A Novel Method (or two) of Accredited*, High Accuracy Temperature Measurement on a Thermal Wafer Chuck in Support of IATF 16949

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Outline

- Background
- Calibration of temperature sensors
- Hybrid IR Method
- Result / Conclusion
- Lab2GO
- Summary
- Continuing work

About Harald Ibele

- 15+ years industry experience
- 2+ years Quality Manager: ISO17025 Temperature Calibration Laboratory
- USA, Asia, and Europe
- Precise thermal chucks; temperature measurement and customer requirements
- Long product development and experience in temperature
- Now independent
- TEMPERATURE

About Sigma Sensors

- **MOBILE Temperature Calibration Laboratories**
- **Driven by customer demand / sensor and automotive test requirements**
- **ISO17025:2017 accreditation pending, expected date Q3/19**
- **Calibration and characterization of:**
  - Sensors, meters, measuring systems with datalogger
  - Complete surface temperature measurement and characterization
  - Drop probes and temperature wafers
- **Supplier and Integrator of K2 temperature sensors for calibration fixtures and measurement devices for wafertest and other thermal test related products**

Novelties

- Each sensor / surface fully characterized
- IATF 16949 / ISO 17025, traceability ITS90
- Hybrid IR method
- LAB2GO

Automotive / Sensors Compliance / Requirements

- Wide temperature range (-55°C to 200/300°C in Wafer Test / Laboratory)
- IATF16949 /ISO17025: temperature certified traceable to ITS90
- Tight Chuck specifications and Accurate Temperature Measurement
- Precision (resolution/repeatability) is easy, Accuracy (ITS90) is not

Many Meters: Many Results

- **Precision/Resolution:** refinement in measurement, calculation, or specification
- **Accuracy:** the degree to which the result of a measurement, calculation, or specification conforms to the correct value or a standard.

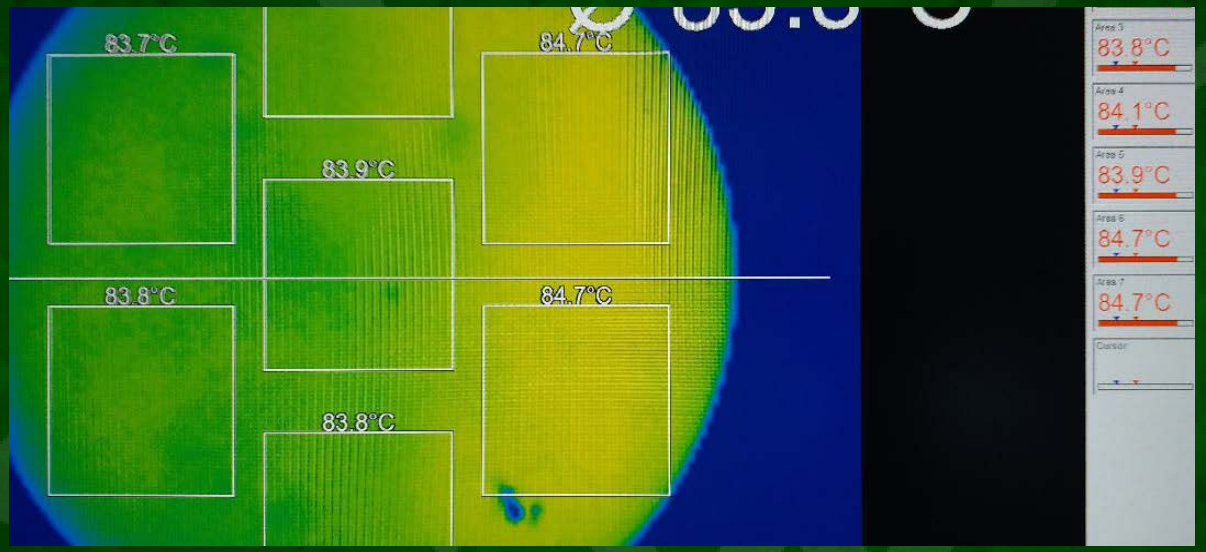
Common Temperature Measurement Methods

Measurement Method	Notes	Pros	Cons
Drop probe / handle probe	Mostly thermocouples	Broadly available, large temp range	High tolerances, inaccurate
Sensor applied directly to chuck	Heat conducting paste	Reliable reference measurement within specified tolerance	Messy, introduces contaminants, possibility of subjective operator bias
Temperature wafer	Mostly PT1000	High resolution, easy to use, repeatable results	Investment Intensive, Fragile, tolerance spec 0°C only

Common Sensor Types

Sensor Types	Notes	Pros	Cons
Thermocouples (mV)	J/K most common **T smallest tolerance**	Rugged Large Temp. Range	**Large off shelf tolerance errors**
PRT (**PT100/PT1000**) (resistance)	**De-Facto Accuracy Standard**	Long term stable, **Predictable** behavior, **Standards available**	**Tolerance specified at 0C only**
NTC Thermistors (resistance)	**Most accurate**	Highest Resolution, Accuracy to ±0.001K	Limited range 0°C-100°C
Infrared (IR)	Most convenient	Take picture Easy to use	**many variables**

But how accurate is IR even under ideal circumstances?



Chuck uniformity and planarity – regulating stability – conductive heat transfer chuck/wafer interface, wafer – sensor accuracy- reflectivity – transmissivity – emissivity – convective heat transfer – environment – XYZ motion – fan motors…

Background

Prober:

- Setpoint ±1°C
- Resolution ±0.1°C

Chuck:

- Setpoint 0.1°C
- Resolution 0.01°C
- Uniformity ±0.1°C (to >1C)
- Stability ±0.1°C (+)
- Display Accuracy

- Test temperature -55°C to +200°C
- Test band > ±2-4°C

- Some uniformity requirements <0.1°C
- Some requirements <0.05°C accuracy
- Generally ±0.5-1.0°C sufficient?

- Depends on chuck system and application
- Accuracy of measurement?

