SWTEST
2021 CONFERENCE
PROBE TODAY,
FOR TOMORROW

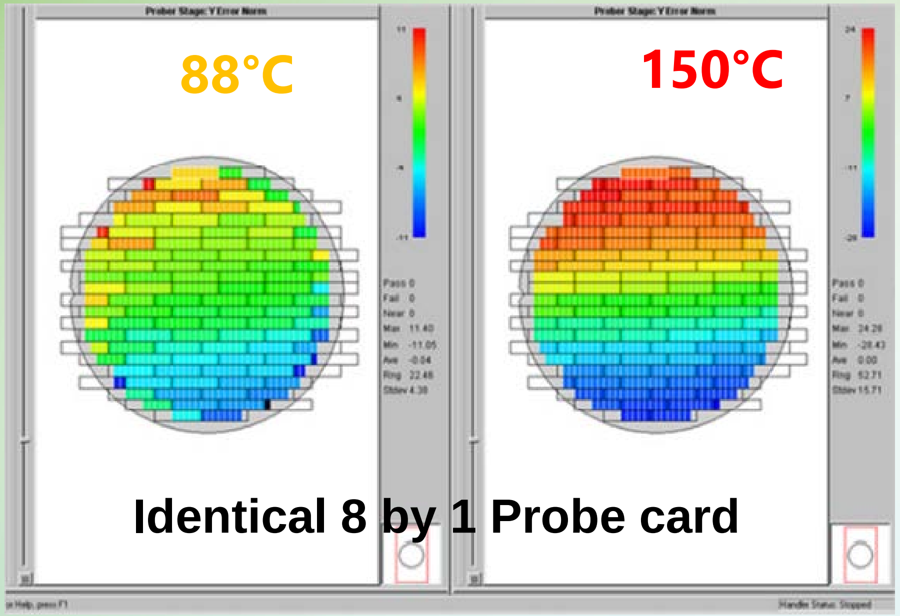
30TH ANNIVERSARY

Process analysis for thermal expansion matching between wafer and large array probe card

