IEEE SW Test Workshop

Semiconductor Wafer Test Workshop

Case studies of Wafer Sort Floor Problems

RUDOLPH TECHNOLOGIES

Process. Control. Yield.

Darren James

SWTW Committee Member

Applying What We Learned

- We've completed Gage R&R Study
- We know we have a solid metrology tool
- We know the limits of our metrology tool

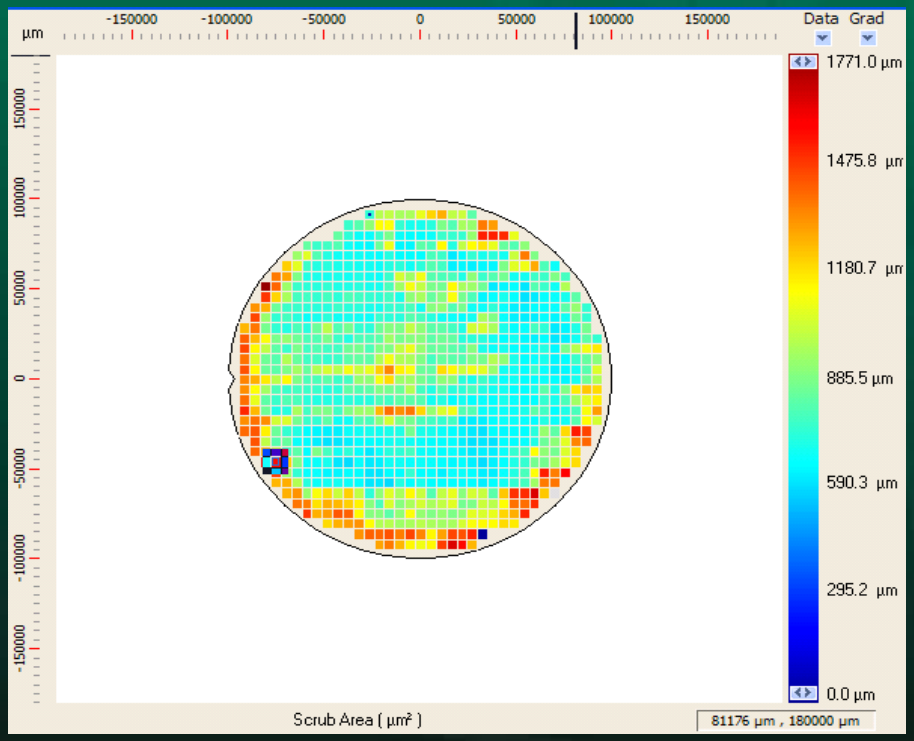
- Now What?

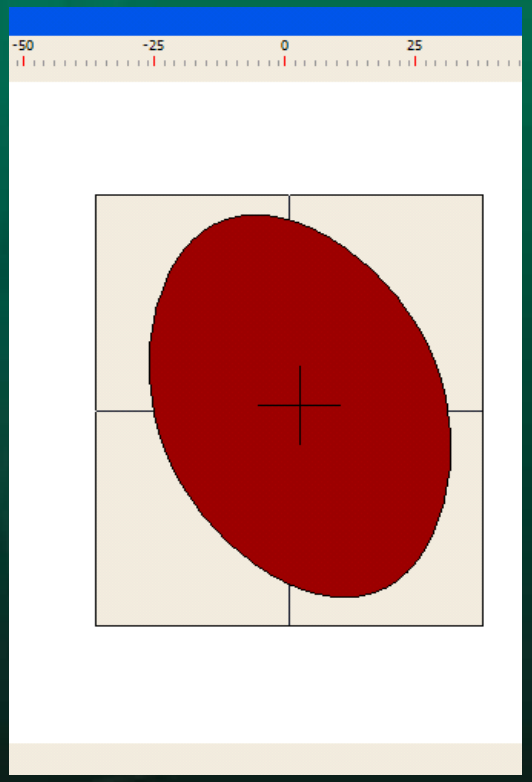
Where to apply metrology

- **Process monitor**
- **New process validation**
  - Test at Temperature
  - Pad Shrink
  - New Technology (i.e. copper pads)
- **Probe card qualification**
- **Probe technology comparison**
- **New equipment qualification**
- **Maintenance monitoring**
- **Tool evaluation and selection**

PROCESS MONITOR

Fab Process Issue

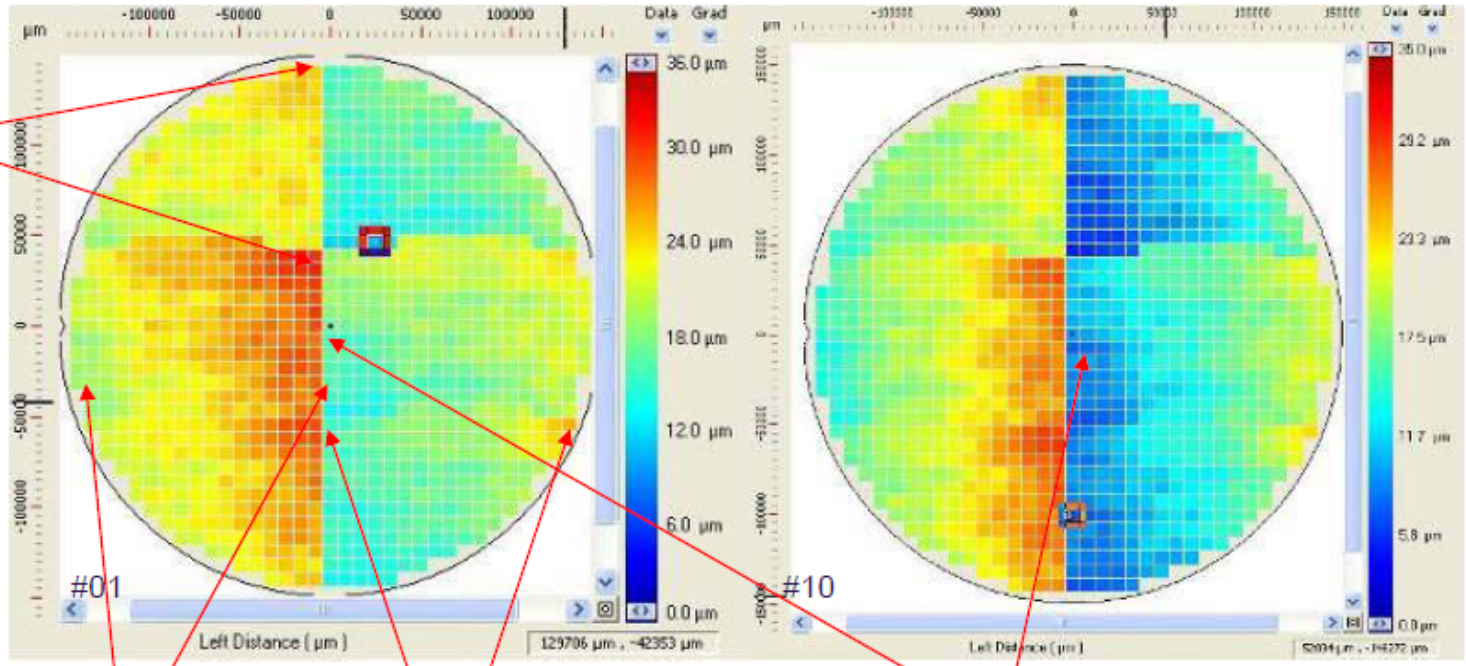




A process issue, pad discoloration, was found during the experiment. WaferWoRx300 picked up the discoloration of the pads as extremely large scrub marks. This was reported back to the fab.

Real-time Process Feedback

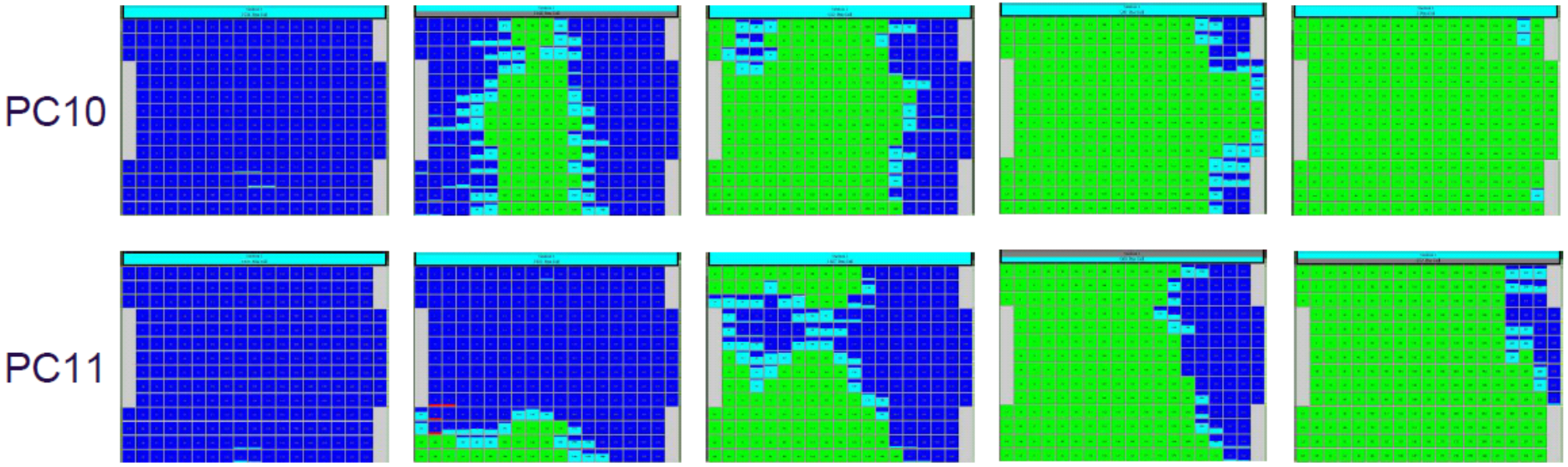
The power of systematic scrub mark analysis …

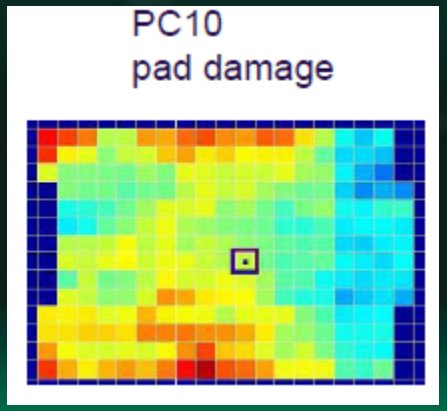


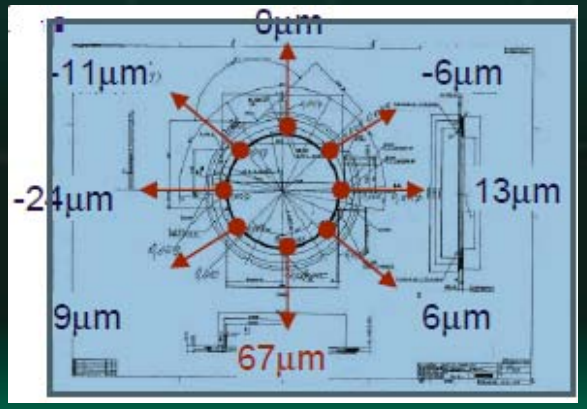
… gives you valuable hints for probing process optimization

