SWTEST

PROBE TODAY, FOR TOMORROW

Large Area High Temperature Copper Pillar Probing

FEINMETALL

Contact Technologies

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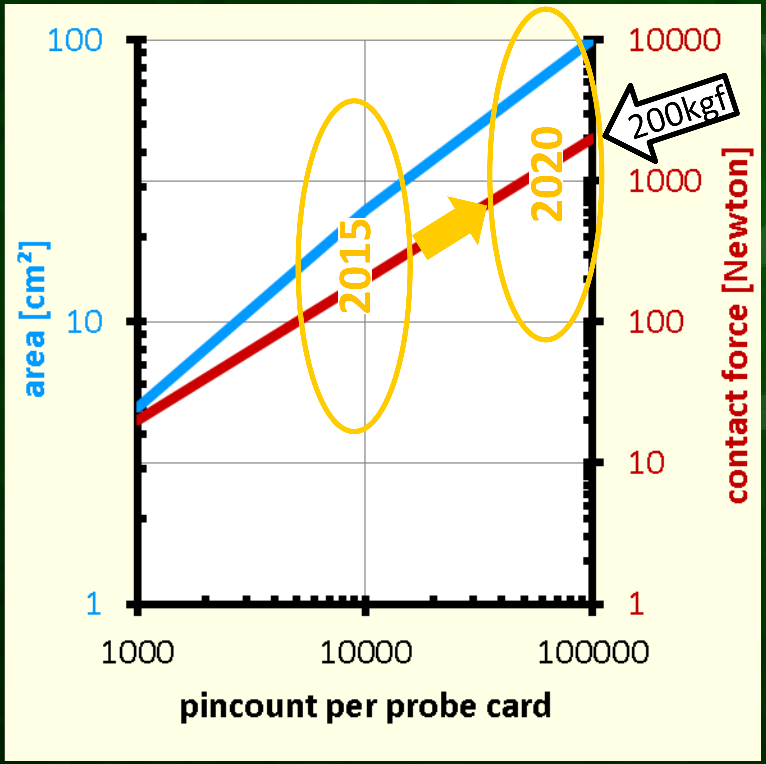
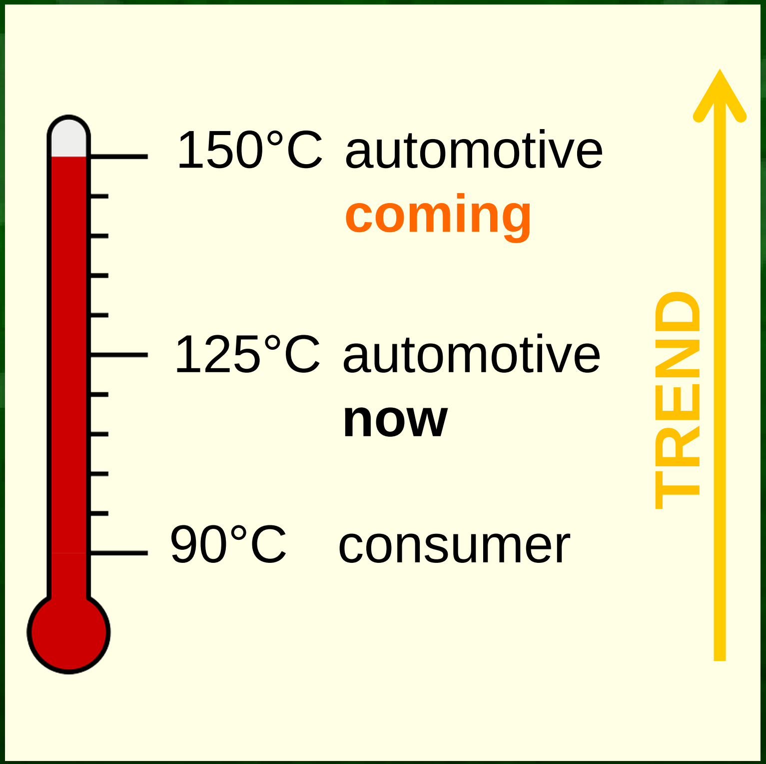
June 2-5,2019

Why Large Area? Why High Temperature? Trends for Copper Pillar Probing

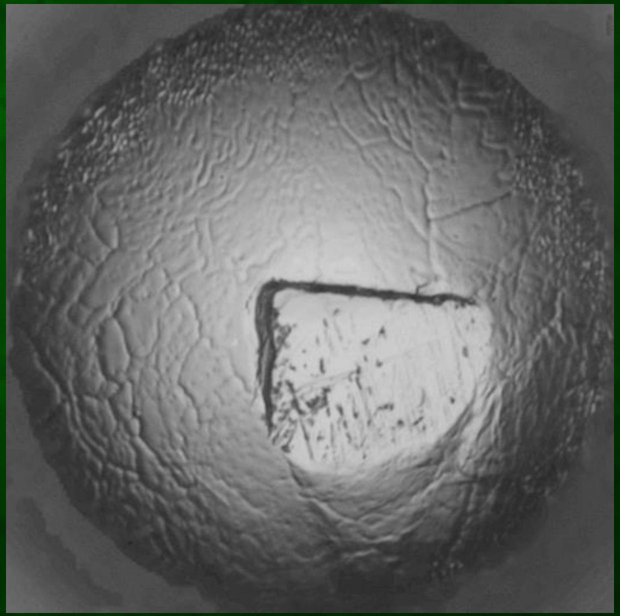
area, total force



probing temperature



if you just heat up the prober…



result of an alignment issue: offset probing, deep impact

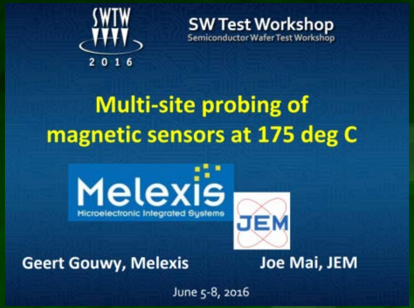
Basics of
Large Area High Temperature Copper Pillar Probing

Temple of Augustus, Pula, Croatia
44° 52' 12,7" N, 13° 50' 30,7" O ,

- Alignment:
  - good needle to needle alignment
  - matching CTE of guide plates
- overtravel:
  - coplanarity wafer to probe card
  - system deflection under control
- small Cu-pillar deformation @ elevated temperature
- low resistance contact mechanism

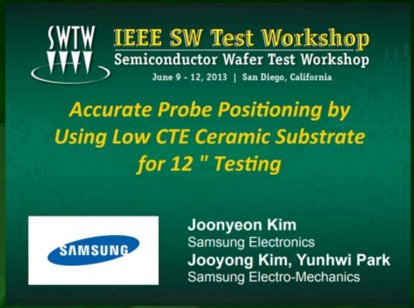
History of SWTW Presentations

CTE
High temperature

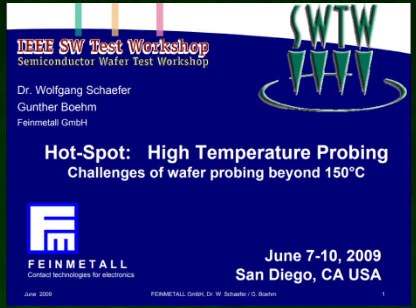


Gouwy 2016

Martens 2013



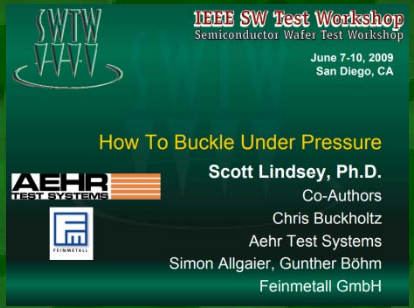
Kim 2013



Boehm 2009

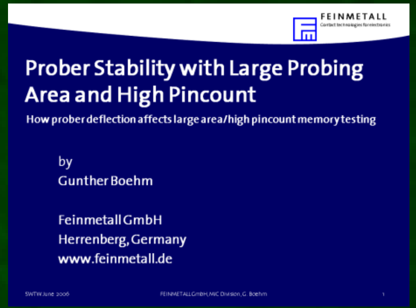
System deflection

Strohm|Greenberg 2012



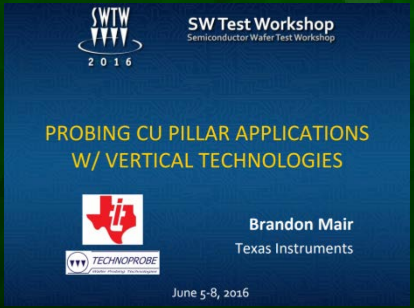
Lindsey 2009

Huebner 2008

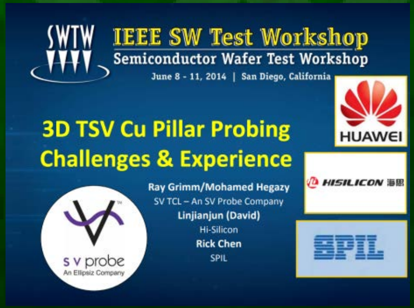


Boehm 2006

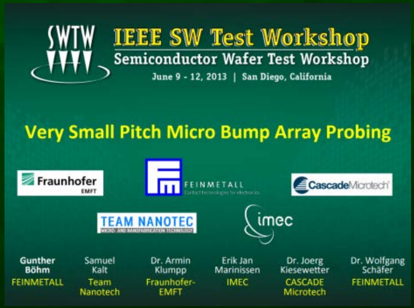
Copper pillar



Mair 2016



Grimm 2014



Boehm 2013

Horas 2012

Topics

- Introduction: Copper pillar, high temperature, high pin count
- Guide plate CTE improvement
- System (test cell) deflection @ high pin count
- Copper pillar contact @ 150°C probing temperature
- Summary

Introduction to CTE I/II

- **Coefficient of Linear Thermal Expansion (α)**
  - Characterizes the materials change of size in response to a change in temperature (ΔT).
    - (Eg.: Thermometer)
  - While heating, the average kinetic energy increases → the volume/length increases:

$$L_T = L_0 \cdot e^{\alpha \cdot \Delta T}$$

(Taylor series) $$L_T = L_0 + \Delta L \approx L_0 + \alpha \cdot L_0 \cdot \Delta T$$

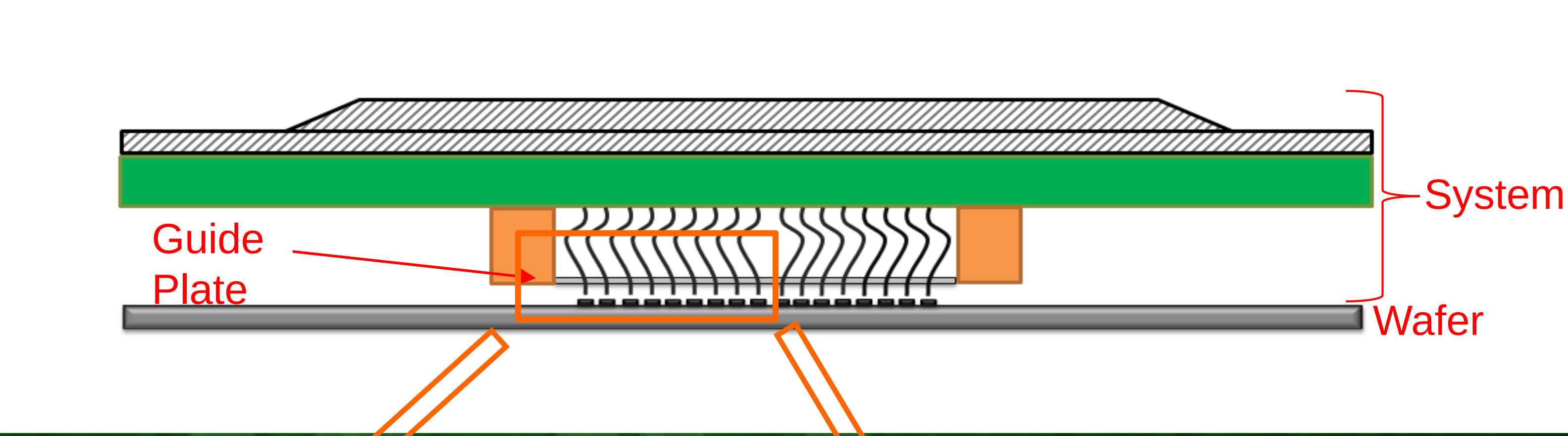
$$\alpha = \frac{1}{L_0} \frac{\Delta L}{\Delta T}$$

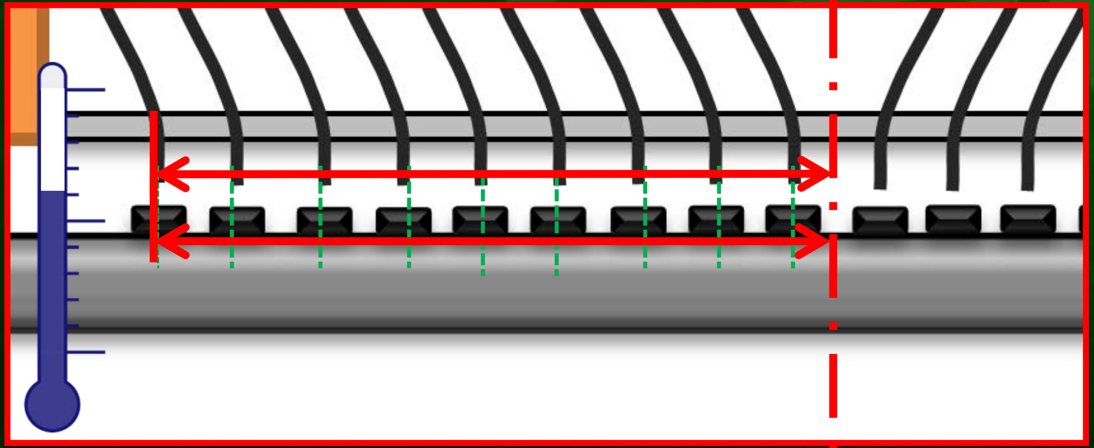
Thermometer

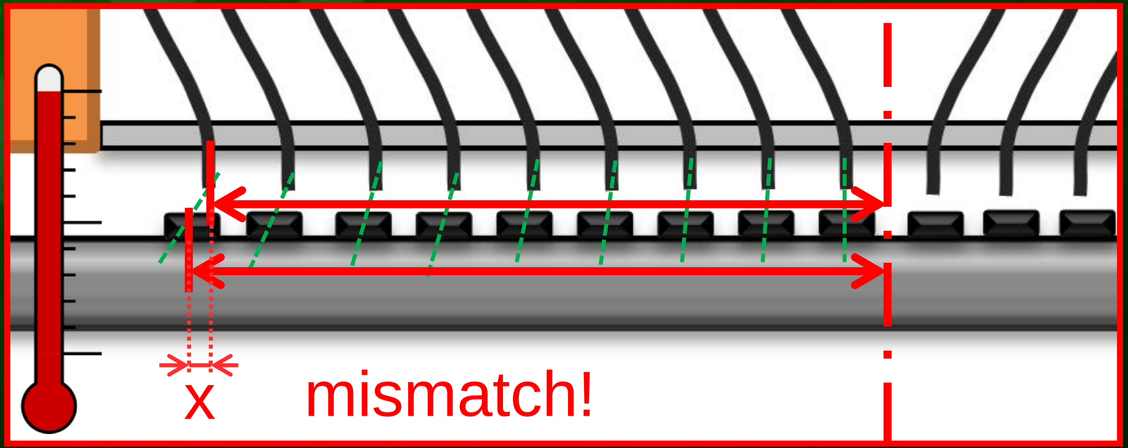
Expansion joint on a road bridge

Introduction to CTE II/II

- **Coefficient of Thermal Expansion (α) of a Probe Card**
  - Many materials with different CTE used!!