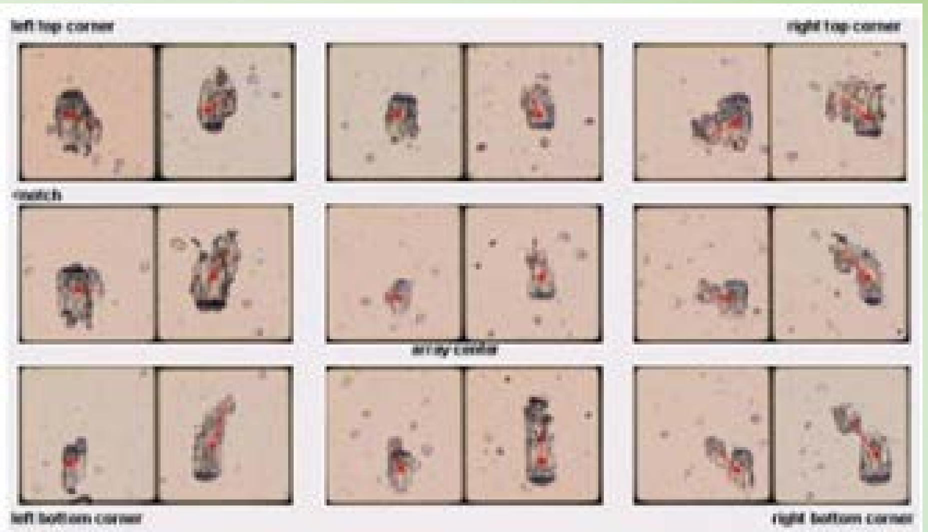
Woo Young Han
Onto Innovation

Aug. 30 – Sep. 1, 2021

Validating New Process – Thermal Movement of Probe Card



Scrub alignment error in Y direction shown at two different temperature



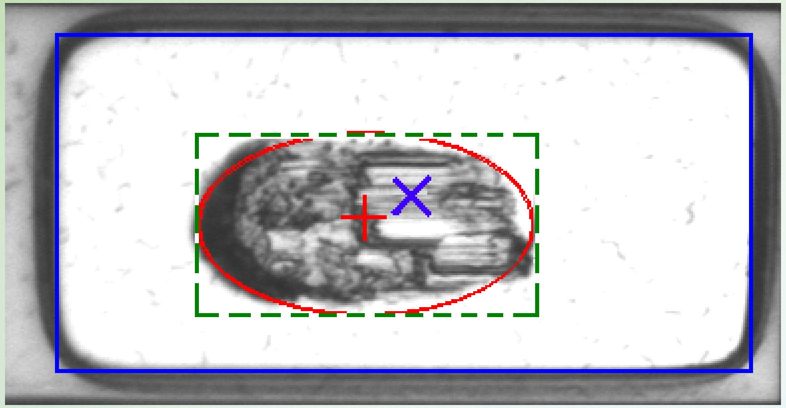
Scrub mark position variation of the individual probe within the wafer due to thermal scaling coefficients mismatch among the wafer, the probe card and the prober

- **Everything moves as temperature changes (Hot & Cold)**
- **Metrology is a key tool for understanding how much contributing components change at temperature such as needle movement, probe array movement, bond pad movement etc…**

Validating New Process – Thermal Movement of Probe Card

- **What is common way to determine real performance of thermal expansion of large array probe card?**
- **Bare silicon wafer and microscope are often used to check performance of probe card by probe card manufacturer.**
- **However, it is not easy to determine thermal expansion/shrinkage matching between probe card on bare wafer as there is no reference (bond pads).**
- **It is critical to understand how things are moving at different temperatures in order to optimize the process and minimize the impact of such movements.**
- **It is also important to understand which temperatures the process is in control and where additional optimization is necessary.**

Scrub Mark Measurement Parameters

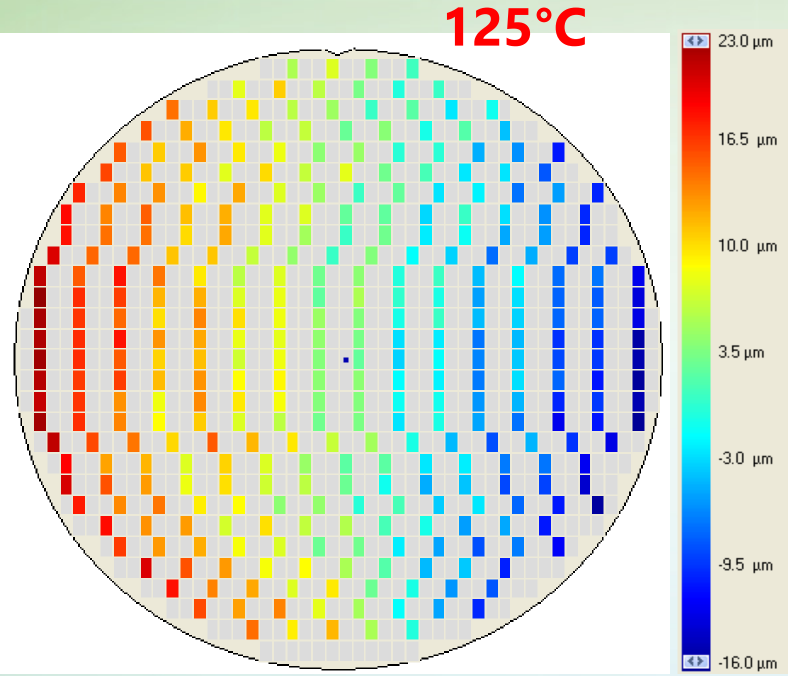


×	**Center of the passivation opening**
+	**Center of the scrub mark**
⬭	**Scrub Mark Area / Size**
⬚	**Bounding Box of the scrub mark**
▭	**Passivation opening size**