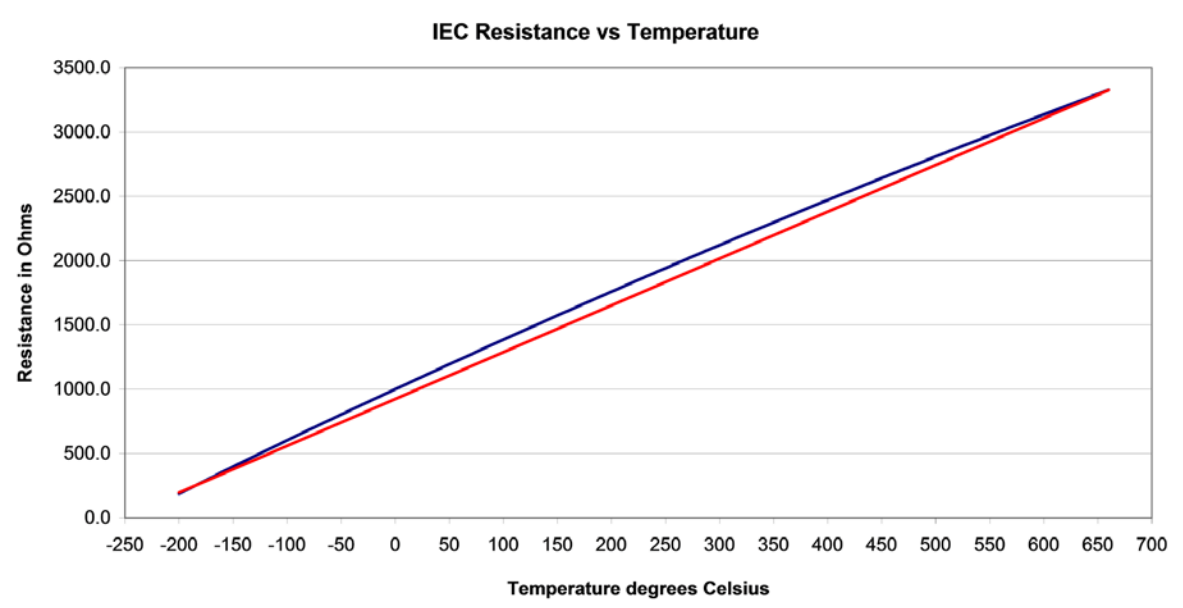
Sensor Calibration

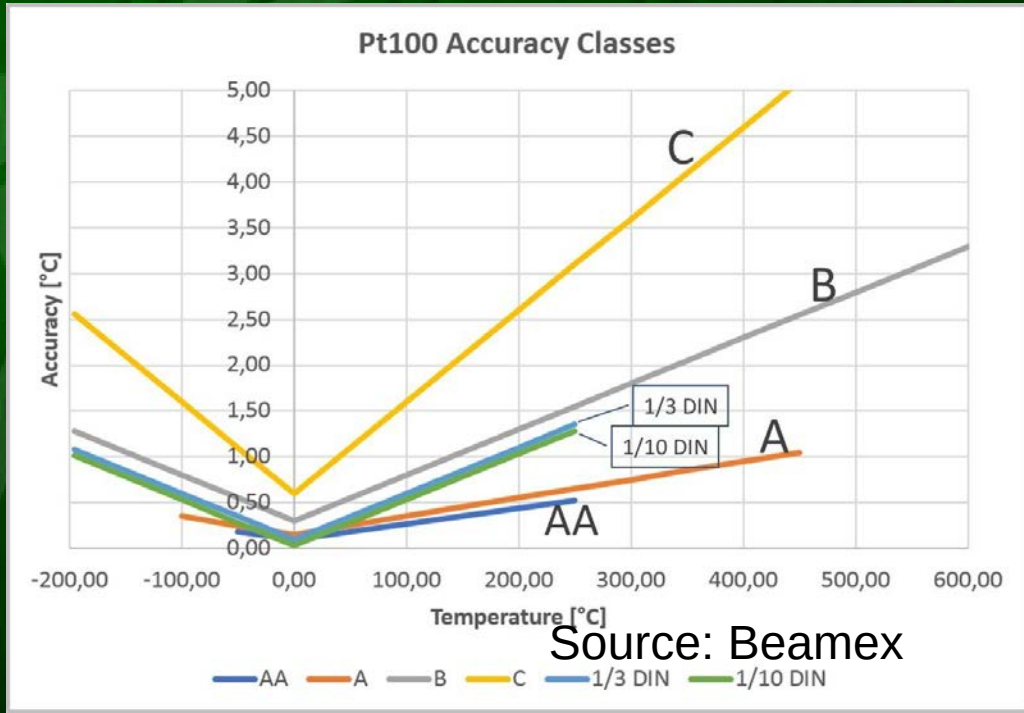
- Primary and Secondary Reference Standards
- Temperature Sources -45°C to +425°C
- Best Measurement Uncertainty <20mK
- Automated Documenting Calibration, 1/1000 K resolution
- Direct comparison measurement to ISO17025 calibrated reference standard

PT100 Accuracy Specification

Accuracy class	Accuracy (Tolerance) Value
AA	± (0.1 °C + 0.17 % of temperature)
A	± (0.15 °C + 0.2 %)
B	± (0.3 °C + 0.5 %)
C	± (0.6 °C + 1 %)

Accuracy class	Accuracy (Tolerance) Value
1/3 DIN	± (0.1 °C + 0.5 %)
1/10 DIN	± (0.03 °C + 0.5 %)



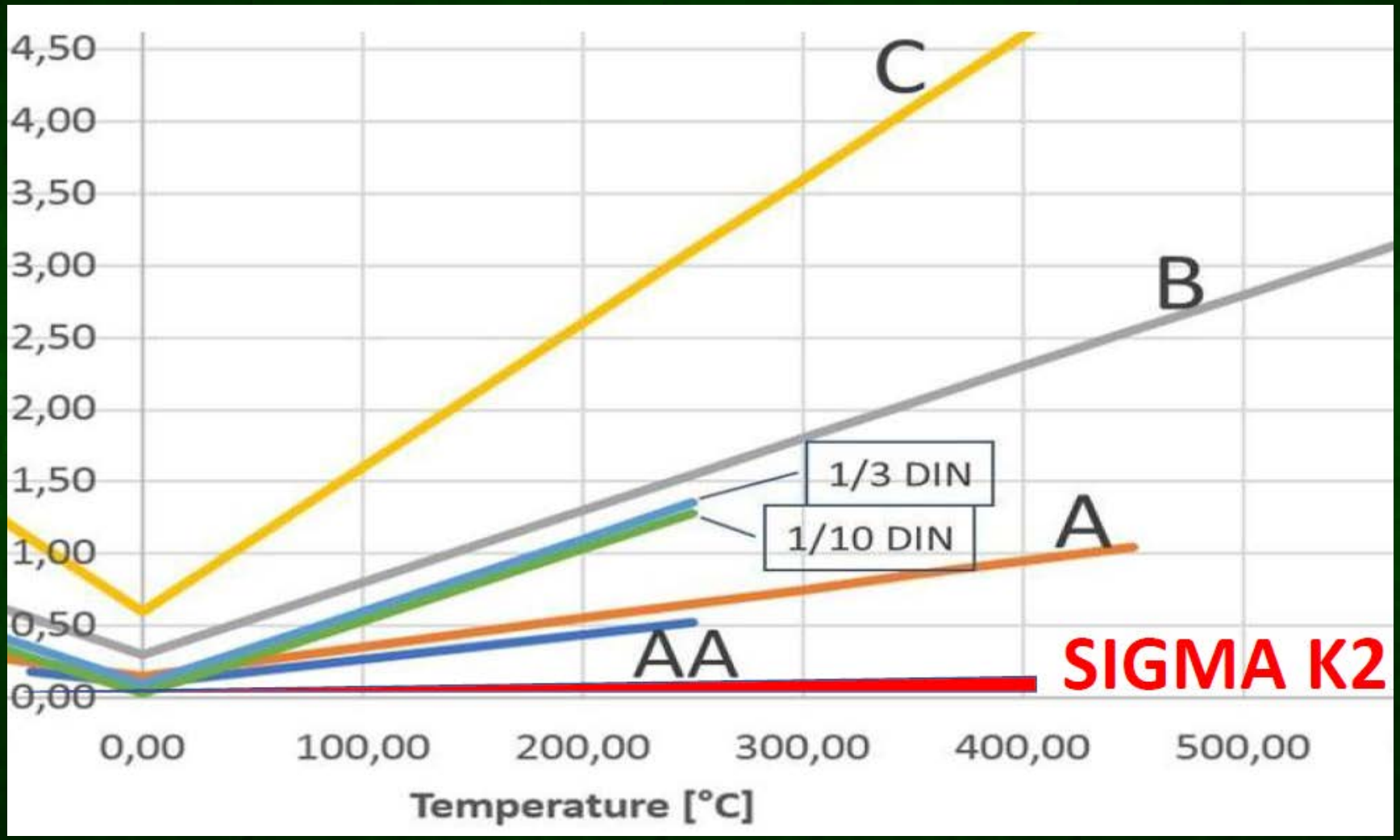


Source: Beamex

Characterization

- **Sensors embedded in temperature source,**
- **Multiple set points -45°C to +425°C**
- **Characterized same as a reference thermometer**
- **CVD and ITS90 coefficients, alpha and beta values**
- **Multiply for expanded uncertainty, k=2, K2**
  - -45°C to 0 ° C ± 0.02K
  - 0°C to 100°C ± 0.03K
  - 100C to 230C ± 0.04K
  - 230C to 425C ± 0.05K
  - **Traceable to ITS90**

