SWTEST
PROBE TODAY, FOR TOMORROW

Absolute temperature accuracy, the rising trend on wafer test – Where are we today?

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Introduction – Market Needs

- Temperature Accuracy keeps gaining importance in wafer testing
- Accurate thermal values are important for multiple applications
- Tendency to shift more thermal test from final test to wafer testing
- Still, temperature measurement is very complex and very hard to trace against standards

“Absolute“ Accuracy – why is it new?

- Shift from final test to wafer test lowers the tolerance for the temperature generating device:
  - One socket for one chip, one chuck for hundreds of chips
- New, innovative devices’ performance needs much tighter temperature tolerances
  - Gas sensor,
  - Temperature sensor
- Temperature sensitive part is within the device – how to measure ?
- Although the chuck has a very uniform temperature on the surface, in some test application it is relevant to prove the actual temperature in the chip

Requirements Regarding Temperature Accuracy

- Every Chip shall be tested in a certain temperature range, **uniformity is more important** than absolute value
- Every chip has to be tested at a certain temperature, **absolute value is more important** than uniformity
- Every chip has to be tested in a certain range at a certain temperature, **uniformity and absolute value are both important**

The Four Influencing Factors

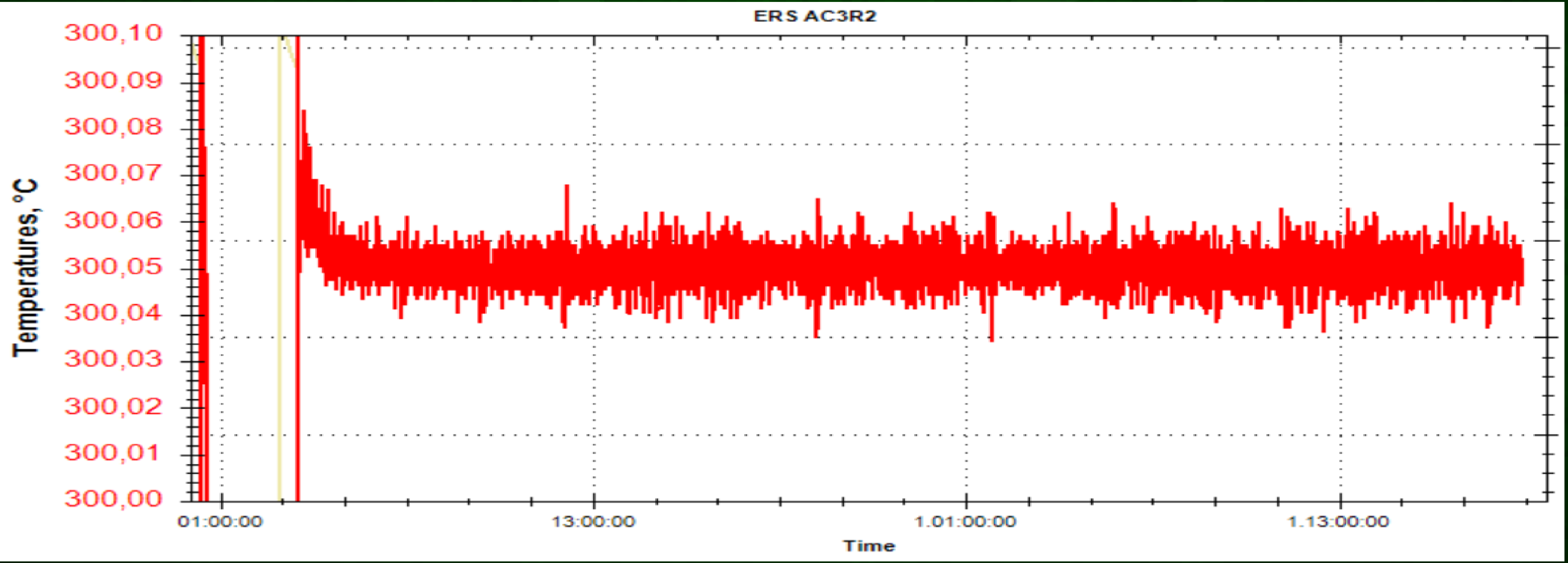
- Stability
- Uniformity
- Repeatability
- Calibration

Stability

- Stability is directly related to the control ability of the chuck system
- Environmental influences like probe tips, induced wattage or fans are overlaying and influencing the stability