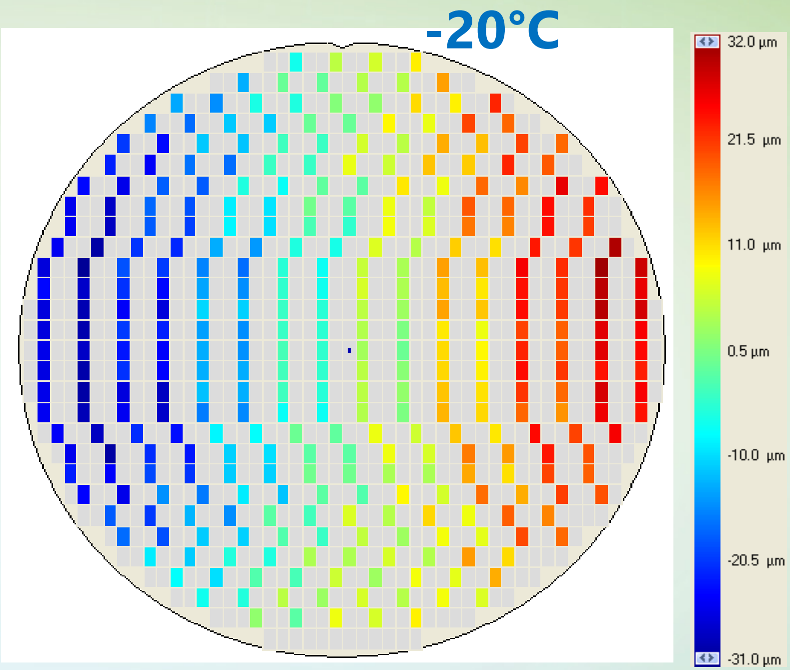
- **Position of scrub mark**
- **Size of scrub mark**
- **Angle of scrub mark**
- **Size of passivation opening**
- **Pad damaged**
- **Scrub mark distance from the edge of the pad.**
- **… Over 40 total parameters**

Case 1: 300mm Probe Array Testing at Temperature

~20um of probe card thermal expansion mismatch found on wafer edge for the burn-in test



Scrub X Alignment at Hot Testing



Scrub X Alignment at Cold Testing

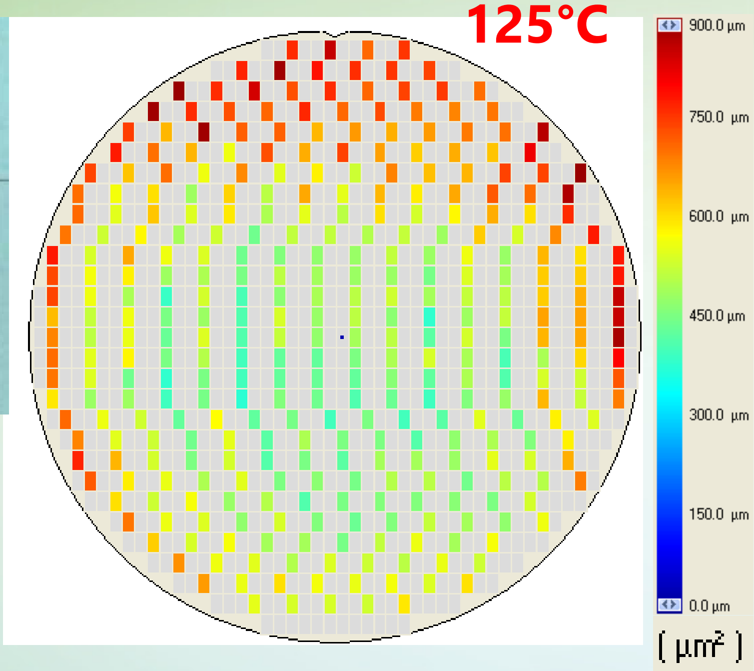
~30um of probe card shrinkage mismatch found on wafer edge for the freeze test

Prototype probe card built and tested on 300mm bare silicon wafer at extreme temperatures.

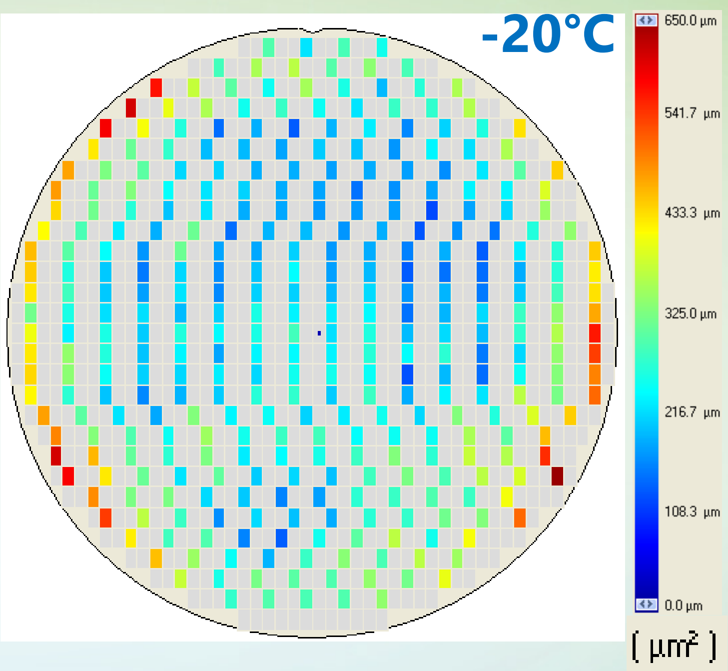
Without bond pads on the wafer, there was no way for the customer to verify the probe card thermal expansion.