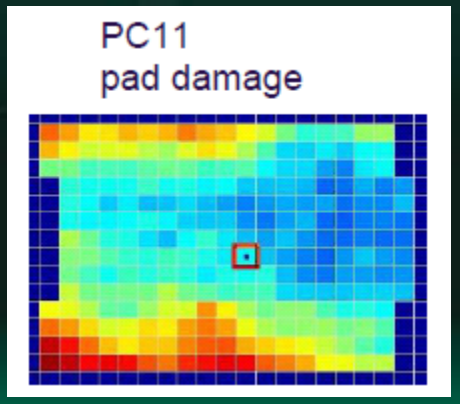
Pietzschmann, et al, SWTW 2005

Controlling the sort process









NEW PROCESS VALIDATION

- Test at Temperature
- Pad Shrink

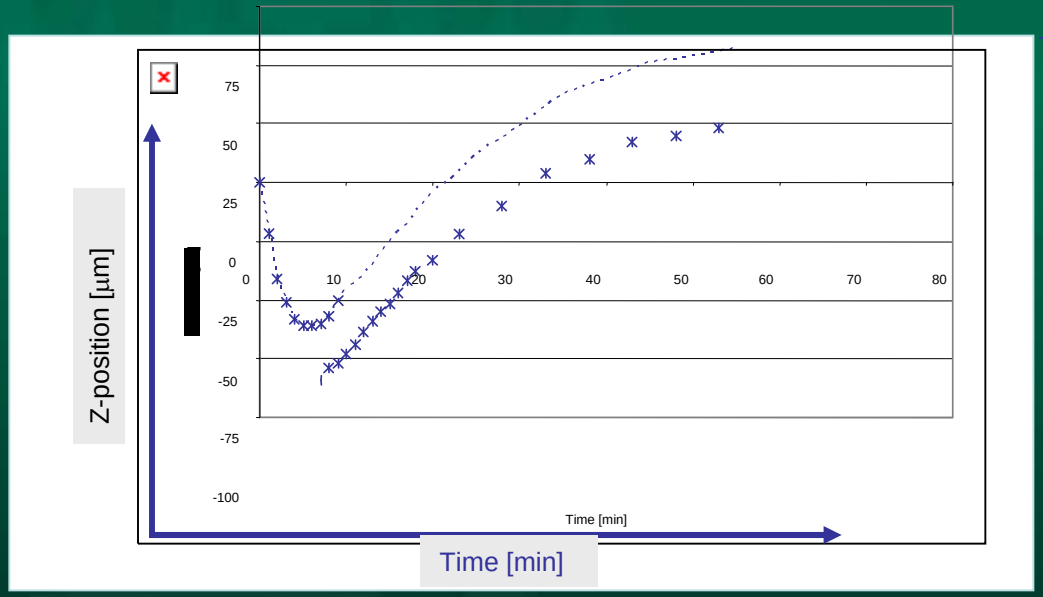
Thermal *Movement of Probe Card*

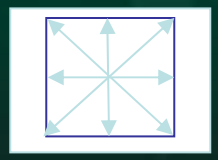
(1) Z movement probe array
- range: up to 110um
- time: over 2h preheating
- direction: -Z or/and +Z

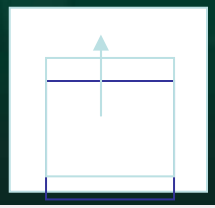
(2) X & Y material expansion
- range: up to 15um / 150mm
- time: < 20min of preheating
- direction: star like

(3) X or Y drift probe array
- range: up to 35um
- time: over 5h preheating
- direction: X or Y

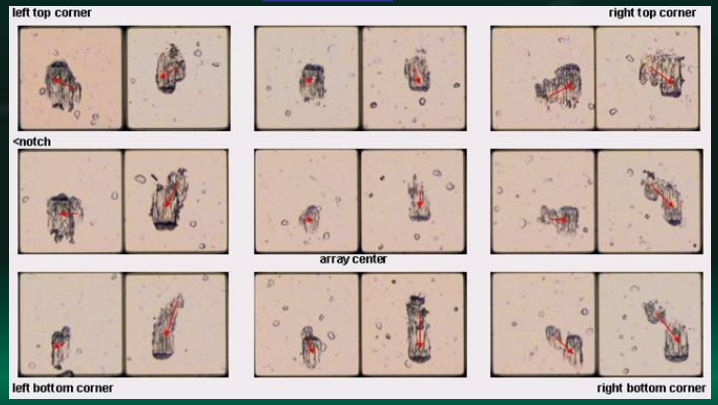
(4) Single needle movement
- range: 3…15um
- time: 1st h of preheating
- direction: each needle different







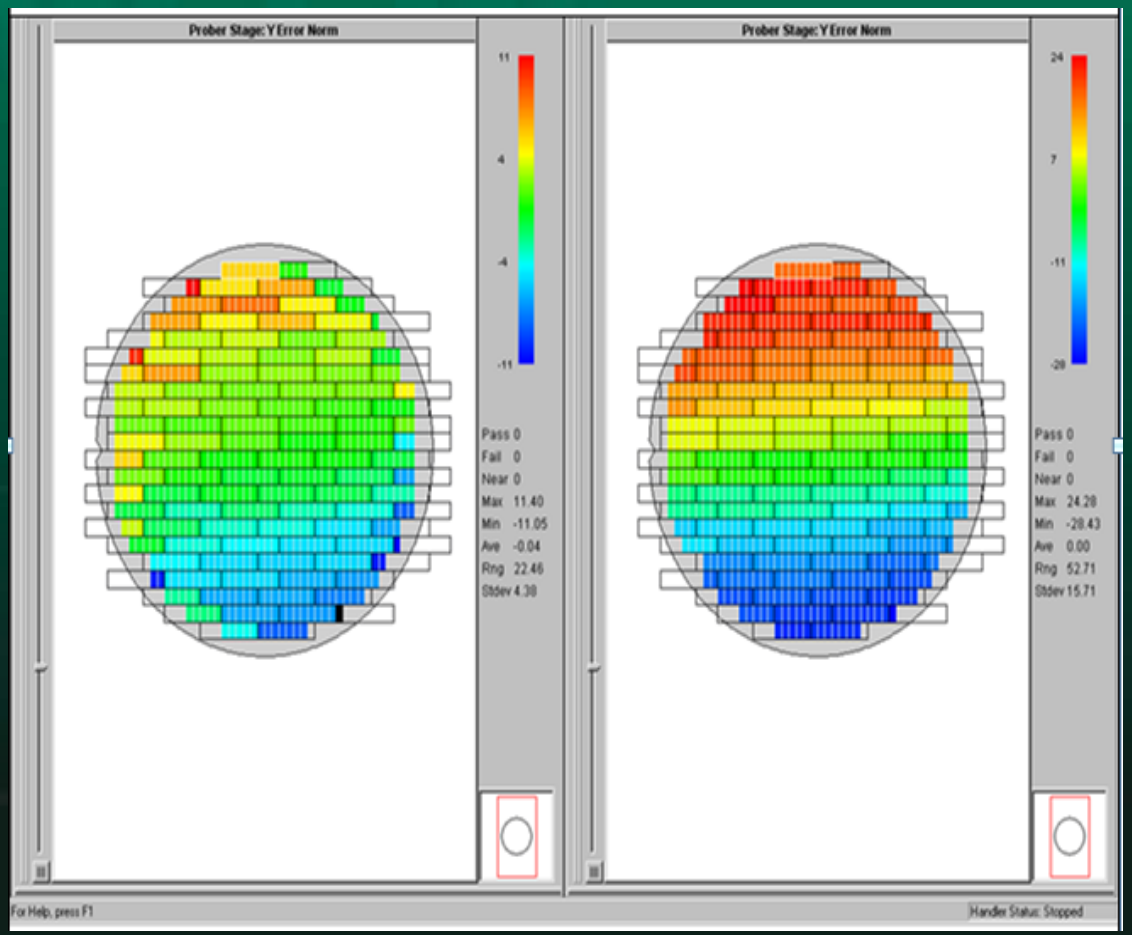
dependency on:
- probe card construction
- used stiffener material
- PCB properties



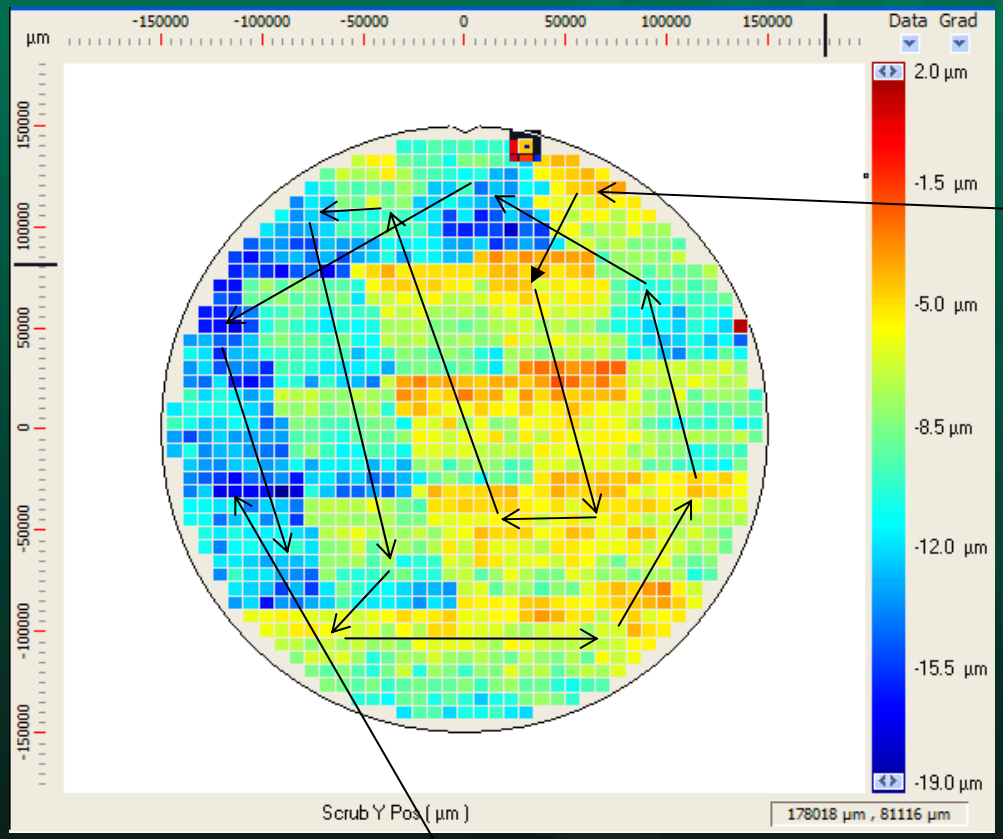
Pietzschmann, et al, SWTW 2005

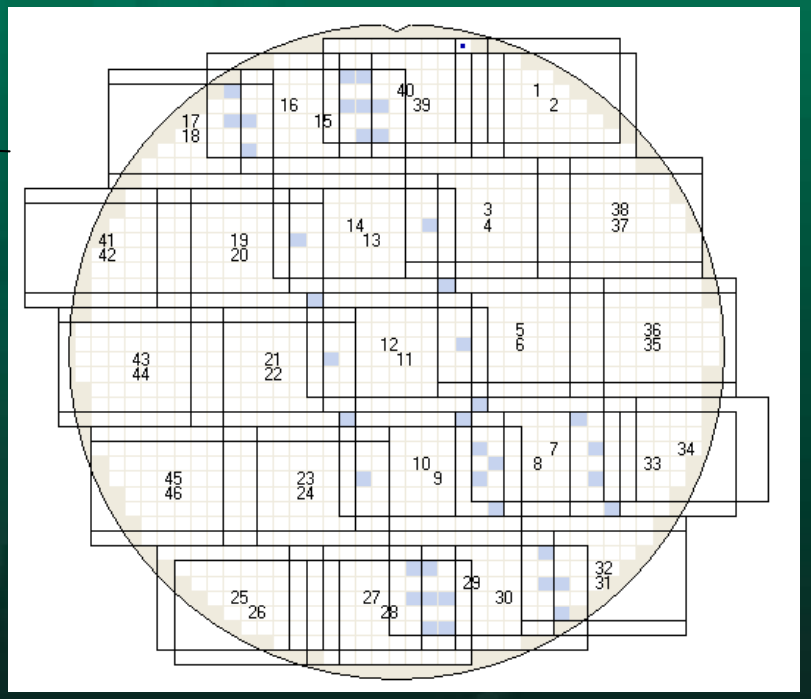
Thermal Movement of Probe Card

- **Comparison of Y Wafer Scale between 2 wafers. Probed at 88°C (L) and 150°C (R).**
- **Y Wafer Scale identifies whether the die-to-die step size is accurate in the Y axis.**
- **An 8x1 probe card array was used to probe this wafer (outlined by black box).**
- **88°C has an error of approx 7µ (aqua-orange), 150°C of approx 33µ (light blue-orange).**