Guide plate CTE vs. System CTE

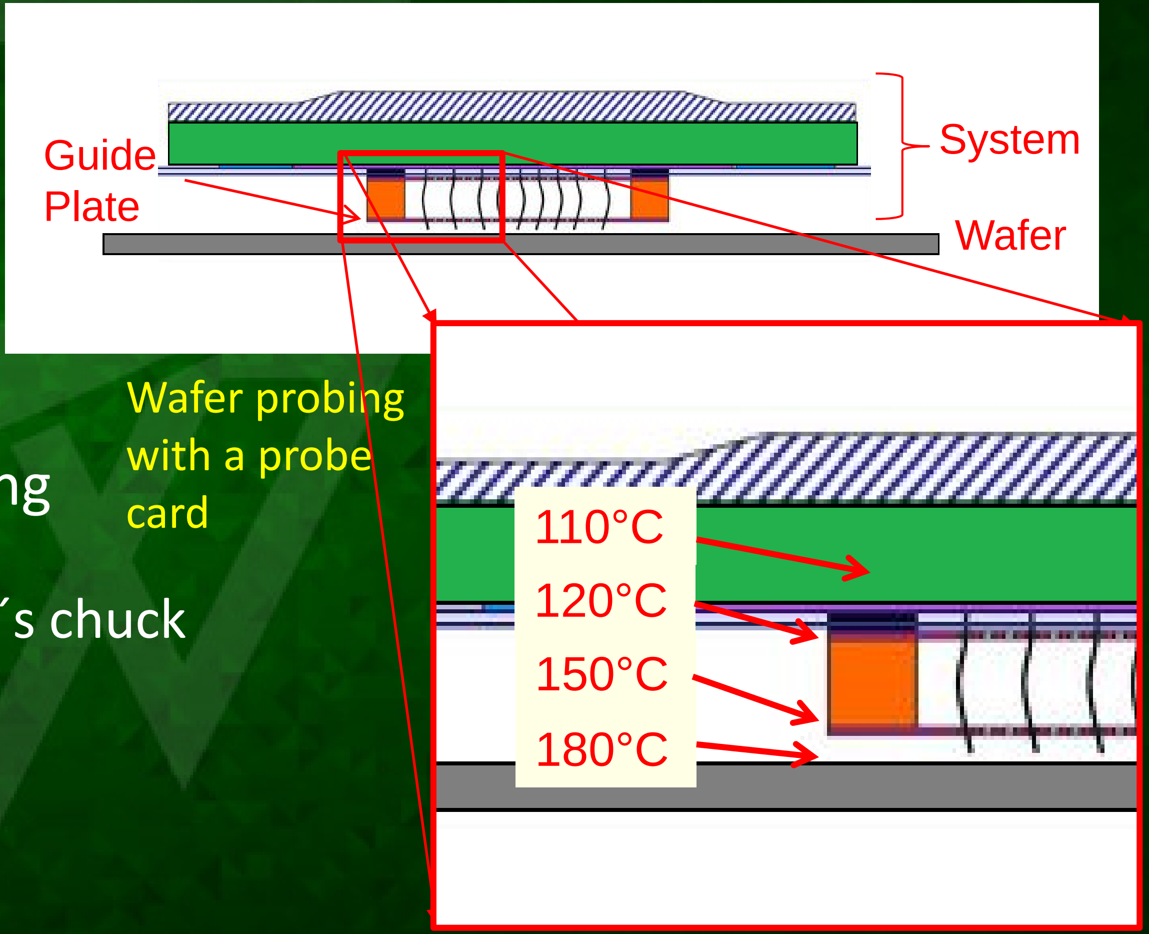
- **Guide Plate (Material) CTE**
  - Material characteristics

$$\alpha = \frac{1}{L_0}\frac{\Delta L}{\Delta T}$$

  - Measurement: optical dilatometer

- **System CTE**
  - Characterizes the situation in a real probing environment
    - The probe head never reaches the prober´s chuck temperature
  - Measurement: real probing environment

$$\alpha = \frac{\ln\left(\frac{L_T}{L_0}\right)}{\Delta T}$$



Wafer probing with a probe card

System temperature

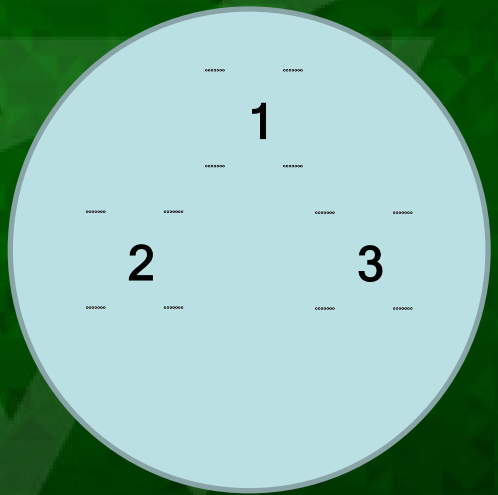
CTE Verification Method I/II

- **Measurement Method**
  - Real probe head (45x45 mm^2 max image size), 14 diagonals measured
  - UF3000 probing on a blanc wafer @:

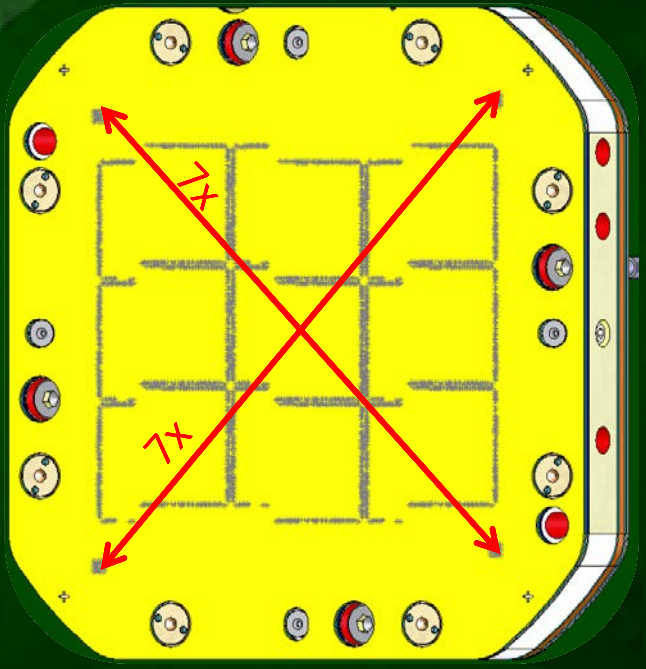
    -40°C
    +28°C
    +85°C
    +150°C
    +180°C

- **Experiment Design:**

  2 systems (high/low pin count)
  5 probing temperatures
  3 touchdowns per temperature
  2 measurements per touchdown
  14 distances per measurement



200mm blanc Al-wafer,
3 touchdowns



Probe head used for
measurements

CTE Verification Method II/II

- **The Measurement of the Scrubmarks:**
  - Coordinate measurement of the scrub position at 20°C
  - Calculating the length for each probing temperature:

α of the silicon wafer

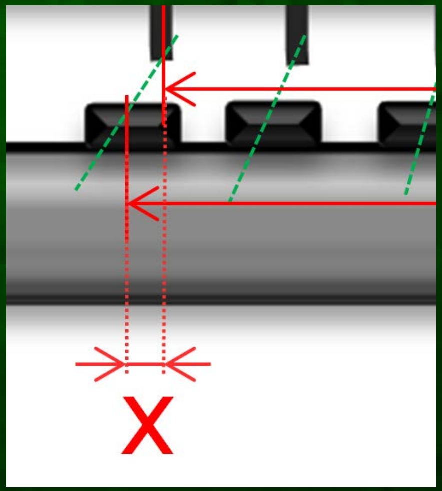
$$L_T = L_0 \cdot e^{\alpha \cdot \Delta T}$$

  - Calculating the CTE of the System:

$$\alpha = \frac{\ln\left(\frac{L_T}{L_0}\right)}{\Delta T}$$

  - Calculating the mismatch:

$$\mathbf{x} = \frac{\Delta L_T}{2}$$

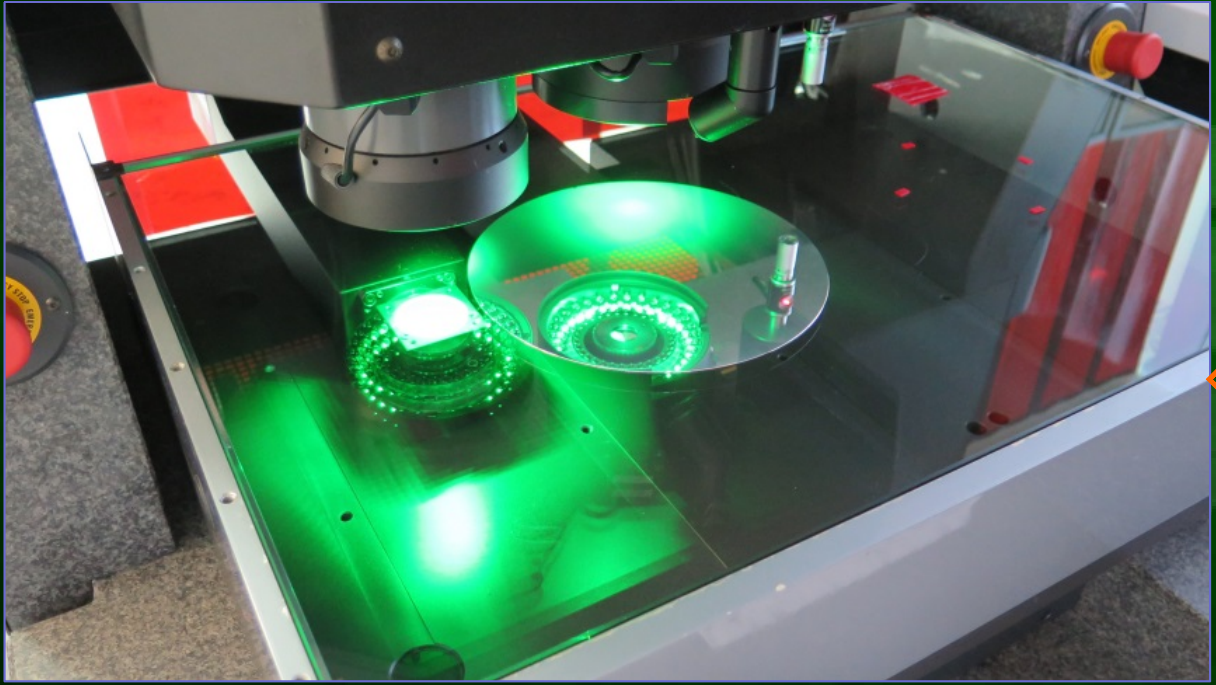


Position mismatch needle to Cu-pillar

Measurement Setup

- **"WERTH IP400" Coordinate Measurement System**

accuracy: $E_2 = 1{,}15\mu m + {}^{L}/_{400}\, m \cdot mm^{-1}$

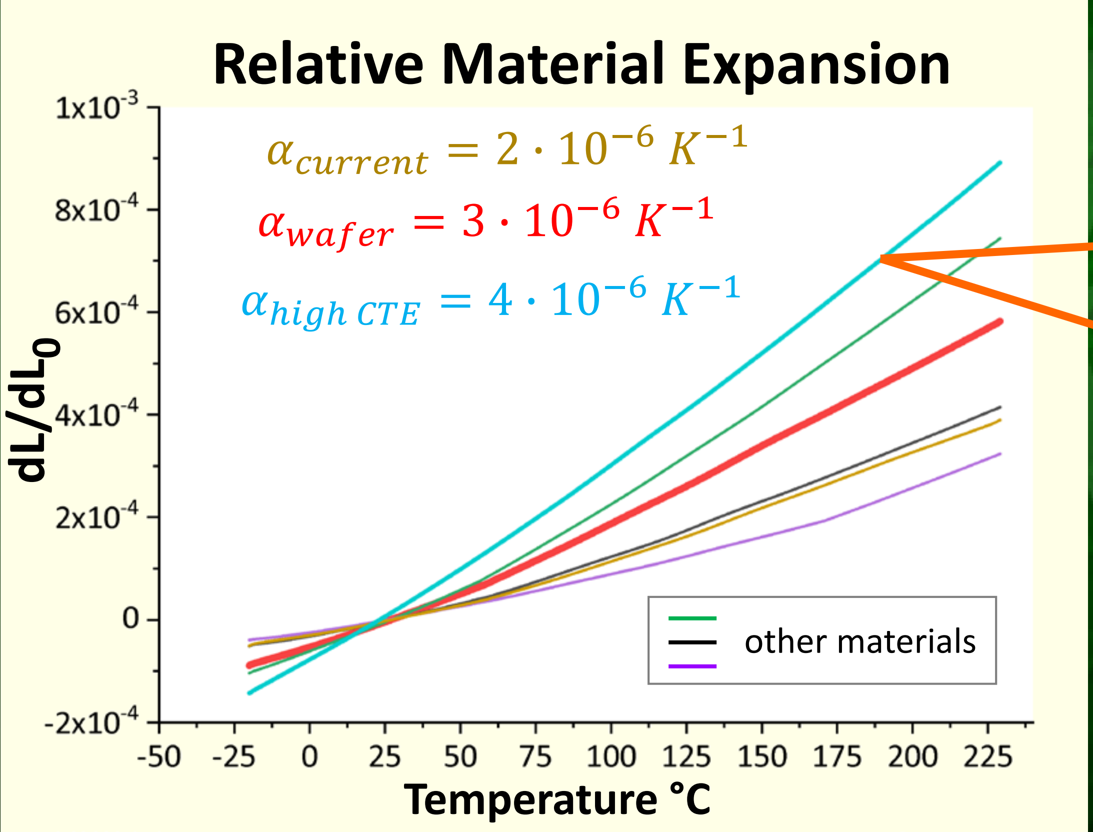


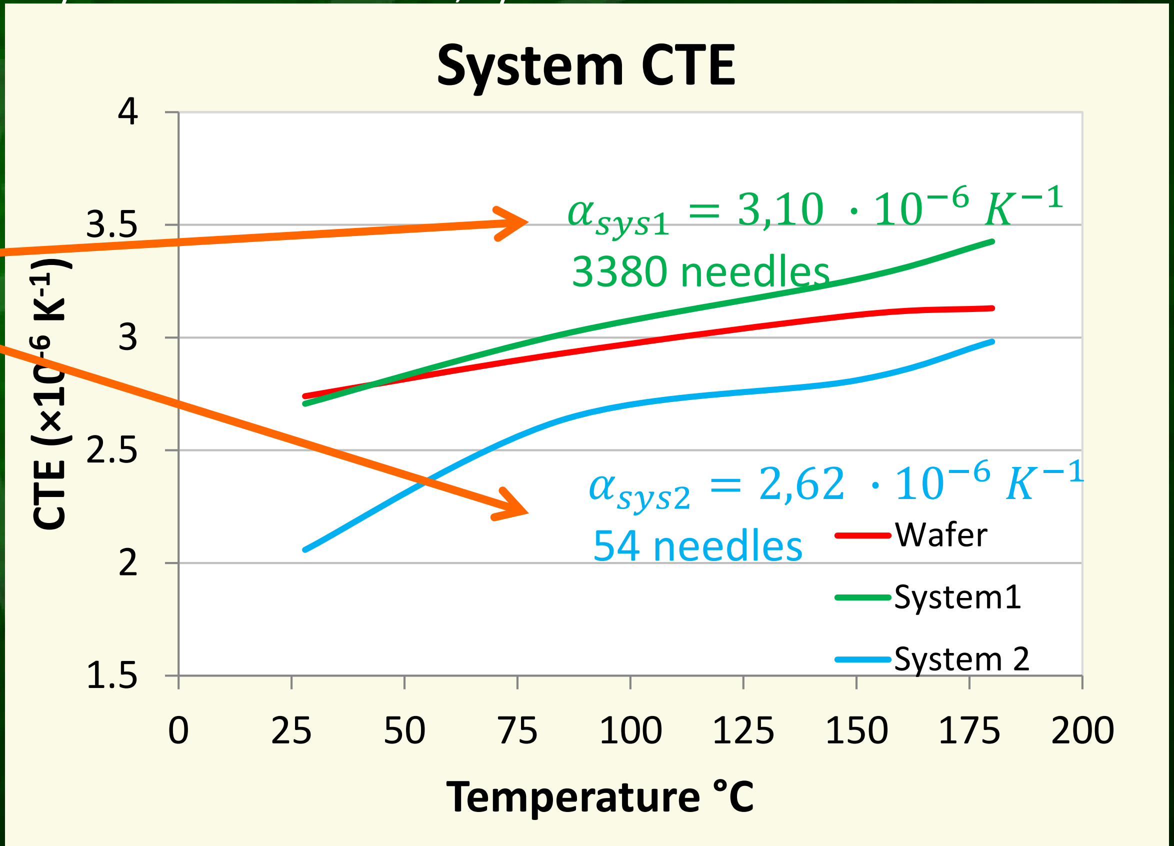
Results

- **Guide Plate CTE ≠ System CTE ≠ System II CTE**

The system* CTE depends on the needle count!

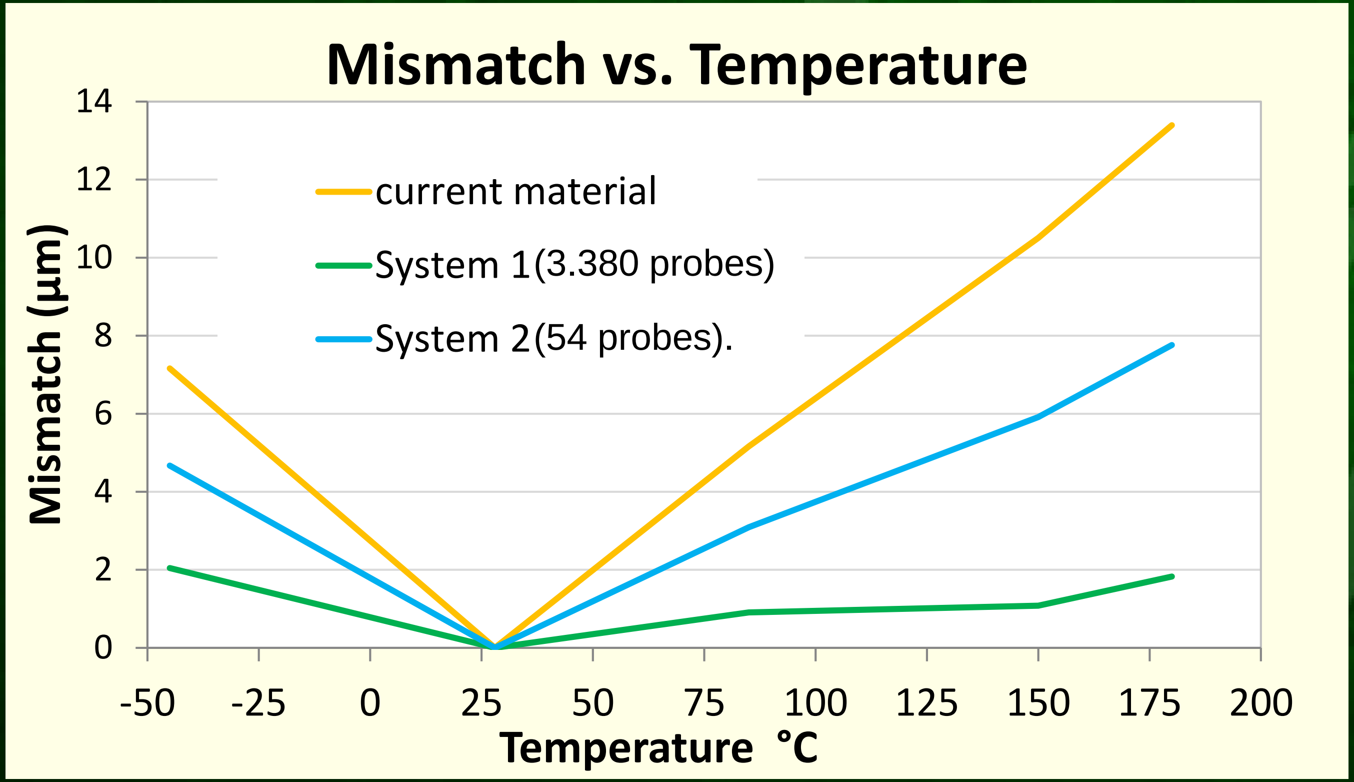
* System 1: 3.380 needles, System 2: 54 needles



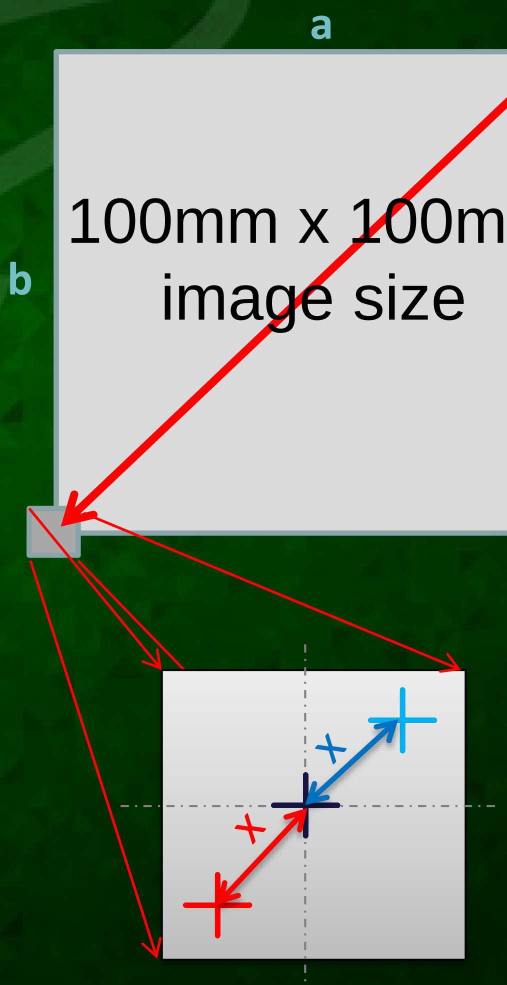


Mismatch vs. Temperature

- **The mismatch (x) describes how the needle tip changes its position on the pad with a change in temperature.**
  - depends on the system CTE and the temperature

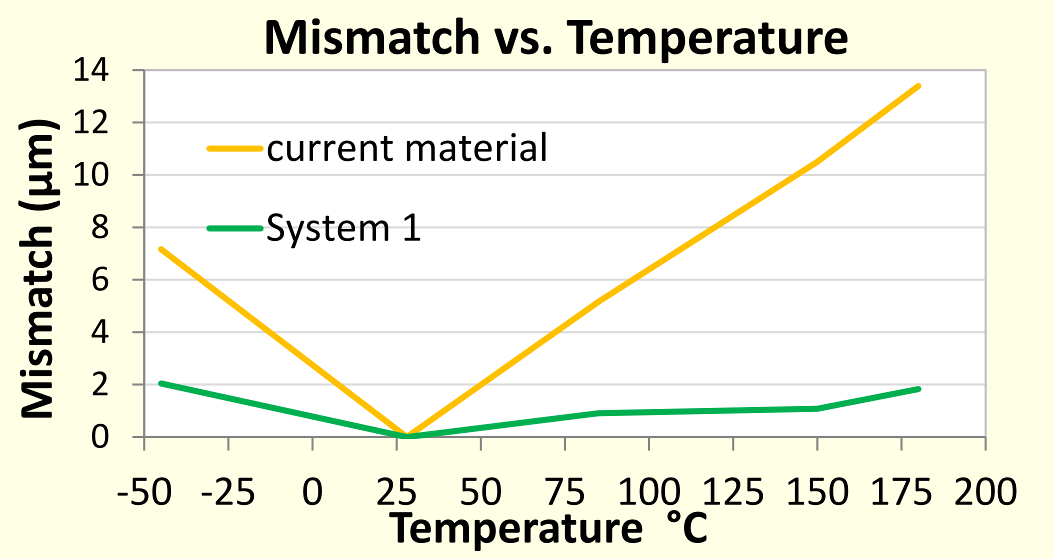


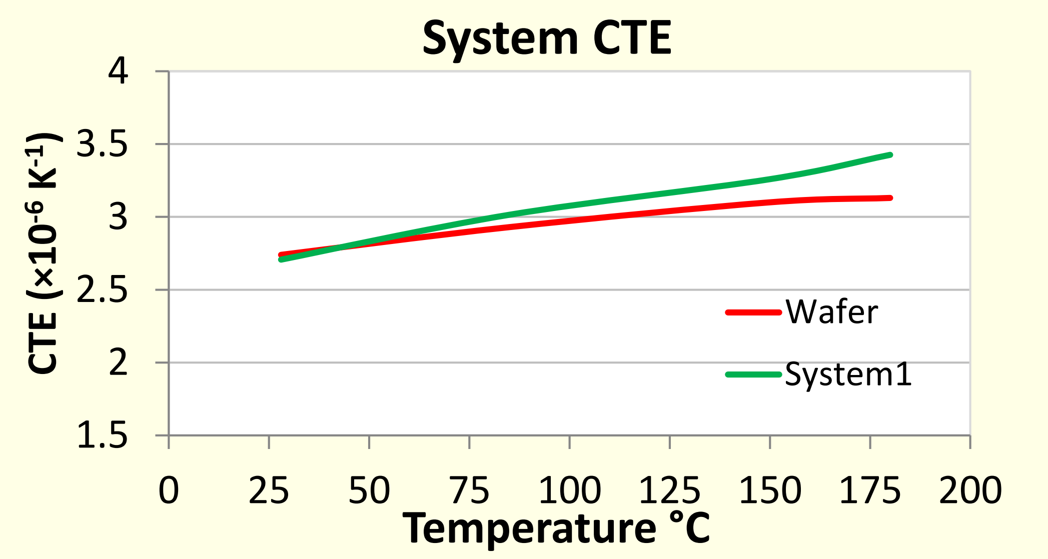
Mismatch for a 100x100 mm² image size probe head



Summary CTE

- We have developed an experimental method to measure the system CTE in the real environment.
- By understanding the physics of the system, we defined the material with the best matching CTE.
- With the new material we optimized the system and minimized the mismatch from **13,4 µm** to **1,8 µm** @180°C for a 100x100 mm^2 image size.



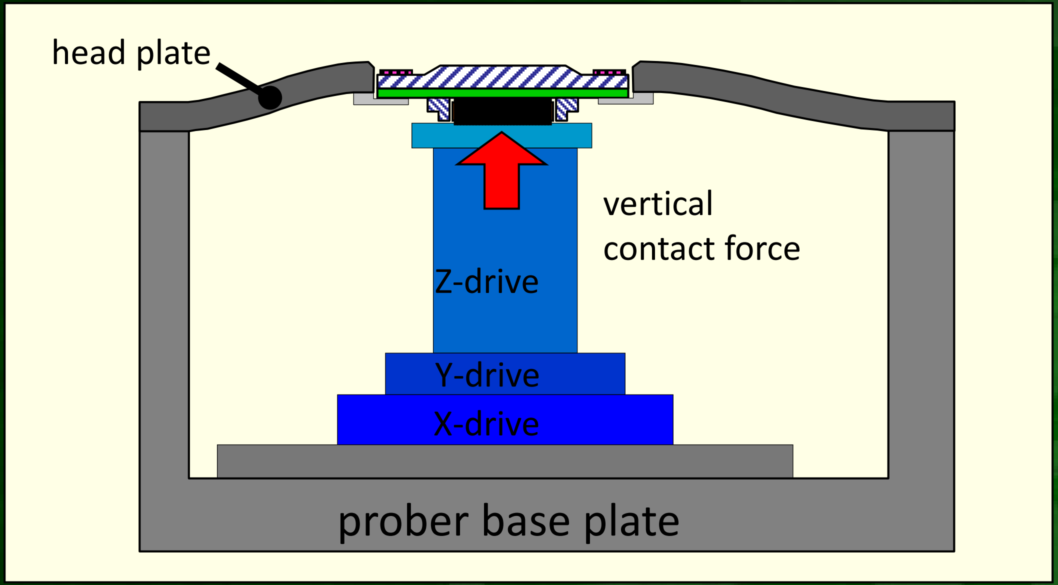


Topics

- Introduction: Copper pillar, high temperature, high pin count
- Guide plate CTE improvement
- System (test cell) deflection @ high pin count
- Copper pillar contact @ 150°C probing temperature
- Summary

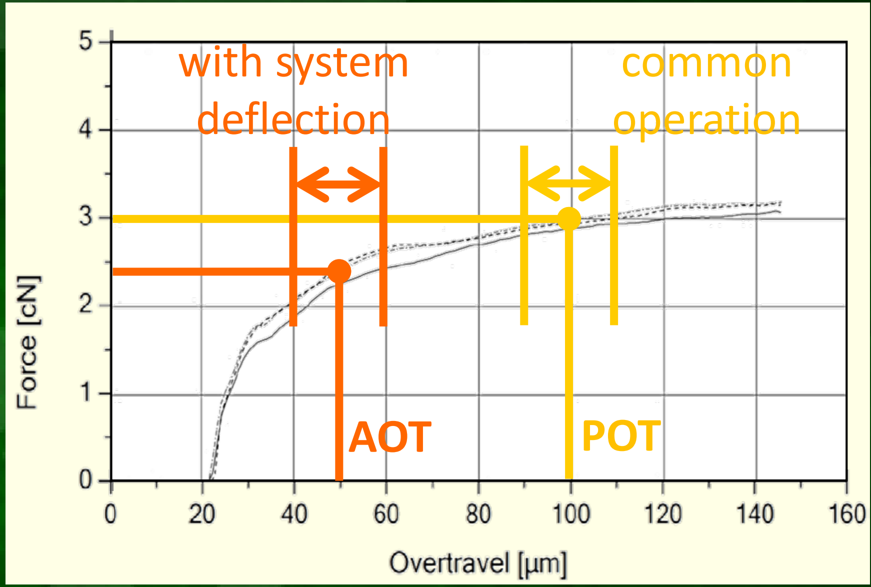
System Deflection Overview

deflection mechanism



reasons for system deflection:
- headplate bending
- chuck deflection and tilt
- probe card bending
- tester interface bending
- temperature effects
  (… but that's a story on it's own)

influence to the contact force



force vs overtravel for ViProbe® T-type

POT = programmed overtravel
AOT = actual overtravel

What is your system deflection?

