SWTEST

PROBE TODAY, FOR TOMORROW

2022 CONFERENCE

Automated calibration: Tackling the challenge of temperature accuracy and uniformity measurements in wafer probing

ERS

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ERS electronic GmbH

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Outline

- Market outlook and calibration reliability
- Objectives
- Concept and set-up
- Results & Key Repeatability Test Data
- Strengths & Challenges
- Conclusion
- Follow-On Work

Introduction – Market Outlook

- More detailed temperature focus can be observed in wafer probing
- Test under temperature moves from final test to wafer probe
- This probing depends on accurate temperature chucks
- Thermal accuracy and uniformity requirements are increasing

- Long term chuck performance
- Validation of accuracy and uniformity
- Calibration to standard

Calibration Reliability

- ERS's CTO Klemens Reitinger presented on the ERS journey towards a more accurate and reliable measurement system in 2019
  - *„Absolute temperature accuracy, a new standard for wafer testing"*
- Previous focus was on the chuck System

ERS chuck system

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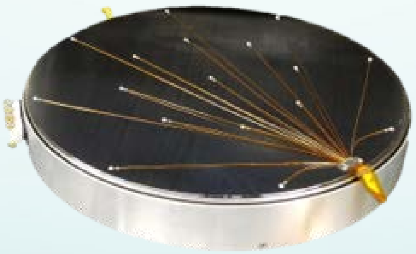
Calibration tool

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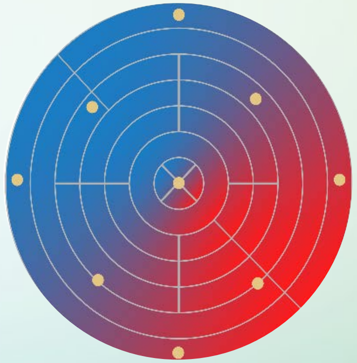

Calibration method

- The reliability was calculated according to the GUM standard
- Combined Uncertainty $U_c = \sqrt{ChuckSystem^2 + CalibrationTool^2 + Method^2}$

Measurement Wafer

Advantages:

- Fast test time
- Instantaneous uniformity data

Disadvantages:

- Sensor-to-sensor accuracy deviation
- Calibration requires high effort (lack of automation)
- Uniformity data does not reflect probing conditions
- High effort at low temperatures to reposition and maintain ice free environment
- Durability issues

Objectives

- **Address the weaknesses of current calibration methods**
  - Sensor-to-sensor accuracy deviation is a weakness
  - Calibration effort is a weakness
  - Operator effort required due to lack of automation
- **Systematically eliminate these weaknesses**
  - One sensor
  - Easy to calibrate
  - Put it into the probing area
  - Automation
- **Enable a wafer prober-dedicated tool for temperature calibration**
- **Goal: Reduction of the overall measurement uncertainty**

Set-up

Prober image provided by MPI Corporation

Measurement Concept

Fig. 1a

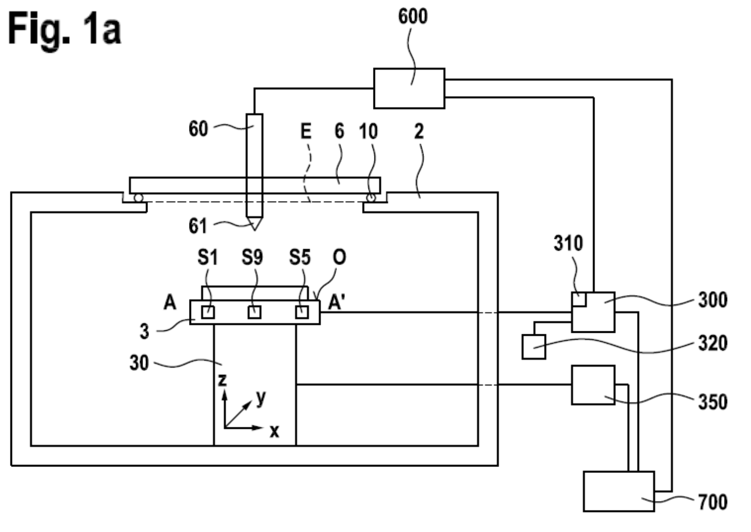
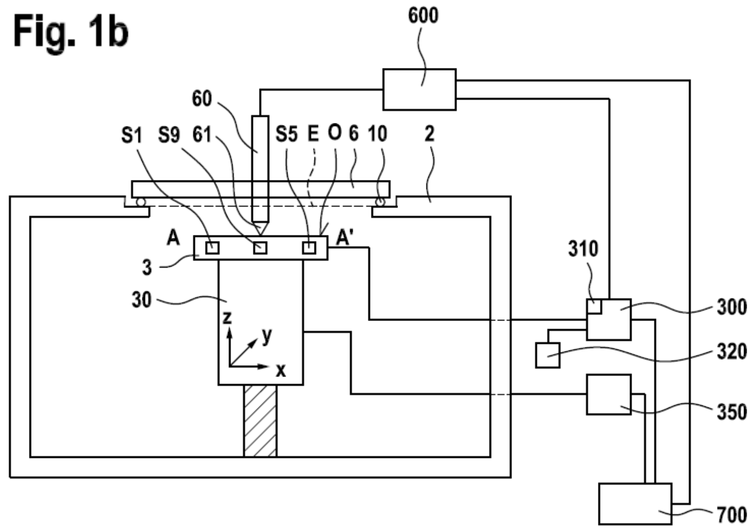