Thermal Drift

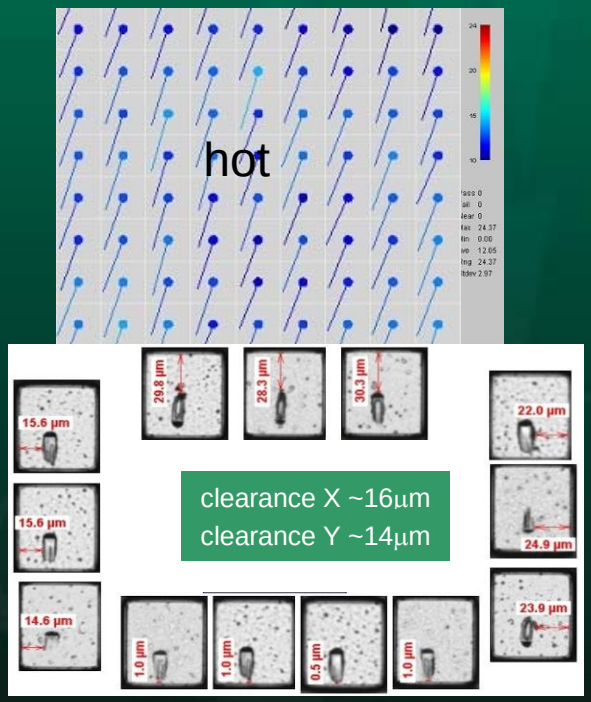




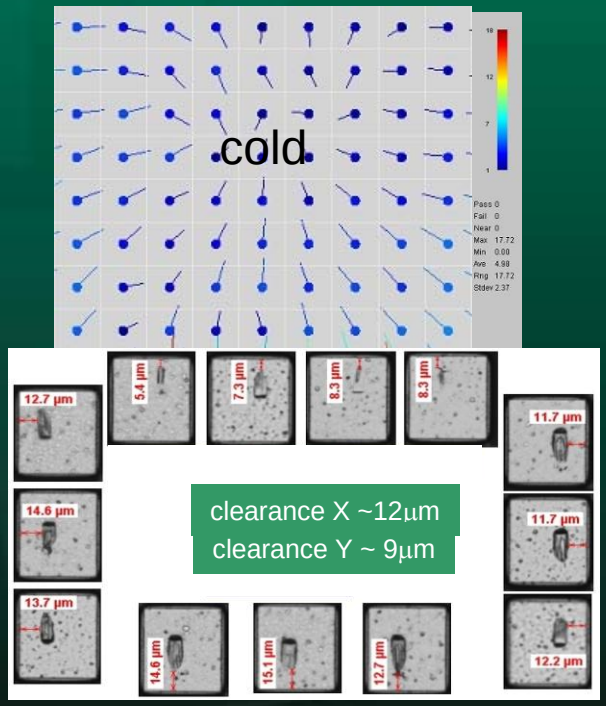
Marks were drifting off of the pads during the probing process. A thermal drift was found on WaferWoRx300, changes to the prober settings helped to correct this issue.

Probe Card Verification at Temperature

Scrub X/Y-Position Error



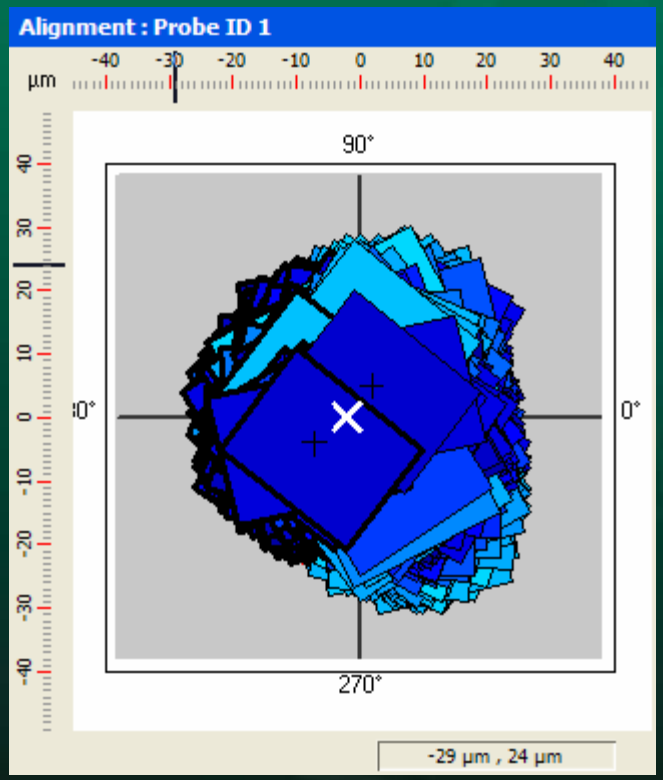
Scrub X/Y-Position Error

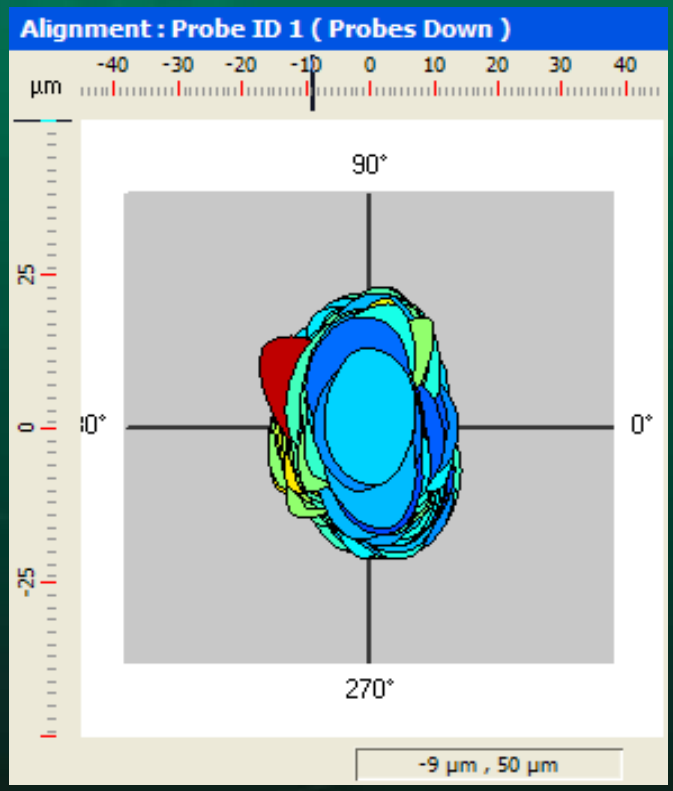


Advanced Optical Analysis - Offset/scaling @ temp Assessment

Pietzschmann, et al, SWTW 2005

Validating Pad Shrink





PCA – scrub measurements

PMA scrub measurements w/prober errors removed

Stacking all of the scrub marks to evaluate total sort process CpK

Evaluating the probe card by removing prober and setup error

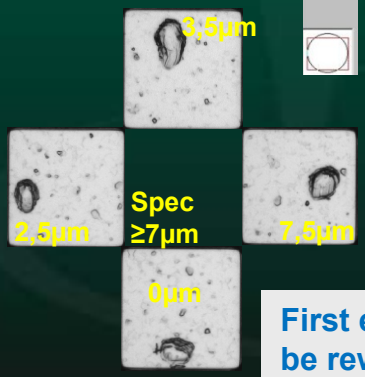
Probe card verification

first delivery ← scrub mark analysis → after feedback

Scrub X/Y-Position Error – Avg. per die

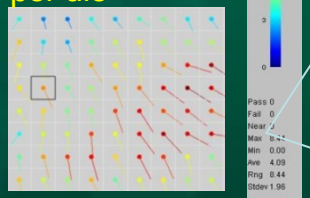
max. 19.5µm
avg. 10.9µm
stdev. 5µm

Pad Edge Distance Worst Case

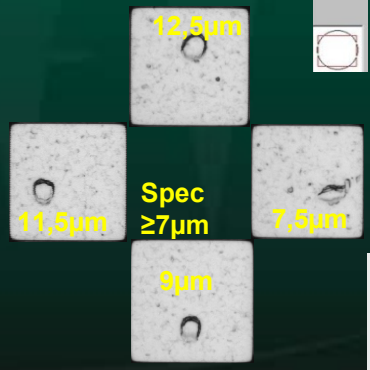


First examples had to be reworked in every case

Scrub X/Y-Position Error – Avg. per die



max. 8.4µm
avg. 4.0µm
stdev. 1.9µm



significant improvement in probing process stability

Test at Temperature – Thermal movement analysis

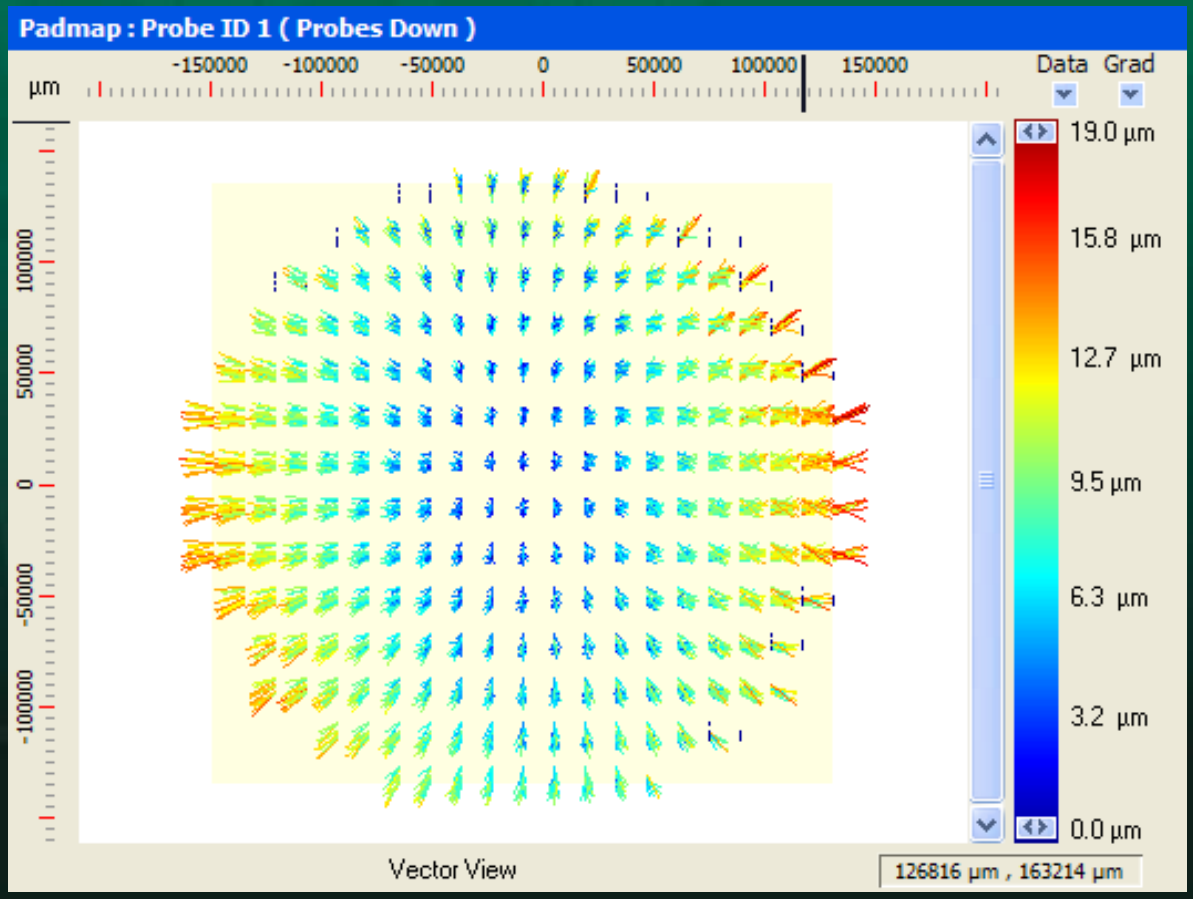
Pietzschmann, et al, SWTW 2005

PROBE CARD QUALIFICATION

New Probe Technology Validation

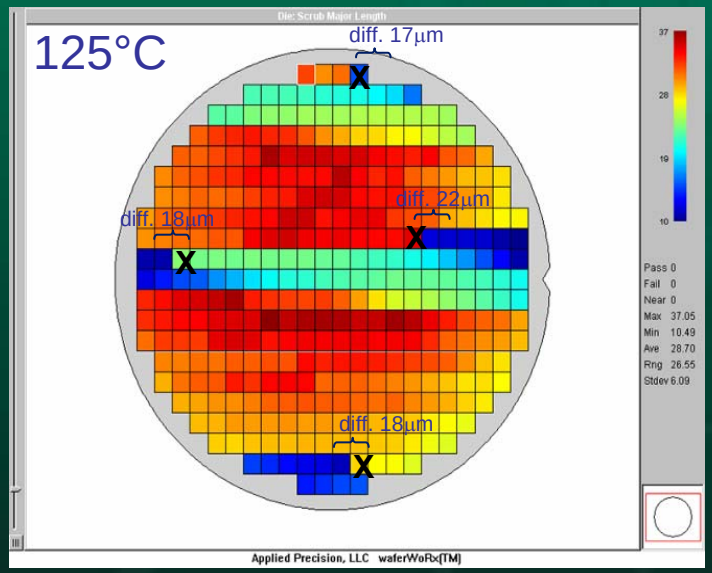
- **Evaluating a new probe card**
- **Plot shows a thermal scaling affect**
- **Card did not pass incoming Q/A**