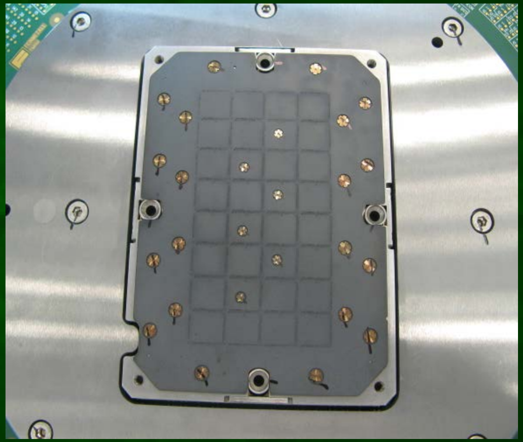
Experiment Objective

To determine the system deflection for a

- **space transformer probe card with 7360 ViProbe T-type needles**
  (equivalent to 257N = 25,7kgf of contact force @ 100µm overtravel)

- **on an Accretech UF3000 EX prober (300mm)**

- **with a J750 tester**


probe card, wafer side

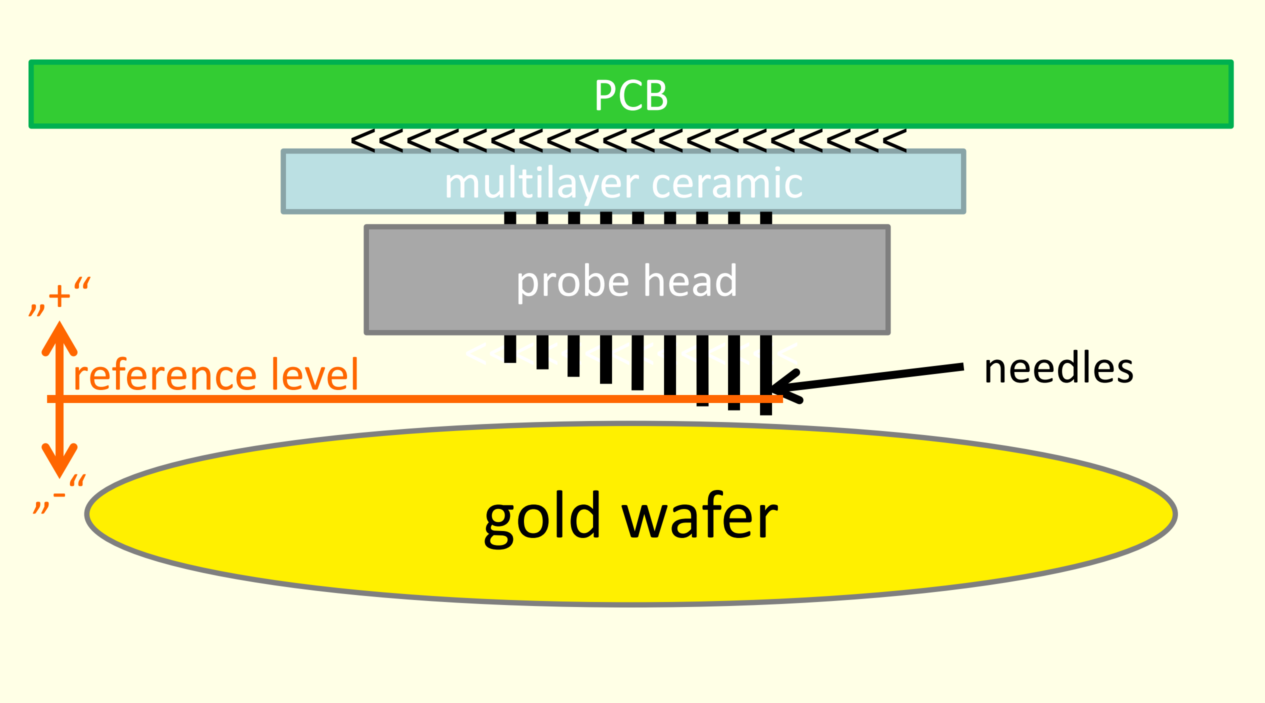
„system“ = probe card + prober + tester

side condition:

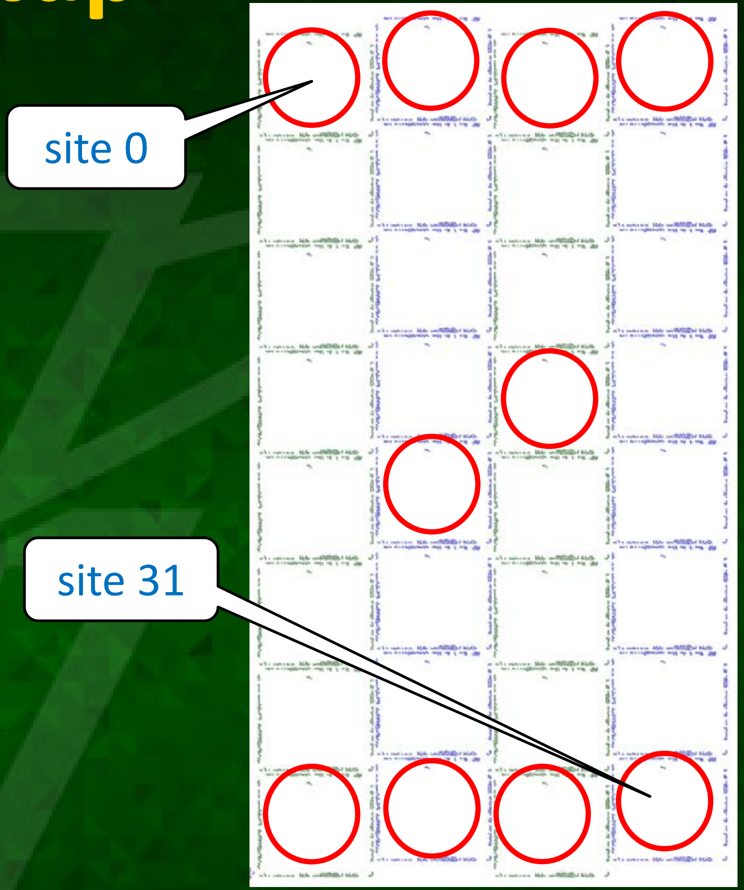
- ambient temperature (to be able to distinguish between force- and temperature effects)

Experiment Setup

- **Probe Head Equipped with Needles of Different Height**



a gold wafer has been choosen
to avoid errors from the contact resistance



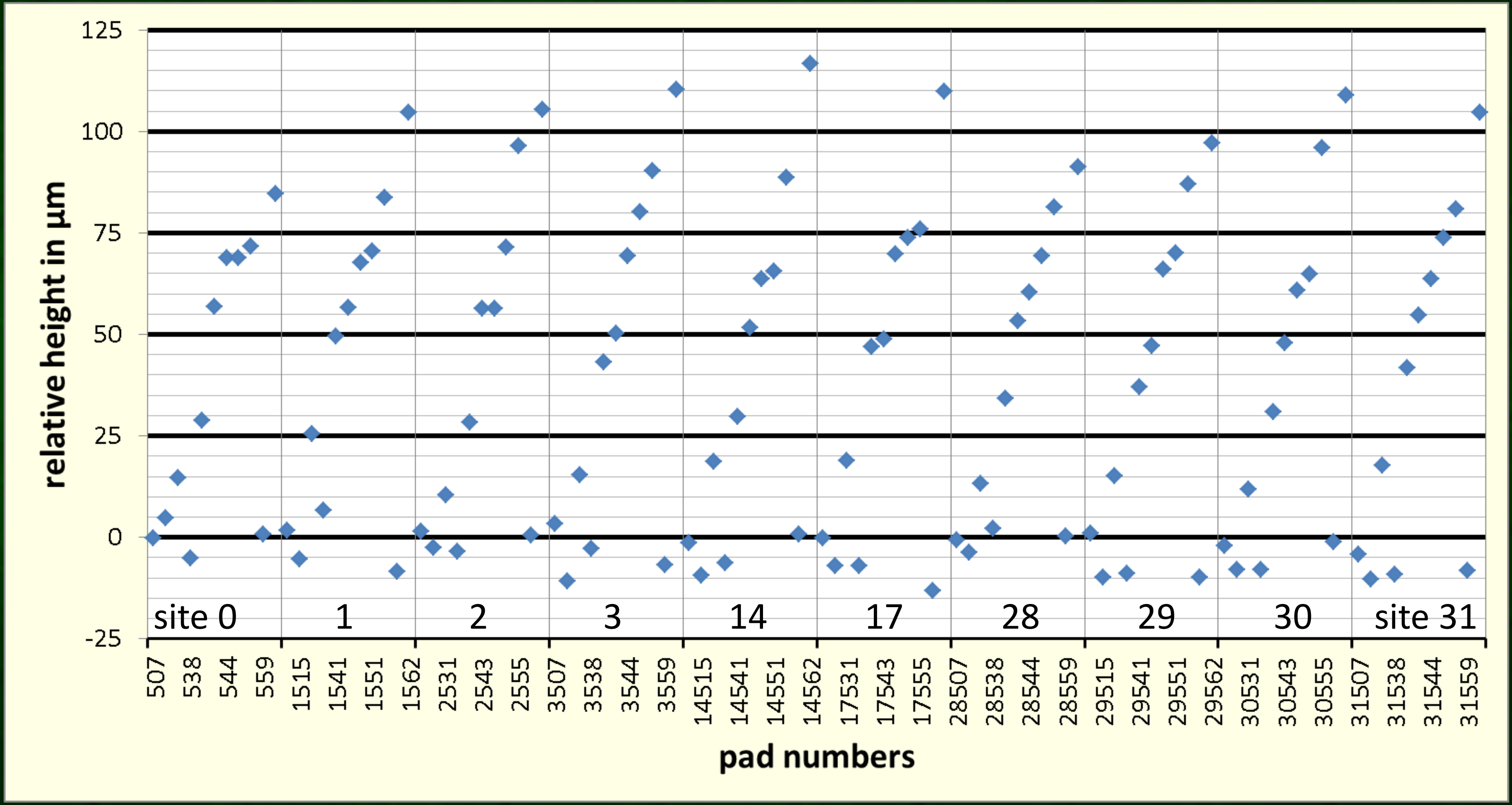
footprint of the probe head
red: sites equipped with special needles

needle height range:
-20µm up to +110µm

Experiment Setup

- **Needle Height Distribution**

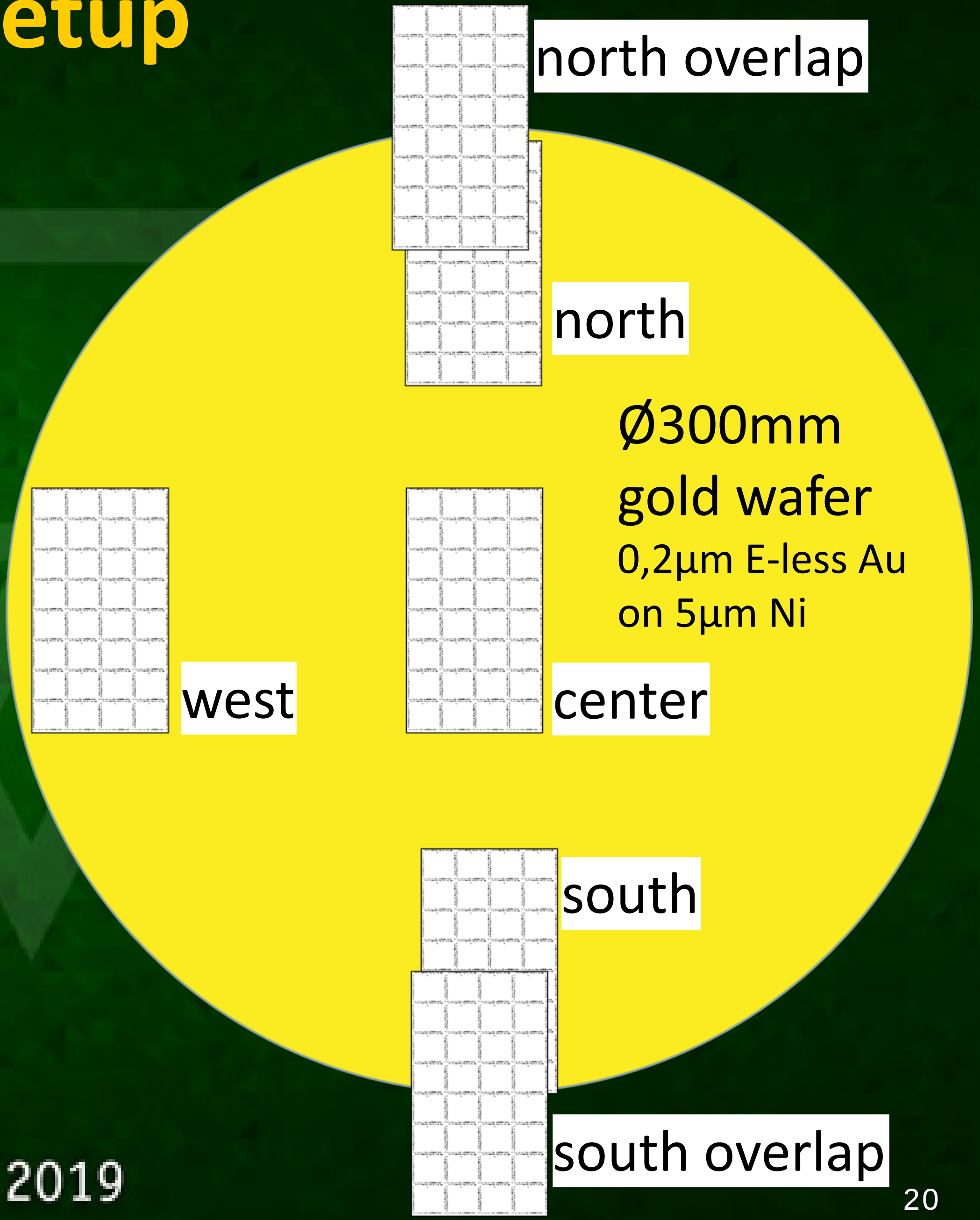
needle heights have been manually measured using a microscope