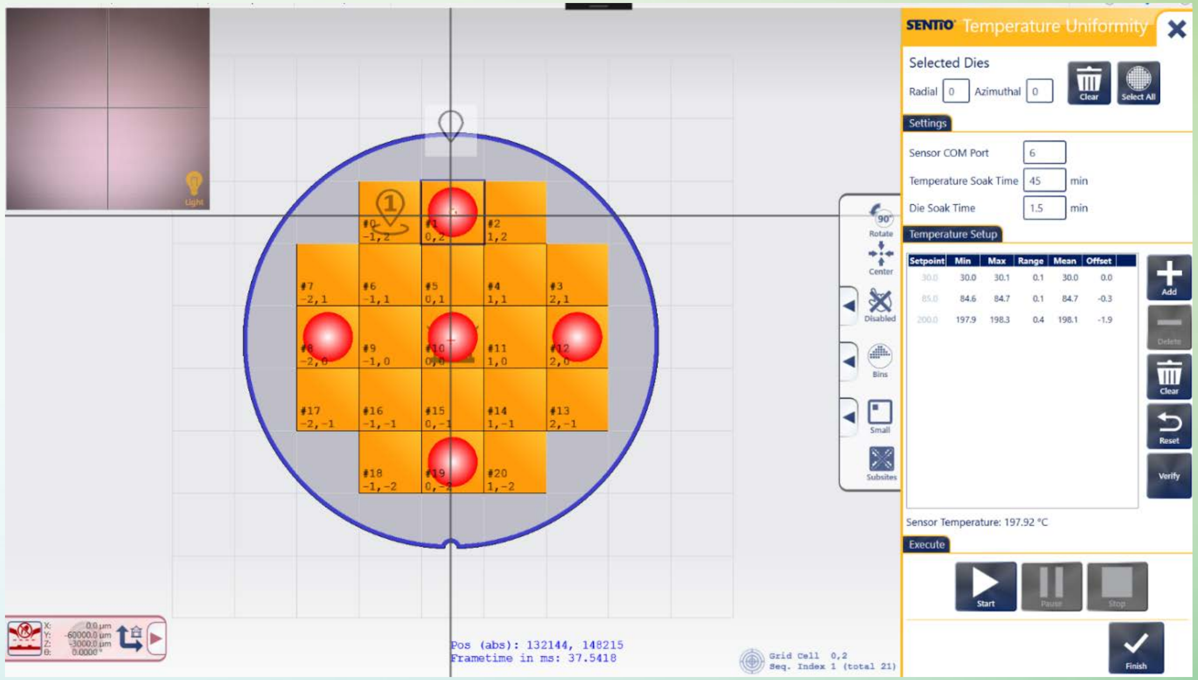
Fig. 1b



- Calibrated sensor jig attached like a probe card (60)
- Touchdown by chuck motion (like wafer probing)
- Fully automated calibration process can be performed
- Chuck with multiple sensors: Positions directly above sensor can be programmed

Automation

- No special operator skill required
- Automated software
- Measurement points can be defined
- Compatible with different prober types and chuck systems