Automated process analysis tool can measure all the scrub marks on the wafer and generate report in less than 10 minutes.

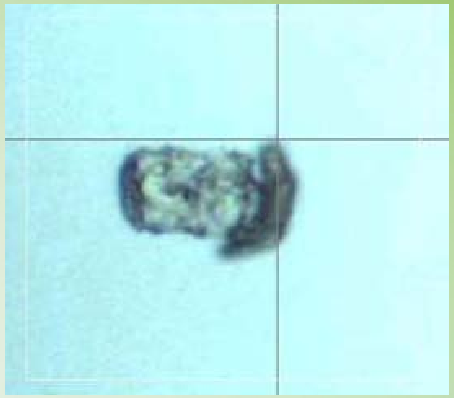
Case 1: 300mm Probe Array Testing at Temperature



Scrub area at Hot Testing



Scrub area at Cold Testing

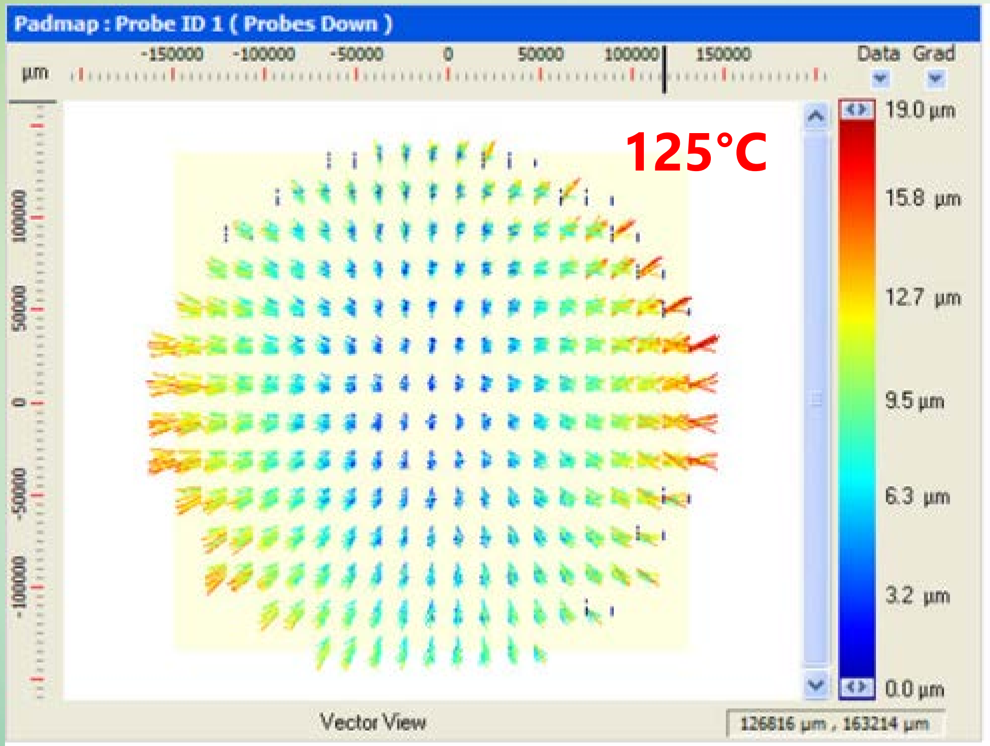


Scrub area analysis is showing that scrub marks are larger on the upper area of the wafer.

Un-even planarity of probes were the root cause of scrub length discrepancy.

Scrub marks are longer and deeper at high temperature compared to cold temperature testing.