Sigma K2 Accuracy vs PT100 Tolerances

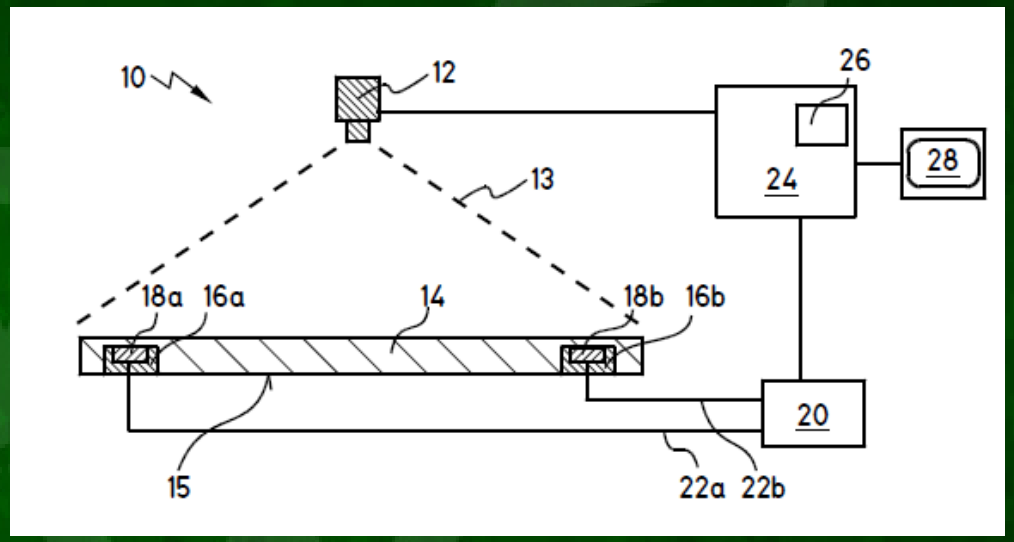


K2 Sensor/System Integration

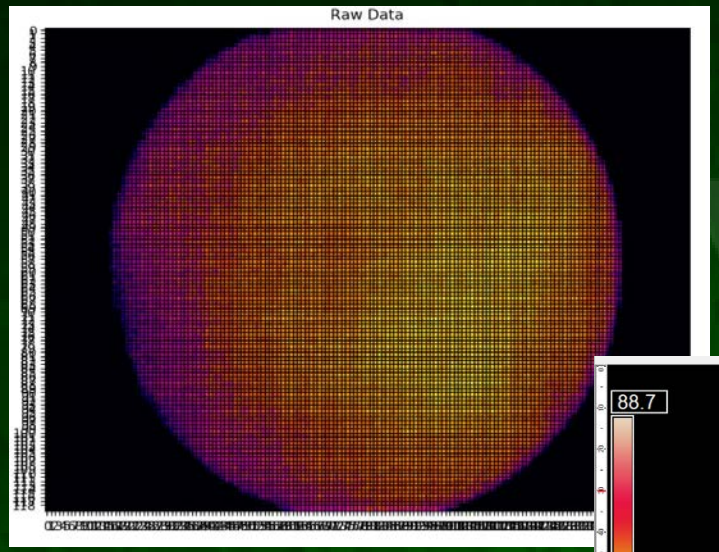
- K2: Drop probe or wafer-integrated
- TC, RTD + or – TCE, depending on Temperature range, resolution and accuracy required
- 1-8 channel meter / datalogger / calibration fixture
- Rugged - mobile use
- ITS90 Accuracy < ± 0.05K

Hybrid IR Method, patent pending

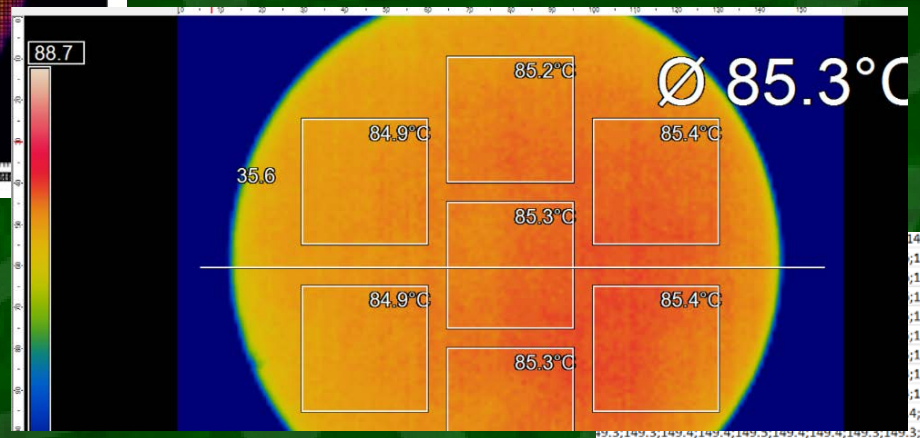
- Sensor-Meter, characterized
- Accuracy <±0.05K
- Resolution: 0.001K
- Wafer, customized
- IR Camera
- Resolution <0.1K
- Many variables



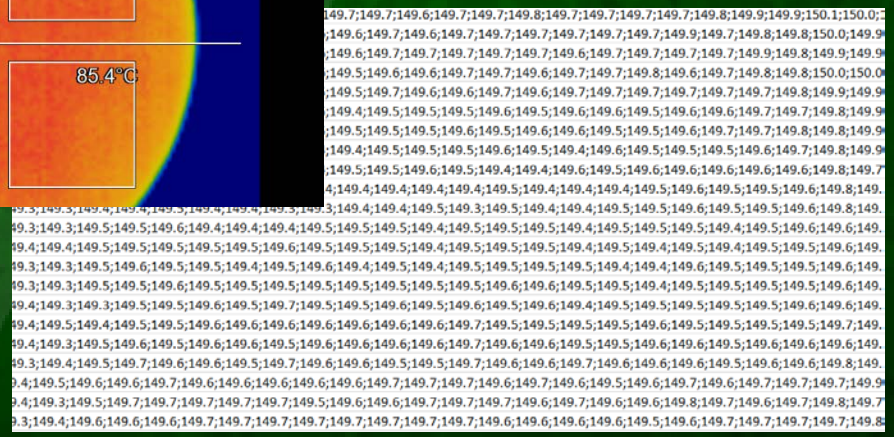
- Characterized sensor(s) embedded
- Reference and IR measurements
- Data overlay
- Graphic and XY Data output