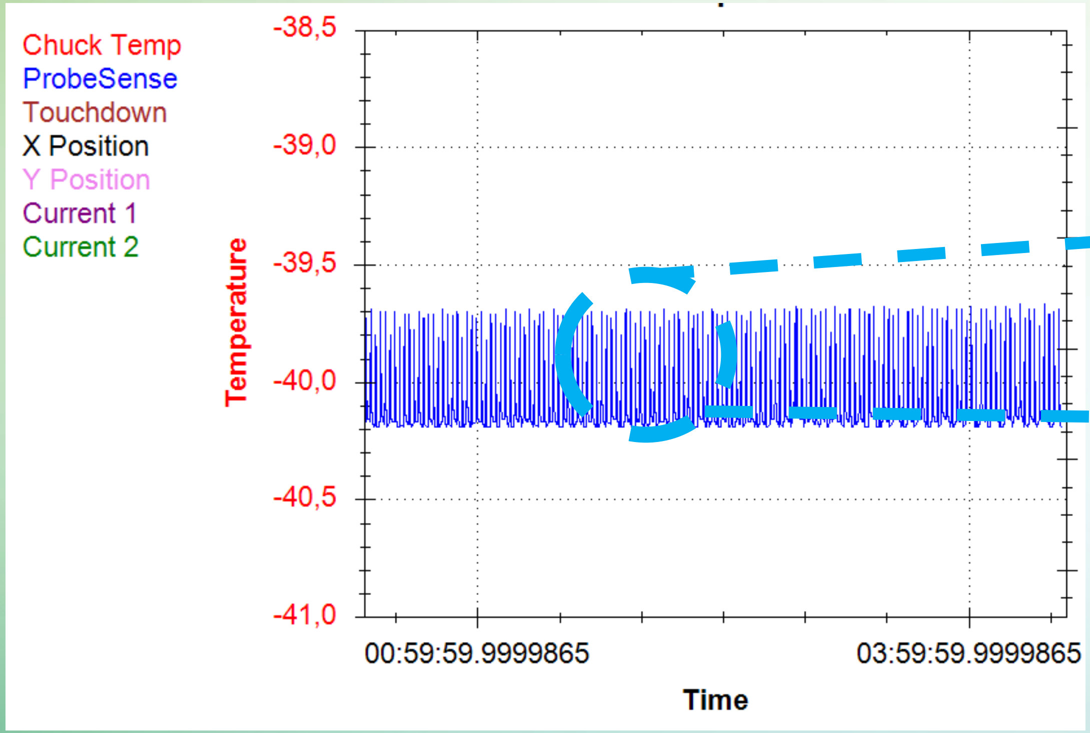


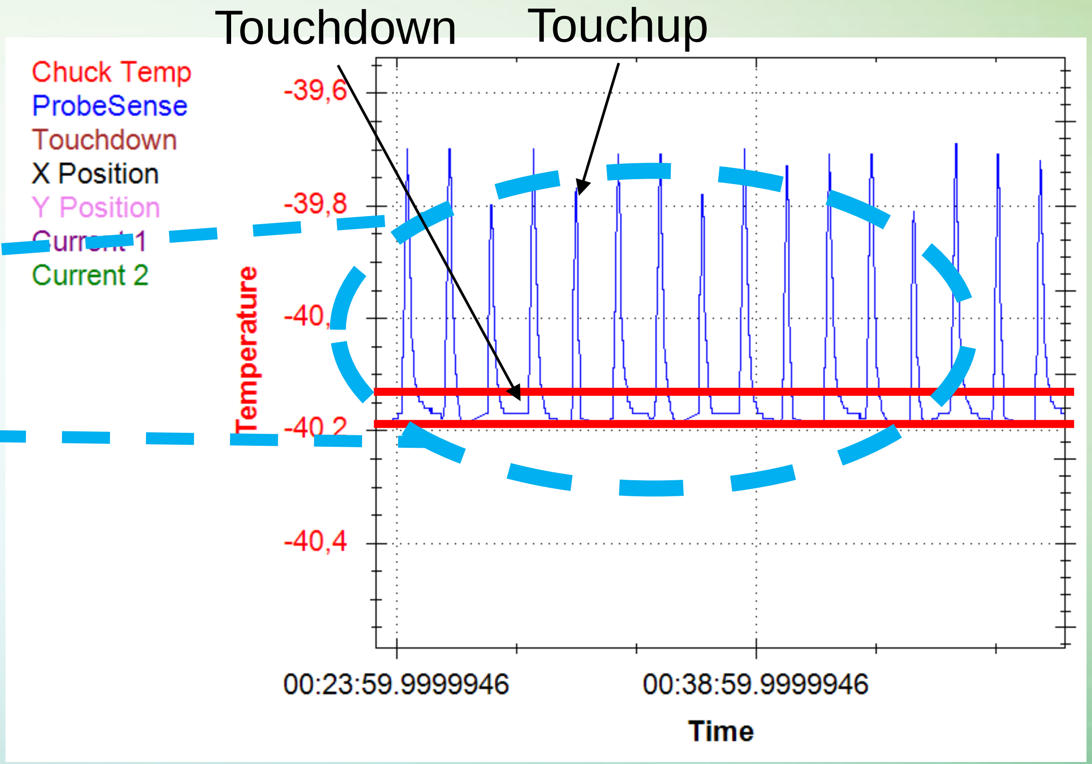
Screenshot provided by MPI Corporation

Results
Repeatability Test Data

Up to 100 touchdowns at -40°C, 20°C, 85°C and 200°C at 1 point

-40°C Repeatability Test