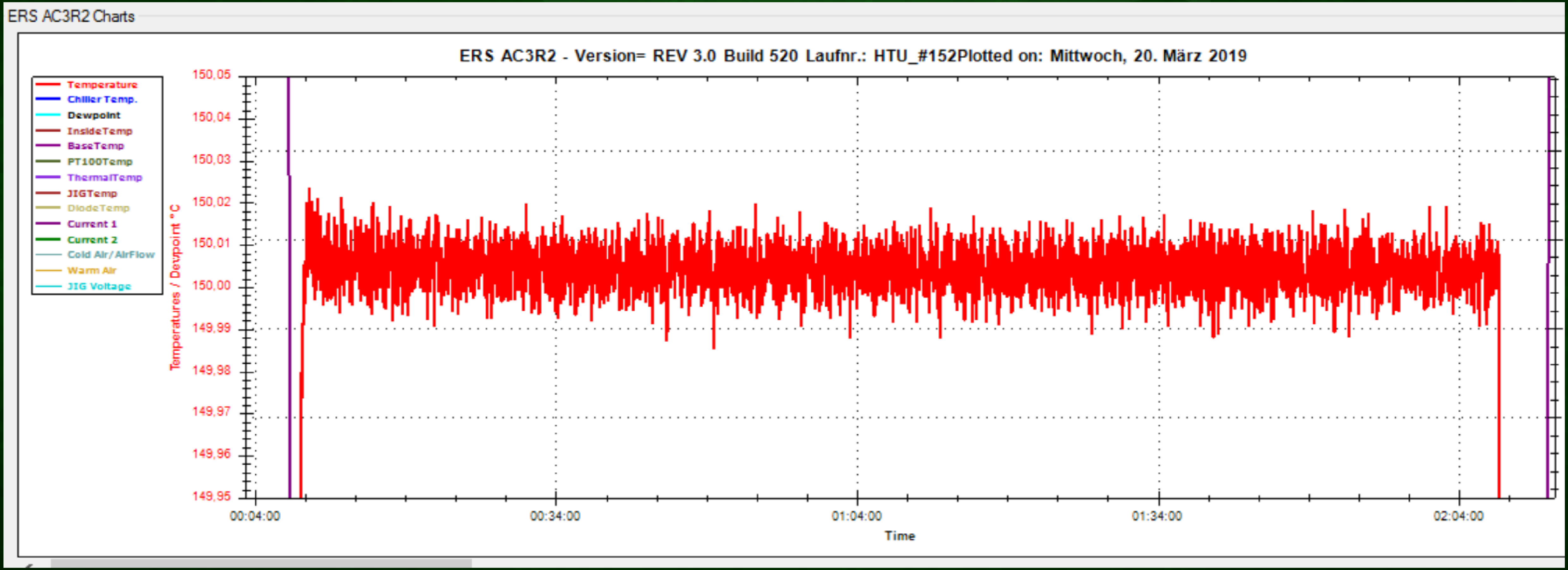
Chuck Alone – Long Term Stability

- 300°C: 1 day 13h less than 0,02°C drift



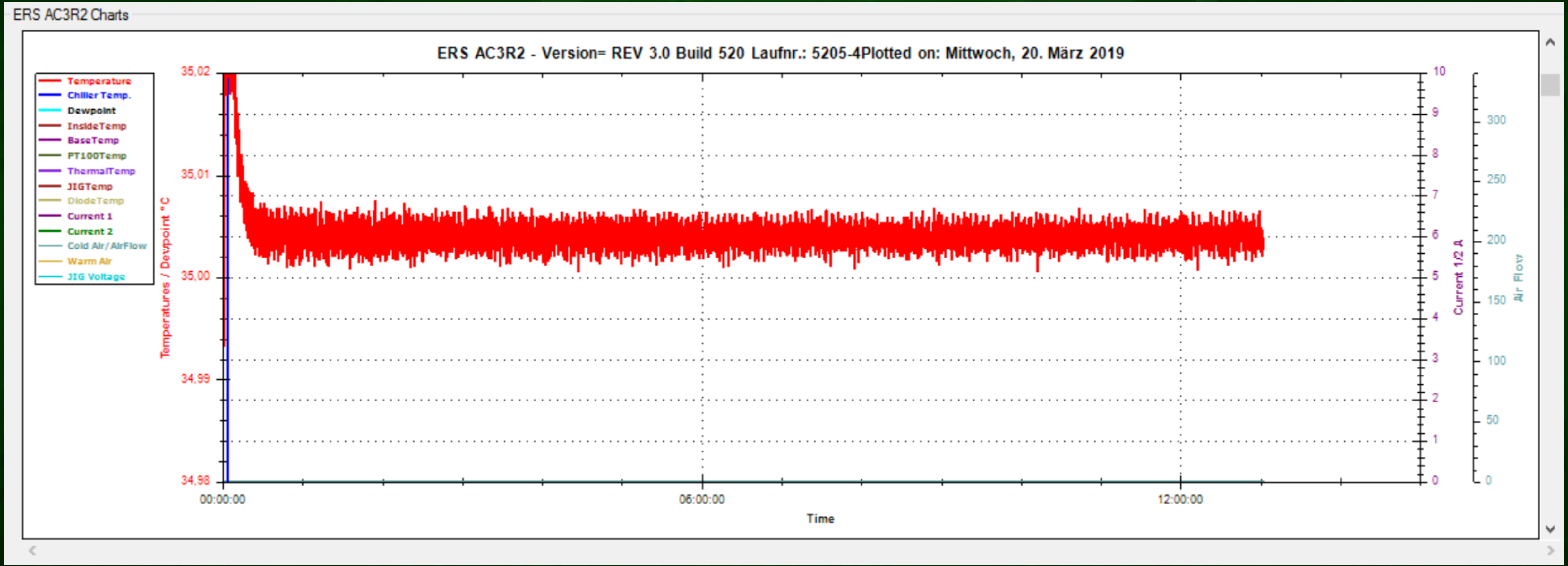
Chuck Alone – Long Term Stability

- 150°C: 2h less than 0,02°C drift



Chuck Alone – Long Term Stability

- 35°C: 12h less than 0,02°C drift



Stability: Chuck in Prober

- Control off during stepping – see sawtooth at the edge!

Temperature Uniformity

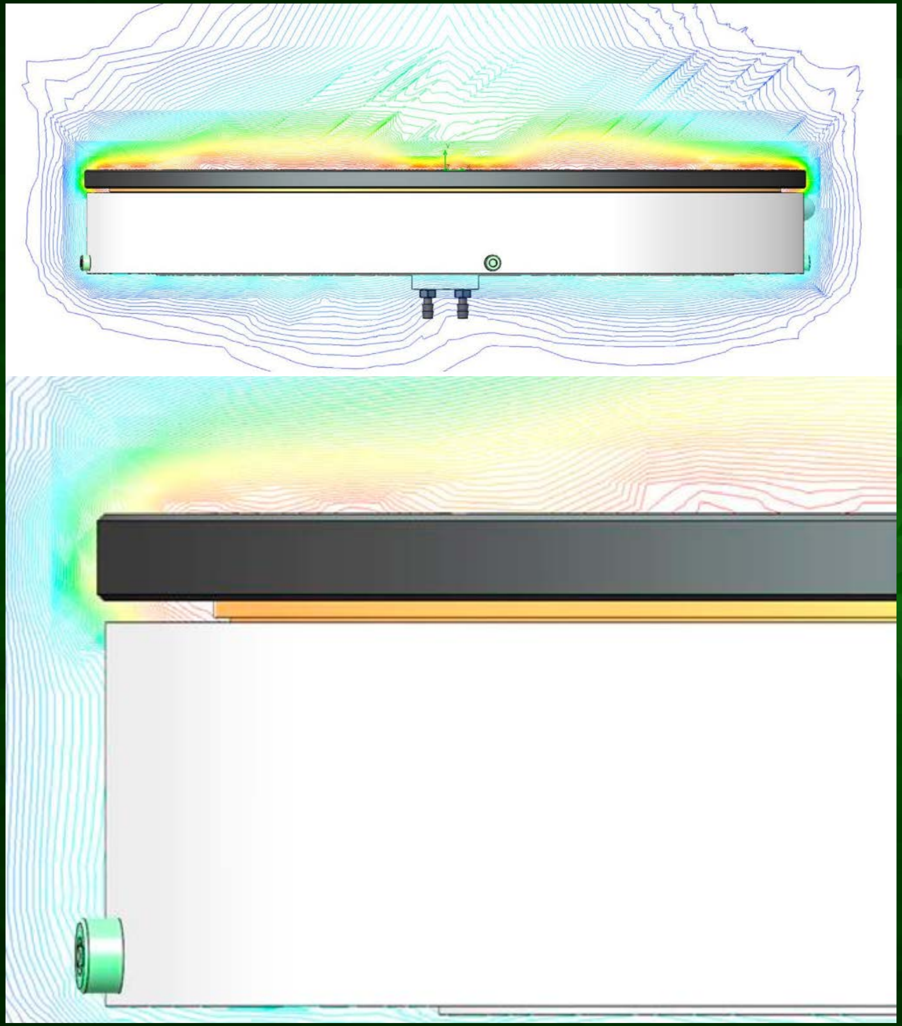
- Uniformity primarily depends on the chuck’s design (heater, cooler and controller)
- Depending on the environment, primary air flow
- Uniformity is dynamic!
  - Even the smallest controller correction will influence uniformity
- Types of Uniformity: static and dynamic