(measurement using a probe card analyzer failed due to insufficient range at optical measurement)

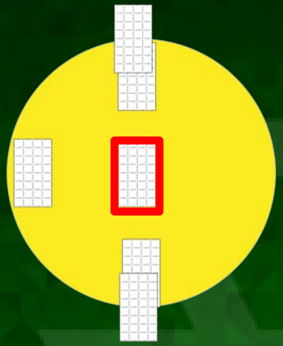
Experiment Setup

- **Experiment Parameter**
  - Six different touchdown positions
  - Special test program: resistance test only
  - current: 10µA
  - Threshold for “contact”: 1000 Ω
  - Manual overtravel control
  - All sites, not only the selected sites, have been included into the measurement to have a bunch of contacts that represent the “zero” height

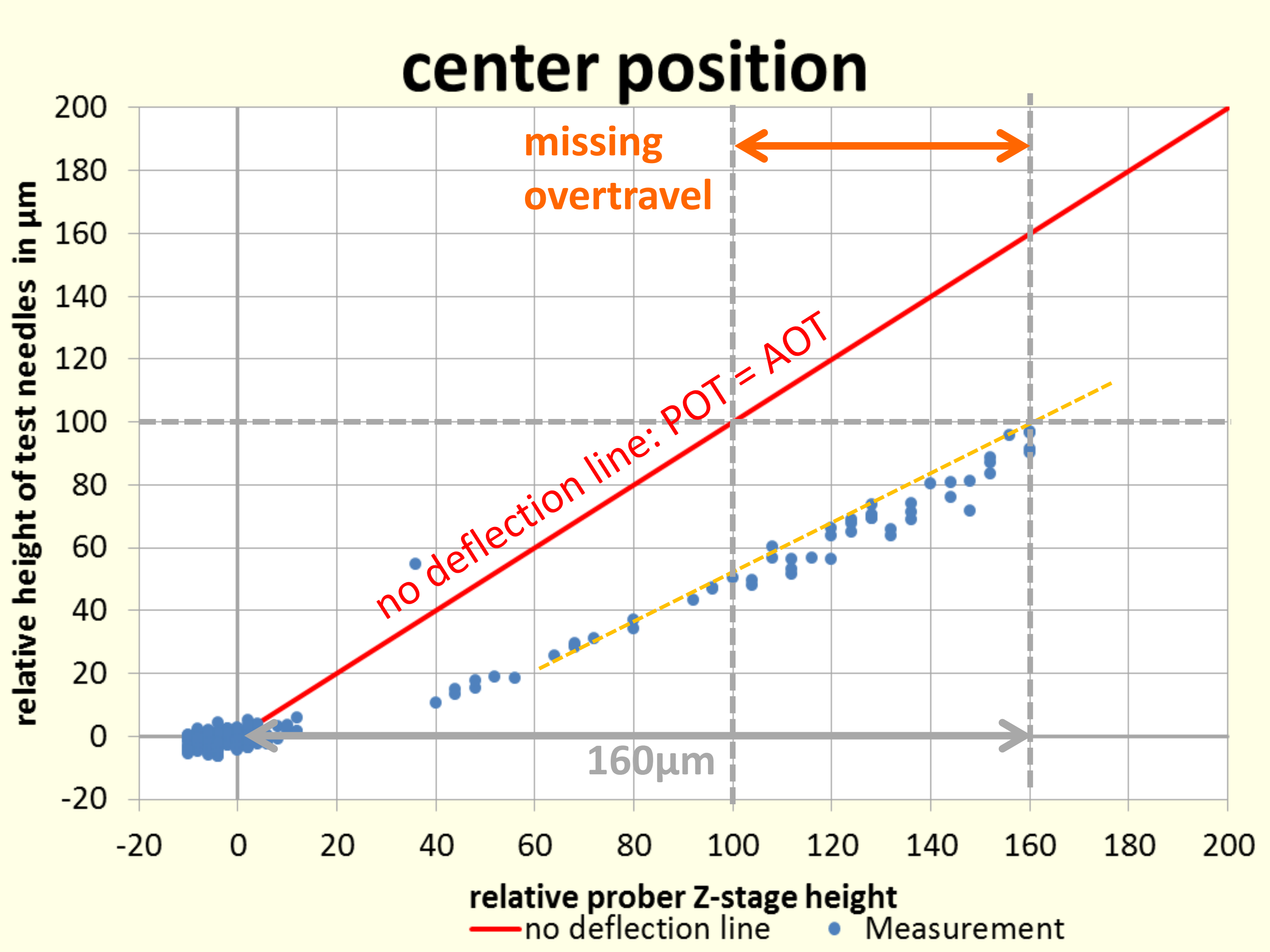


Measurement Data

- **Center Position**



To get 100µm AOT a POT of **160µm** is required.



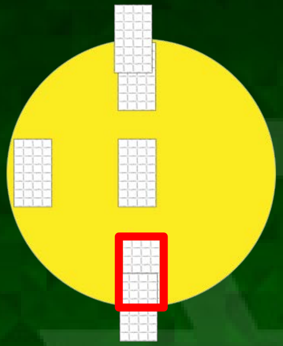
POT = programmed overtravel
AOT = actual overtravel

A data point in the diagram means:

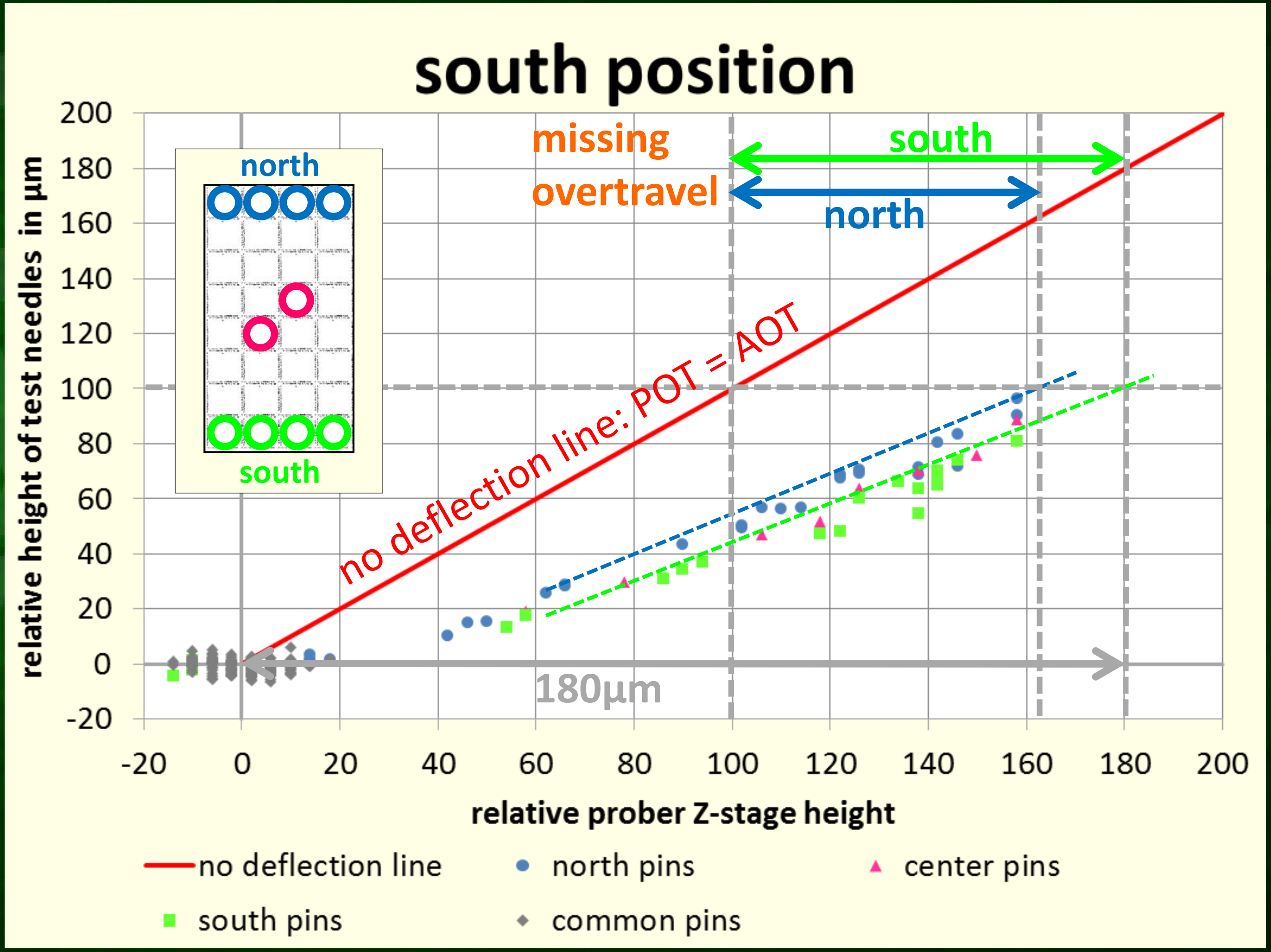
- it's X-value is the relative prober Z-stage height when this needle had first contact to the wafer
- it's Y-value is the previously measured relative needle height

Measurement Data

- **South Position**



To get 100µm AOT
a POT of **165-180µm** is required.
A **tilt** is clearly visible.



POT = programmed overtravel
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A data point in the diagram means:
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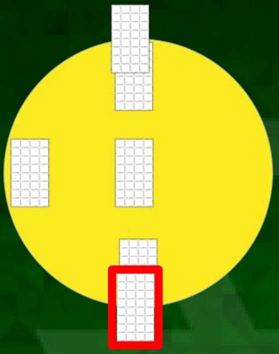
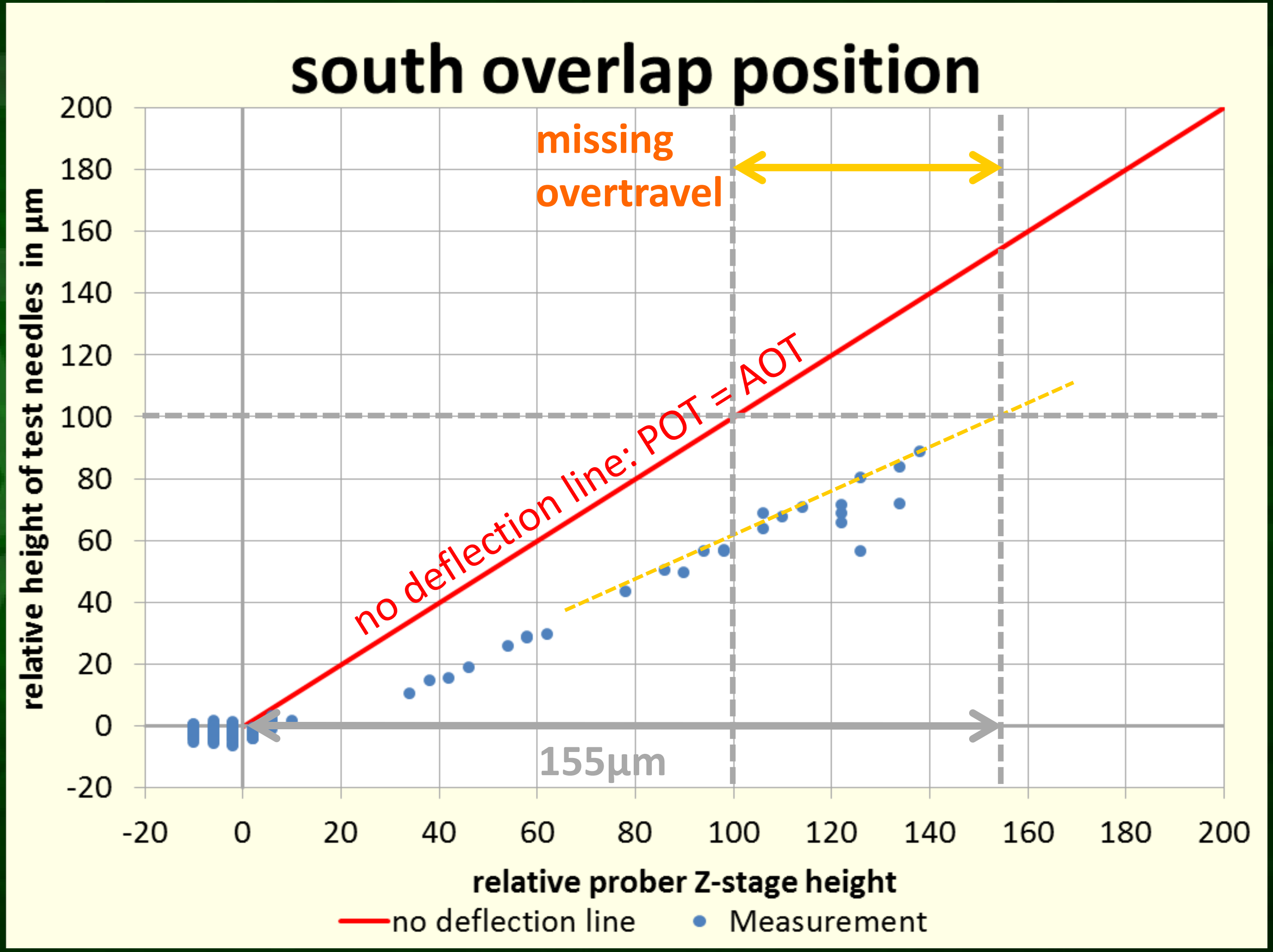
- it's Y-value is the previously measured relative needle height

Measurement Data

- **South Overlap Position**



To get 100µm AOT
a POT of **155µm** is required.
50% of the force reduces the deflection only gradually.