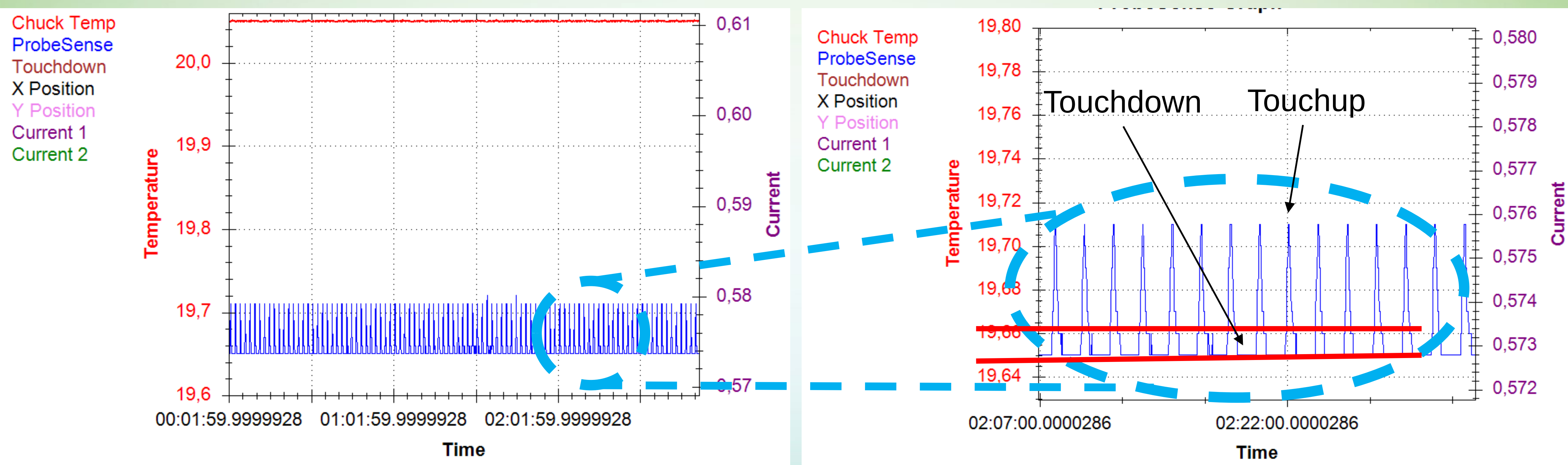




The observed temperature repeatability was **~20mK**

Measurement done on an Accretech UF3000 prober

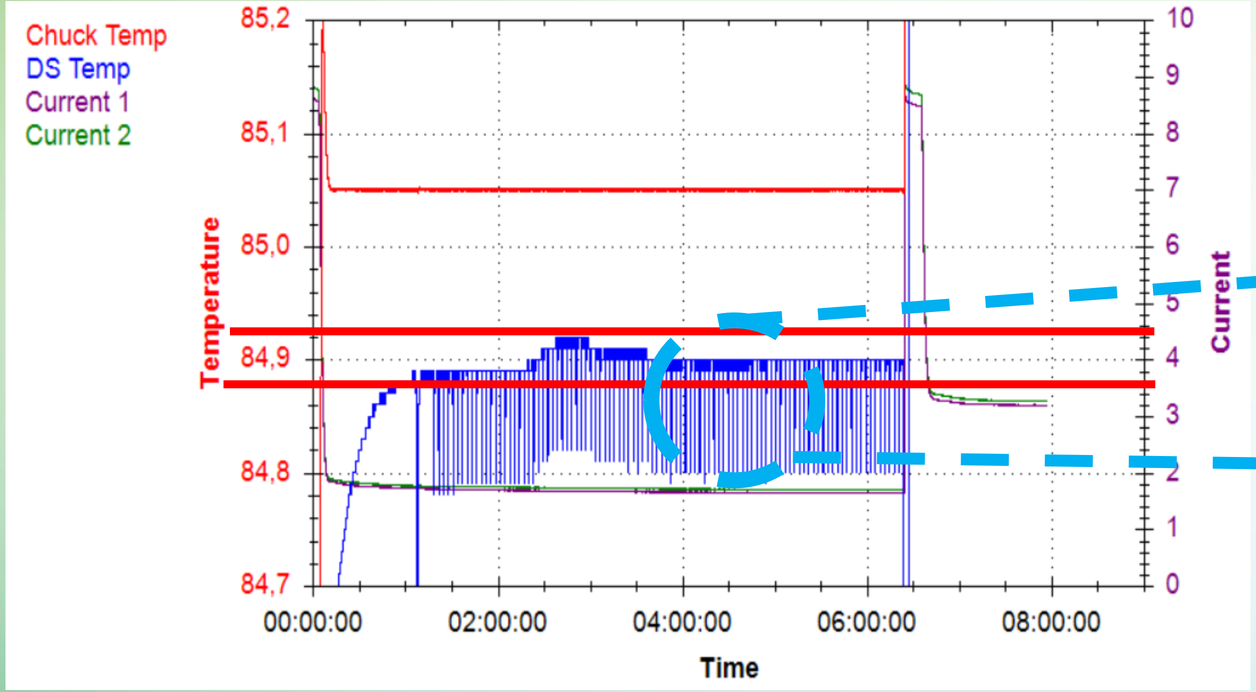
20°C Repeatability Test

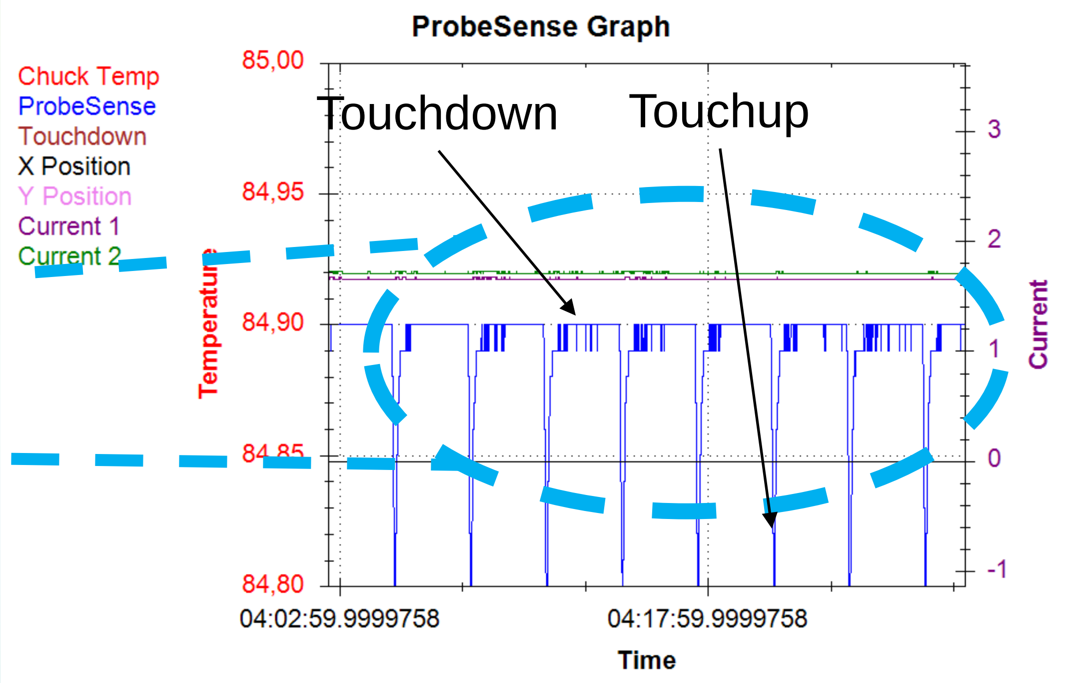