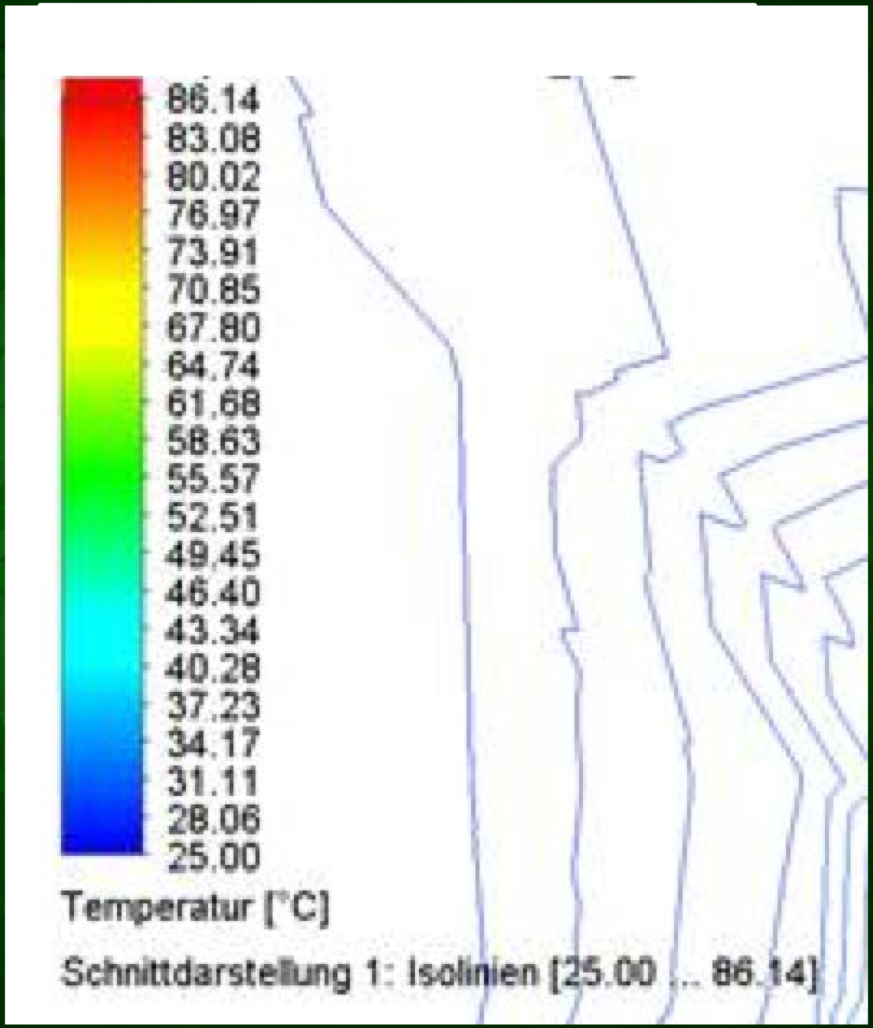
Static and Dynamic Uniformity

- Static: Sensors placed on the chuck and monitored
- Dynamic: Touchdown on sensor – stepping – monitoring profile of DUT

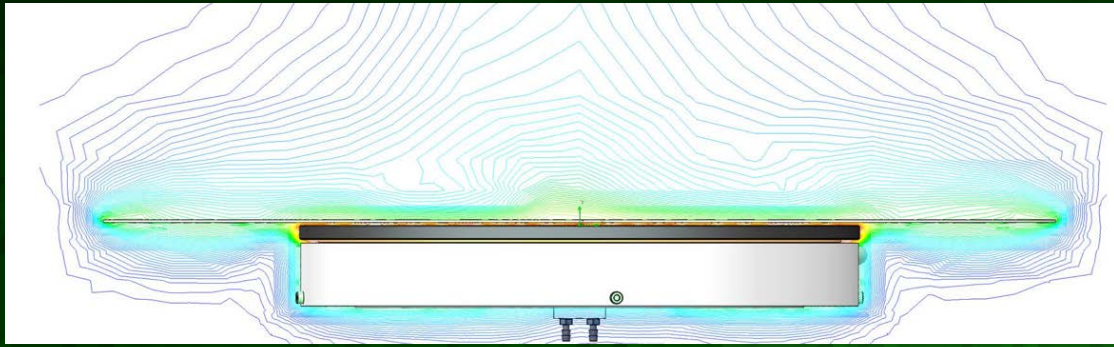
		Measuring Points											
		1	2	3	4	5	6	7	8	9	Max	Min	Total
35°C	Static	35.110	35.128	35.105	35.040	35.050	35.043	35.087	35.098	35.102	35.128	35.040	0.088
	Dynamic	35.116	35.118	35.108	35.024	35.041	35.072	35.091	35.095	35.106	35.118	35.024	0.094
	Variation	-0.006	0.010	-0.003	0.016	0.009	-0.029	-0.004	0.003	-0.004	0.016	-0.029	0.045
50°C	Static	50.092	50.104	50.106	50.052	50.073	50.038	50.050	50.083	50.065	50.106	50.038	0.068
	Dynamic	50.070	50.112	50.103	50.040	50.069	50.050	50.040	50.081	50.088	50.112	50.040	0.072
	Variation	0.022	-0.008	0.003	0.012	0.004	-0.012	0.010	0.002	-0.023	0.022	-0.023	0.045
70°C	Static	70.065	70.047	70.048	69.993	70.049	69.947	69.971	70.045	69.999	70.065	69.947	0.118
	Dynamic	70.050	70.105	70.102	69.984	70.035	69.978	69.970	70.070	70.050	70.105	69.970	0.135
	Variation	0.015	-0.058	-0.054	0.009	0.014	-0.031	0.001	-0.025	-0.051	0.015	-0.058	0.073

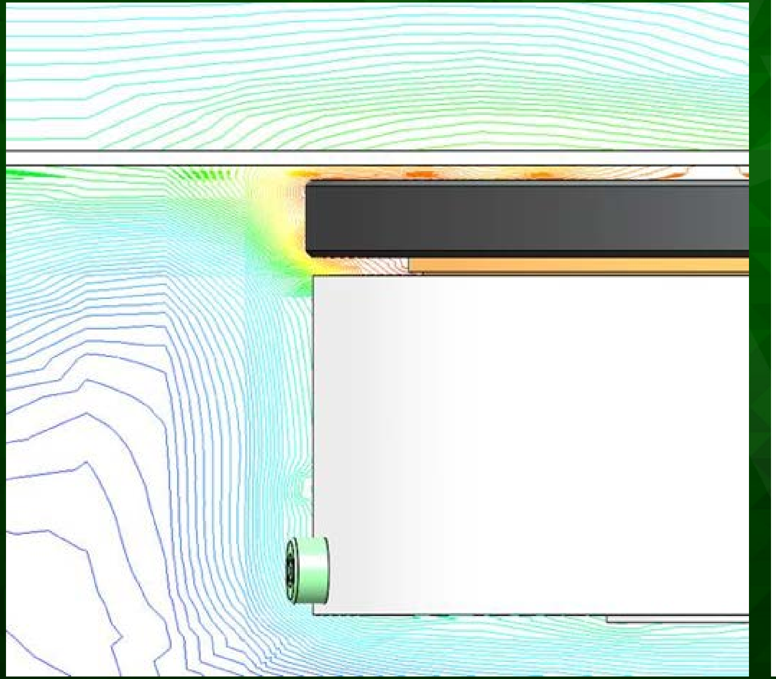
Simulation of Shielding (Without Shield)

