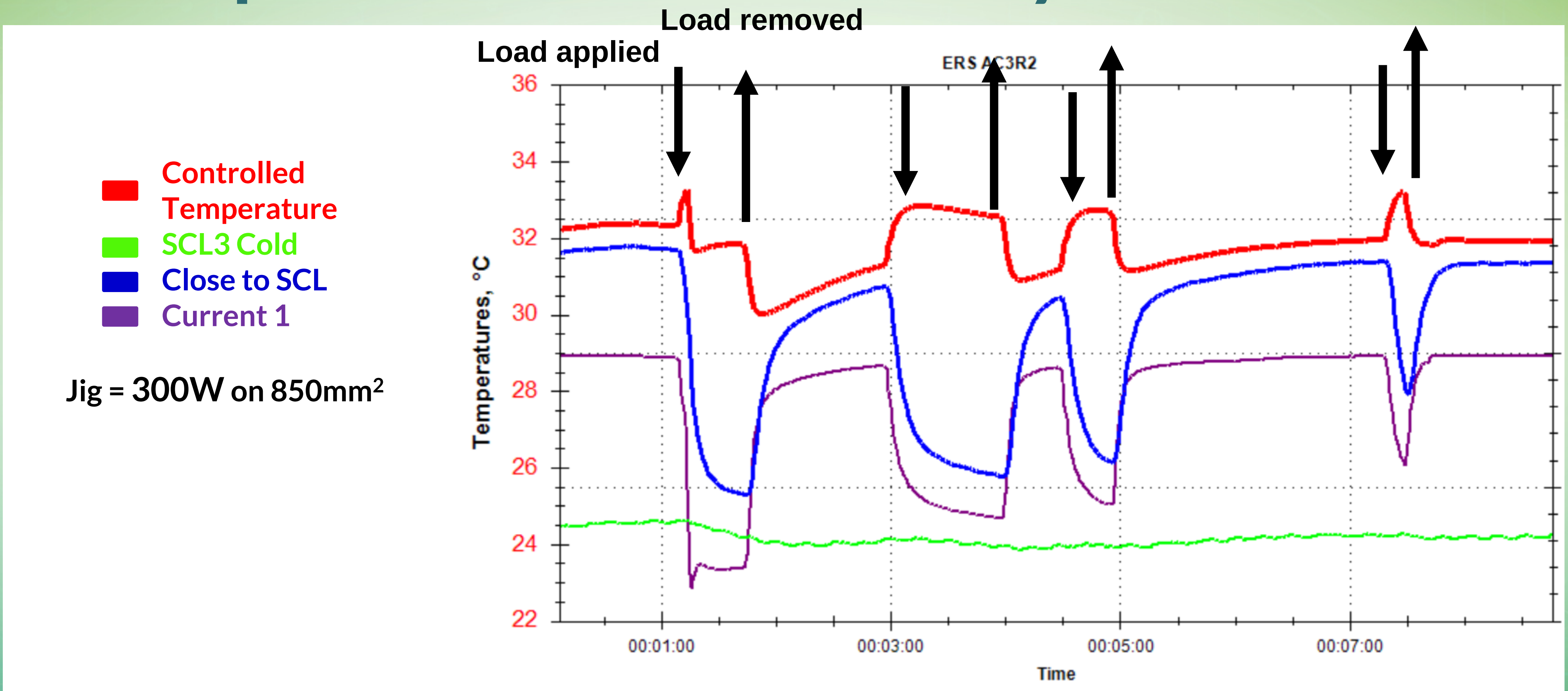
Temperature Controlled by SCL