The observed temperature repeatability was **~10mK**

Measurement done on an Accretech UF3000 prober

85°C Repeatability Test



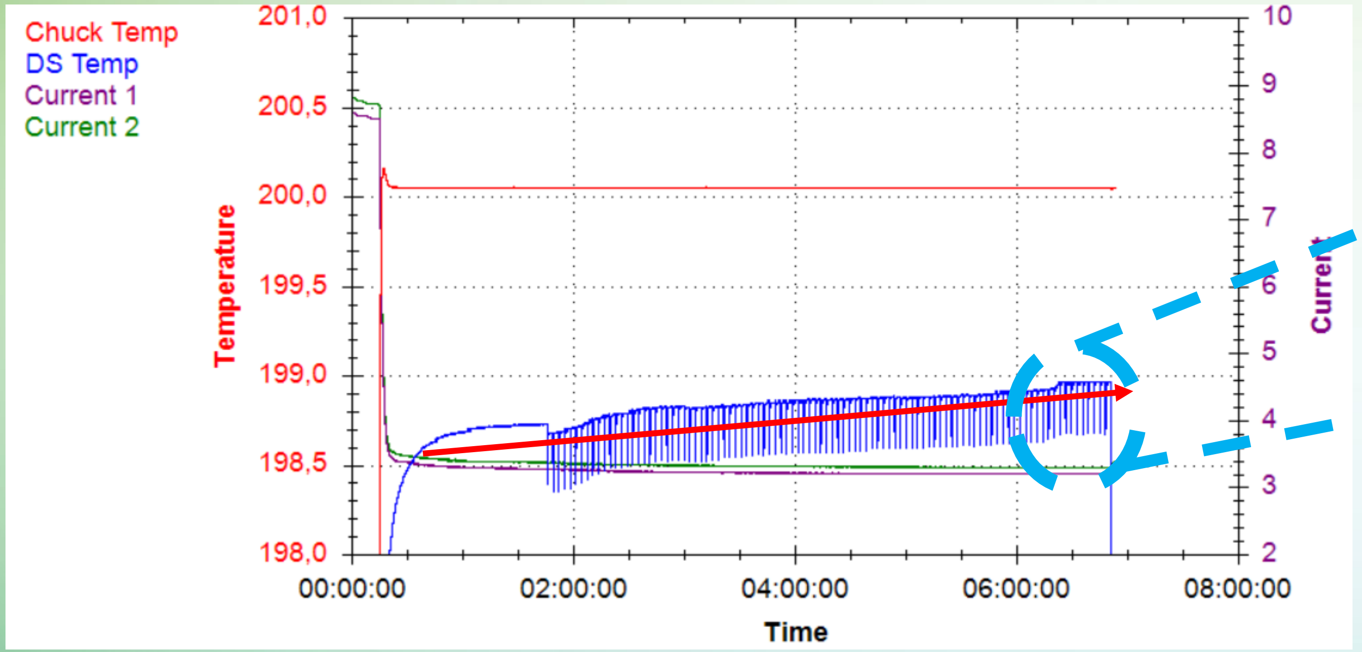


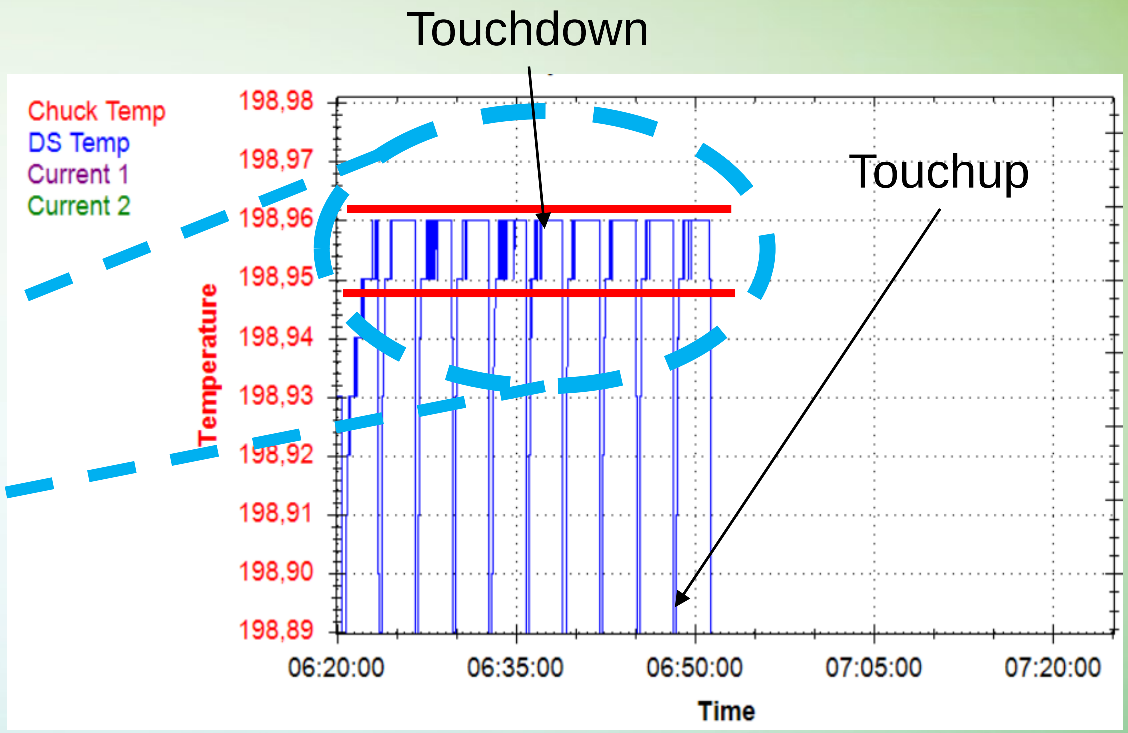
With 100 touchdowns at 85°C **~30mK** temperature repeatability over 5 hours