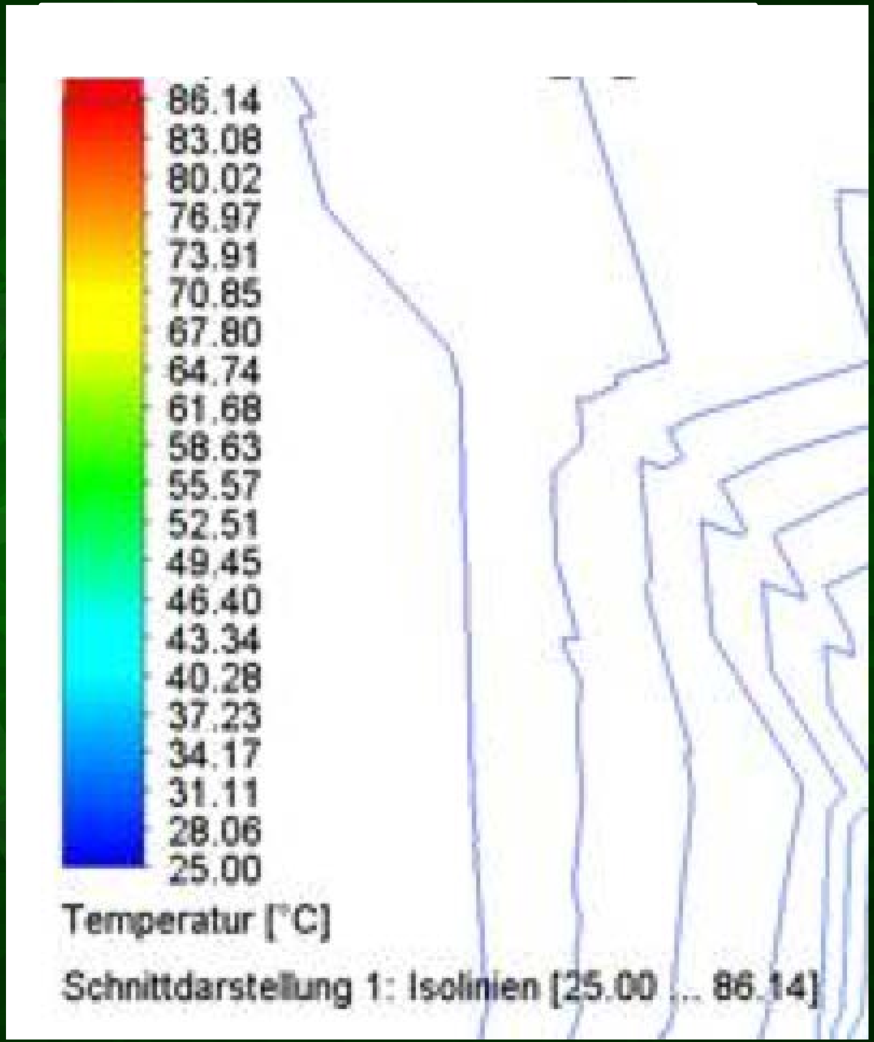




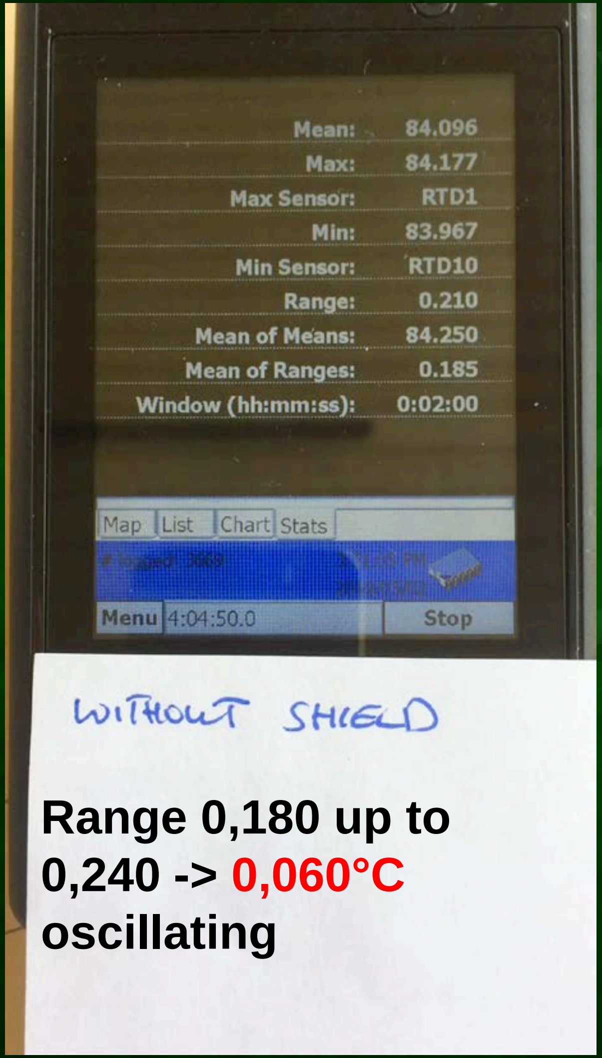
Simulation of Shielding (With Shield)



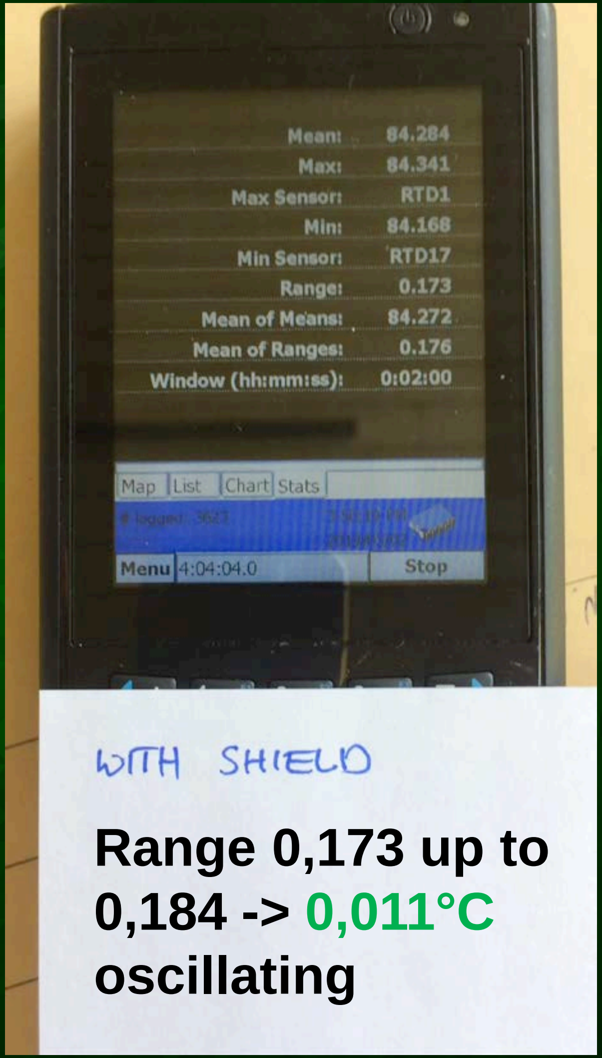




Influence of Shielding



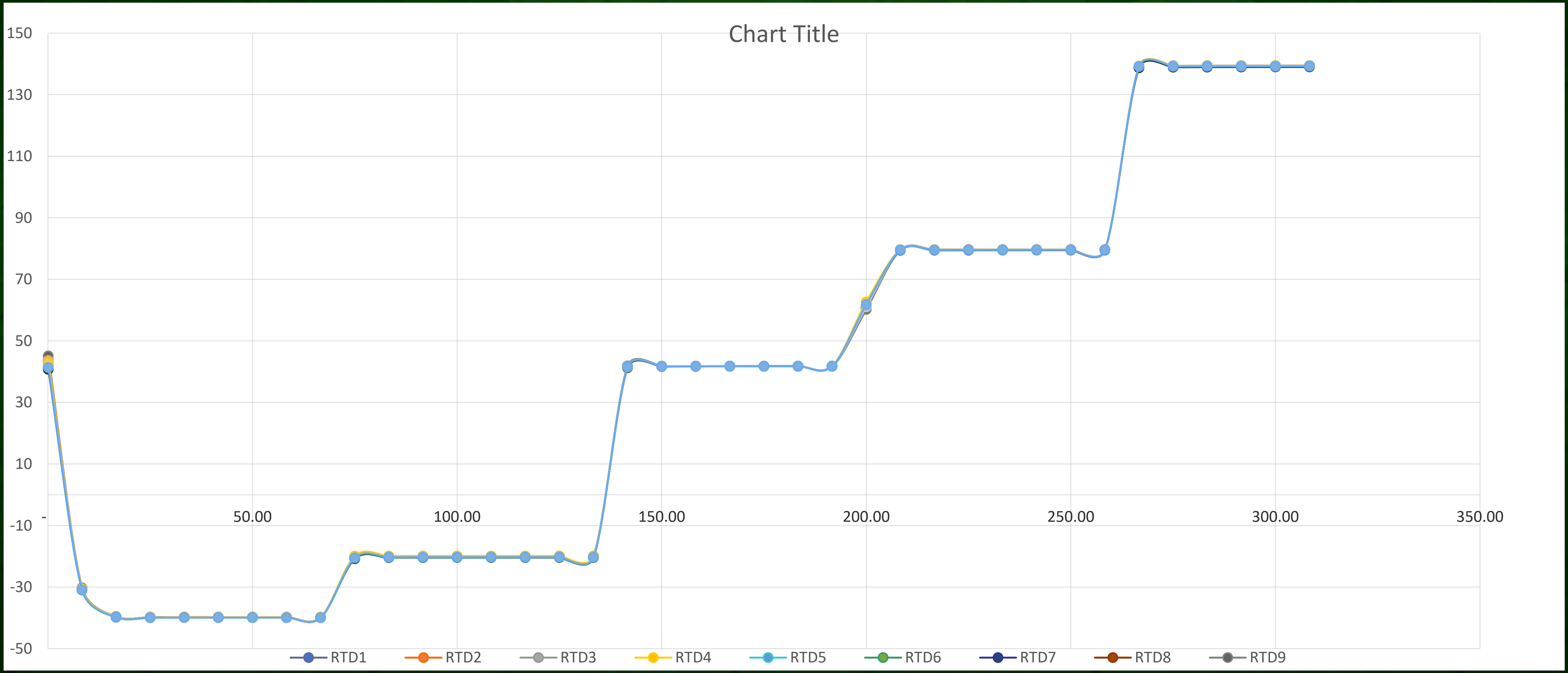
Range 0,180 up to 0,240 -> 0,060°C oscillating