Vector view

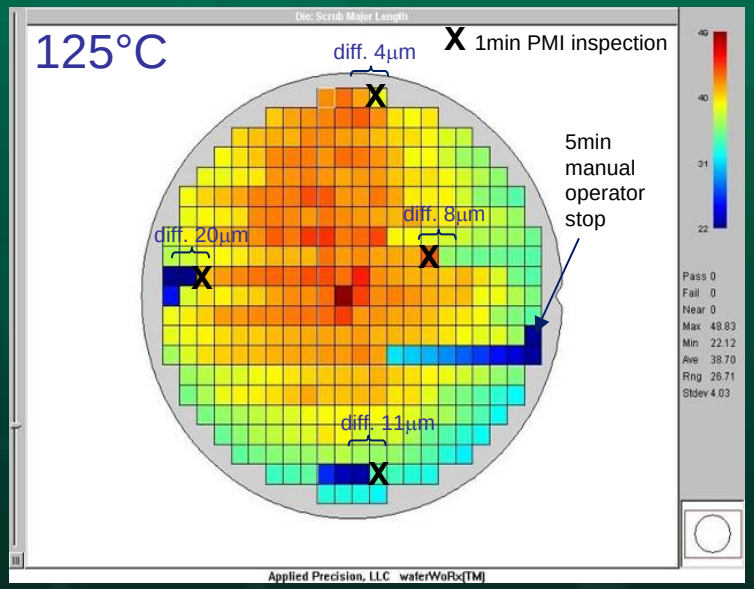


Blank/un-patterned wafer analysis
Vector view of scrub X-Y position

Validating Probe Card Design



old probe card



probe card with new stiffener

Thermal effects caused by probe card stiffener.

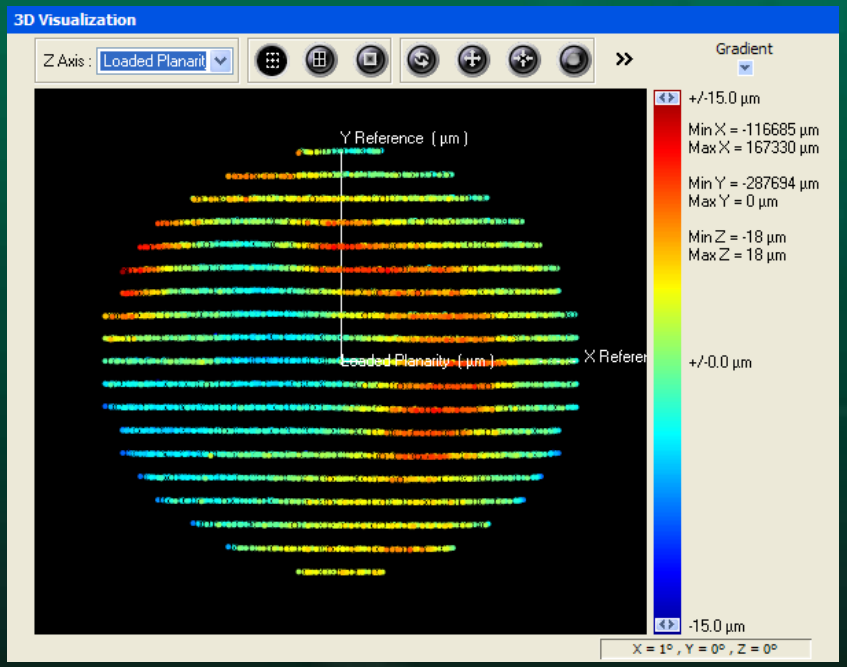
New stiffener design provided better performance

same product

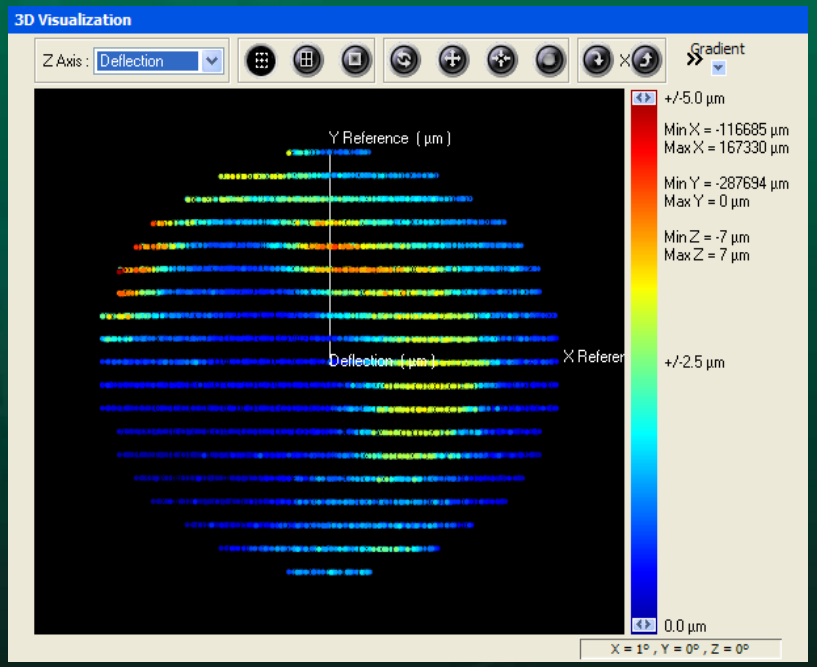
Comparison Major Scrub Lengths

Automated Deflection Test

Loaded Planarity

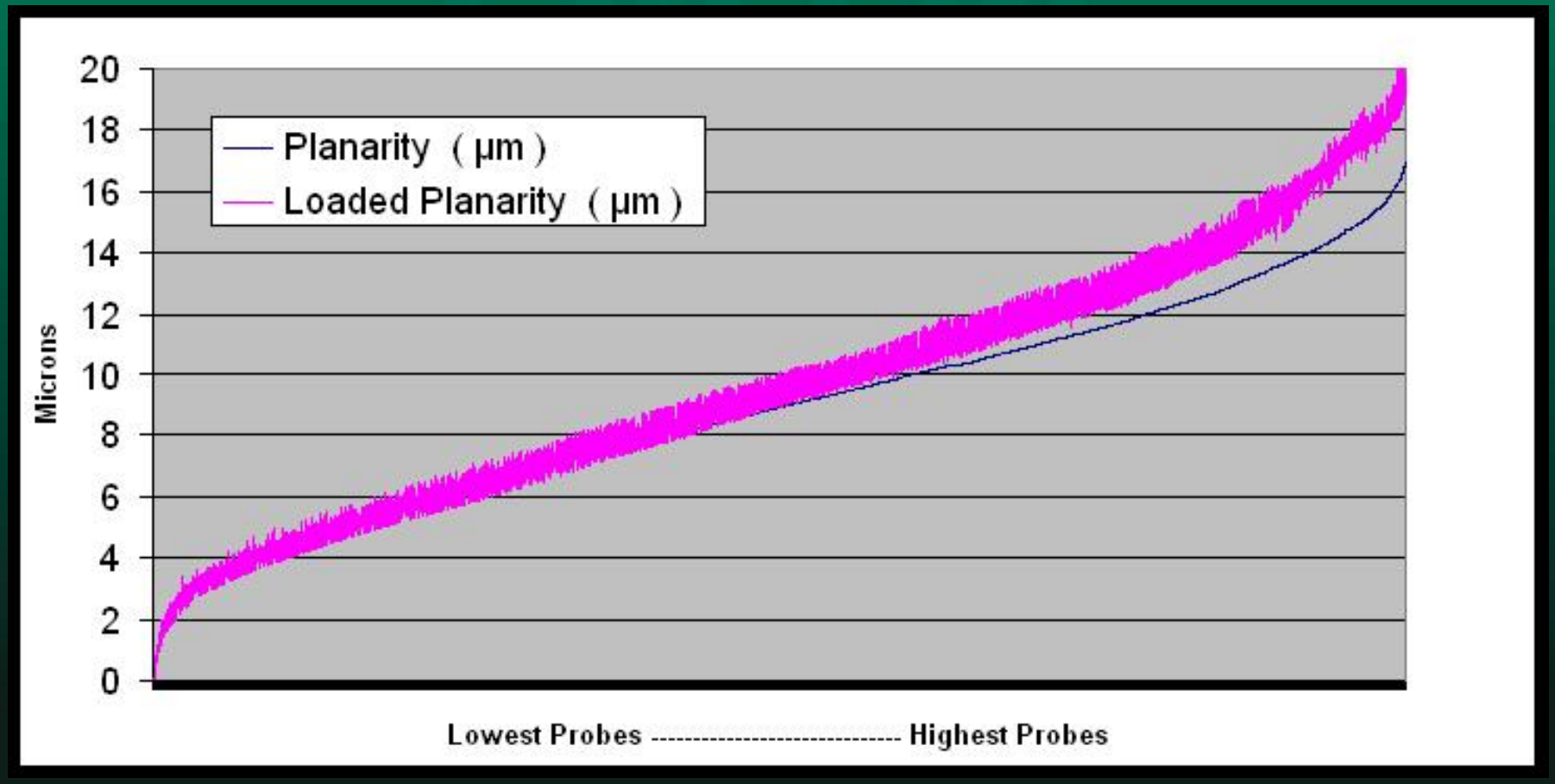


Deflection

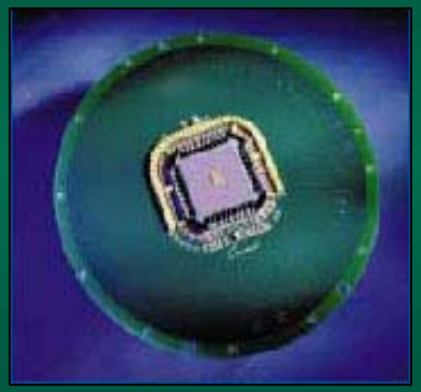


- Deflection of probe card from no over travel until all probes are touching ~5 microns
- Low probes no deflection
- High probes drift up as the probe card is over travelled

Probe Card Deflection Graph

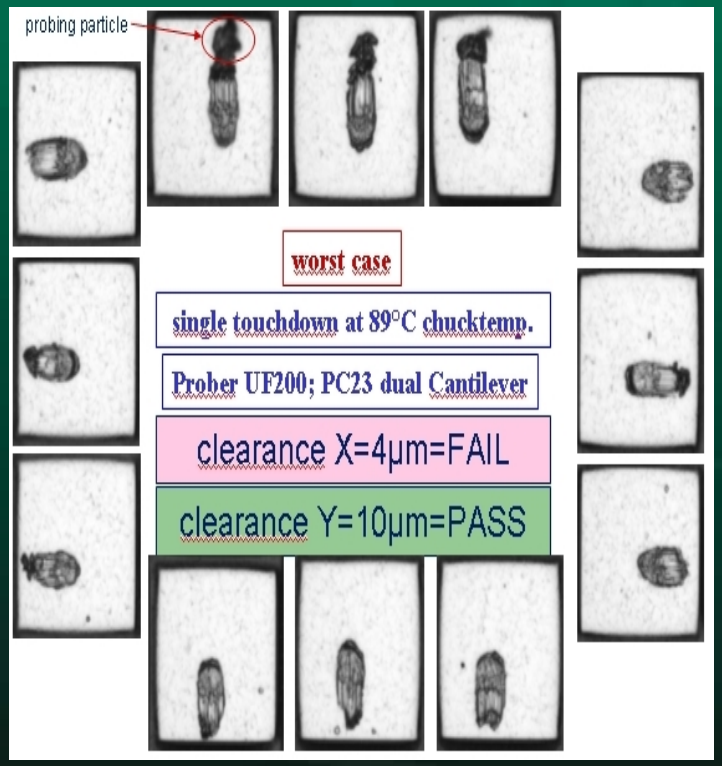


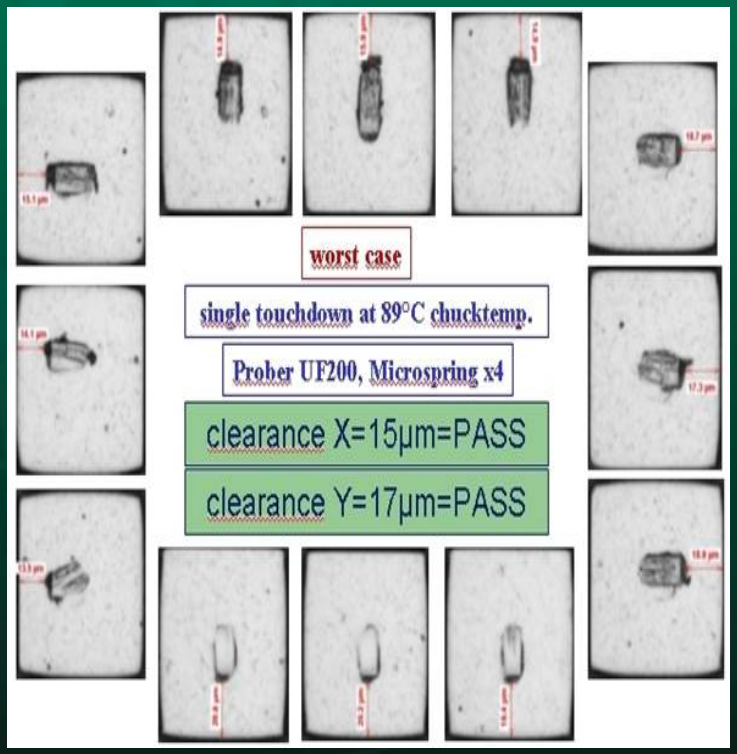
Plotting actual position versus expected position, shift is seen and Z loading increases causing pins to translate up with card deflection.