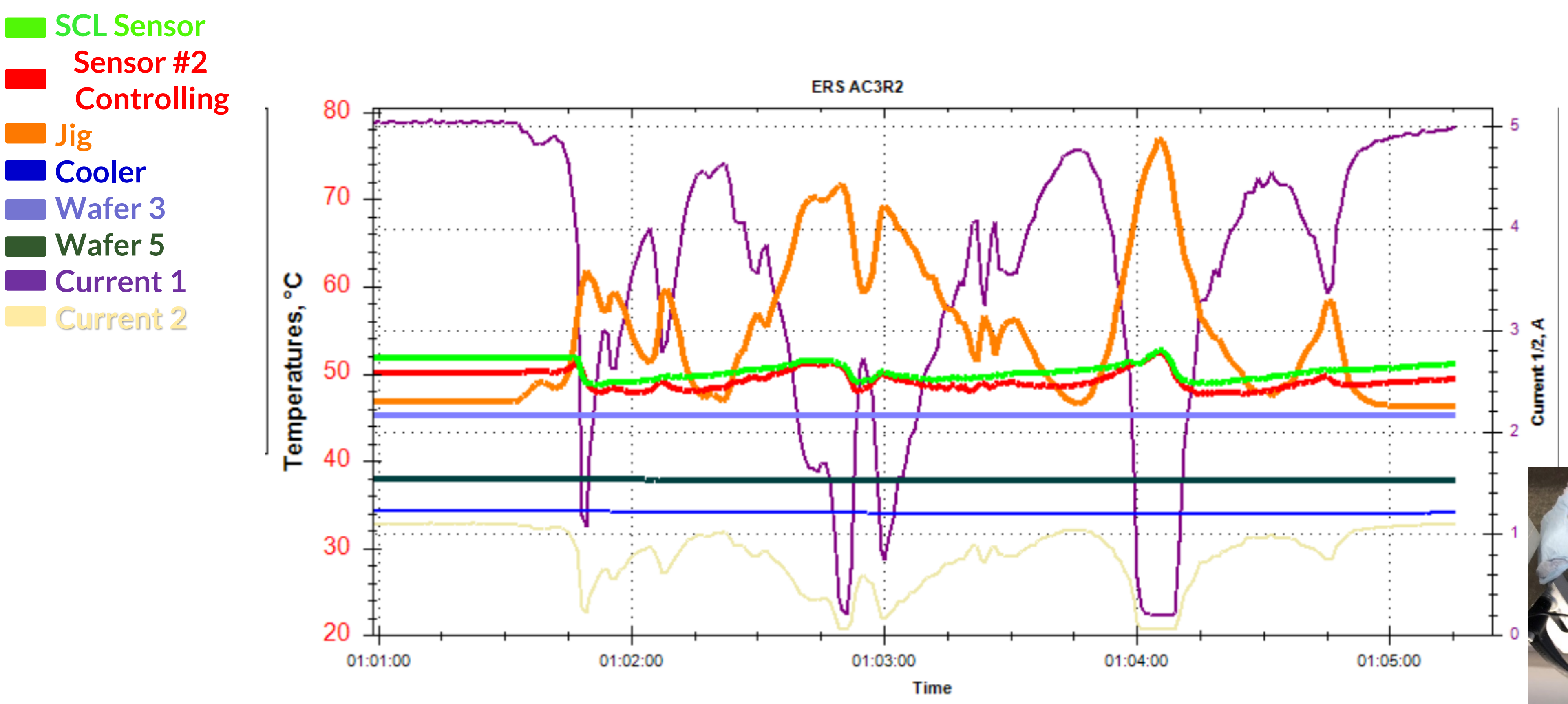
Temperature Difference DUT Power OFF – ON = 35-29,5 = <u>5,5°C</u>