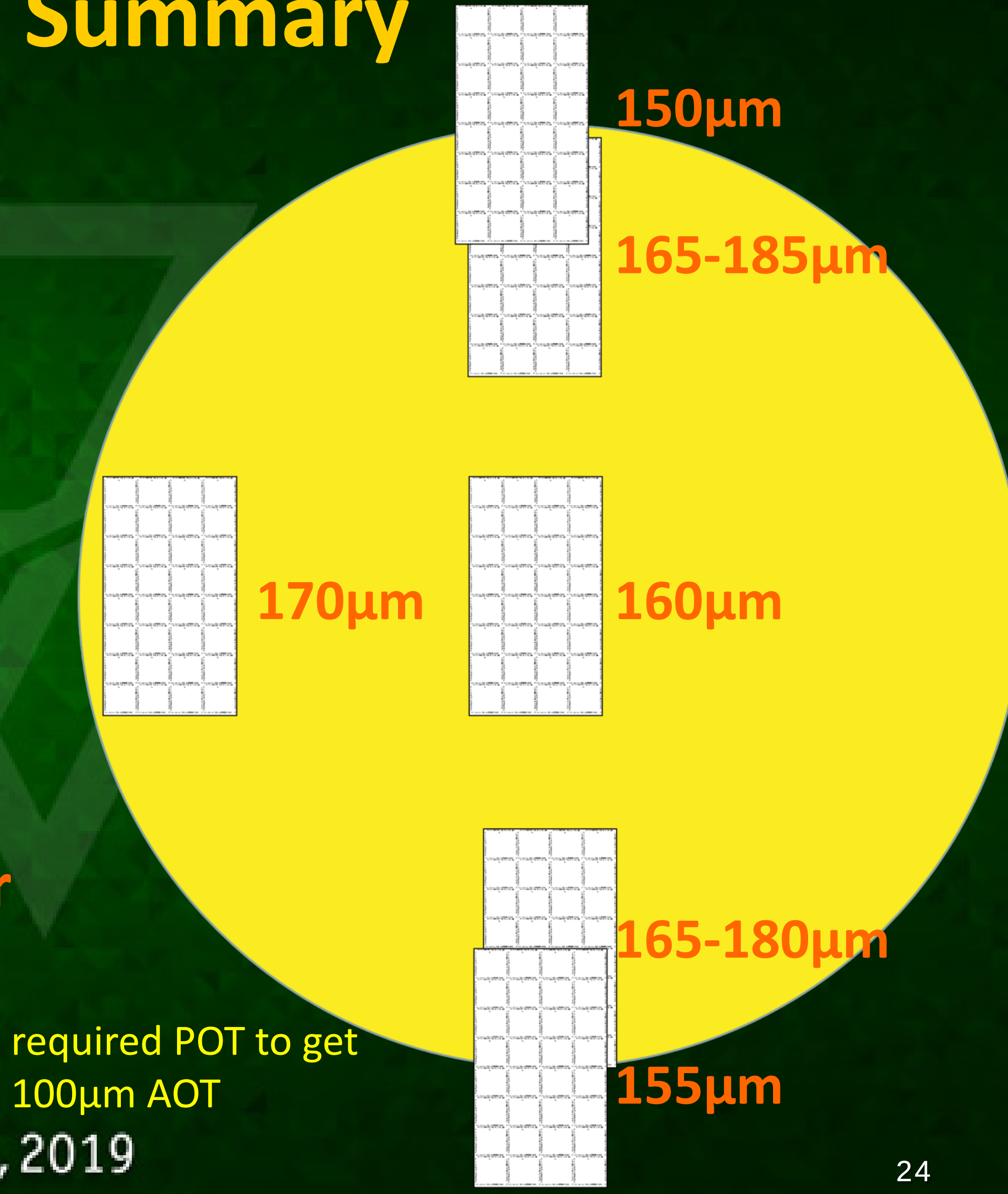
POT = programmed overtravel
AOT = actual overtravel

A data point in the diagram means:

- it's X-value is the relative prober Z-stage height when this needle had first contact to the wafer
- it's Y-value is the previously measured relative needle height

System Deflection Summary

- System deflection has been measured for 257N (25,7kgf) contact force
- System deflection (POT minus AOT) is 60µm in the chuck center for 160µm POT
- At the wafer edge the system deflection can rise up to 85µm due to tilt of components
- System characterization is essential to get your high pin count probing process under control



Topics

- Introduction: Copper pillar, high temperature, high pin count
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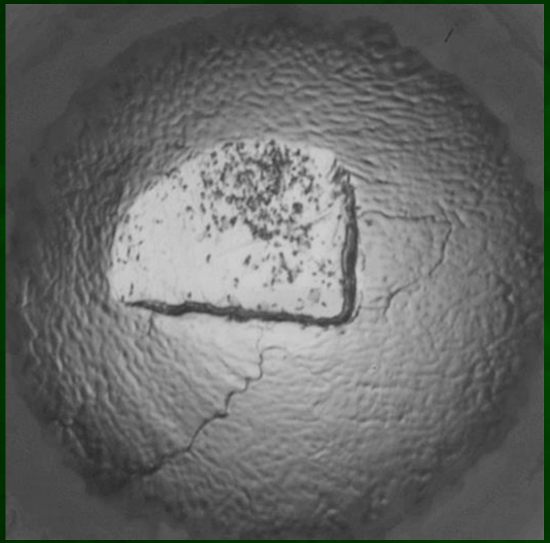
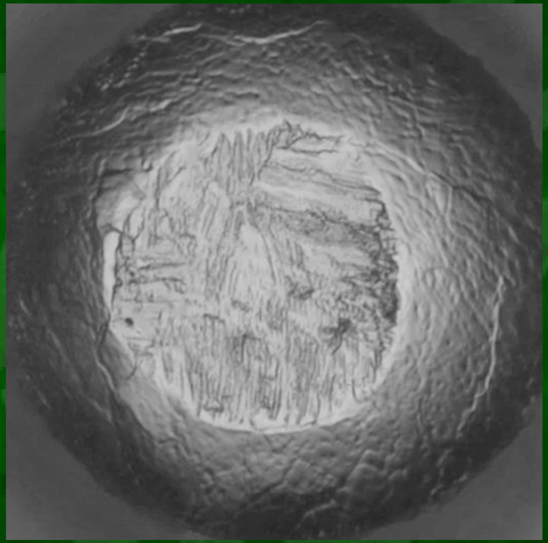
Cu Pillar Contact at 150°C Probing Temperature

- **Pictures from 150°C Cu Pillar Probing Trials**



position offset

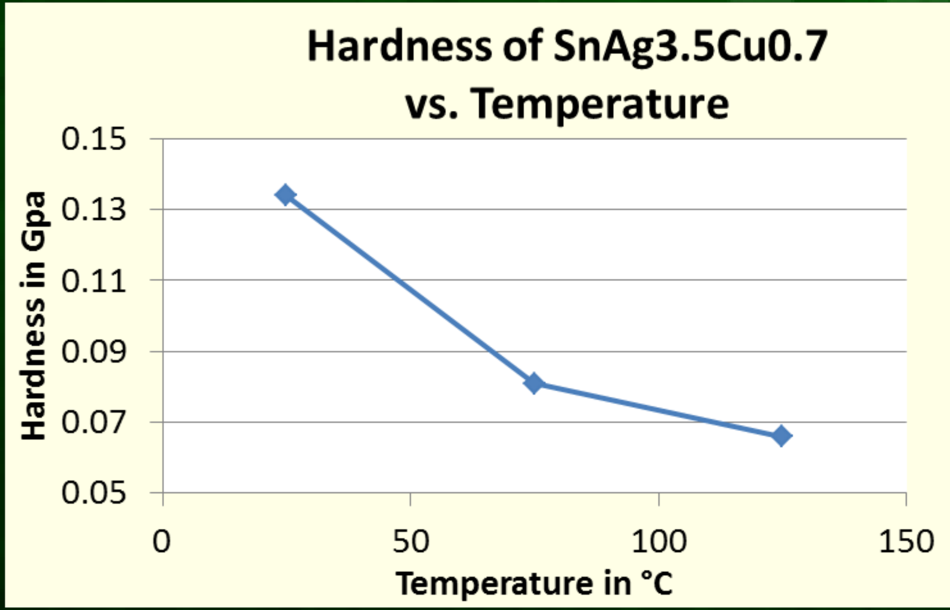
deep impact,
fissure



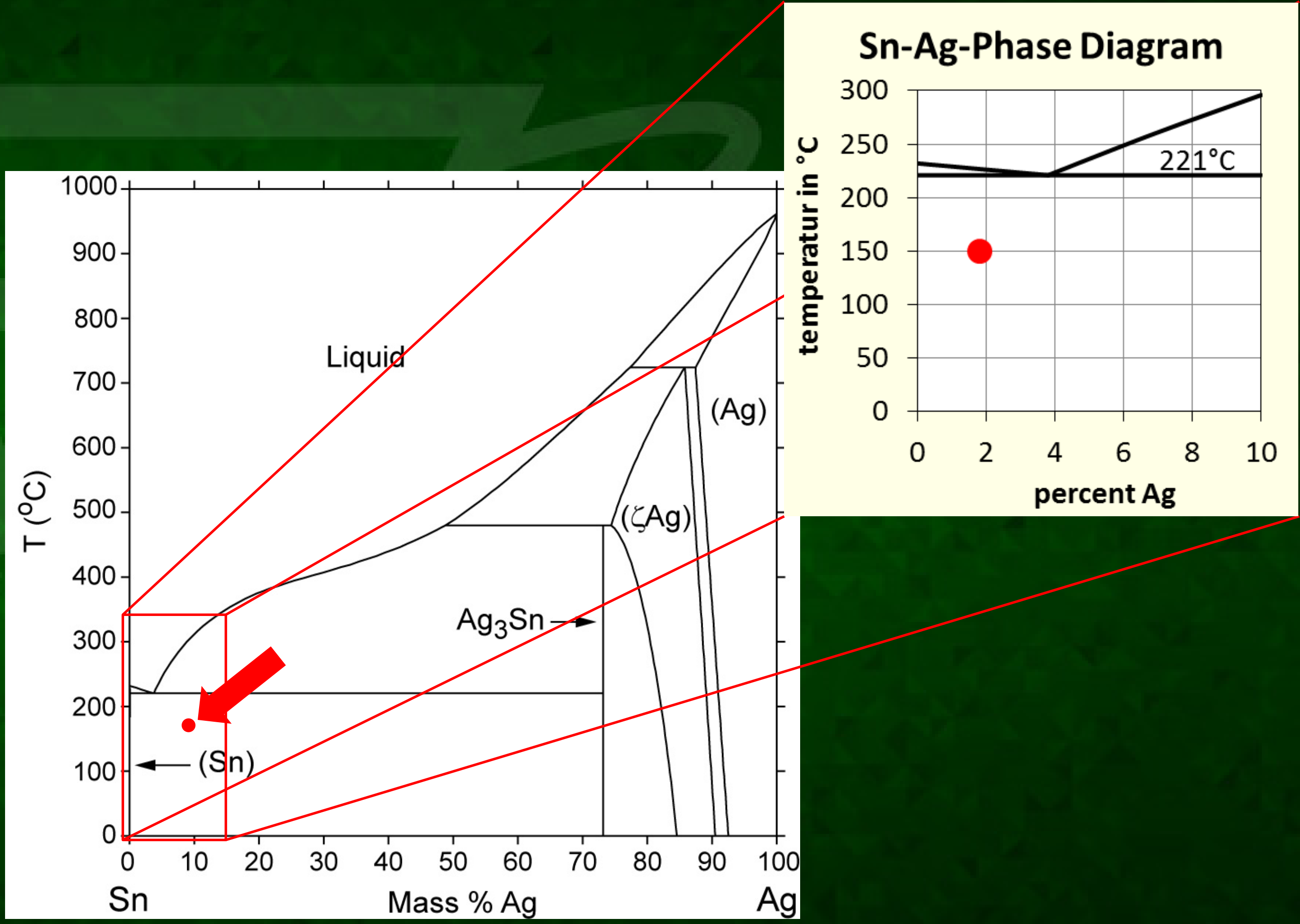
large deformation

Material characteristic of the used Cu pillar

- **Solder Cap**
  - Alloy: SnAg1.8
  - High temperature is critical due to
    - Reduced hardness at high temperature
    - Thicker oxide layer on solder cap



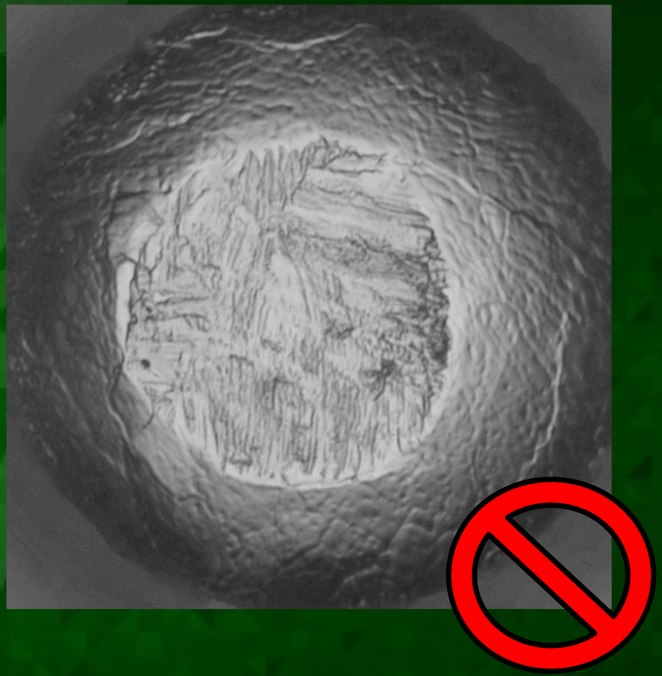
Han, Jing, Nai, Xu: “Temperature dependence of creep and hardness of Sn-Ag-Cu lead-free solder”; Journal of Electronic Materials 39(2):223-229 February 2010



https://www.metallurgy.nist.gov/phase/solder/agsn.html

Challenges at 150°C test temperature

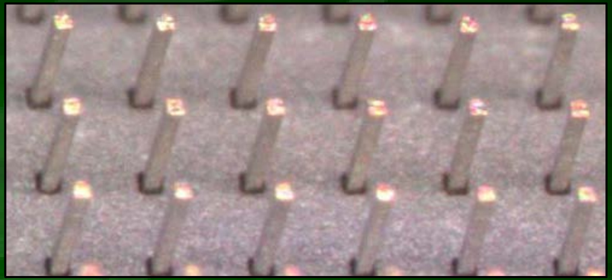
- **Requirements**
  - Stable contact resistance
  - Small bump deformation
  - Similar bump height after probing
- **Adjustable parameter**
  - Overtravel
  - Contact force
  - Contact surface

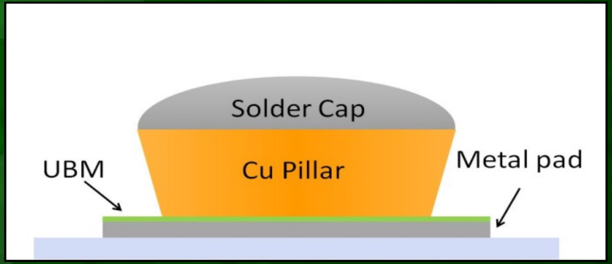


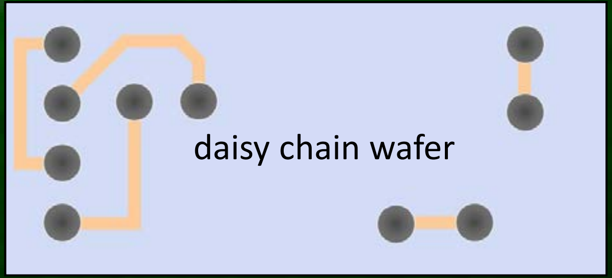
Soft mechanical contact with good contact resistance!