PROBE TECHNOLOGY

Comparing Probe Card Technologies



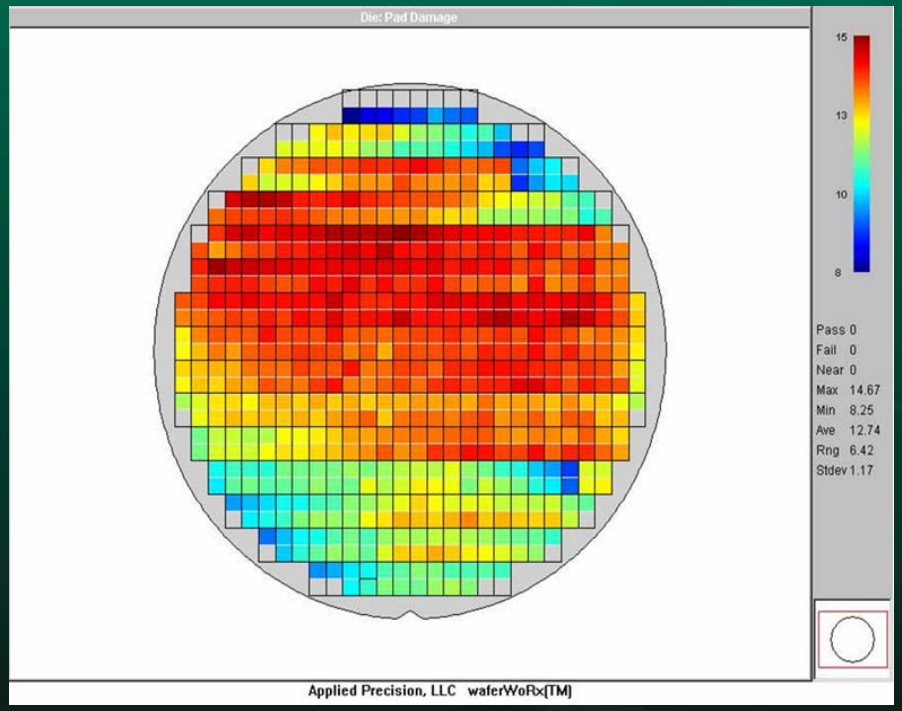


Pietzschmann, et al, SWTW 2005

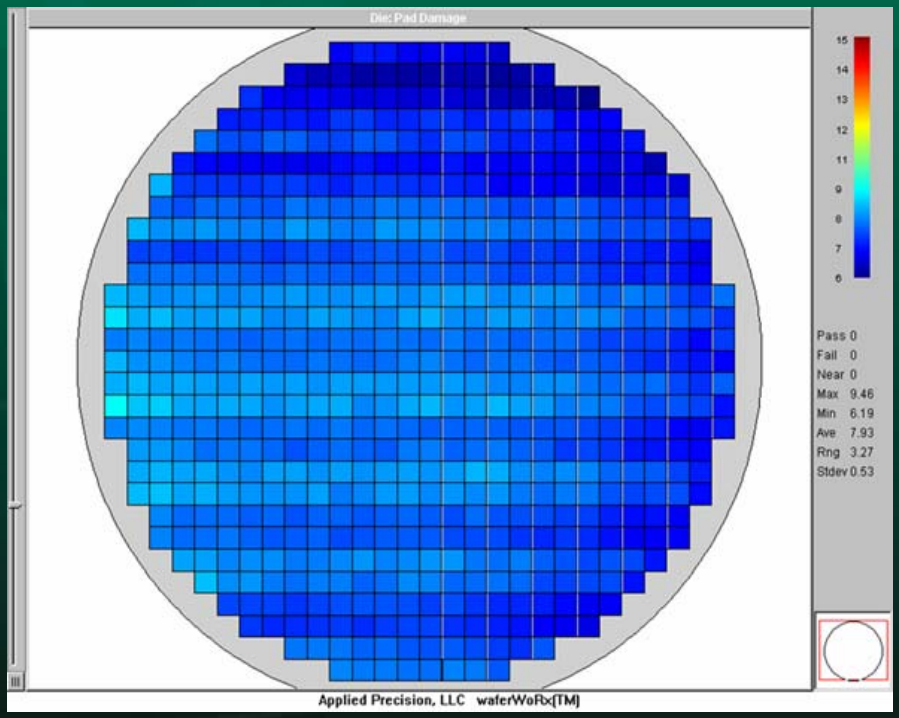
Comparing different probe card technologies and validating which on will work with new smaller pad sizes.

Comparing Probe Card Technologies

Cantilever Dual DUT



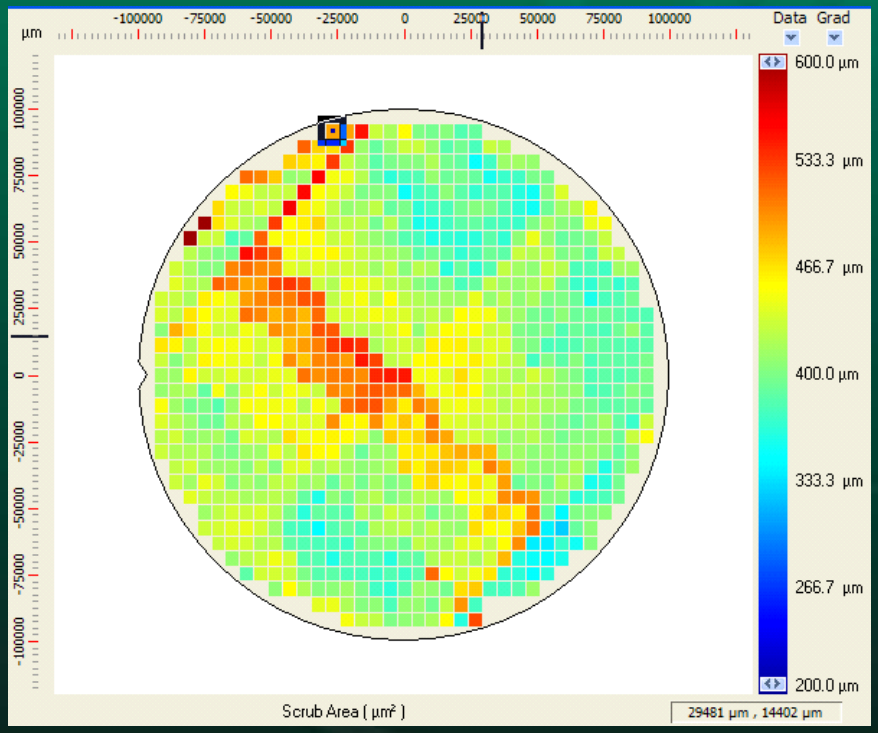
MEMS card Quad DUT

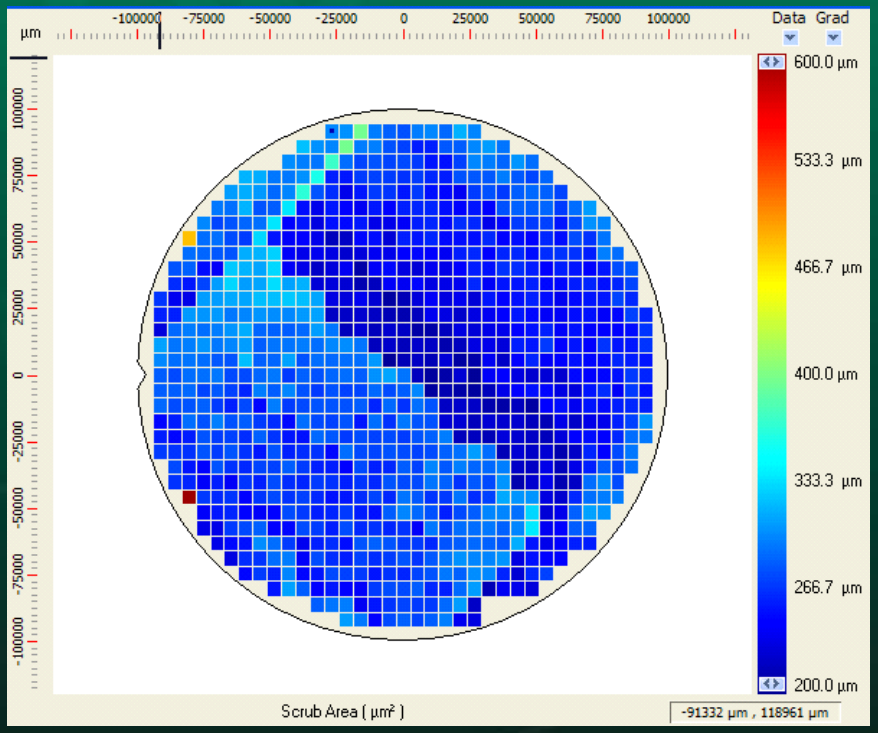


Comparing different probe card technologies.

This plot shows scrub length.

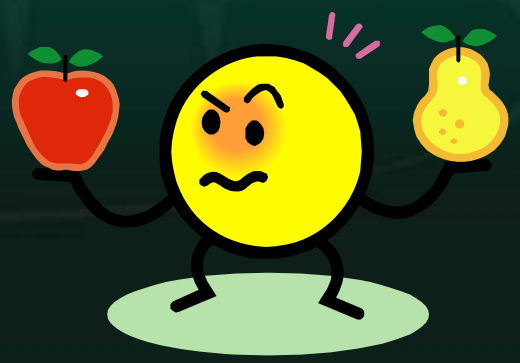
Card to Card same prober



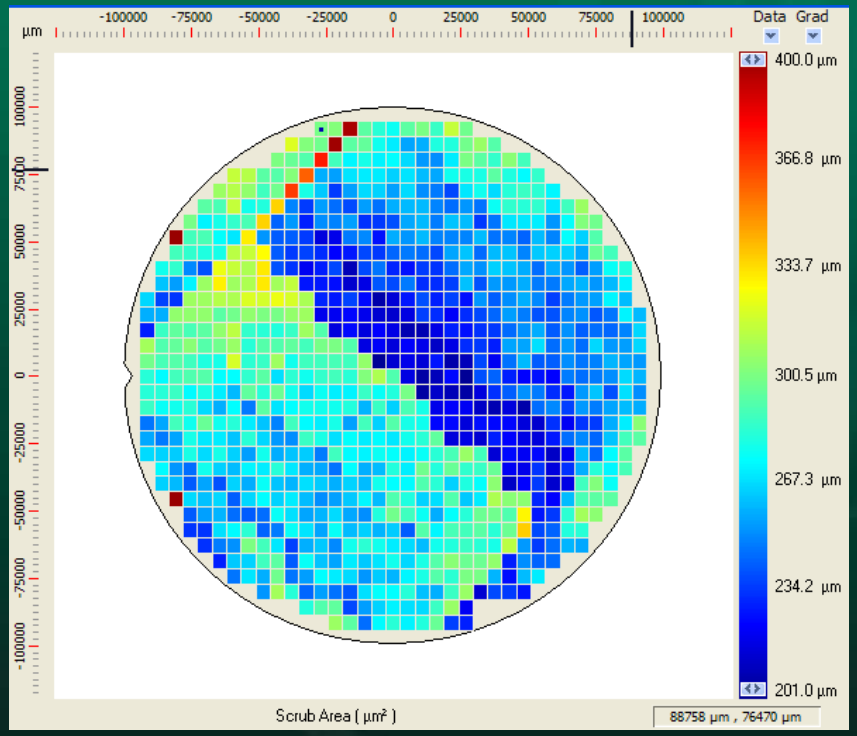


Test was ran to determine variance between two different types of cantilever probecards. The same prober, prober settings, same time and temperature were used. Obvious difference found in the amount of pad damage between probe tip types. Less damage to pads while maintaining good contact with die is better.