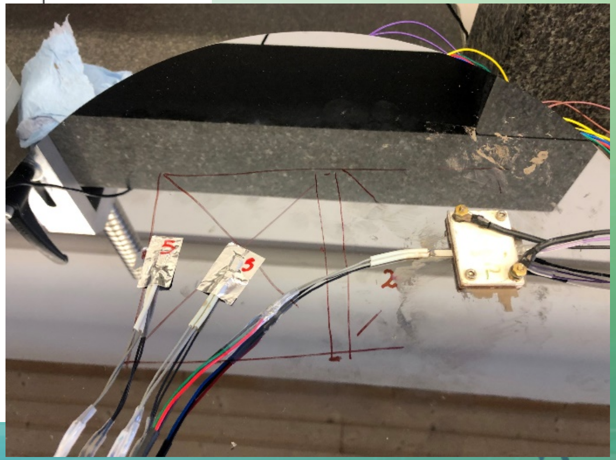
Temperature Controlled by the Device



Temperature Difference DUT Power OFF – ON = 33,1-30,5 = 2,6°C

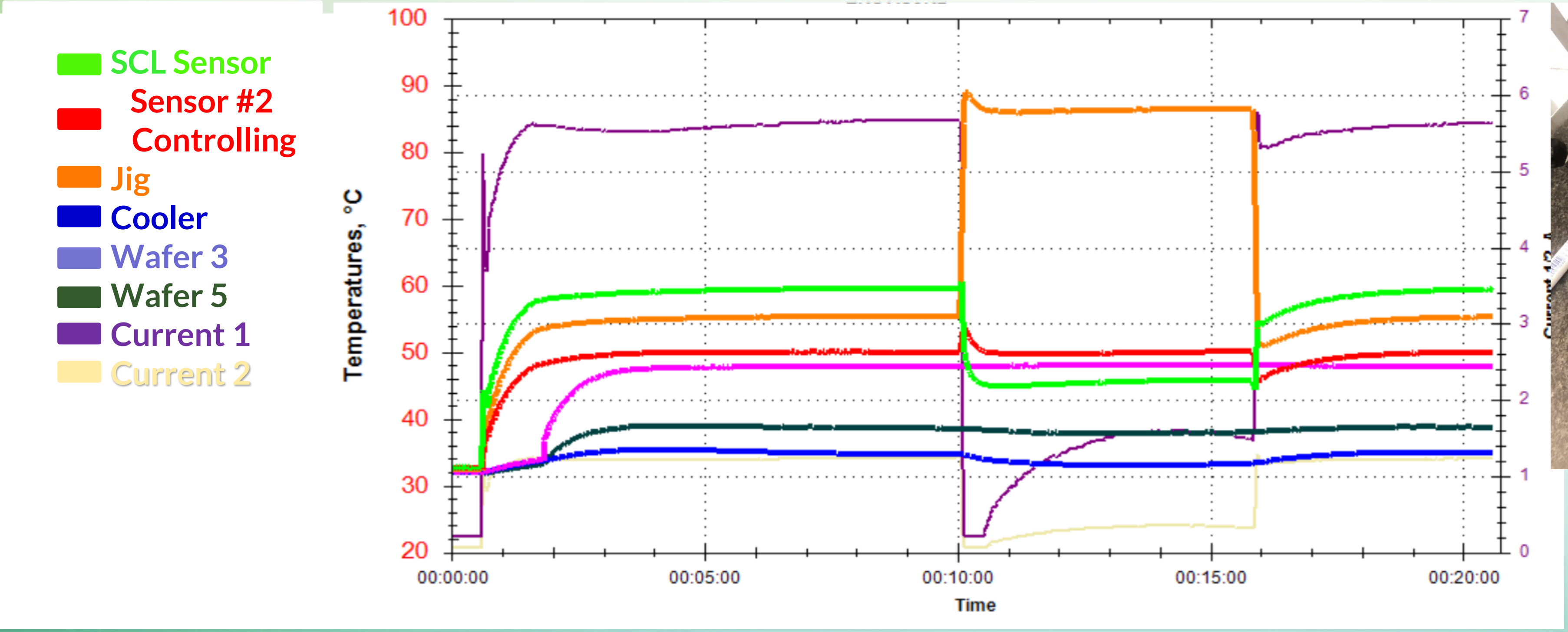
Temperature Controlled by the Device dynamically