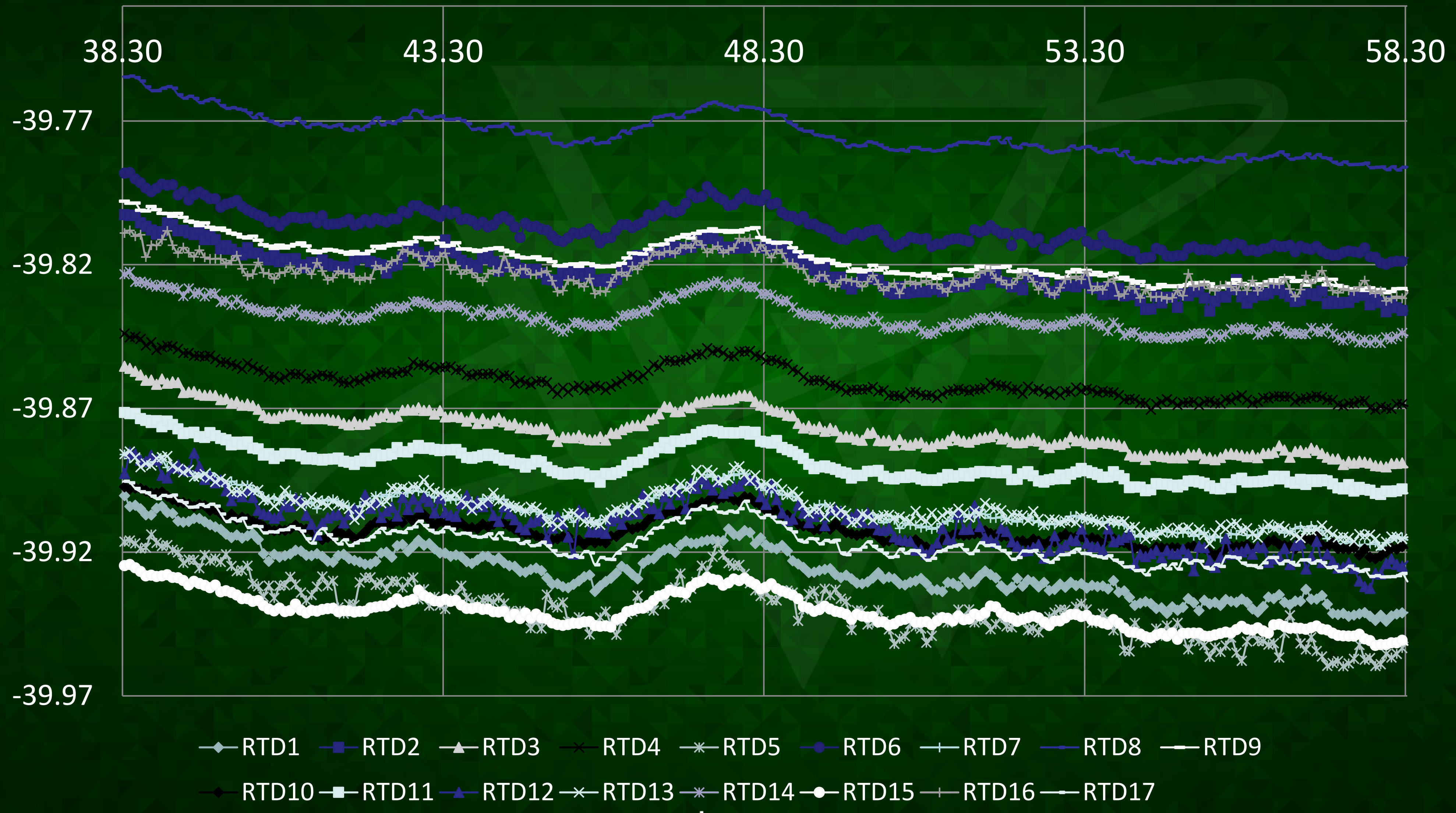
Range 0,173 up to 0,184 -> 0,011°C oscillating

Uniformity in Reality

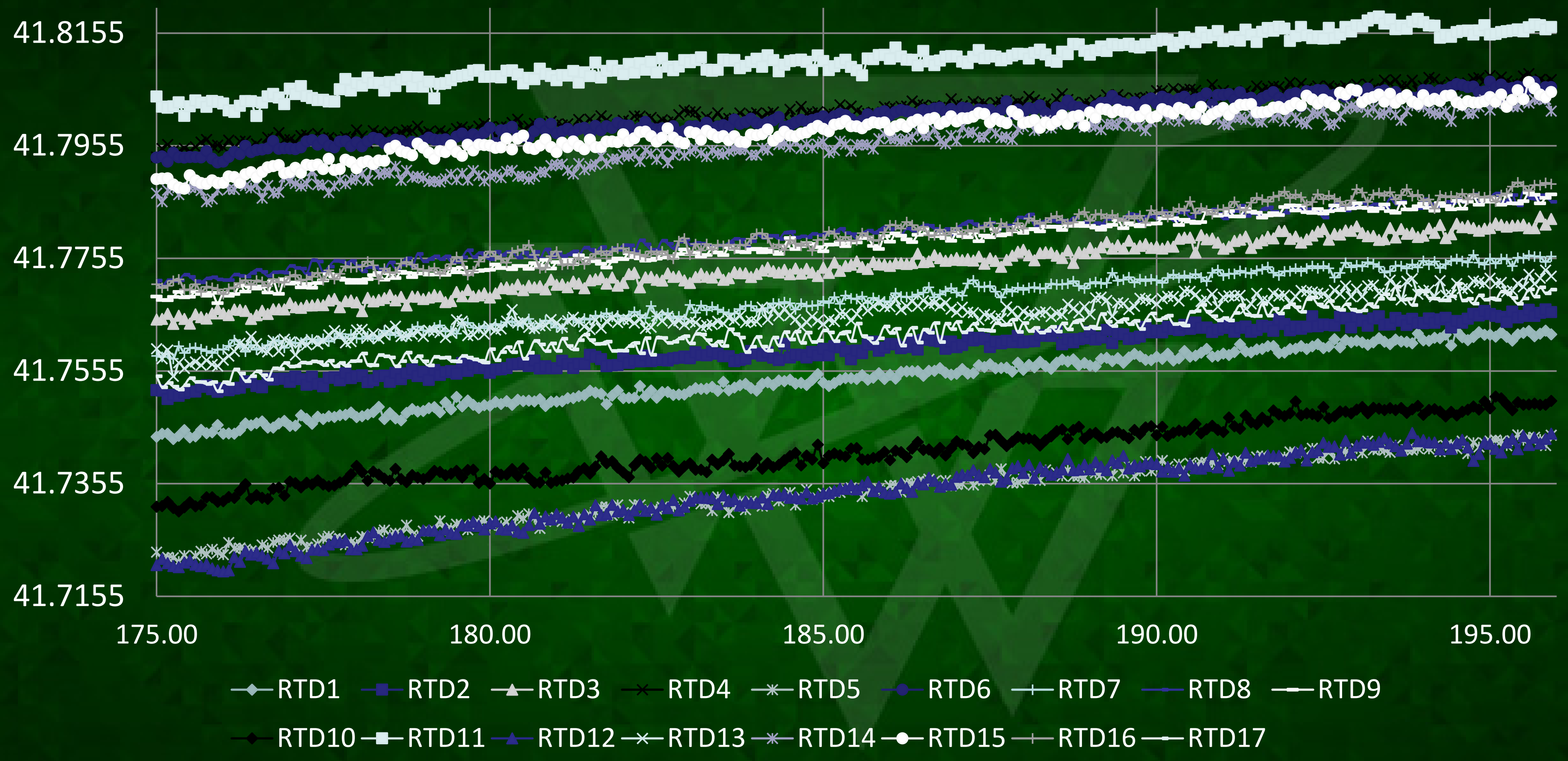
Measurement with SenseArray Wafer shielded environment