Case 2: New Probe Card Qualification



125°C

Vector View of Scrub X,Y Alignment

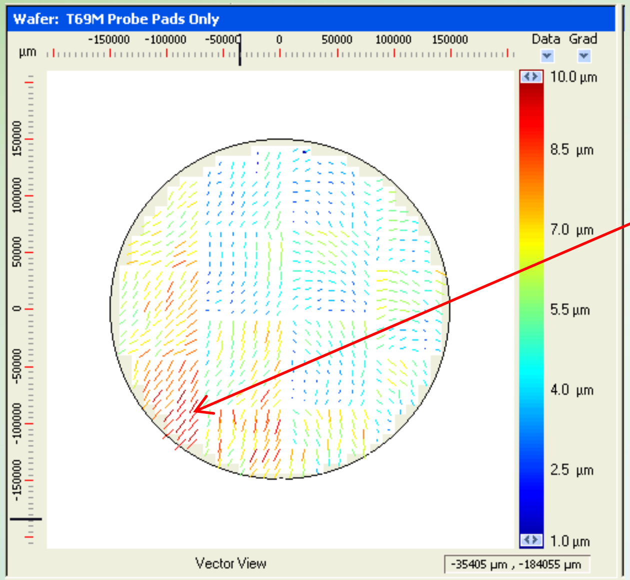
New 300mm single touchdown probe card delivered to device manufacturer.

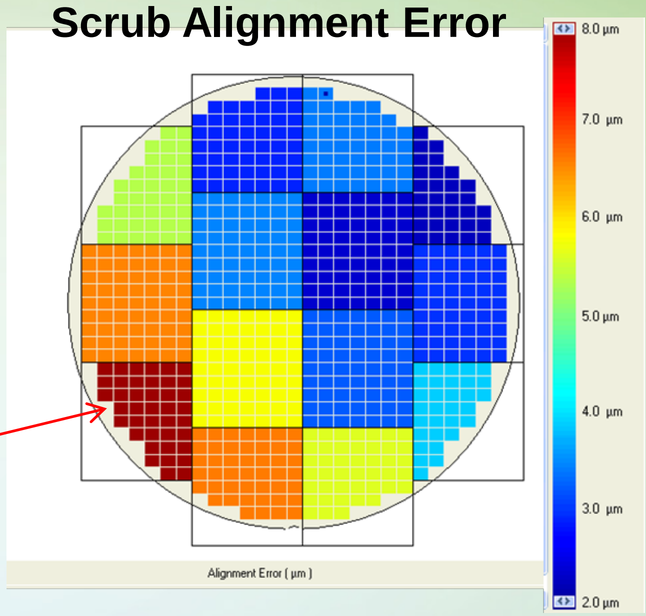
The new card was tested on 300mm bare silicon wafer at hot temperature (125°C).

The scrub analysis is showing that up to 20um of thermal mis-match was found on wafer edge.

This probe card did not pass incoming inspection and returned back to the vendor.

Case 3: Large Probe Array Test at Temperature on 300mm Wafer





Problem Statement:

Scrub marks too close to pad edge.

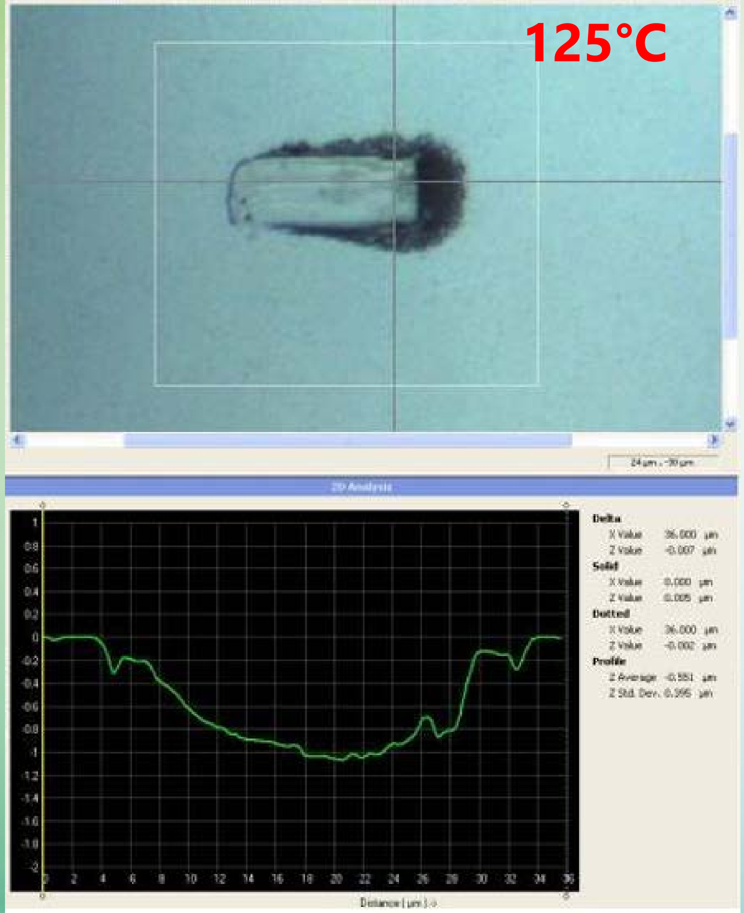
Root Cause Analysis:

Temperature scaling causing shift in needle location on pad during cold testing.

Root Cause:

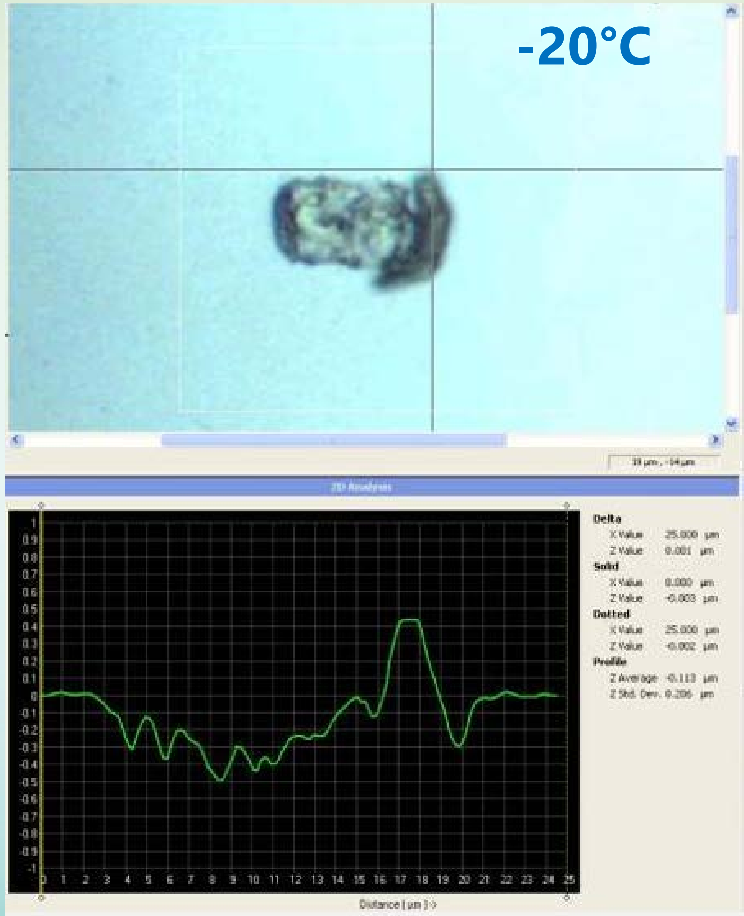
Prober not optimized for wafer scaling and chuck flatness at cold temperature. Combination of chuck tilt and stepping error resulting in a shift in the probe location.

Case 4: Scrub Mark Depth Metrology Solution



Delta
X Value 36.000 µm
Z Value -0.007 µm
Solid
X Value 0.000 µm
Z Value 0.005 µm
Dotted
X Value 36.000 µm
Z Value -0.002 µm
Profile
Z Average -0.551 µm
Z Std. Dev. 0.395 µm