Over a 30 minute timeframe, **~10mK** temperature repeatability is observed

Measurement done in collaboration with MPI Corporation on a TS3500

100 Touchdowns at 200°C





With 100 touchdowns at 200°C a gradual increase in surface temperature is observed (0.2°C over 5hrs)

Over a 30 minute timeframe, **10mK** temperature reliability is observed

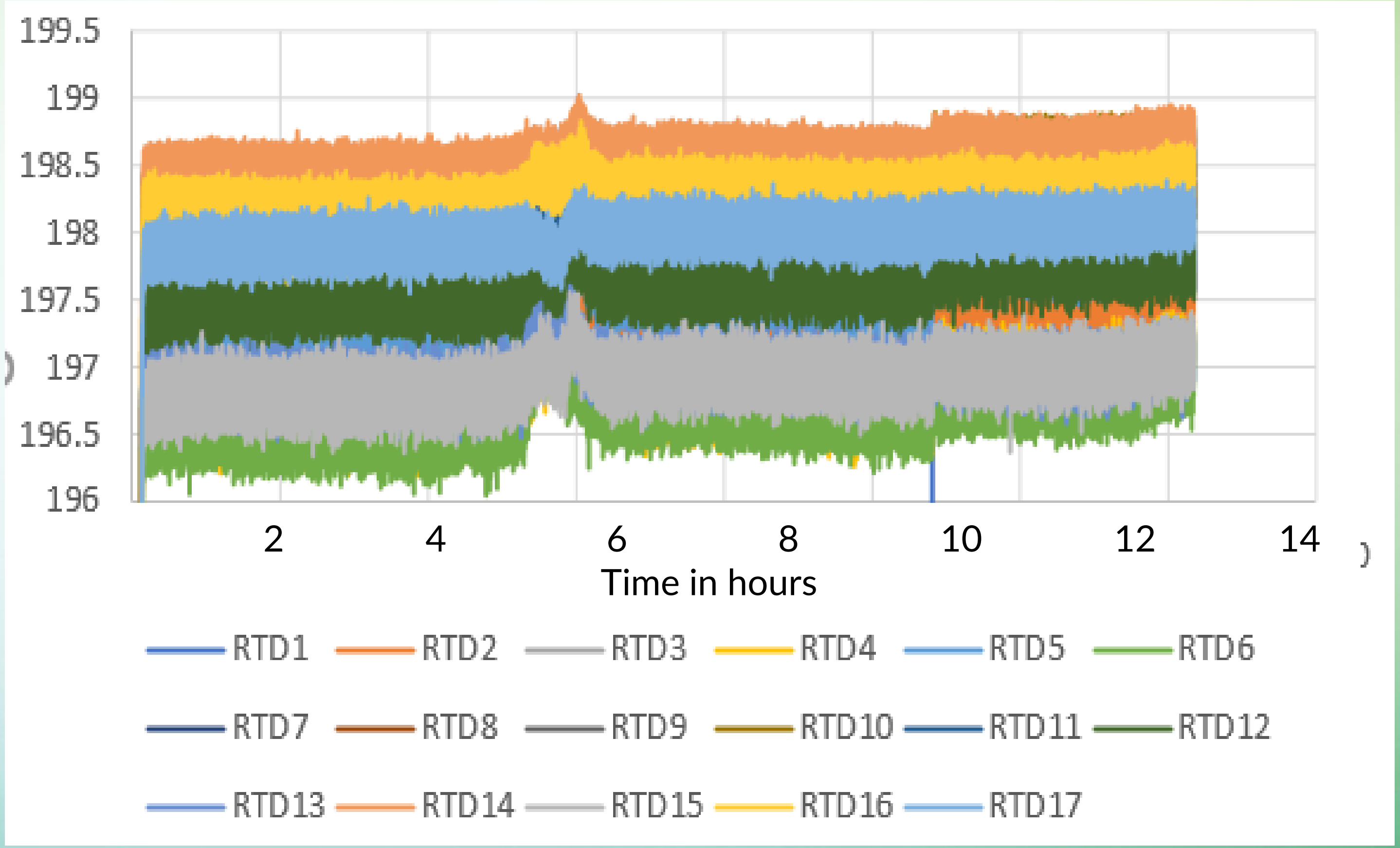
Measurement done in collaboration with MPI Corporation on a TS3500