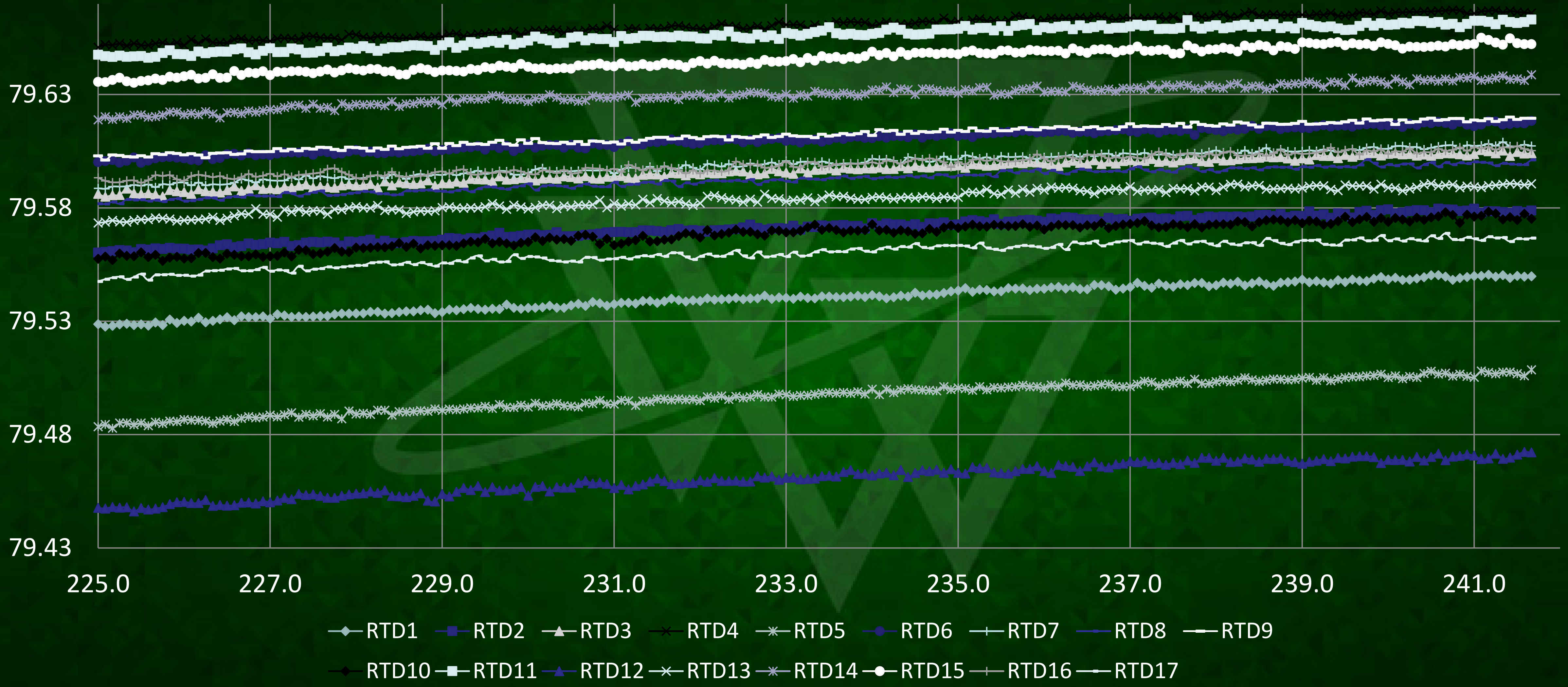
Uniformity Detail at - 40°C



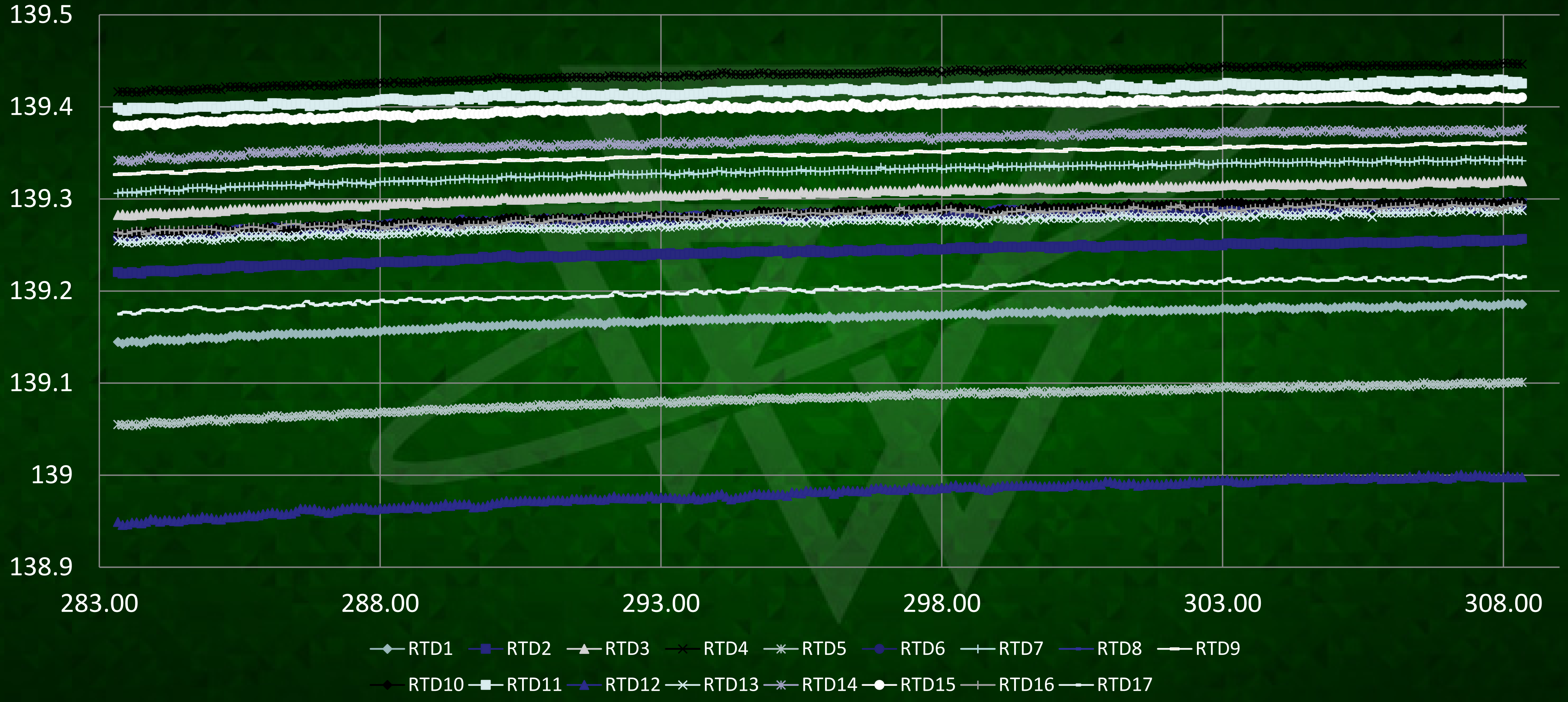
Uniformity Detail at 42°C



Uniformity Detail at 80°C



Uniformity Detail at 140°C



Repeatability

- Chuck surface uniformity : DUT to DUT accuracy
- Power induction: DUT to DUT accuracy
- Differences in thermal contact : DUT to DUT accuracy
- Particles below wafer : Wafer to Wafer accuracy
- Test at multiple temperatures, chuck system needs to be back at exactly the same temperature: Lot to Lot accuracy

Reachable Accuracies of Reference Thermometers

- Calibrated Single sensor instruments best in class: 0,5mK ± 0,1mK GUM at k=2
- Calibrated Single sensor instruments typical: 2mK up to 70mK
- Special calibrated singe sensor instruments: 2mK (up to +30°C) up to 45mK (up to +400°C)
- Wafer embedded multiple Sensors, wired: 100mK, 60mK Sensor to Sensor
- Wafer embedded multiple Sensors, wireless: 200mK, including Sensor to Sensor
- Thermal camera:

100mK calibrated to correct emission (!)

Calibration Strategies (1)

Multiple Sensors embedded in a wafer

+

- Easy to use