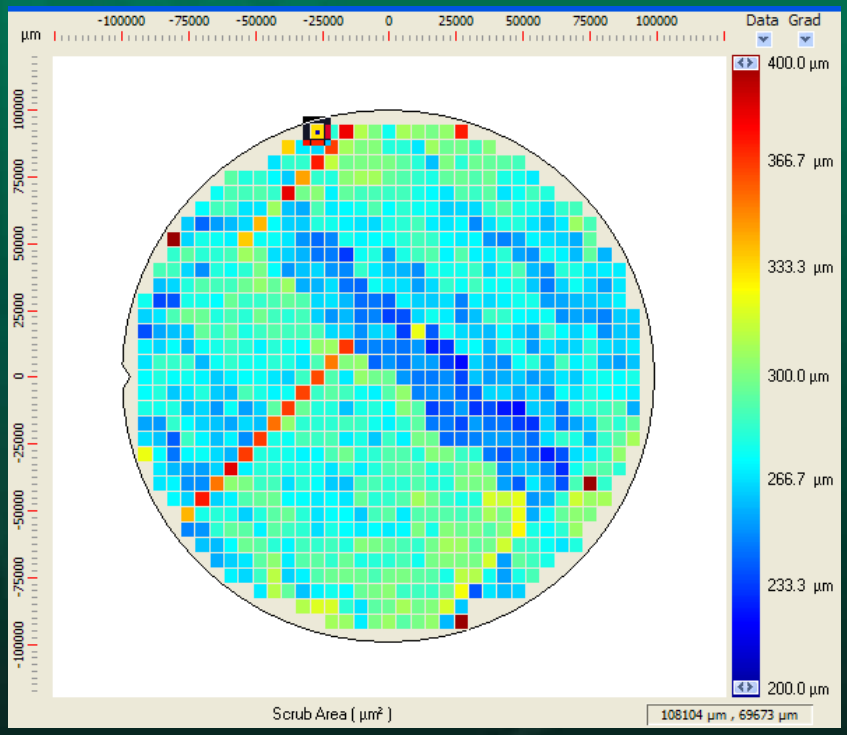
EQUIPMENT COMPARISON



prober to prober



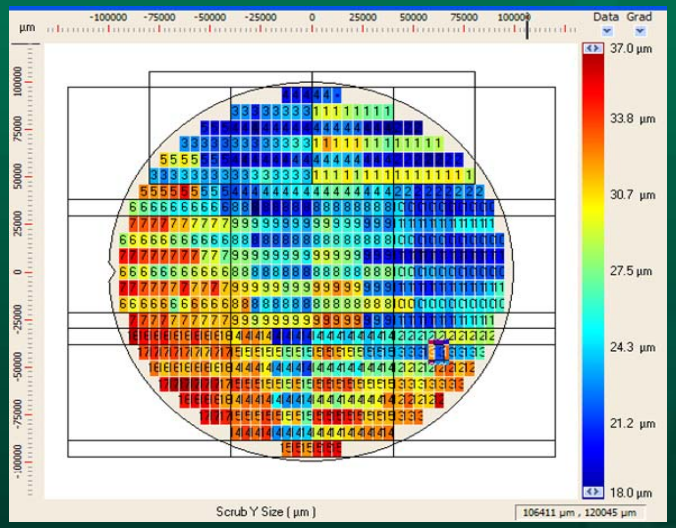
Chuck tilt is present
Card planarity
Card to Chuck parallelism



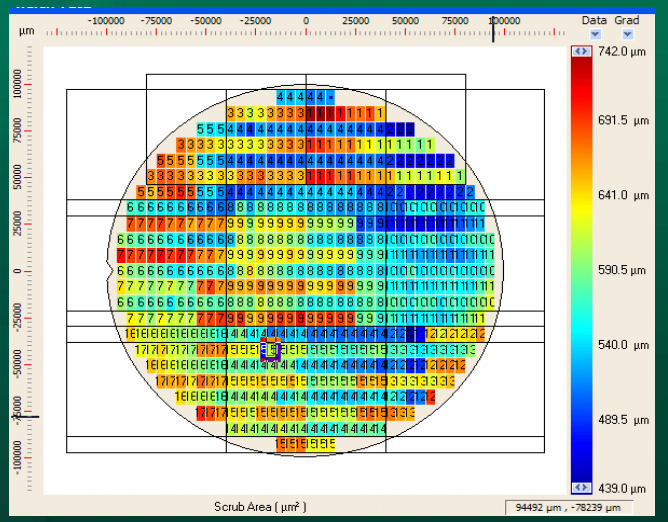
Double touch is occurring during probe mark inspect on prober

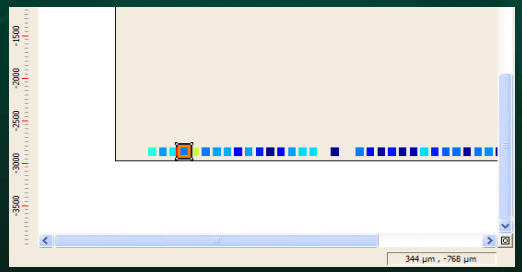
Test was ran to determine prober to prober variance. The same card, same prober settings, same time and temperature were used. Chuck tilt and head stage to chuck parallelism were found and fixed.

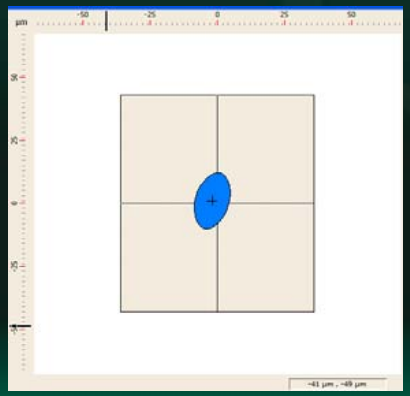
Translation Effects



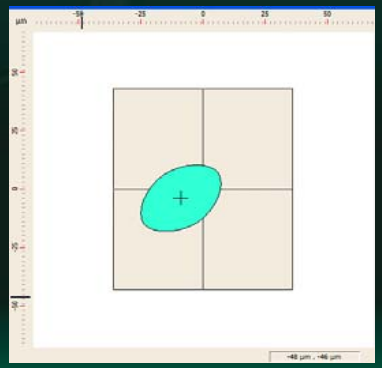
Some marks were failing probe mark inspection on the edges of the die. After running WaferWorx300, translation was determined to be the leading factor.







Note the change not only in area of the same probe mark from one td to the next, but also in shape and direction of scrub. This is due to effects of deflection and translation.



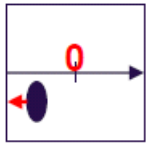
MAINTENANCE MONITOR

Using the Data to Address Equipment Problems

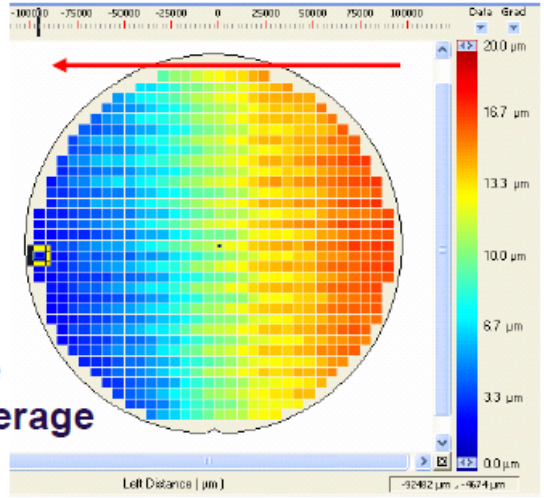
X- Wafer Scaling Data Sources at WWX 300:

Left Distance (Example)

Defines the minimal Distance of the Scrub Mark edge to the left pad edge in µm



Wafer View:

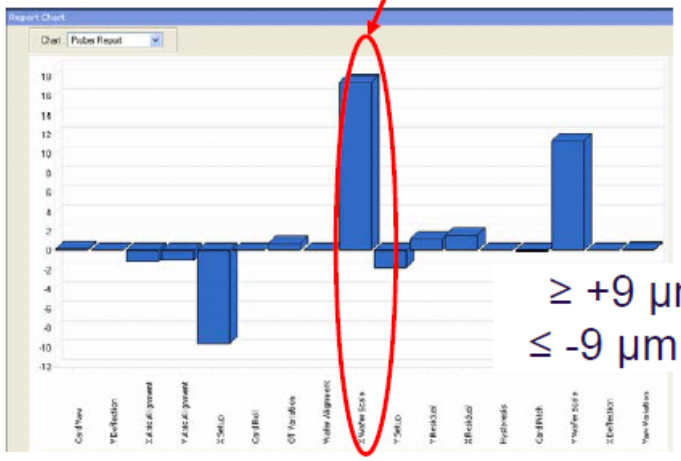


Die Average

Report Chart (Main Data Source)

Prober Report Chart:

Report Table	OT Variation (µm)	Wafer Alignment (µm)	X Wafer Scale (µm)
Value	0.714		17.450
Confidence			0.229



≥ +9 µm Stepping too far
≤ -9 µm Stepping too small
Spec.:

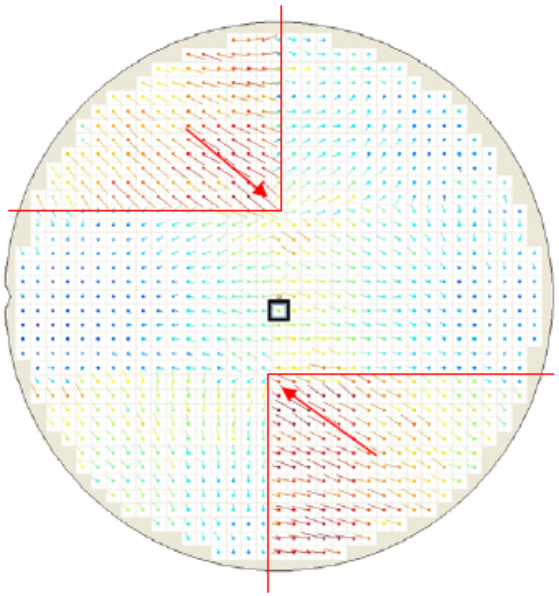
All discovered Data Sources at WWX300 for X Wafer Scaling:

- Left Distance
- Right Distance
- Vector View
- Pad Edge Distance
- X Error
- Alignment Error
- X Wafer Scale

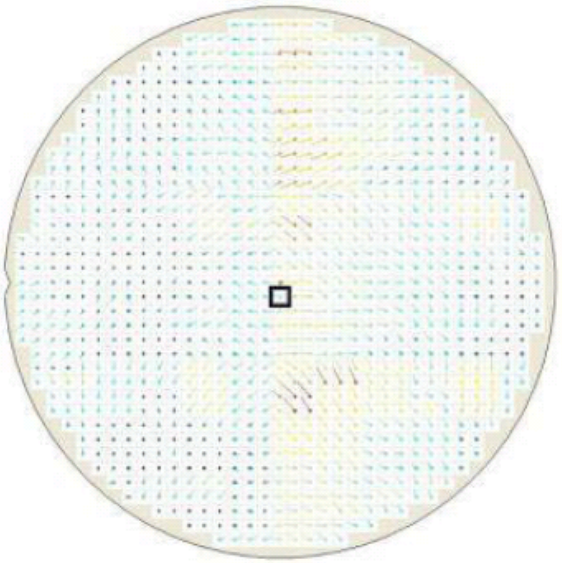
Maintenance Validation

The power of systematic scrub mark analysis …

Scrub x/y- position vector view

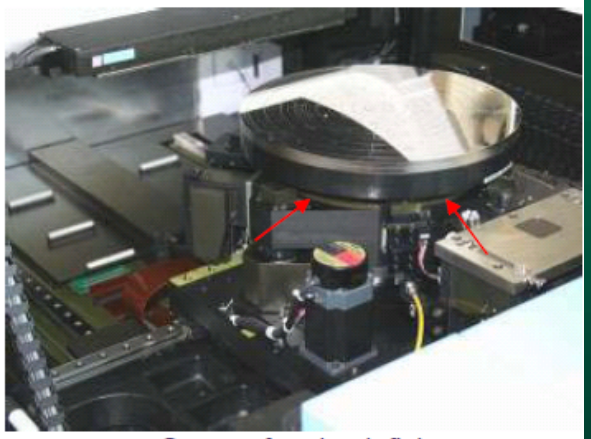


typical pattern
"chuck with loose screws"