Style / Format Guidelines

- **Experiment Setup**
  - MµProbe® M-Type
    - Contact force 3.8cN
    - Cleaning material 3M pink (3µm)
  - MµProbe® N-Type
    - Contact force 2.0cN
    - Cleaning material 3M pink (3µm)
  - Cu pillar with solder cap
    - Solder material SnAg
    - Bump height 85µm
    - Bump diameter 100µm
  - Accretech UF3000
    - Voltage|Current 2V|20mA
    - Prober acceleration 0.05g
    - Prober velocity 18000µm/s

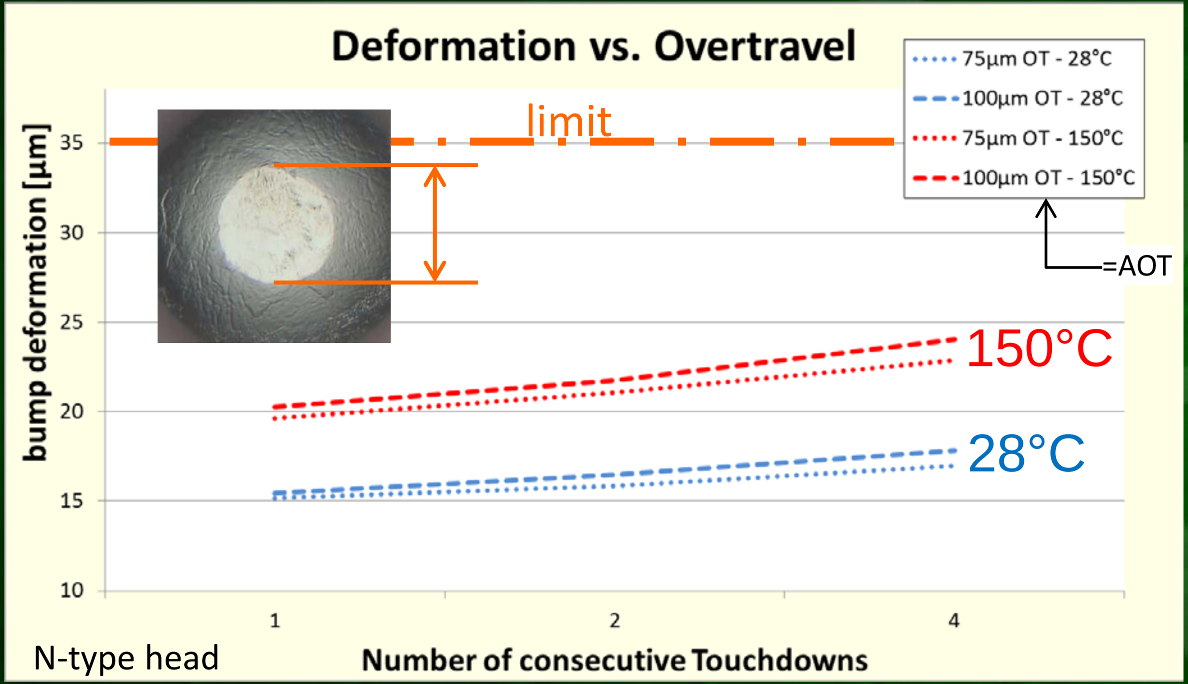


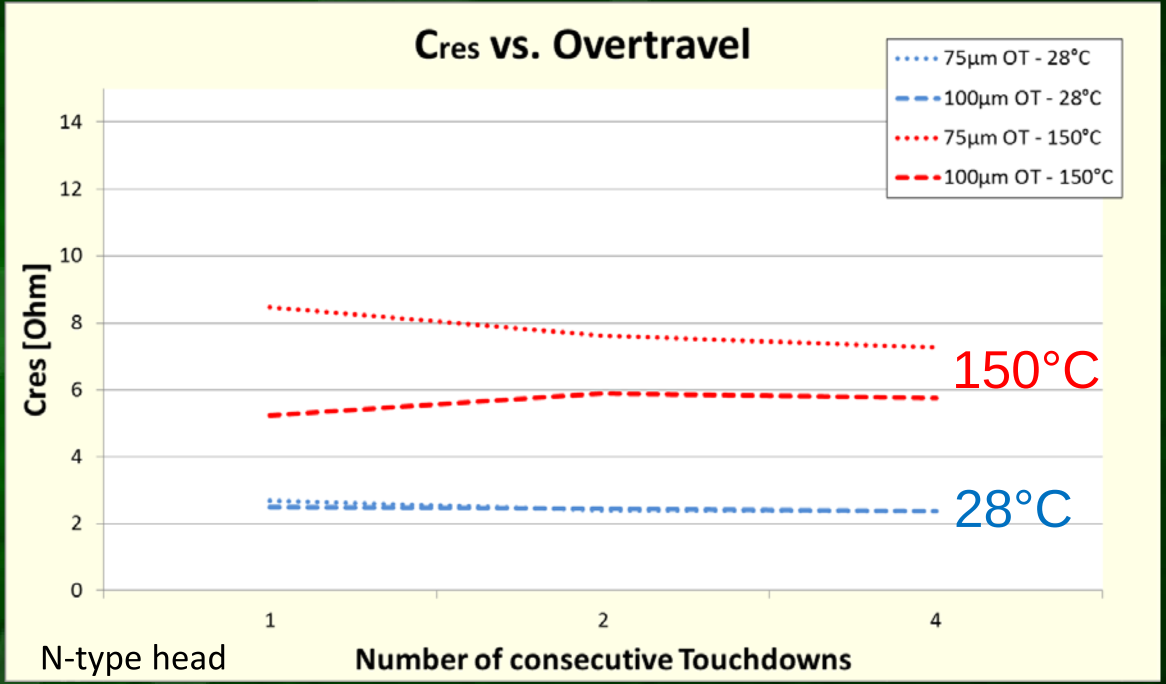




Measurement Data

- **Influence of the Overtravel**



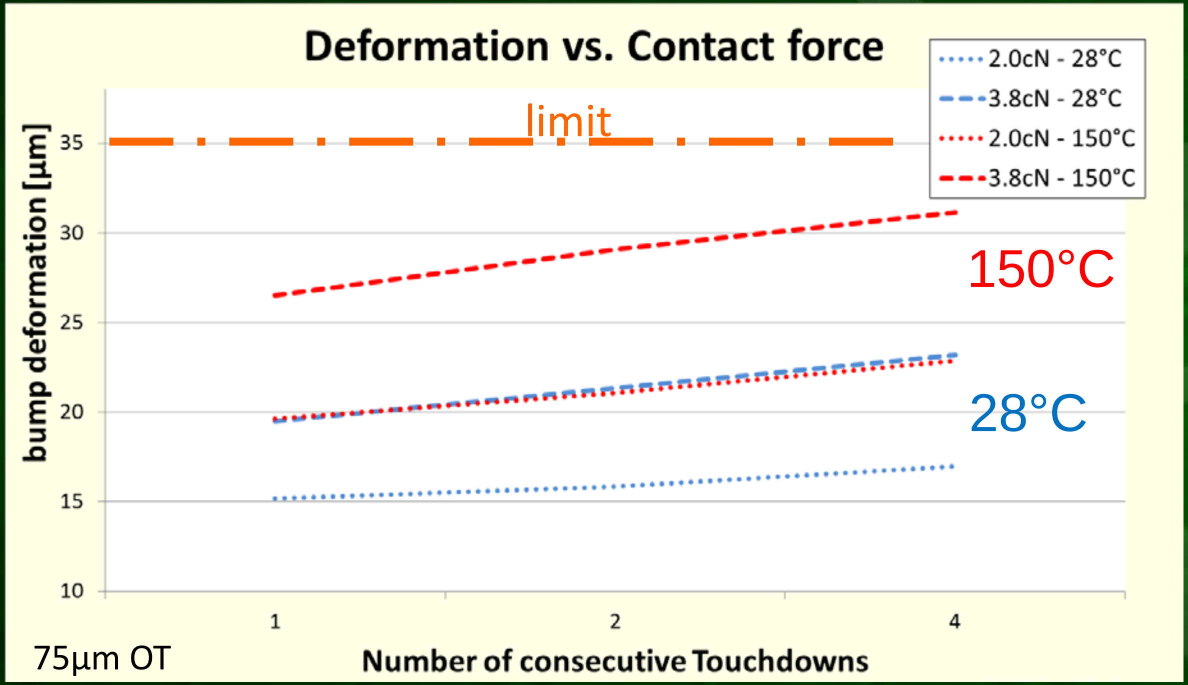


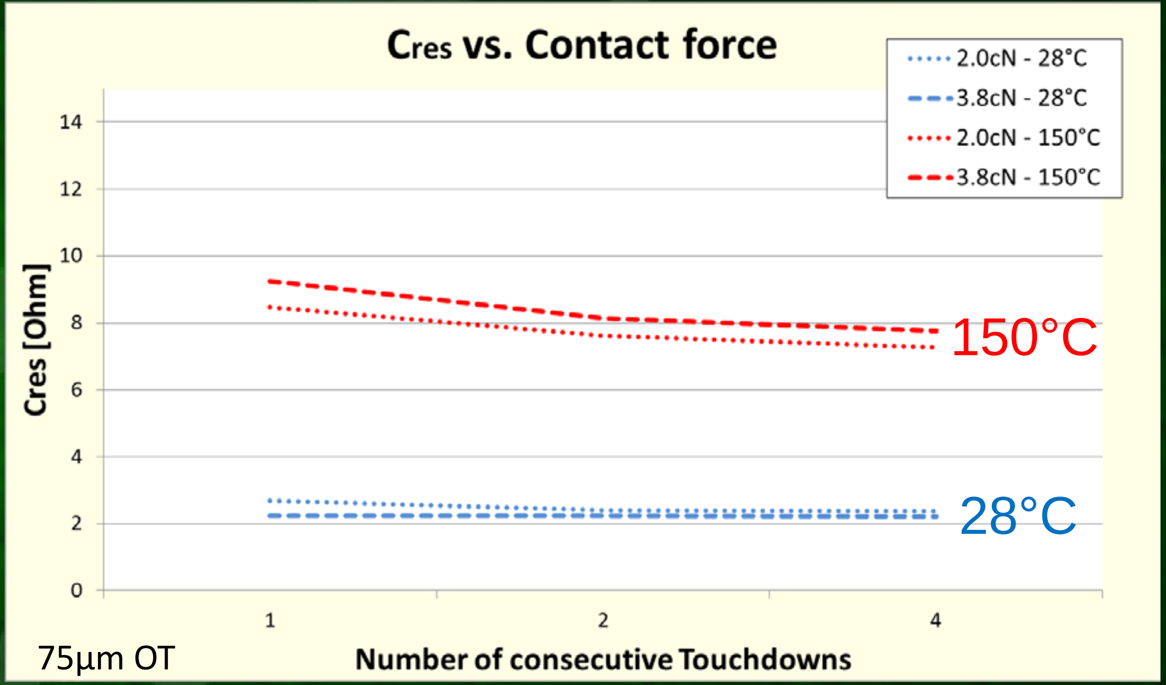
More overtravel shows almost no difference

Correlation between Cres and overtravel @ high temperature only

Measurement Data

- **Influence of the Contact Force**





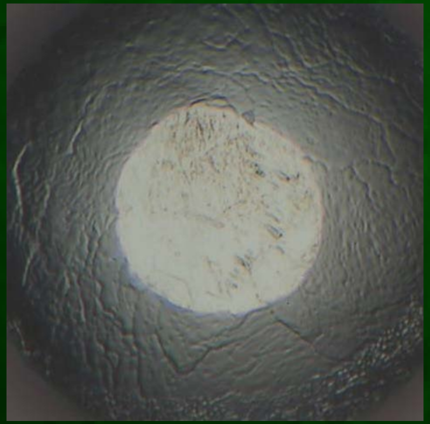
A higher contact force leads to more deformation, especially at high temperature

No correlation between bump deformation and Cres, the temperature matters

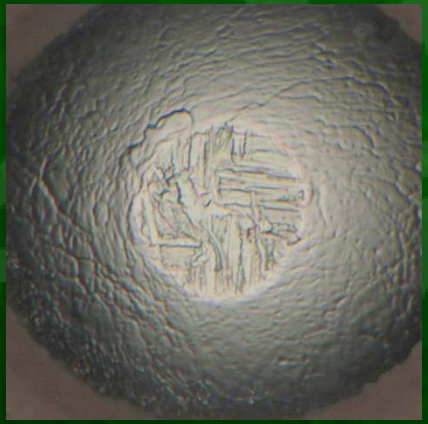
Measurement Data

- **Influence of the Contact Surface**

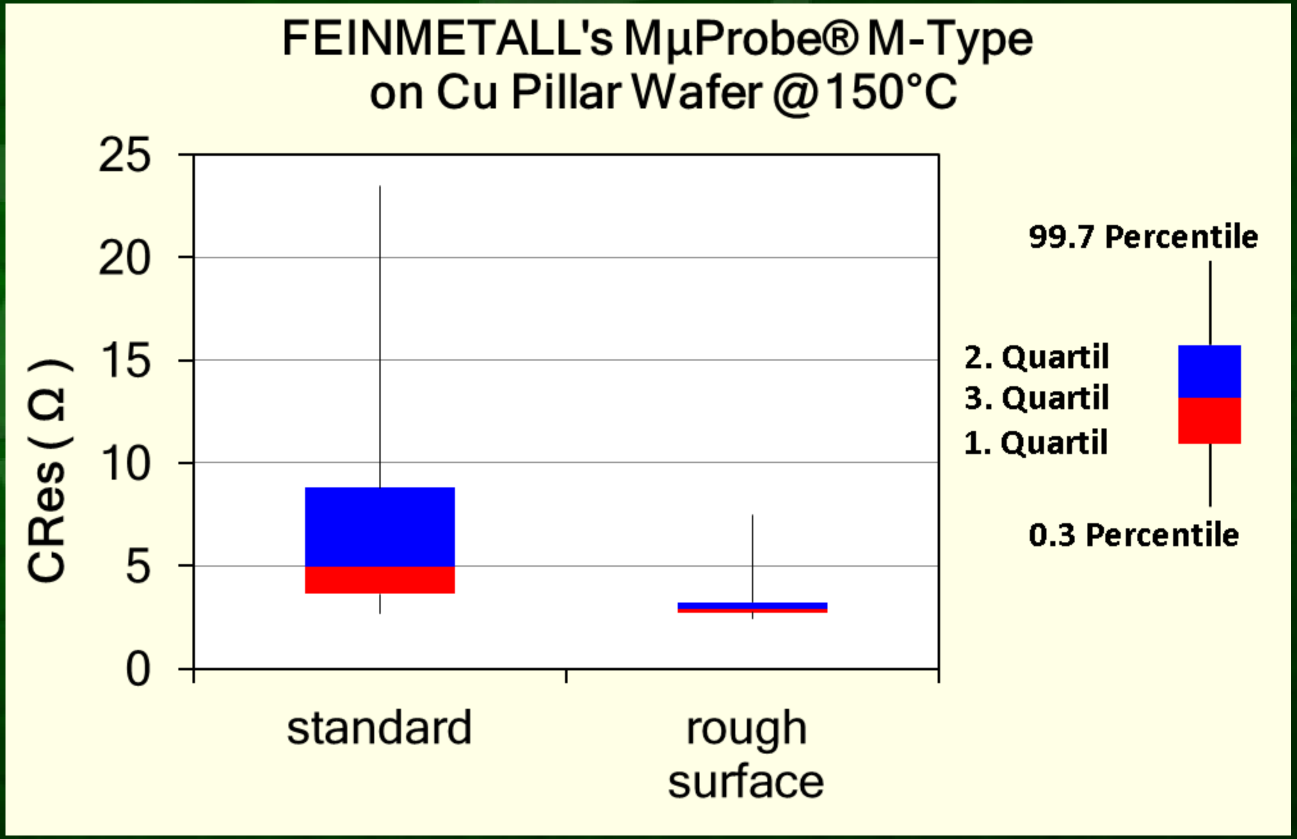
MµProbe® M-Type
- Contact force 3,8cN
- Overtravel 100µm