- Tool can be calibrated with no prober down time (second tool needed)
- High accuracy
- Fast measurement results

−

- Adding sensor to sensor accuracy
- Tool is expensive
- Difficult to calibrate

Calibration Strategies (2)

Single Sensor Surface Thermometer

+

- Easy to use
- Very accurate to calibrate
- Highest instrument accuracy
- No sensor to sensor variation
- Cost effective

−

- Adding application uncertainty
- Time consuming data collection

Calibration Strategies (3)

Single Sensor Insertion Thermometer

+

- Less error in application
- Very accurate
- Shows closest value of chuck temperature as possible
- Highest instrument accuracy
- No sensor to sensor error
- Cost effective

−

- Limited uniformity information
- Maybe complicated to implement (constrains around the chuck in prober)
- Each additional hole in chuck lowers uniformity performance

Calibration Strategies (4)

Contactless (IR camera)

+

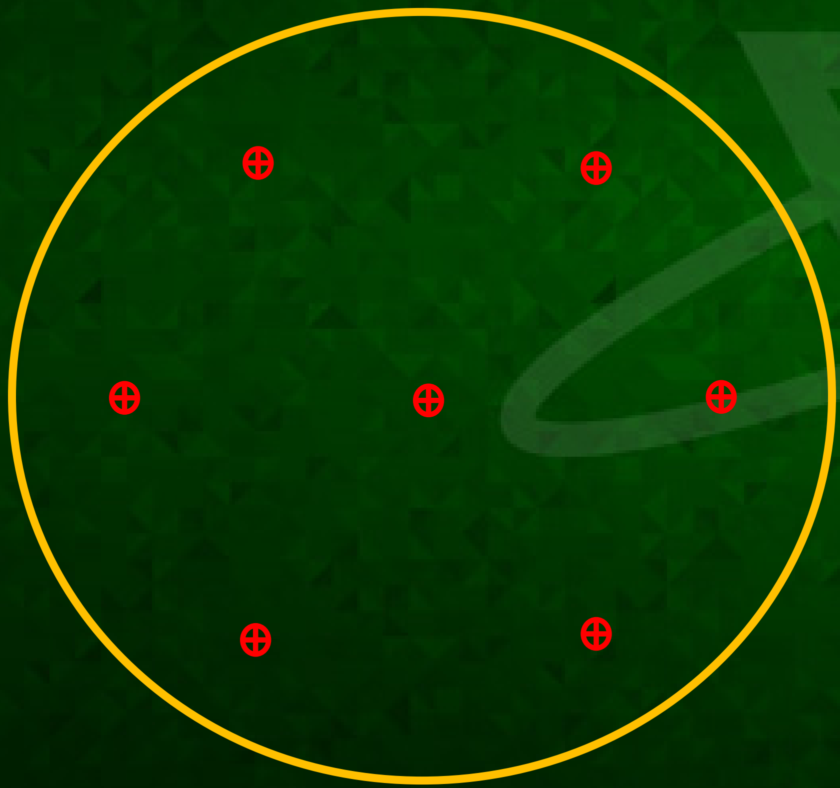
- Measuring surface
  - not sensor!
- Fast results

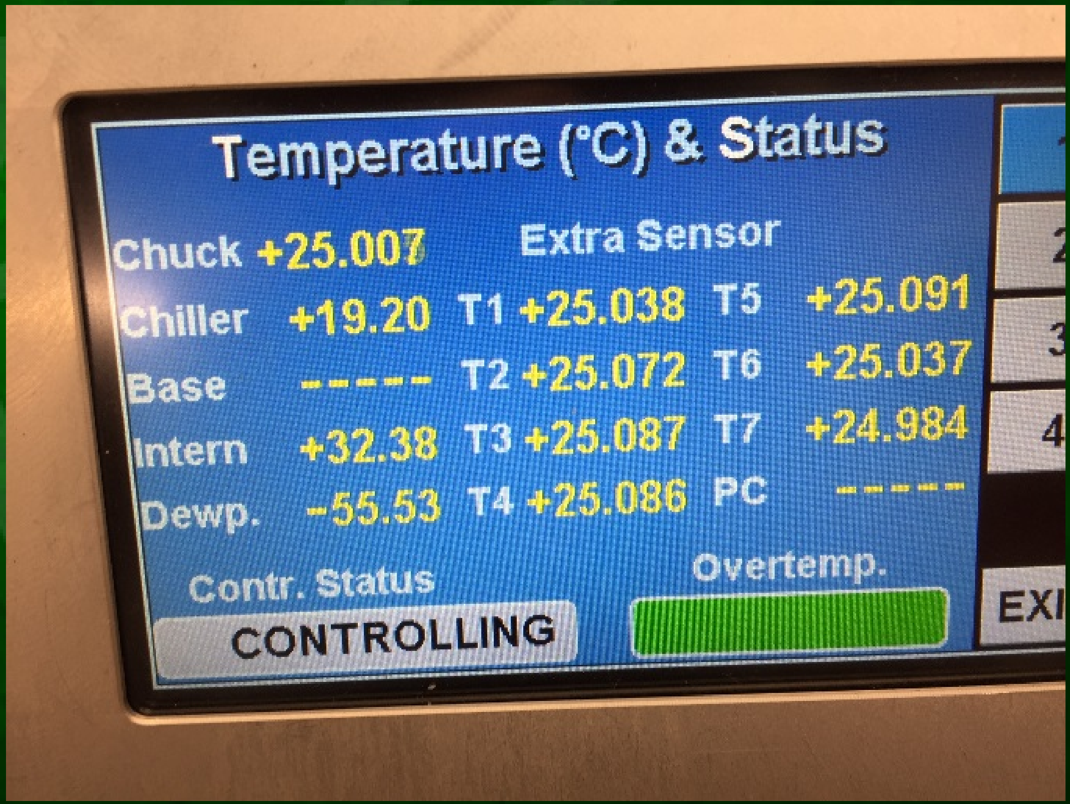
−

- Difficult to calibrate
- Very hard to use in accuracies below 1°C
- Accurate tool very expensive