20,000 Measuring Points
T Ref >0.05K ITS90 k=2



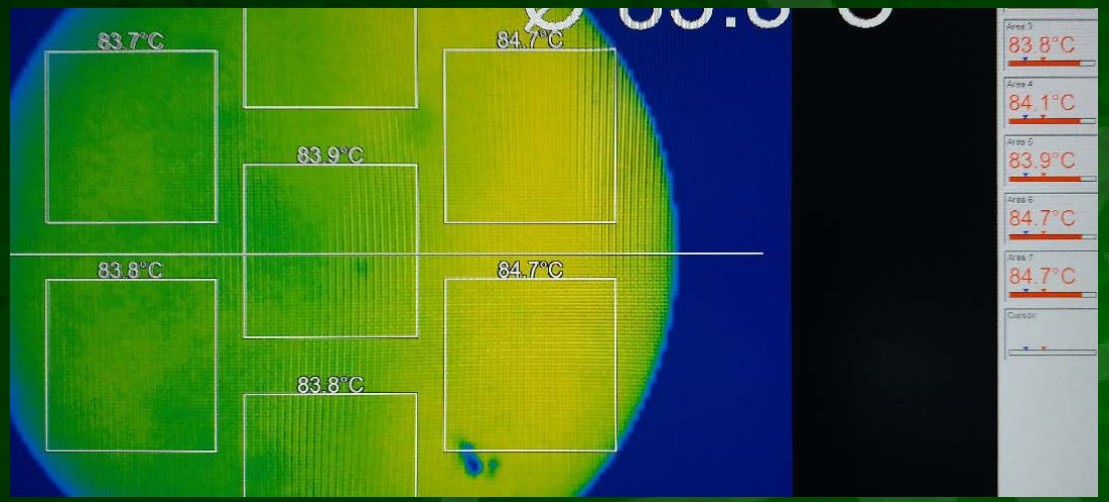
Raw Data
Normalized



By area or pixel
>0.5K ITS90 k=2

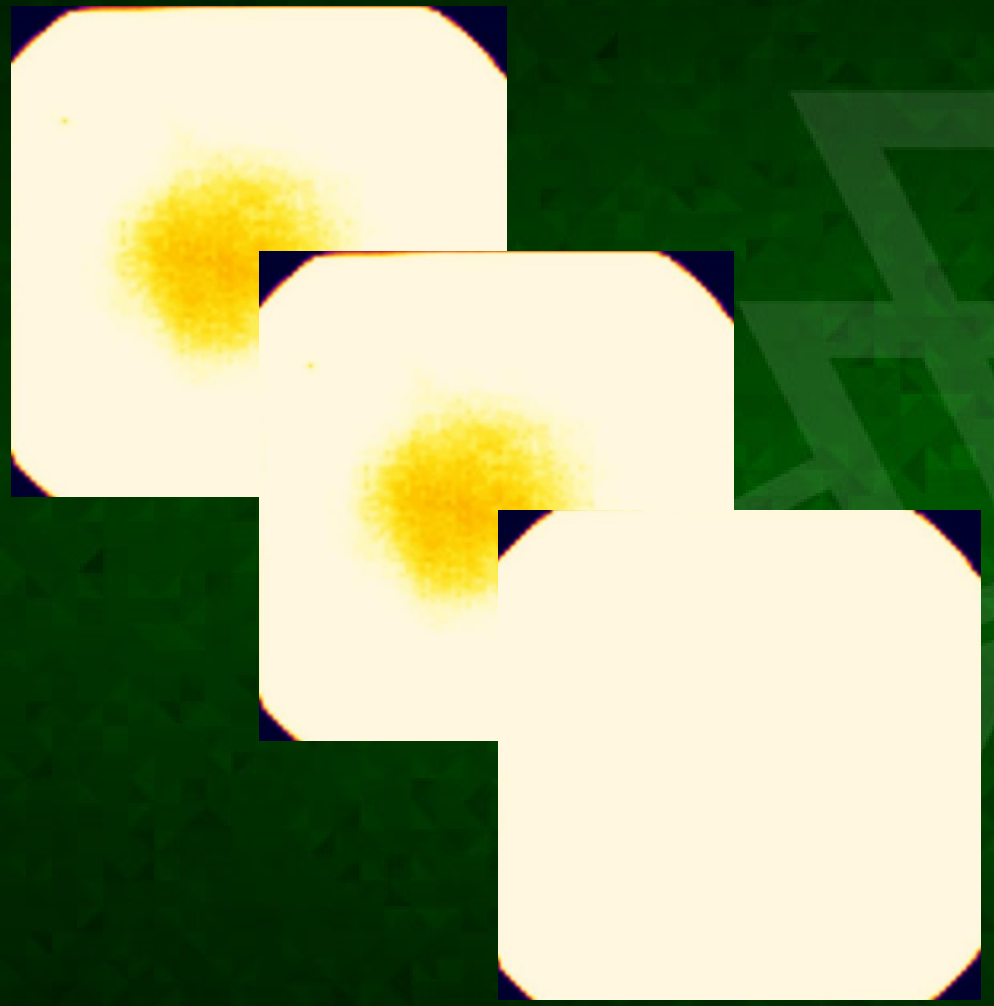
Data set X / Y temperature
Accuracy <1K ✅ <0.5K ✅ <0.2K possible

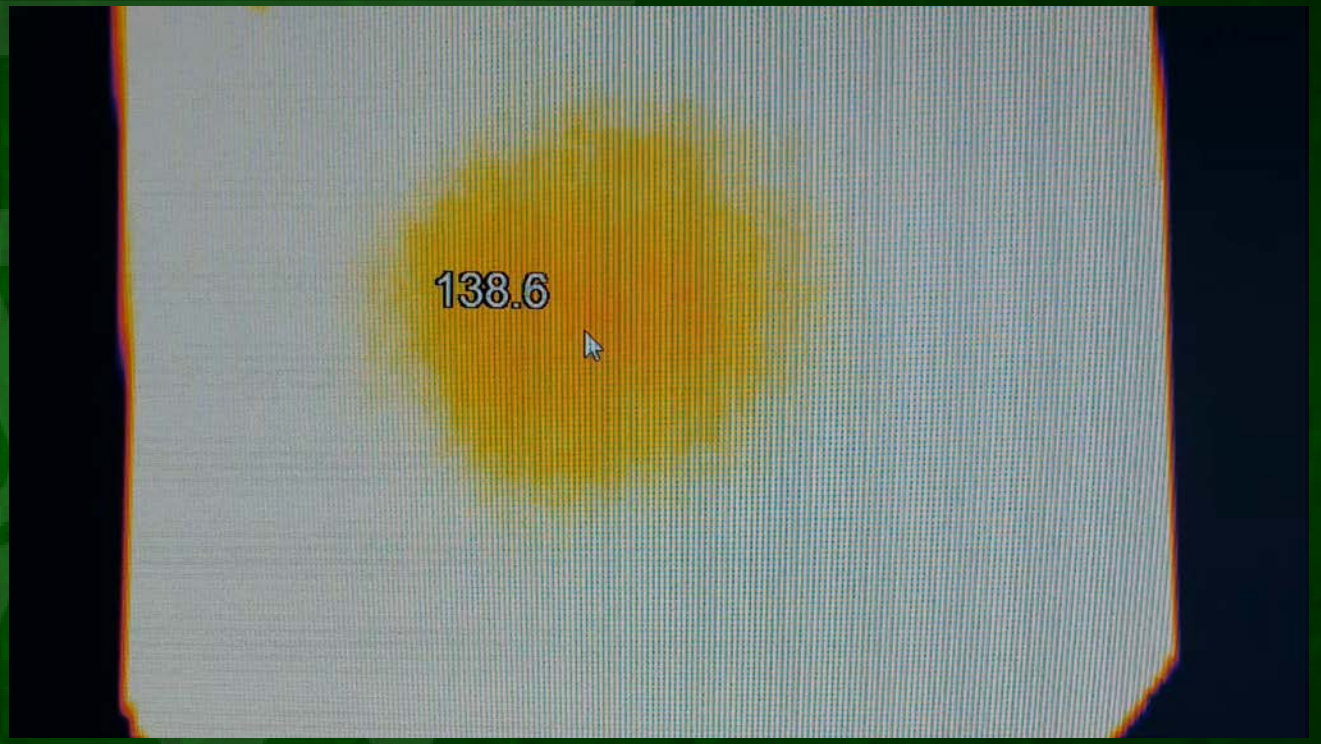
Back to slide 10 influences



- Uniformity, planarity and regulating stability of chuck
- Measurement uncertainty of camera and sensors
- Surface temperature measurement of wafer, not embedded or transition zone
- Environmental factors IR
- To a certain extent showing the influence of the environment