Temperature Drift

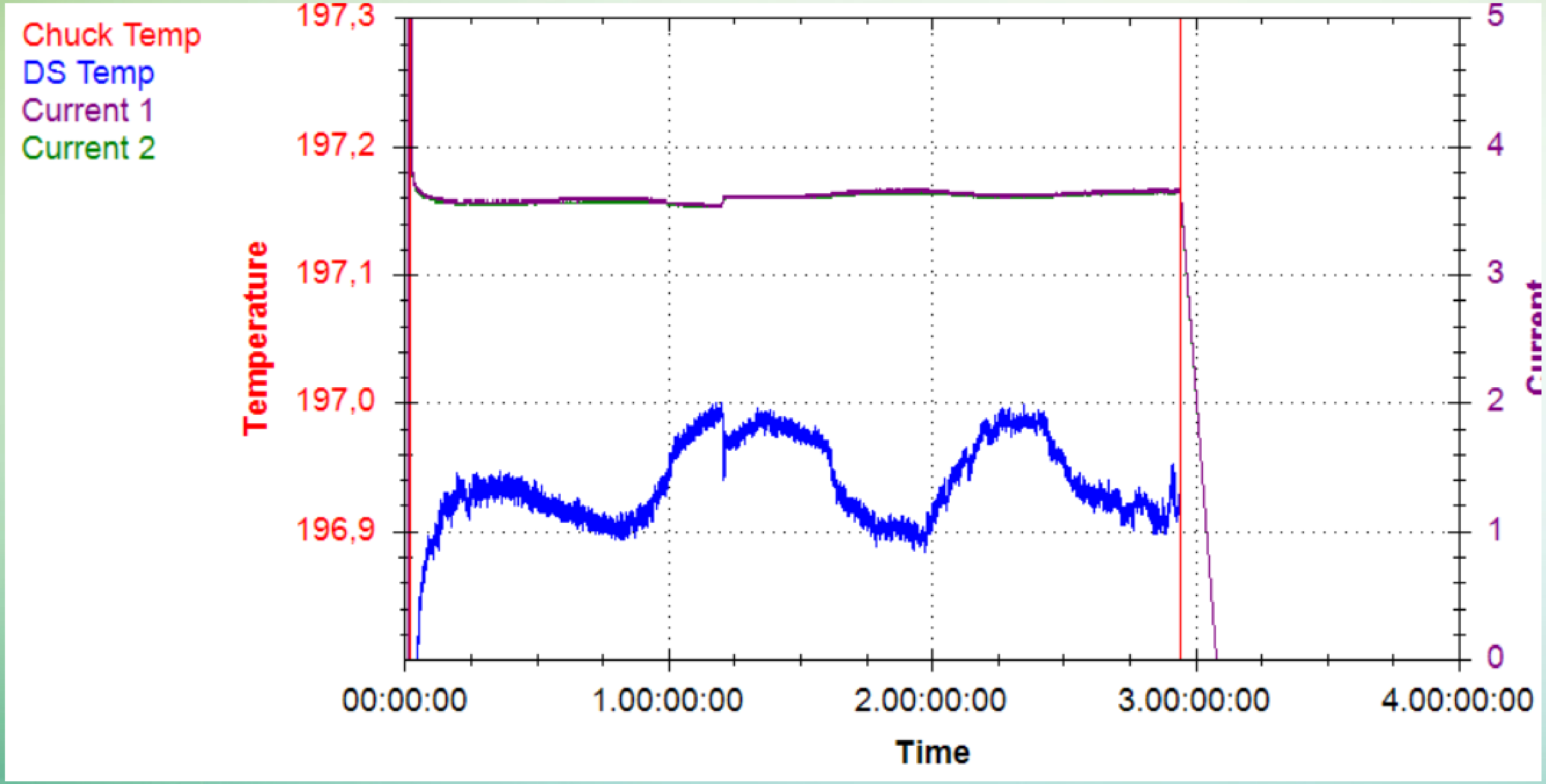
200°C

Measurement Wafer Comparison at 200°C

- Completed the same test with a measurement wafer
- Gradual heating effect is reflecting the temperature of the chuck surface



Temperature Drift at 200°C



1) Test environment is in a closed chamber
2) Not an air conditioned environment
3) The drift corresponds to changing environment temperature

Temperature Drift

- **Corresponds to environmental changes in temperature**
  - Coldest point during the night
  - Effect is not noticed inside the chuck, only on the surface
  - Drift is not observed below 100°C
  - Not observed in a climate controlled room
- **Chuck construction is important**
  - ERS Ultra Low Noise (ULN) chucks have a larger deviation than ERS Low Noise (LN or HTU) chucks

Wafer Comparison

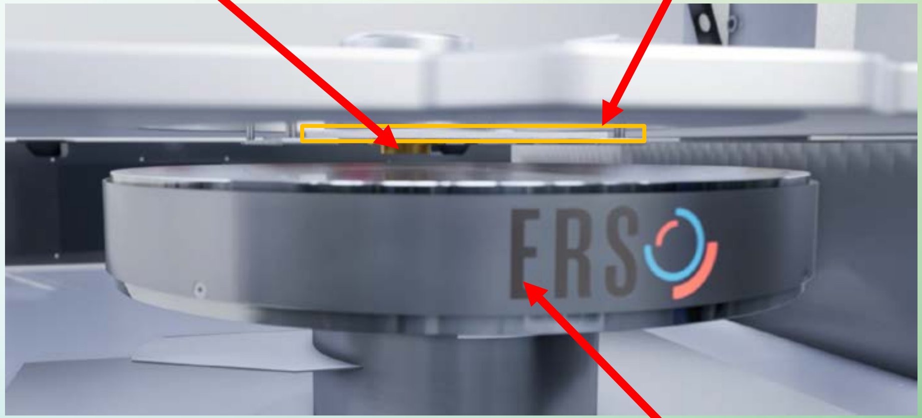
ProbeSense™ Solution

Advantages:

- Automated testing
- Measurements in probing condition
- Highly repeatable
- Single sensor reduce accuracy deviation
- Robust and ice-free testing

Disadvantages:

- Long initial settling time



Measurement Wafer vs ProbeSense™

- **Measurement wafer repeatability (method)**
  - Experimentally placing wafer multiple times on chuck surface
  - 0.03°C repeatability

- **Calibrated by an ISO 17025 certified laboratory**
  - 0.01°C (Temperature range -60°C to 100 °C)
  - 0.02°C (Temperature range 100°C to 230 °C)
- **Calibration method**
  - 0.01°C established from repeatability data

ERS chuck system

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Calibration tool

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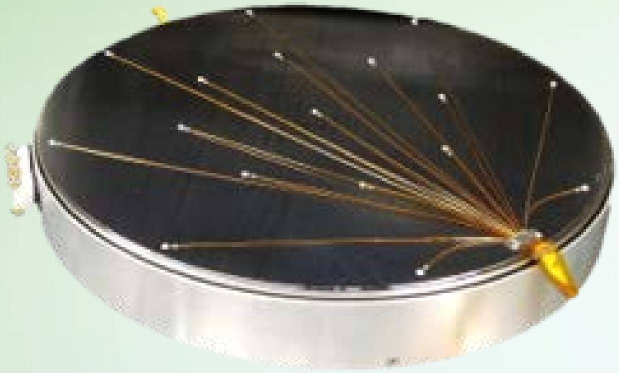
Calibration method

Measurement Wafer vs ProbeSense™



Calibration reliability:
- 0.058°C device uncertainty
- Method uncertainty = 0.03°C (repeatability test)

- **Combined method + device = 0.065°C**

Calibration reliability:
- 0.01 to 0.02°C device uncertainty
- Method uncertainty = 0.01°C

- **Combined method + device = 0.022°C**

Static and Dynamic Uniformity

- **Static: Sensors placed on the chuck and monitored (chuck doesn't move)**
  - 2022 static measurement with measurement wafer
- **Dynamic: Touchdown on sensor – stepping – monitoring profile of DUT**
  - 2022 Dynamic measurement with ProbeSense™
- **Reproducing the results with manual handling was difficult**

2022 (ProbeSense vs. wafer) MPI Prober				
		Max	Min	Total
30°C	Static	30.180	30.036	0.144
	Dynamic	30.080	30.030	0.050
	Variation	0.100	0.006	0.096
85°C	Static	85.167	84.791	0.376
	Dynamic	84.900	84.600	0.300
	Variation	0.267	0.191	0.076
200°C	Static	199.220	197.999	1.221
	Dynamic	198.980	197.960	1.020
	Variation	0.240	0.030	0.201

2022 (ProbeSense vs. wafer) ACCT Prober				
		Max	Min	Total
30°C	Static	30.34	29.710	0.630
	Dynamic	30.252	29.607	0.645
	Variation	0.088	0.103	0.015
85°C	Static	85.824	85.269	0.432
	Dynamic	85.392	84.814	0.455
	Variation	0.578	0.555	0.023
200°C	Static	198.95	199.6	1.01
	Dynamic	198.02	198.59	0.93
	Variation	0.35	0.43	0.08

Thermal Accuracy Budget

- **Consider various factors**
  - Chuck system: Chuck sensor accuracy, temperature uniformity, thermal resistance (in chuck), environment temperature
  - Calibration device/method: wafer
- **+35°C reachable accuracy without calibration**
  - Deviation range is 0.395°C
- **+35°C reachable accuracy with ProbeSense™ calibration**
  - Deviation range is 0.274°C

ERS chuck system

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Calibration tool

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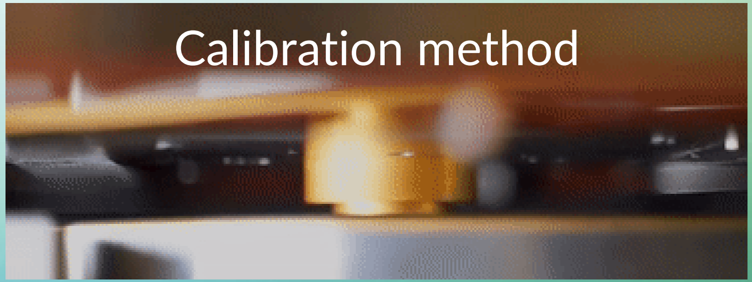
Calibration method

Wafer Comparison

- **Cold spots and hot spots in the same area**
- **Max sensor values deviate**
  - Using GUM we get 0.070°C accuracy deviation between wafer and ProbeSense™
- **Uniformity data is similar (dynamic vs. static case)**
  - ProbeSense™ gives a better uniformity since the probe card slot is smaller than the chuck on the MPI prober (shielding effect)
  - On Accretech UF3000 prober, dynamic and static is similar due to larger probe card size

Conclusion

- **ProbeSense™ is a chuck temperature calibration tool that addresses challenges of a traditional wafer-based calibration**
  - Reducing the uncertainty of the calibration method through automation
  - Relying on a single calibrated sensor to improve accuracy
  - Increased temperature range of measurement accuracy
- **More accurate picture of temperature uniformity in wafer probing**
  - Dynamic vs. static temperature measurement

Follow-on Work

- **Extending the calibration range to 300°C**
- **Adding a power jig to simulate the effect of power dissipation from probing**
- **APC compatibility to further improve automation**
  - Exploring the use of different type of sensors to make it more compact
  - Exploring wireless sensor readout options

Credits

- Sebastian Giessmann and Stojan Kanev from MPI Corporation
- Klemens Reitinger, Bernd Krafthoefer, Sophia Oldeide, Flora Huang from ERS electronic GmbH