Monitoring Concepts (1)

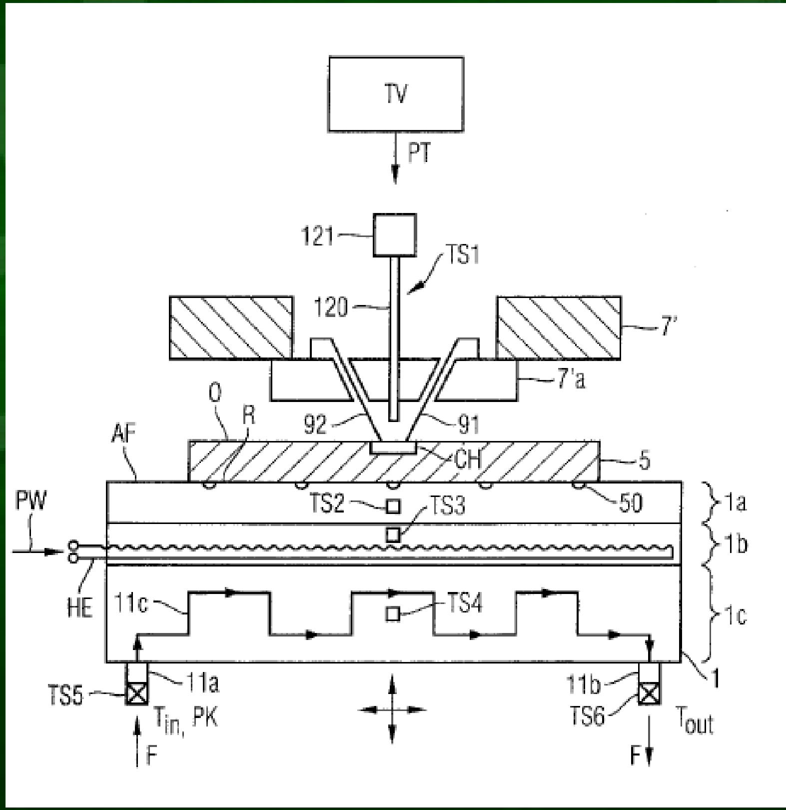
- Multiple sensors in chuck
- Supports area specific accuracy





Monitoring Concepts (2)

- In situ IR monitoring
- Supports real time temperature measurement of a DUT under load



Now, How Accurate Can You Be?

- During test, typically, the chuck's temperature is measured, not the device's temperature
- Exceptions:
  - Sensor in device
  - In situ IR measurement
- Both exceptions far from <1°C accuracy
- <u>You always measure the temperature of the sensor – not the temperature of the device itself</u>
- How accurate can a sensor inside the chuck be calibrated?
- How accurate is it to measure the chuck's temperature?
  - What is the difference between the chuck's temperature and the wafer's temperature?

Thermal Accuracy Budget

- +35°C Reachable Accuracy without Calibration
- Example:

Boundary Conditions

Prober Inside Temperature (°C)	30
thermal resistance between sensor and chuck (°C)	0,001
thermal resistance between sensor and chuck (°C)	0,01
Needle Temperature (°C)	30
Influence of Needle (°C)	0,01

	Absolute Accuracy on Wafer		
	°C	°C	
Calculation	35	35	
Display	-0,02	0,02	
Sensor	-0,0475	0.0475	
Sensor to Chuck	-0,005	-0,005	
Controlling	-0,03	0,03	
Temperature Uniformity	-0,1	0,1	
Wafer to Chuck	-0,05	-0,05	
Needles	-0,05	-0,05	
Result	MIN	MAX	Range
Reachable Accuracy	34,698	35,093	
Deviation	-0,303	0,093	0,396
Compensated	34,803	35,198	0,395

Thermal Accuracy Budget

- +35°C Reachable Accuracy with Calibration
- Example:

Boundary Conditions

Prober Inside Temperature (°C)	30
thermal resistance between sensor and chuck (°C)	0,001
thermal resistance between sensor and chuck (°C)	0,01
Needle Temperature (°C)	30
Influence of Needle (°C)	0,01

	Absolute Accuracy on Wafer	
	°C	°C
Calculation	35	35
Display	0	0
Sensor	0	0
Sensor to Chuck	0	0
Controlling	-0,03	0,03
Temperature Uniformity	-0,1	0,1
Wafer to Chuck	0	0
Needles	-0,05	-0,05

Result	MIN	MAX	Range
Reachable Accuracy	34,820	35,080	
Deviation	-0,180	0,080	0,260
Compensated	34,87	35,13	0,26

Thermal Accuracy Budget

- +200°C Reachable Accuracy without Calibration
- Example:

Boundary Conditions

Prober Inside Temperature (°C)	30
thermal resistance between sensor and chuck (°C)	0,001
thermal resistance between sensor and chuck (°C)	0,01
Needle Temperature (°C)	30
Influence of Needle (°C)	0,01

	Absolute Accuracy on Wafer	
	°C	**°C**
Calculation	200	200
Display	-0,02	0,02
Sensor	-0,13	0,13
Sensor to Chuck	-0,17	-0,17
Controlling	-0,03	0,03
Temperature Uniformity	-0,5	0,5
Wafer to Chuck	-1,7	-1,7
Needles	-1,7	-1,7

Result	MIN	MAX	Range
Reachable Accuracy	195,750	197,110	
Deviation	-4,250	-2,890	1,360
Compensated	199,32	200,68	1,36

Thermal Accuracy Budget

- +35°C Reachable Accuracy without Calibration
- Example:

Boundary Conditions

Prober Inside Temperature (°C)	30
thermal resistance between sensor and chuck (°C)	0,001
thermal resistance between sensor and chuck (°C)	0,01
Needle Temperature (°C)	30
Influence of Needle (°C)	0,01

	Absolute Accuracy on Wafer	
	°C	**°C**
Calculation	200	200
Display	0	0
Sensor	0	0
Sensor to Chuck	0	0
Controlling	-0,03	0,03
Temperature Uniformity	-0,5	0,5
Wafer to Chuck	0	0
Needles	-1,7	-1,7

Result	MIN	MAX	Range
Reachable Accuracy	197,770	198,830	
Deviation	-2,230	-1,170	1,060
Compensated	199,47	200,53	1,06

Conclusions and Outlook

- The demand of going below 1°C accuracy in Wafer Test exists
- Data collected on multiple systems within a year shows that very tight tolerance down to ±0.1°C can be reached in a certain temperature range(0°C to 85°C)
- Chuck temperature uniformity and long term control stability are available
- Additional tools are needed to maintain this tight accuracy in production environment
- The high accuracy thermal wafer probing has arrived in wafer probing
- There is still work to do in the chuck at high and low temperature end
- There is work to do on the calibration method

Credits

- Miguel A. Resendiz (ERS)
- Bengt Haunerland (ERS)
- Patrick Mabinda (ERS)

Thank You

Q&A