M-Type: standard



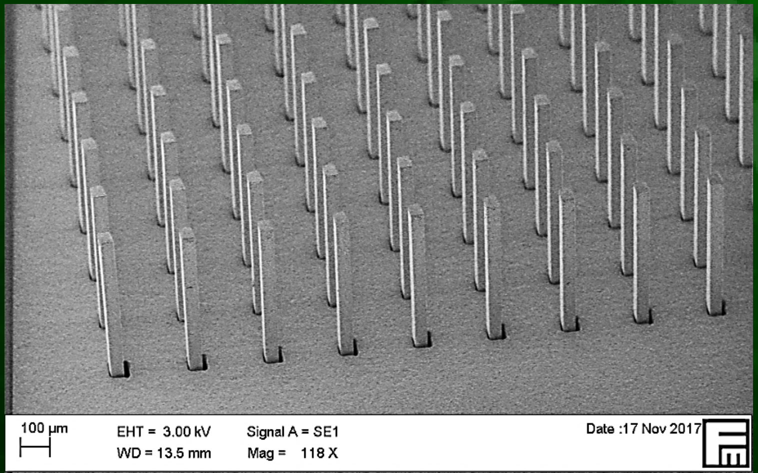
M-Type: rough surface



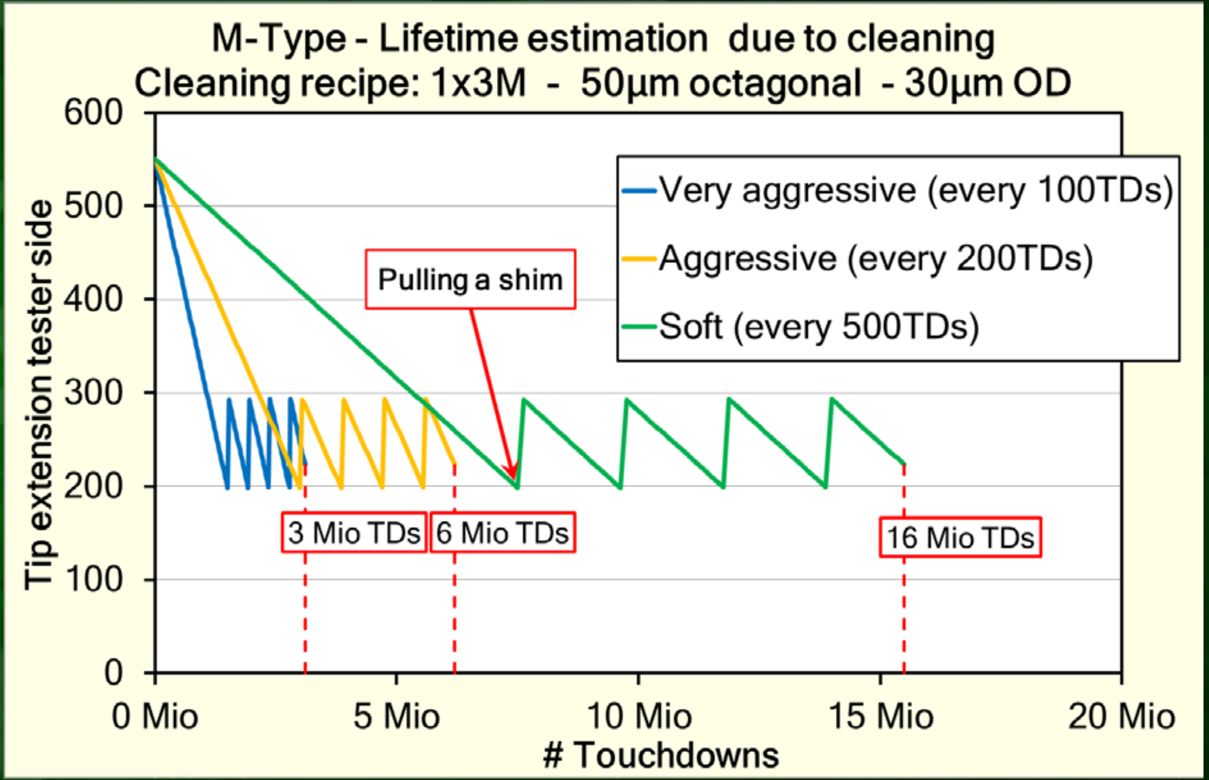
Probe Card Data

- MµProbe® M/N-Type: Solution for 150°C Bump and Cu Pillar Probing

	N-Type	M-Type
Full array pitch	80 µm	90 µm
Contact force	2,0 cN (gf)	3,8 cN (gf)
CCC @ 28°C	500 mA	717 mA
CCC @ 150°C	470 mA	667 mA



M-Type head, wafer side view

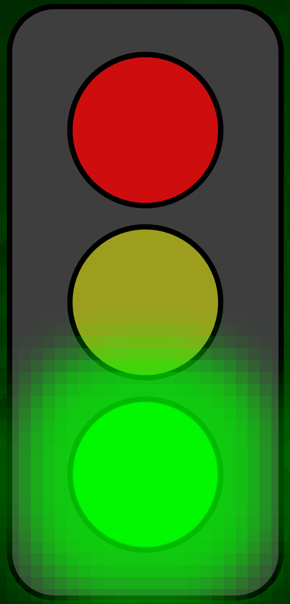


M-Type Lifetime Chart: „Shimming“ leads to extended lifetime

→ US pat. no.: US 7795888 B2

Cu Pillar Contact Summary

- **Influence of Parameter Changes**



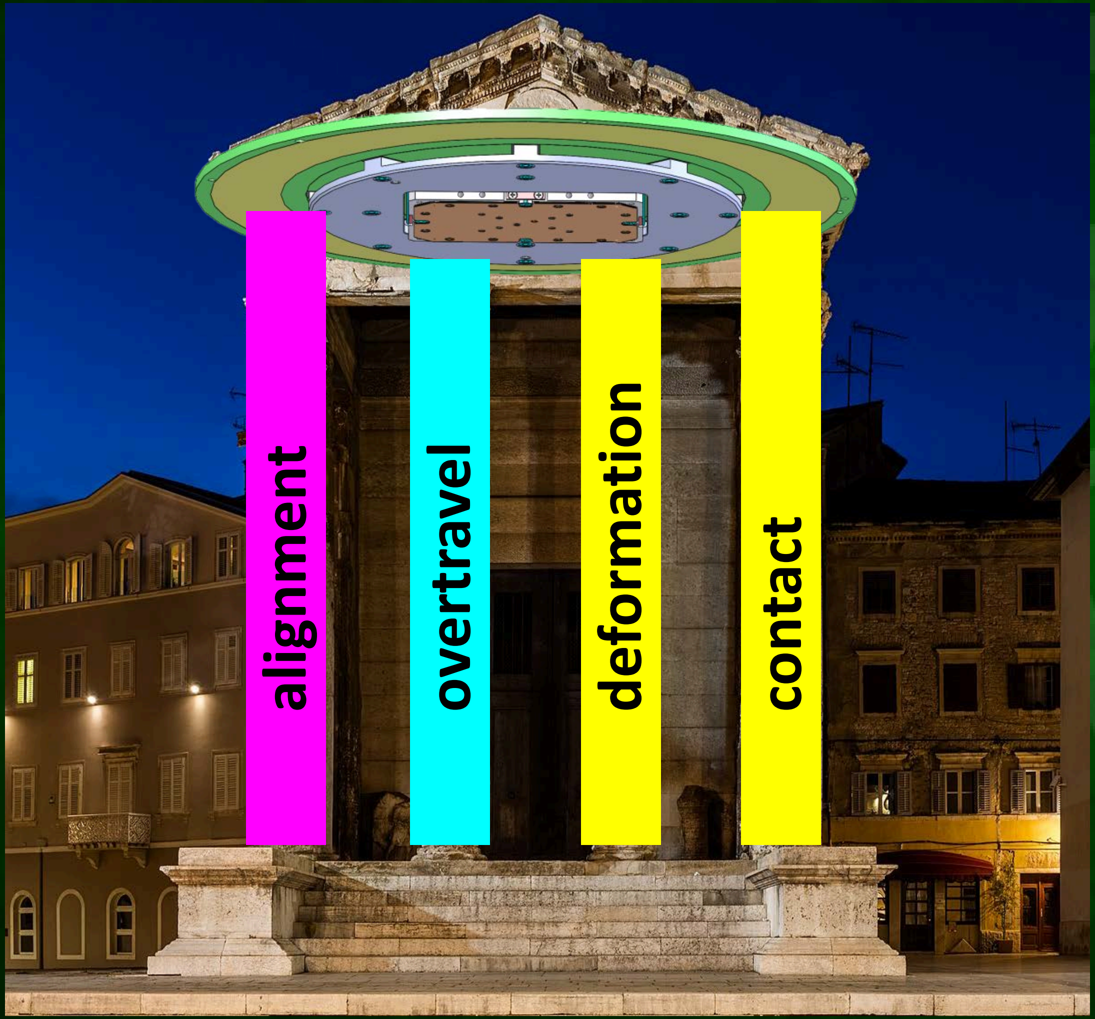
Higher contact force → increased bump deformation

More overtravel → C_{res} improvement @ 150°C

Rougher contact surface → better and more stable C_{res}

→A rough surface is the key to low contact resistance!

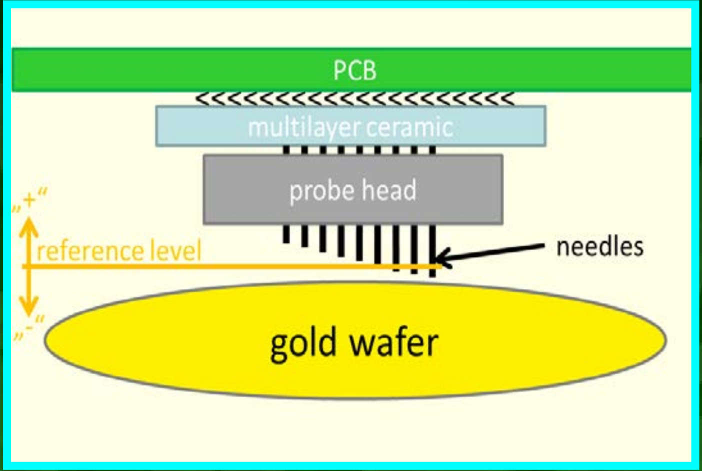
Necessary Basics of Large Area High Temperature Copper Pillar Probing

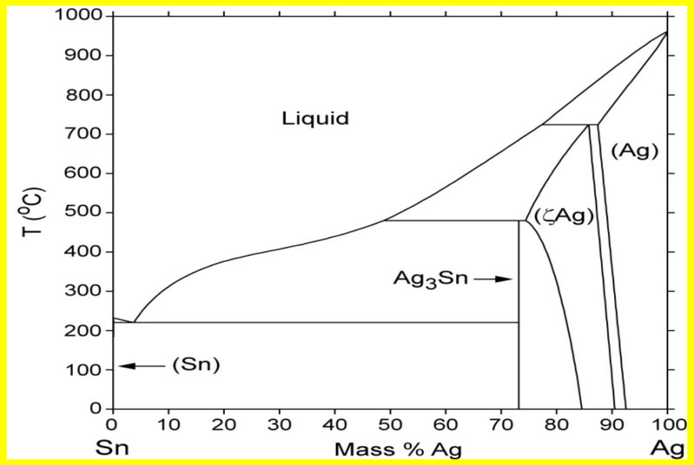


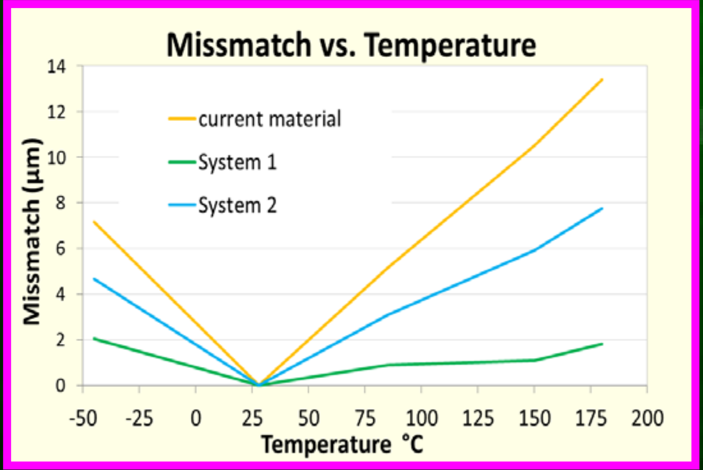
Temple of Augustus, Pula, Croatia
44° 52' 12,7" N, 13° 50' 30,7" O ,

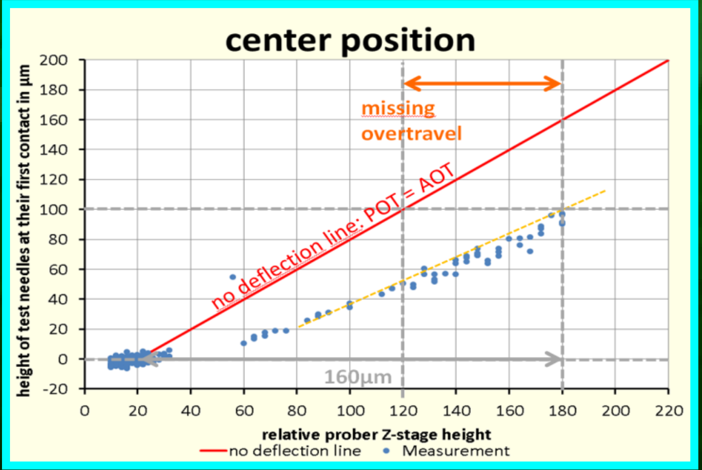
- High CTE ceramic enables high temperature large area probing
- Knowing your AOT is essential to deal with high force | high pin count probe cards
- Probing SnAg Cu pillar @ 150°C is feasible. Online cleaning needs special attention.

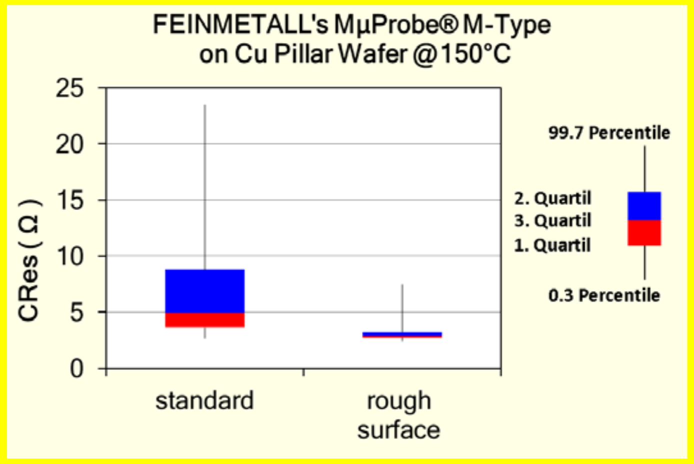
Presentation Highlights











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