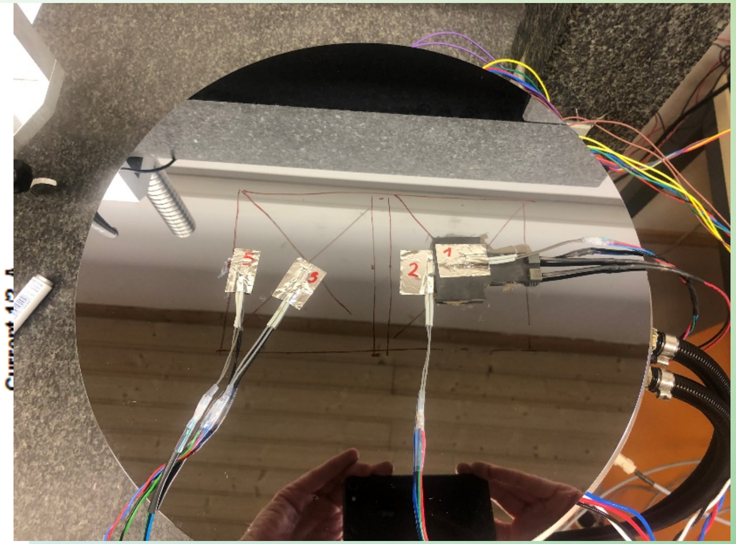




Mediocre vertical thermal conduction

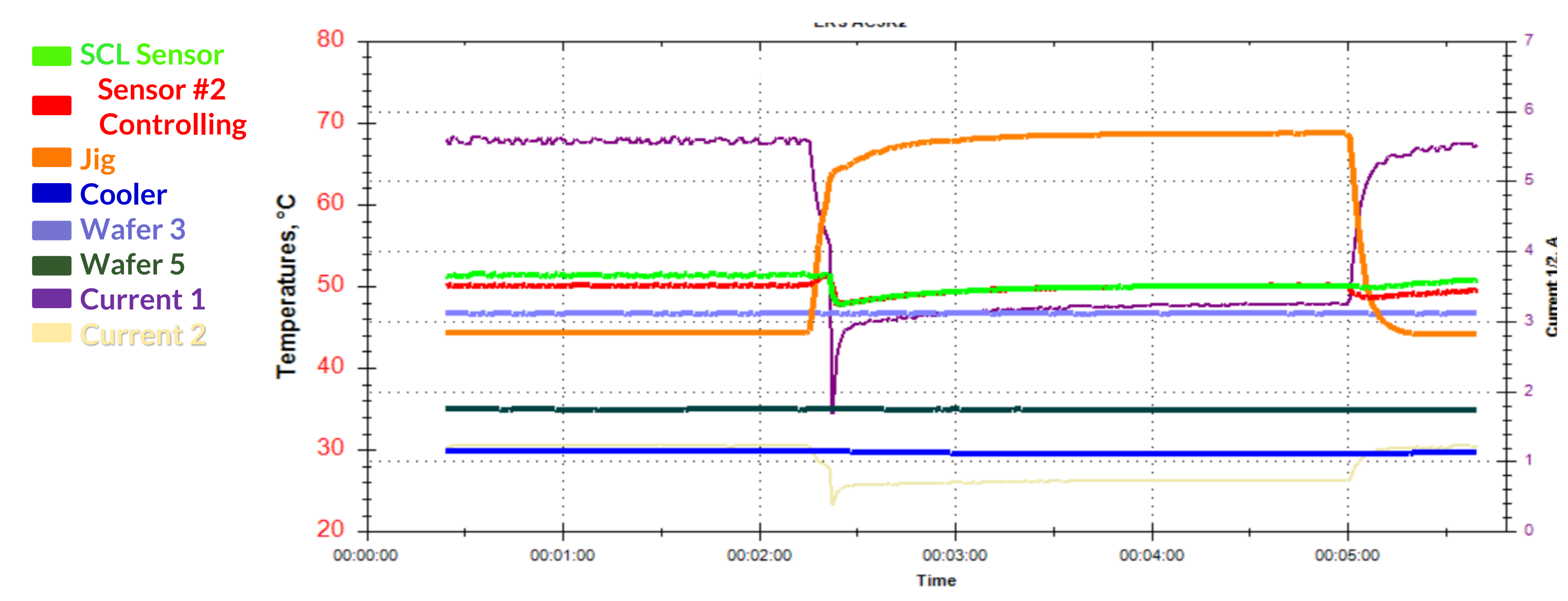
- 200W change on Jig leads to 440W peak and 406W change reaction on SCL

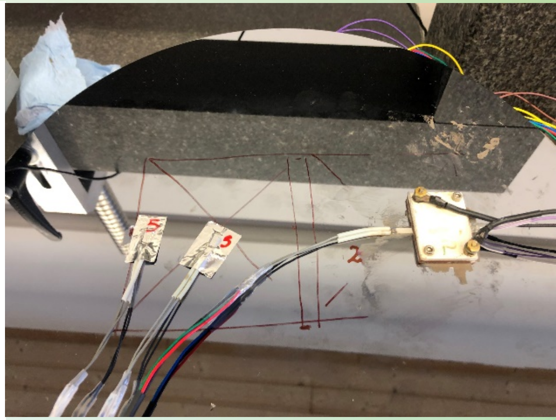




Excellent vertical thermal conduction

- 300W change on Jig leads to 430W peak and 290 W change reaction on SCL





Discussion

- It can be seen very clearly that with our new concept the temperature of the die directly can be kept constant
- Main reason is that we were able to minimize the thermal mass being responsible for the temperature control
- In the comparison between regular cooling chuck and new dynamic controlled chuck you clearly see the hurdle of thermal resistance was also overcome
- This is a way, in which all tests on CPU/GPU could be done at wafer-level like they are done in final test now

Strengths and Weaknesses

Strengths

– It's possible to do it on wafer test
– Opens completely new path of doing wafer test in this accuracy range with dynamic power application
– Very flexible to different die sizes and power applications

Weaknesses

- Quite high design and material effort
- High integration effort into existing wafer prober

Summary

- The new concept of keeping the temperature constant while adding power to the DUT is very promising
- With the sectional sensing and controlling (SCL), the thermal inertia of a thermal wafer test chuck can be overcome
- Combination of vertical good thermal conduction and lateral good thermal isolation is key

Follow-on Work

- Installation into a 300 mm wafer prober
- Doing the test set up with ProbeSense™
- Using real product to control the temperature

- TIMELINE:
- Evaluation in 300 mm prober with ProbeSense in the next two months (Q3 2023)
- Using real product to control the temperature via diode (Q4 2023)

Acknowledgements

- Bengt Haunerland, Patrick Mabinda, Thomas Bögle, ERS electronic GmbH