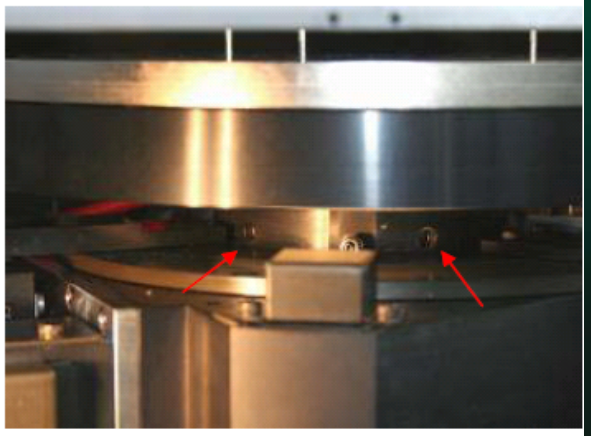


up to 10um increased end of scrub distance
to the pad edge after maintenance

… will increase your yield!

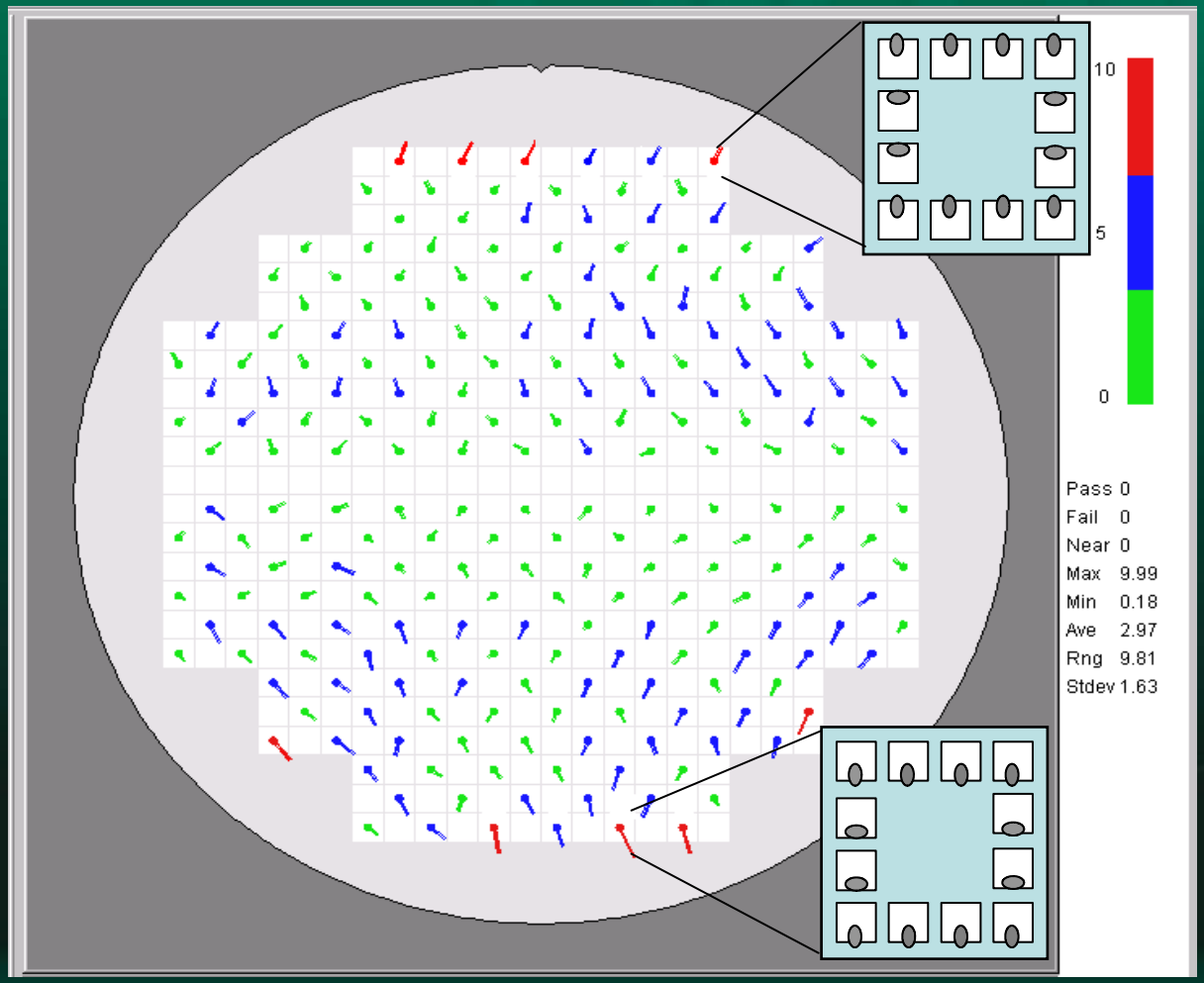


Screws for chuck fixing

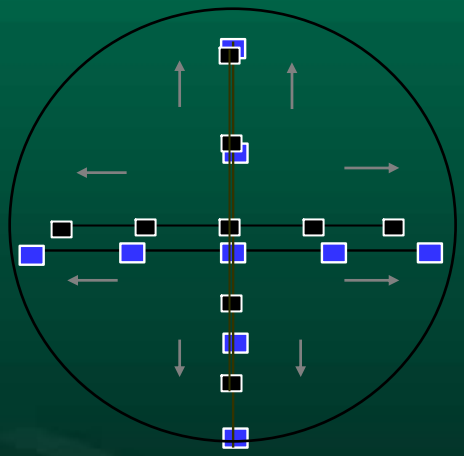


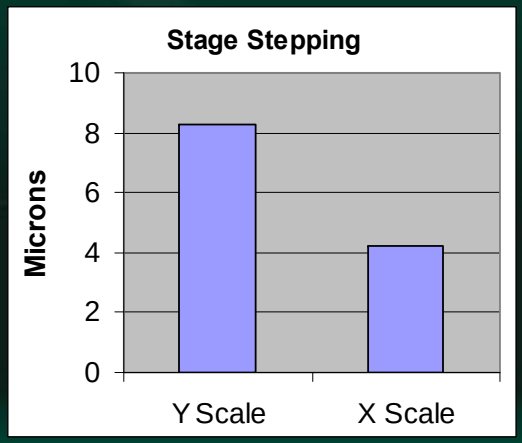
Screws getting loose due to
temperature change & probing force