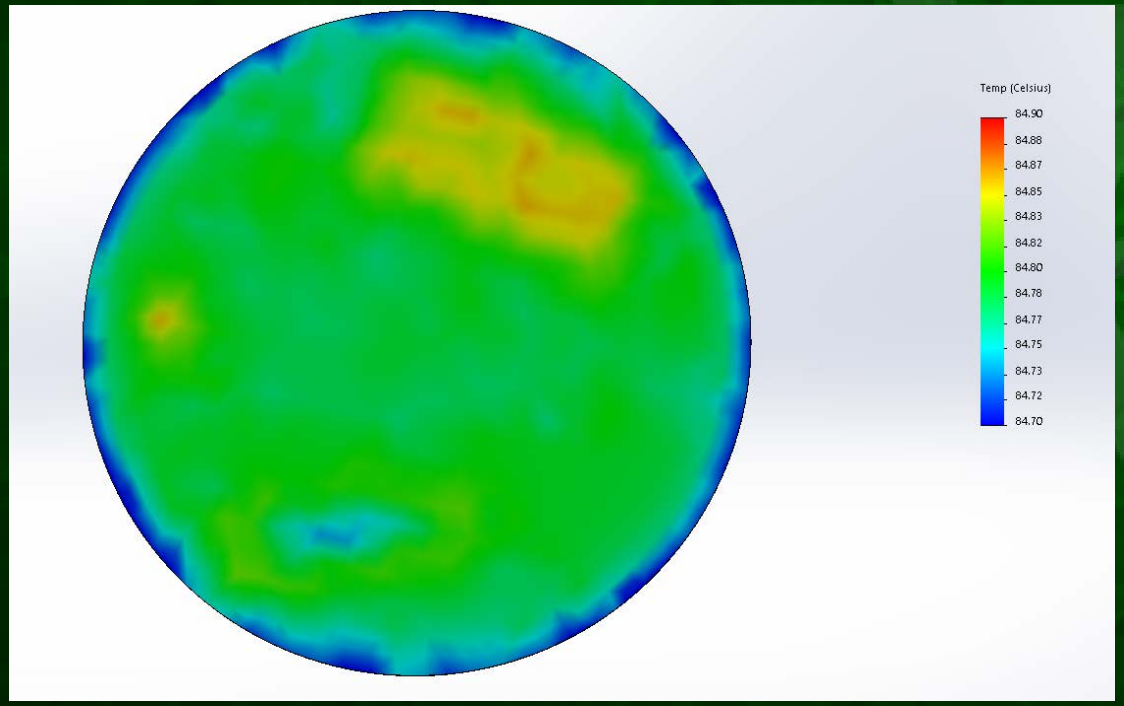
Surface Contact and Effect of Vacuum



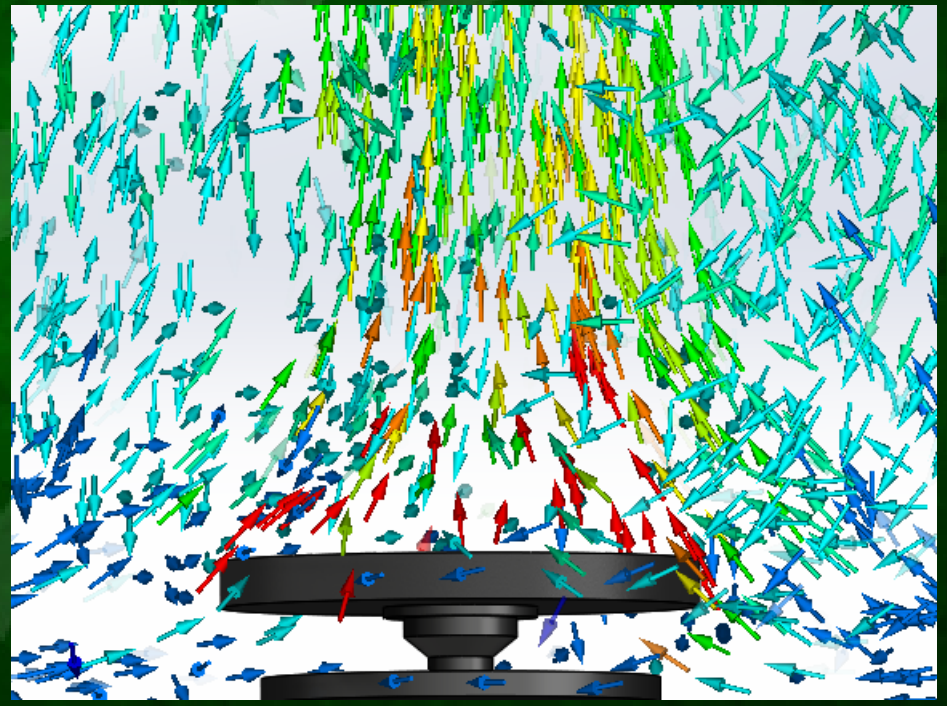


Convective Dynamics

Heat in through chuck/wafer interface

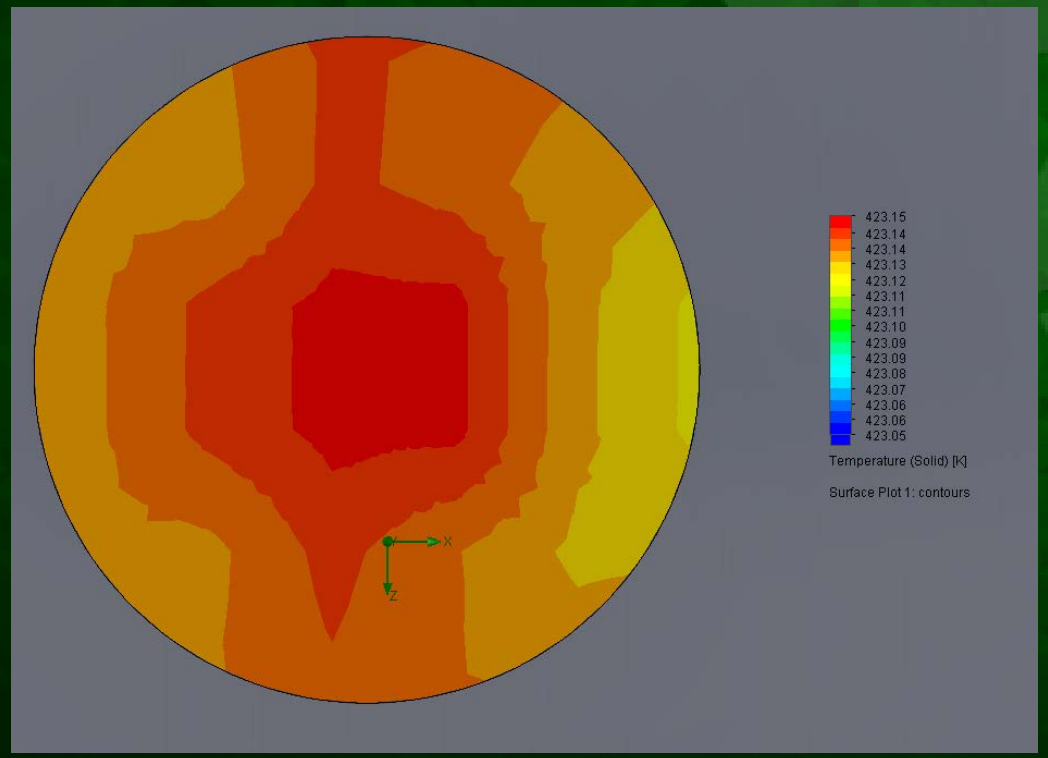


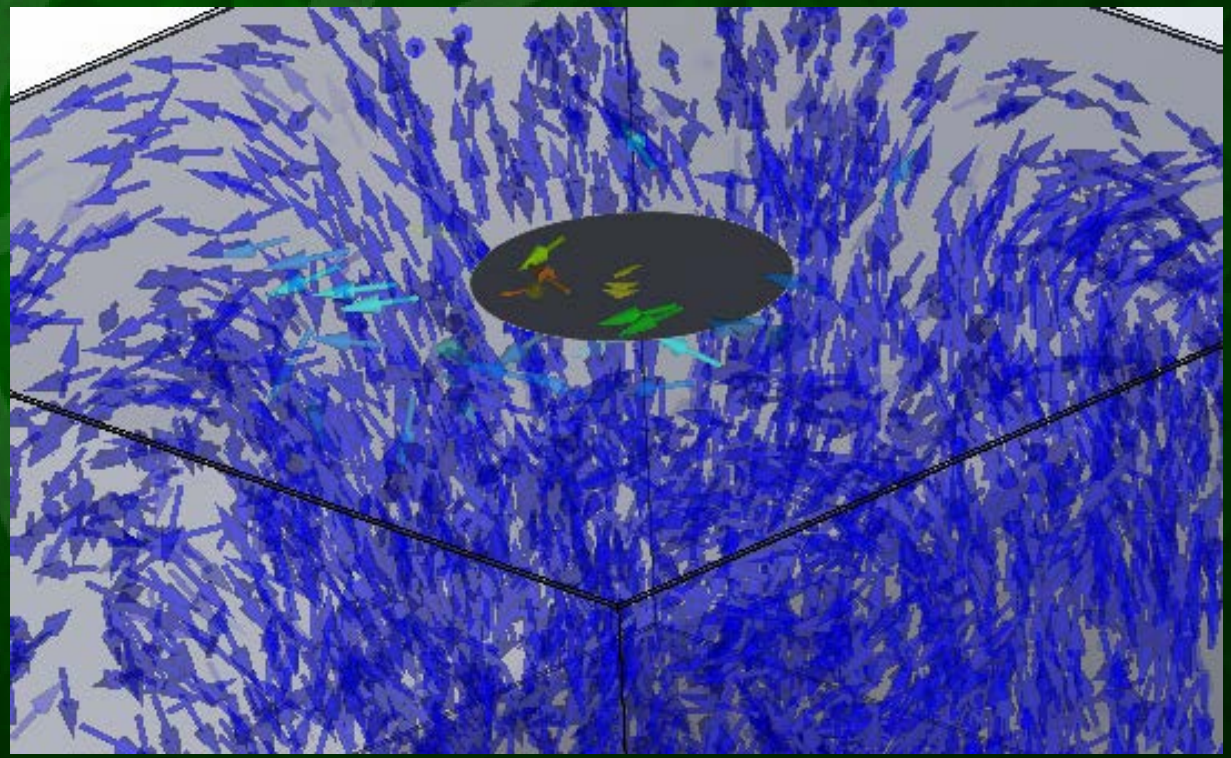
Heat out through (primarily) convection



System Geometry (5cm space above wafer)