Stage Stepping Accuracy

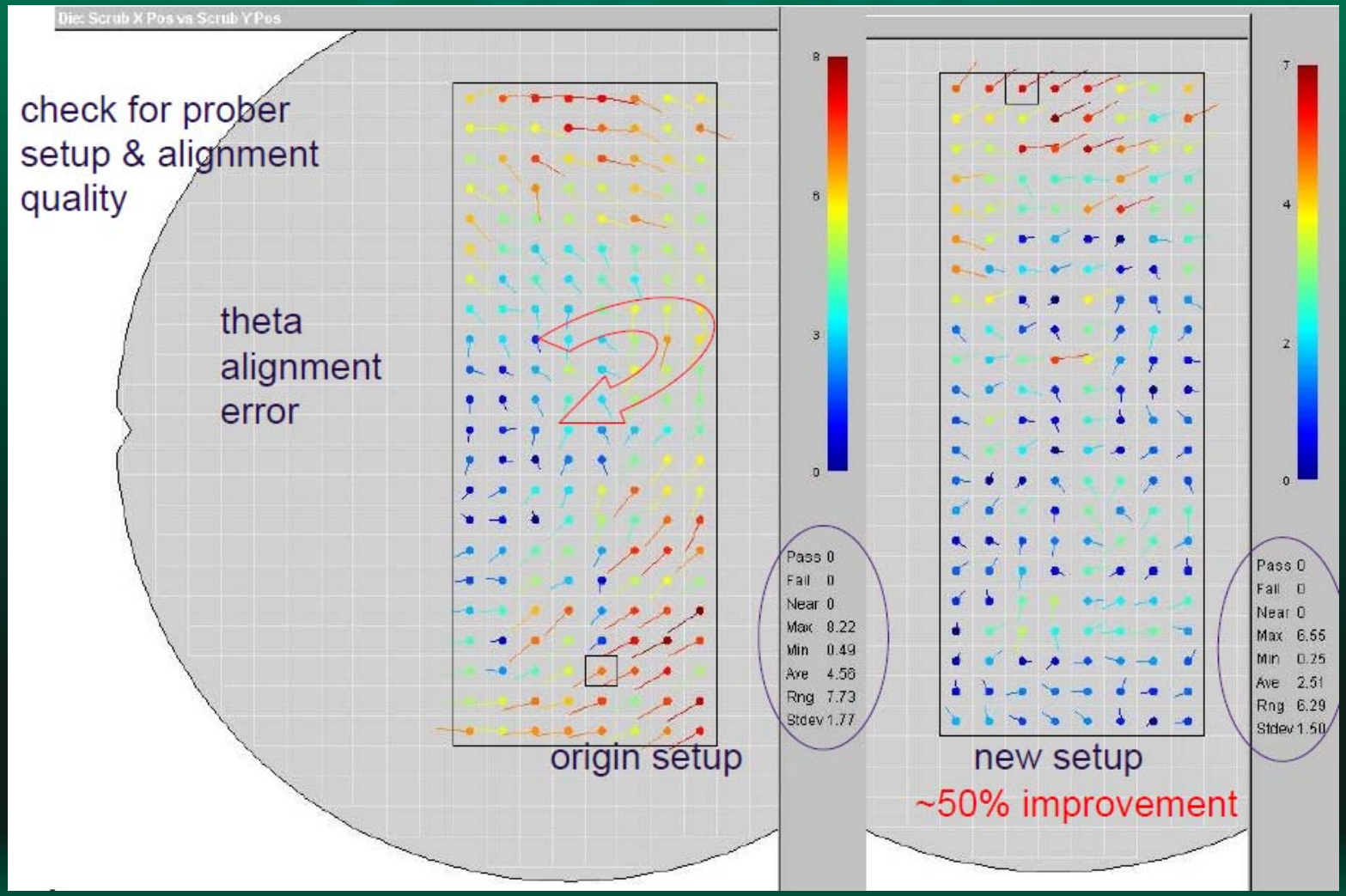


Scaling & Stepping Errors

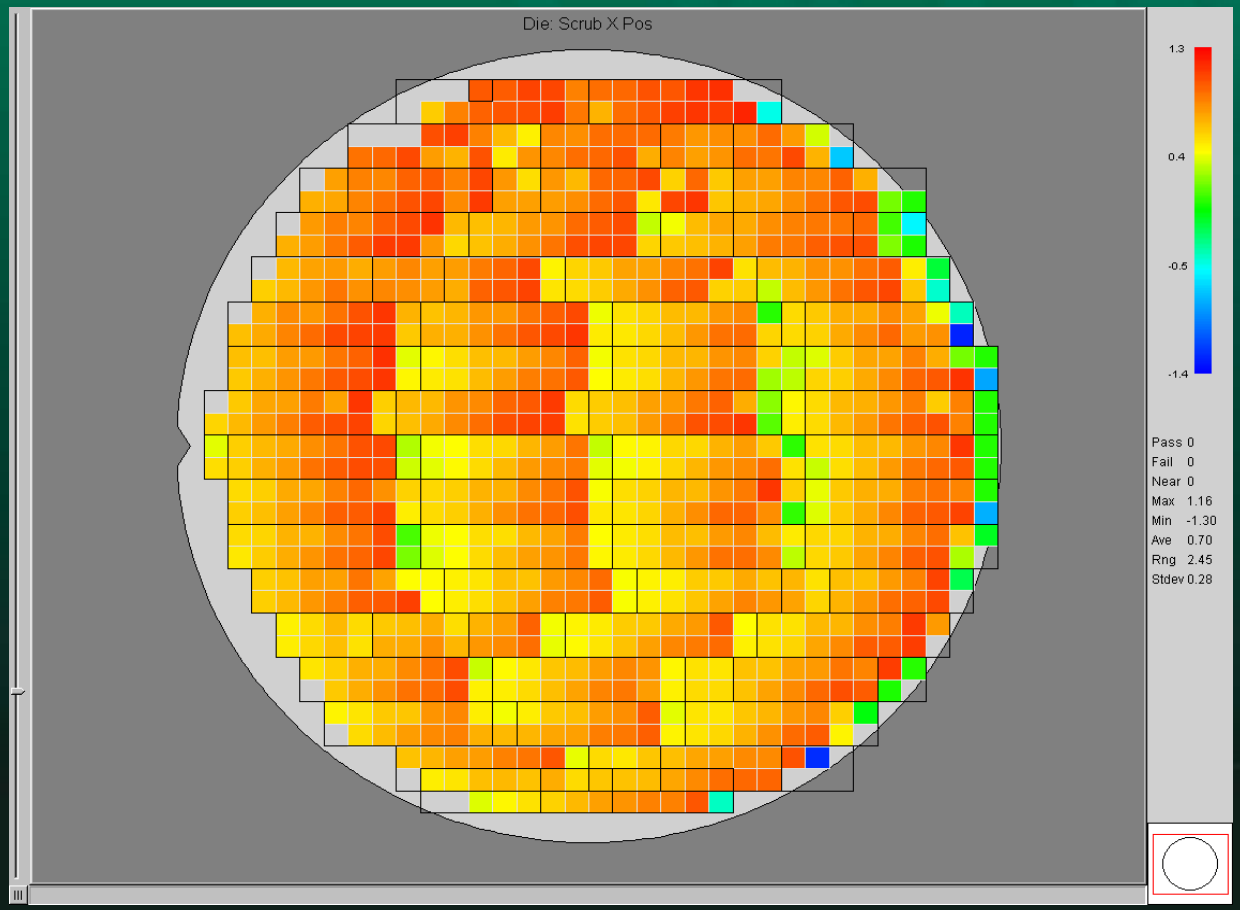




Setup Validation

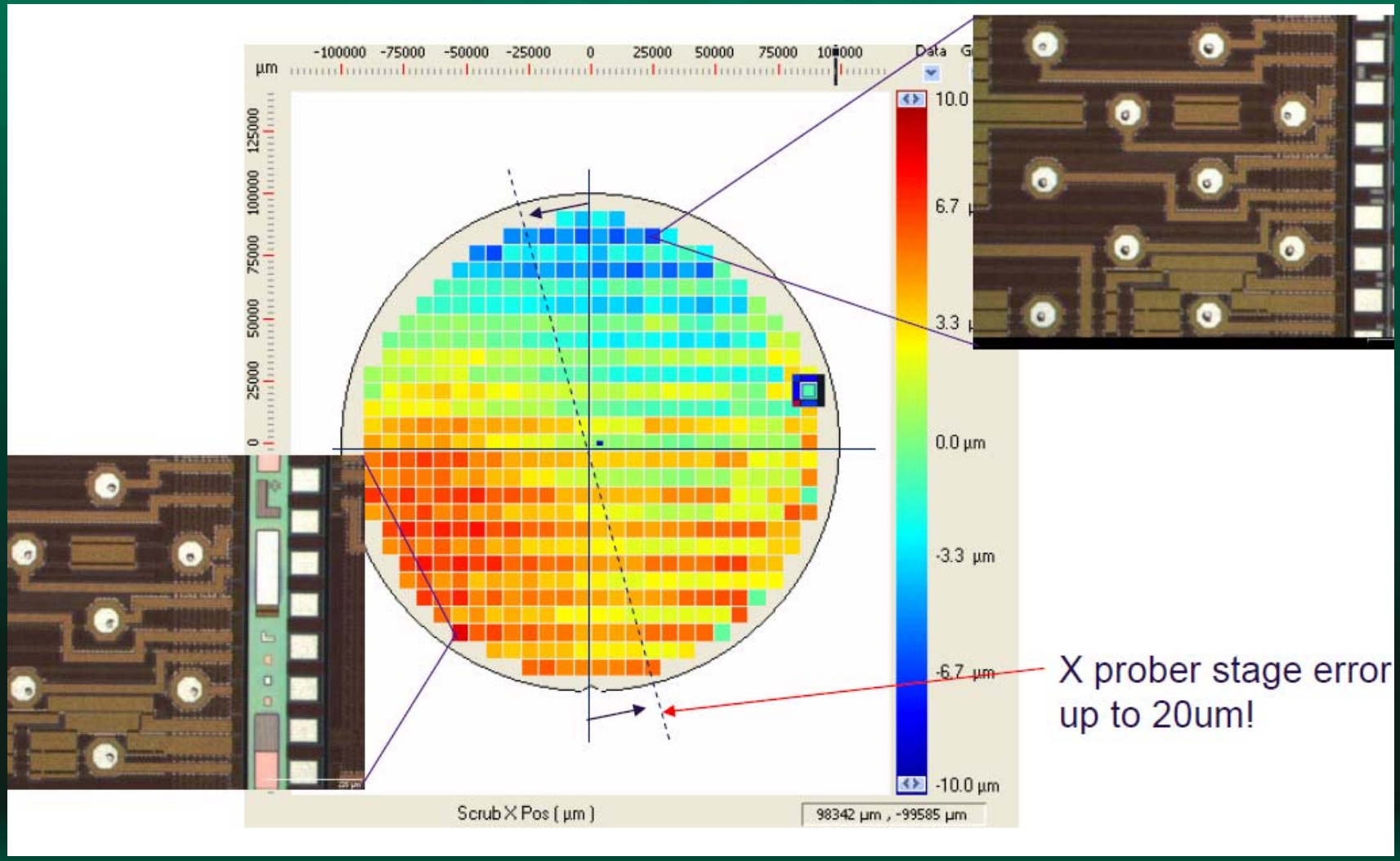


Probe Card Setup Errors

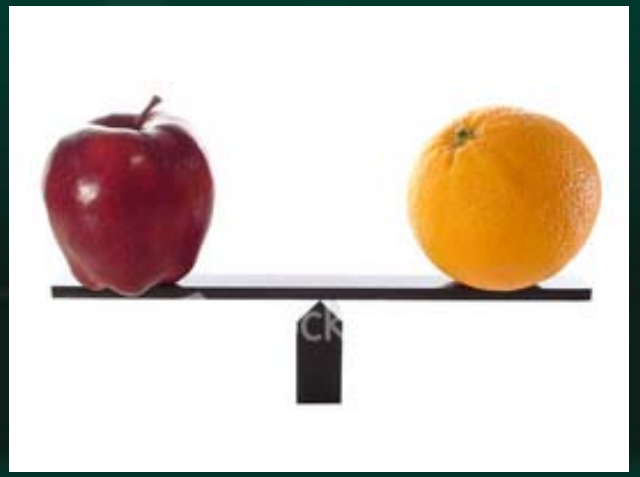


Operator Setup results in X-Axis Offset Error

Prober Setup Error



TOOL EVALUATION

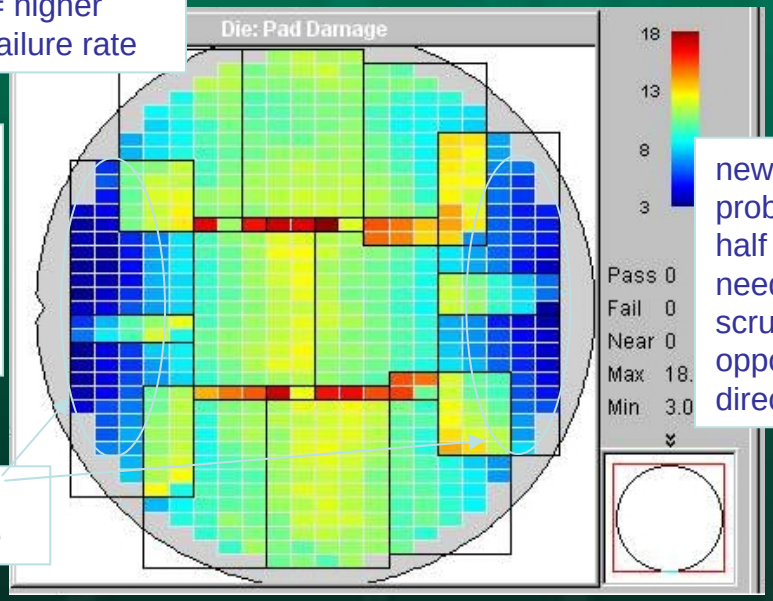


Prober vs Probe Card

Inconsistent pad damage = higher failure rate

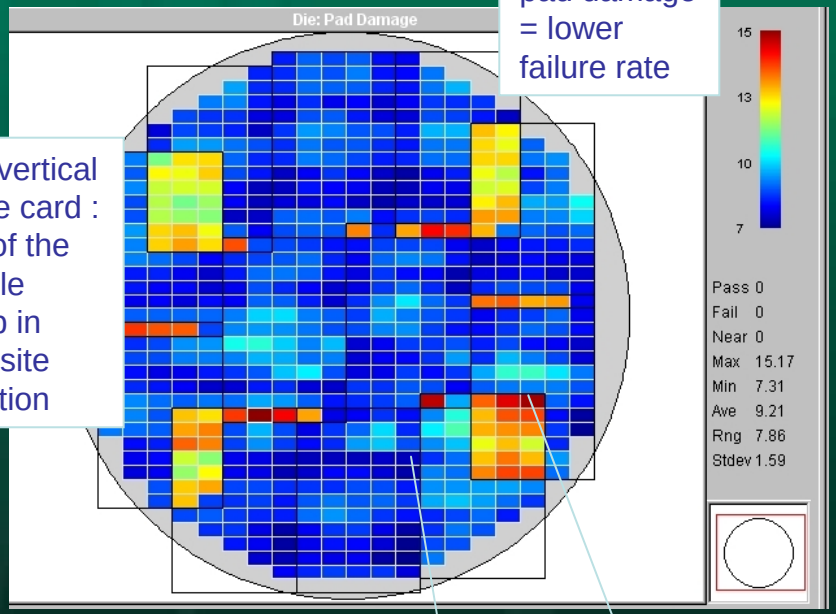
standard vertical probe card : all needles scrub in one direction

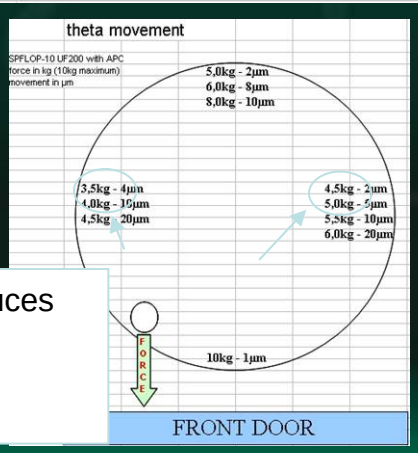
highest failure rate



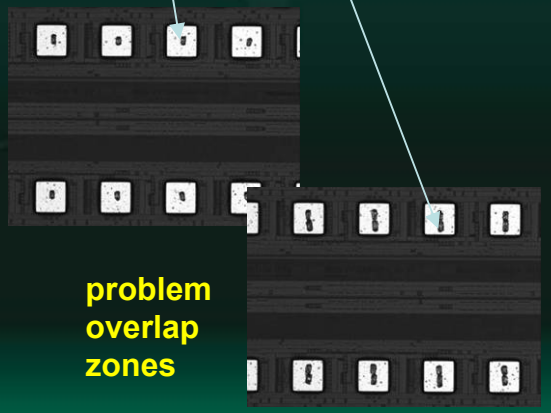
new vertical probe card : half of the needle scrub in opposite direction

Consistent pad damage = lower failure rate





This movement reduces the scrub length = online cleaning necessary



problem overlap zones

Pietzschmann, et al, SWTW 2005

Failure Signature Example – chuck movement (theta)

Acknowledgements

- Frank Pietzschmann

- Equipment used to gather the data