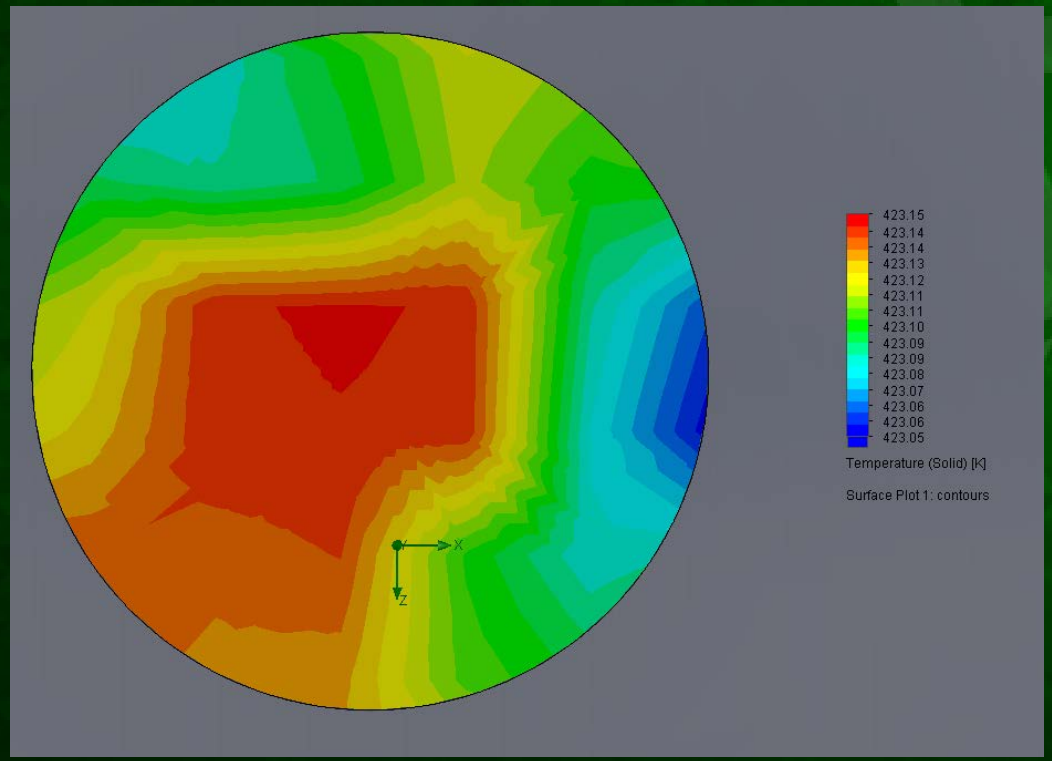
3/100ths degree difference

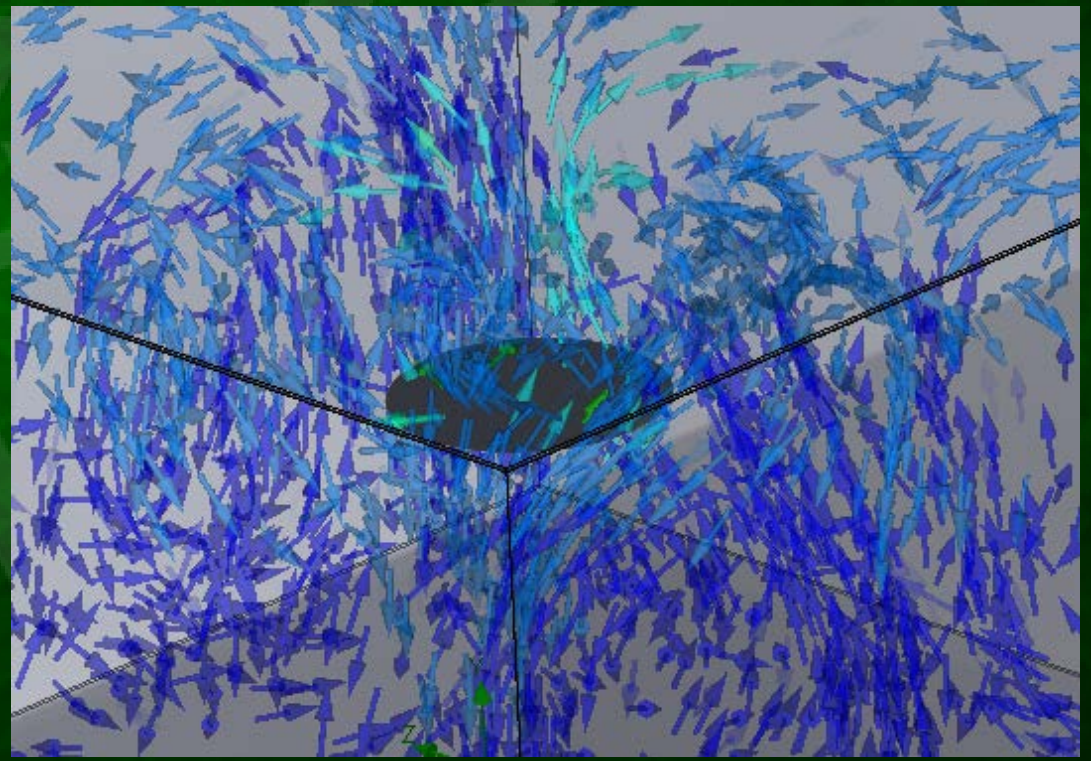




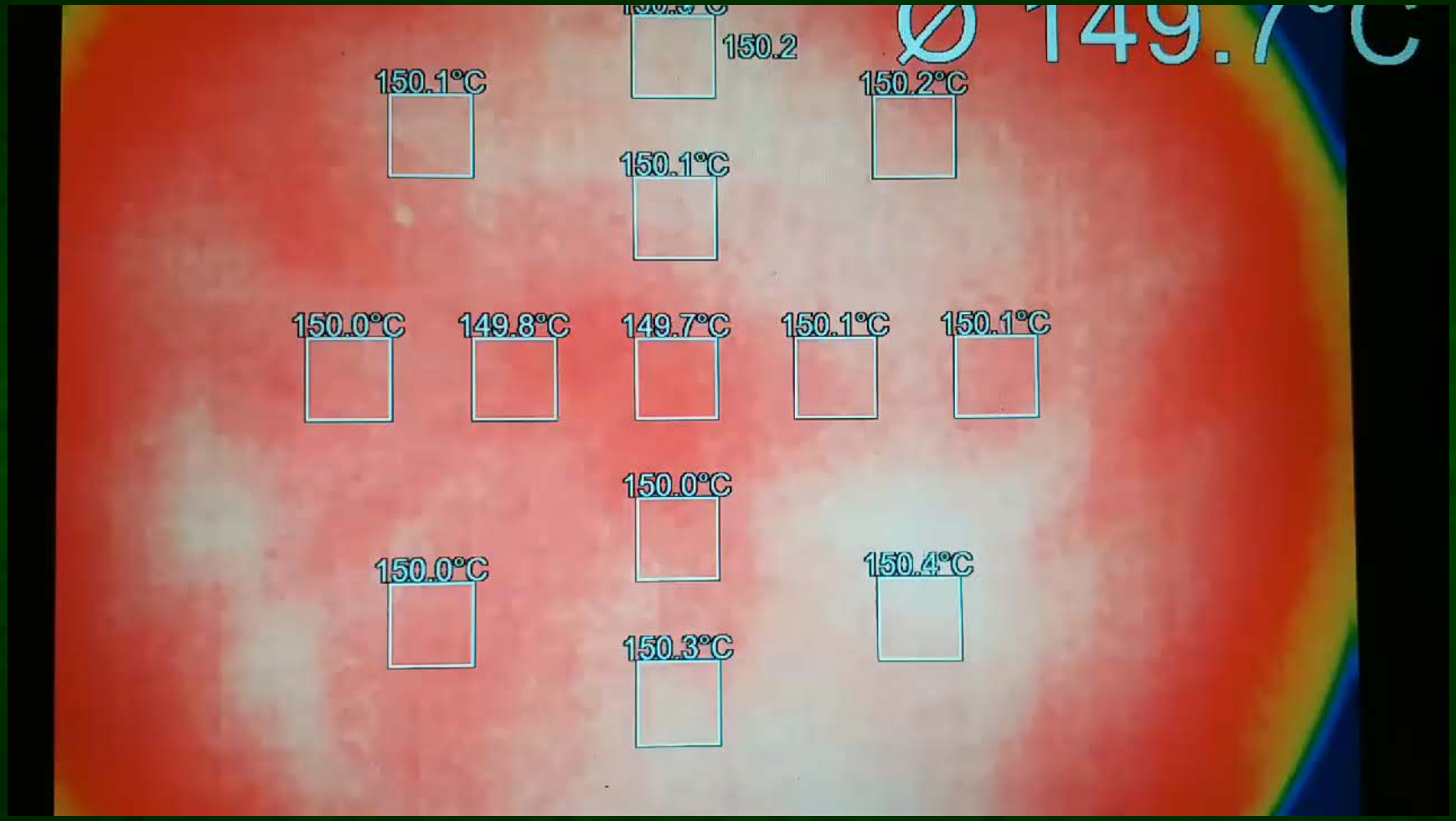
System Geometry (30 cm space above wafer)

1/10ths degree difference





Convective Dynamics @150°C

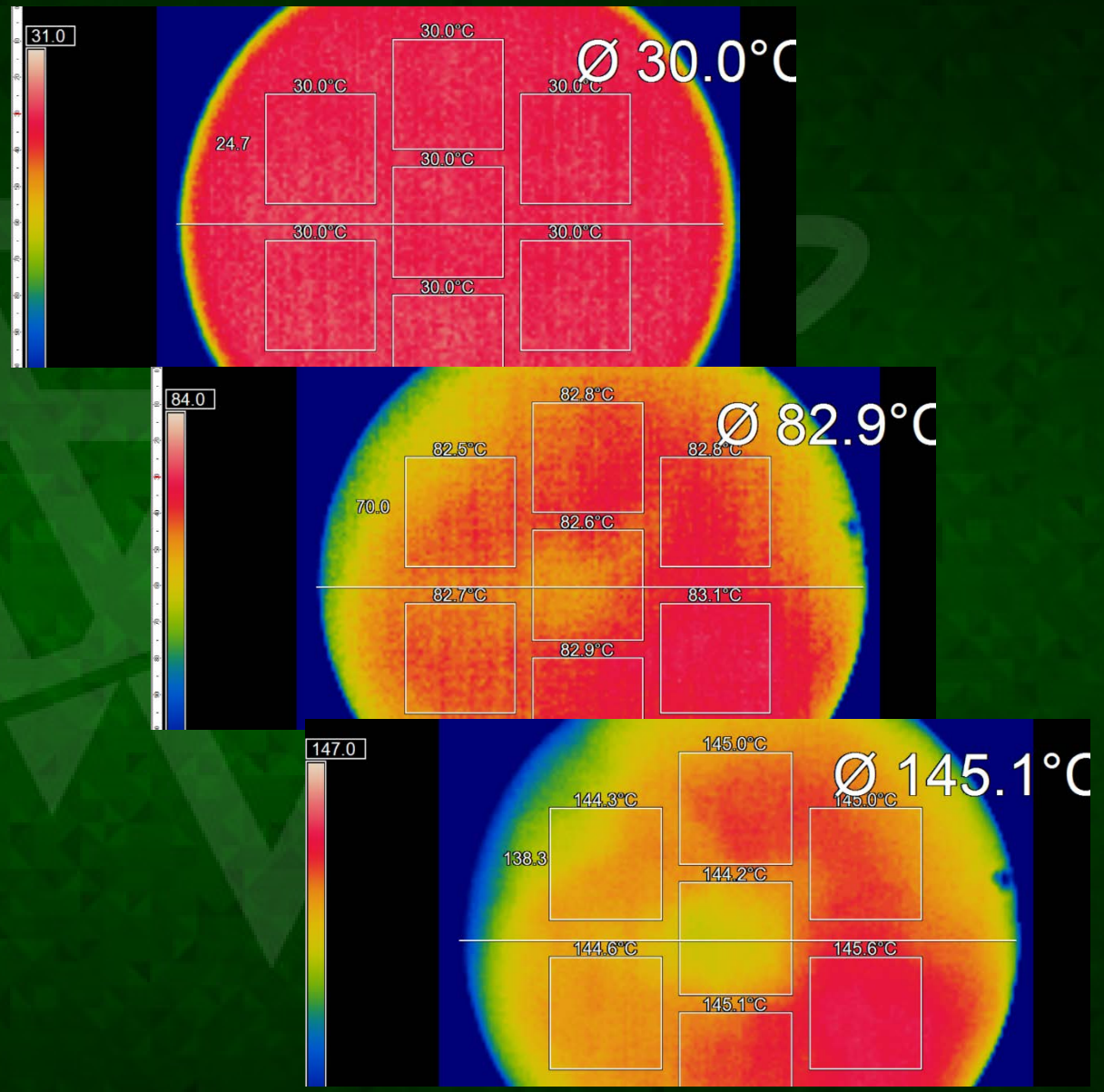


Chuck A

- 200mm ERS AC chuck, 2009
- Ambient to 200C
- Spec +-0.5K uniformity

- Measured (T wafer)
- 30C +-0.05K
- 85C +-0.15K
- 150C +- 0.35K

- In spec after normalization / compensation
- +-0.5K

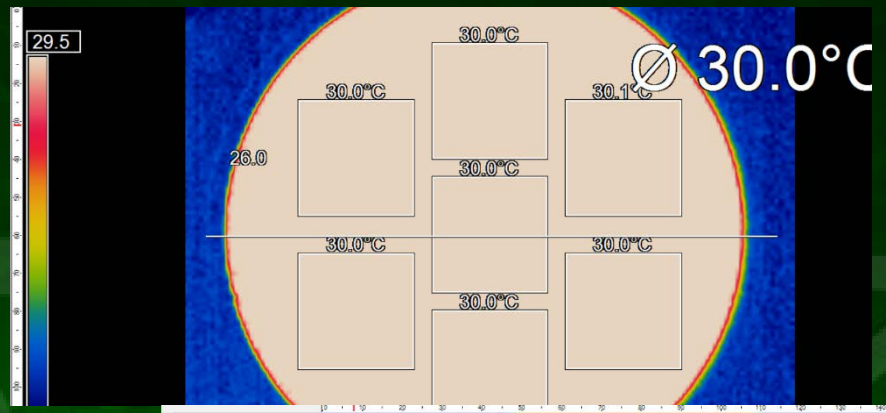


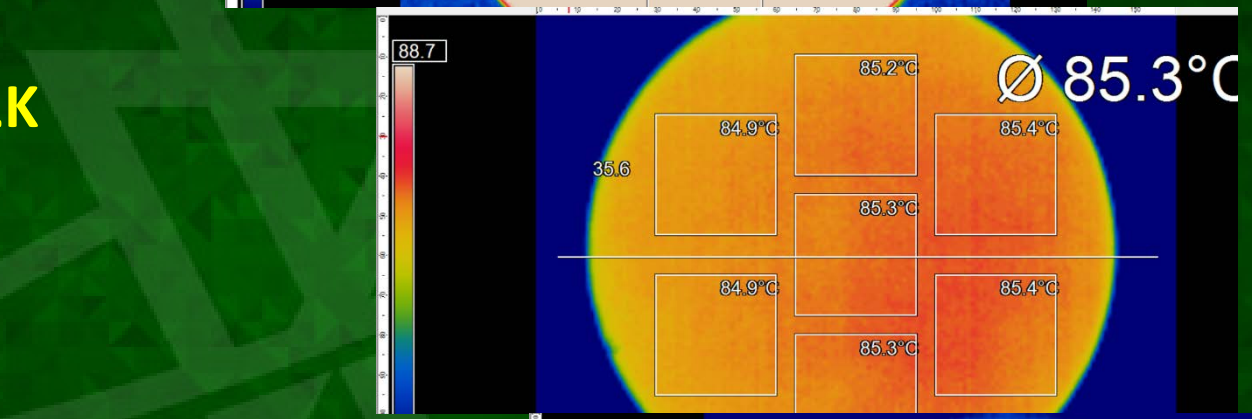
Chuck B

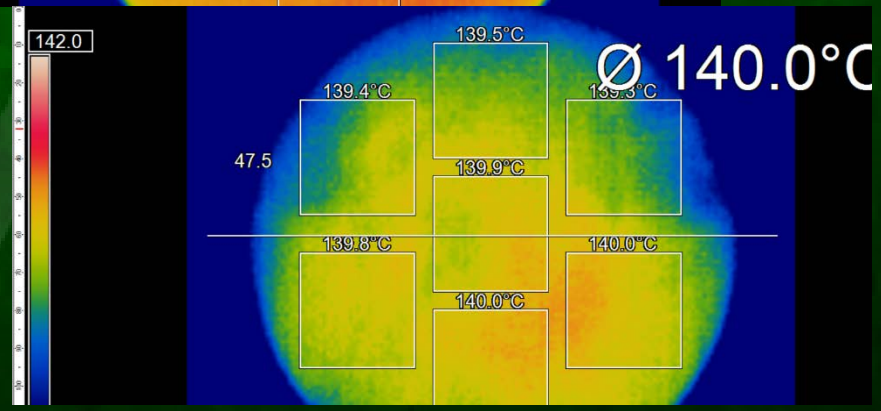
- 300mm ATT HTU chuck, 2019
- -45C to +200C
- Spec 30C -0.1K, 85C +-0.2K

- Measured (T wafer)
- 30C range 0.02K
- 85C range 0.12K

- In spec after cleanup / compensation
- +-0.2K







Conclusion

- IR picks up wafer surface temp
- Simulations consistent with measurement results showing lower temperature on wafer periphery
- Accuracy via K2 Sensor
- Data correlates well with temperature wafer
- IR can work within its limitations
- Suitable for accuracy less then 1K (+-0.5K) with 1 reference
- Up +-0.2K verification possible
- Environmental factors can be minimized or compensated

LAB2GO, Mobile Calibration/Characterization

- Place temperature wafer/ drop probe on chuck, set temperature
- Gather, transfer data
- Automatic generation of electronic calibration certificate
- Storage of calibration records in physically separate locations with online access
- ISO 17025 accredited (exp. Q3/19)*, IATF16949 compliant
- Optionally picture or video
- Graphic and XY temperature distribution data

Summary

- DIN / ISO spec sensors specified at 0°C only
- Characterized Sensors = Less measurement uncertainty
- Suited to be merged with IR measurement
- Complete surface temperature characterization possible
- Documented uncertainty and datasets
- Traceability to ITS90
- Cost efficient alternatives to existing methods

Driven by Customer Demand

- Each sensor accurate
- ISO 17025
- Hybrid IR method, patent applied for
- LAB2GO
- Integrated in Thermal Test Systems and Components

Continuing Work

- Pre-production phase; sensor, drop probe and fixtures: customer evaluations
- IR refinement: extended temperature range, resolution, portability
- AI pattern recognition and automated normalization
- Migrate to RF, interchangeable sensors w/ calibration data stored in device

Acknowledgements

- My family
- Austin Ibele
- Knut Linke
- Joe Benke
- Sebastian Pfeiffer
- ERS and ATT for chuck system loaner and access
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Thank you.
Any Questions?

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