Scrub mark depth measured 1.1um from Hot temperature test

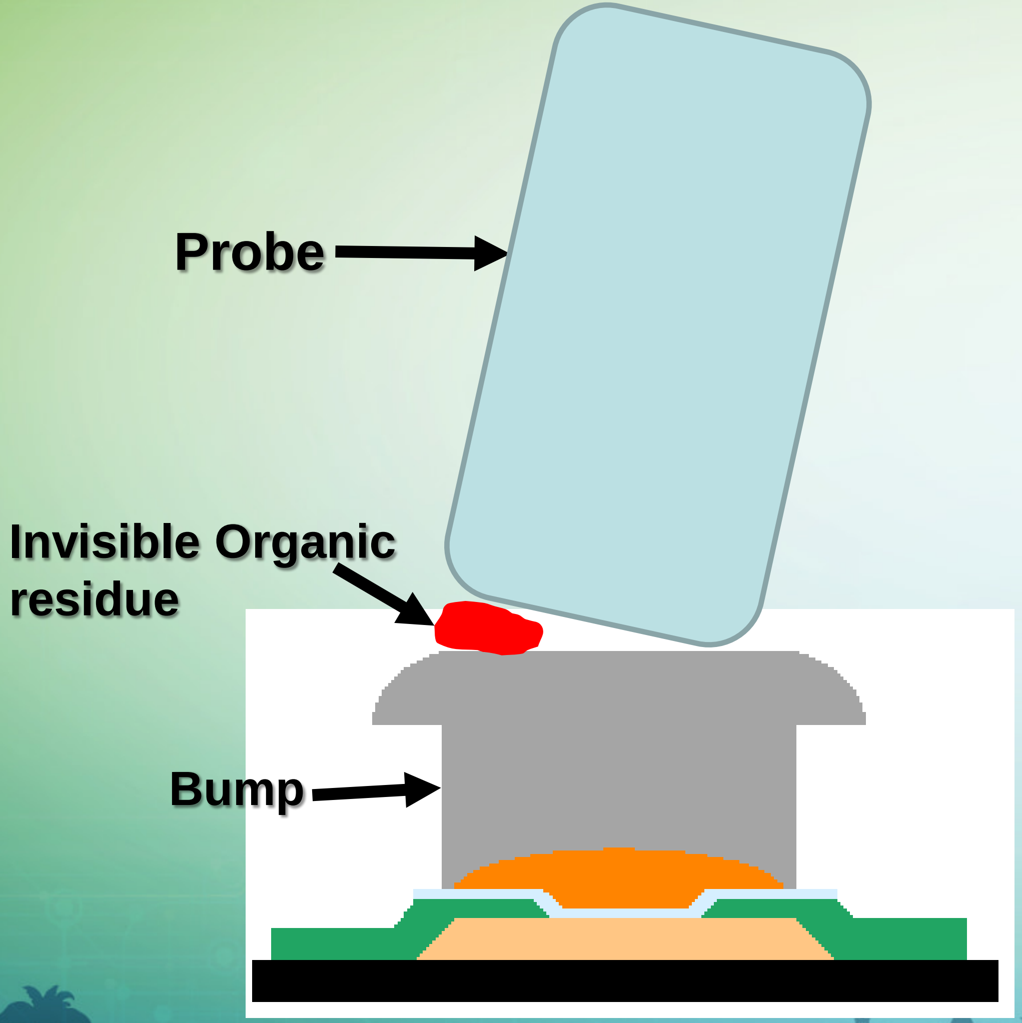


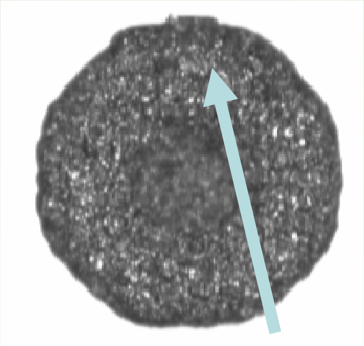
Delta
X Value 25.000 µm
Z Value 0.001 µm
Solid
X Value 0.000 µm
Z Value -0.003 µm
Dotted
X Value 25.000 µm
Z Value -0.002 µm
Profile
Z Average -0.113 µm
Z Std. Dev. 0.206 µm

Scrub mark depth measured 0.5um from Cold temperature test

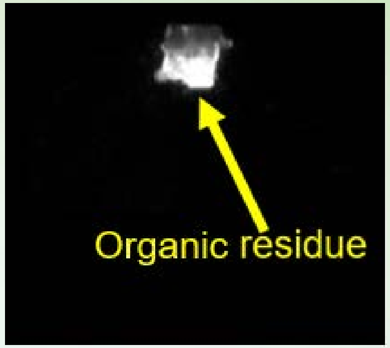
- Scrub marks get larger and deeper as testing temperature increase.
- Need to monitor scrub mark depth on wafer to control prober chuck over drive distance for temperature tests.
- Need to ensure needles do not punch through bond pads during higher temperature testing and needles penetrate deep enough during cold temperature tests.

Case 5: Invisible Yield Killer – Organic Residue





Invisible organic residue under BF illumination

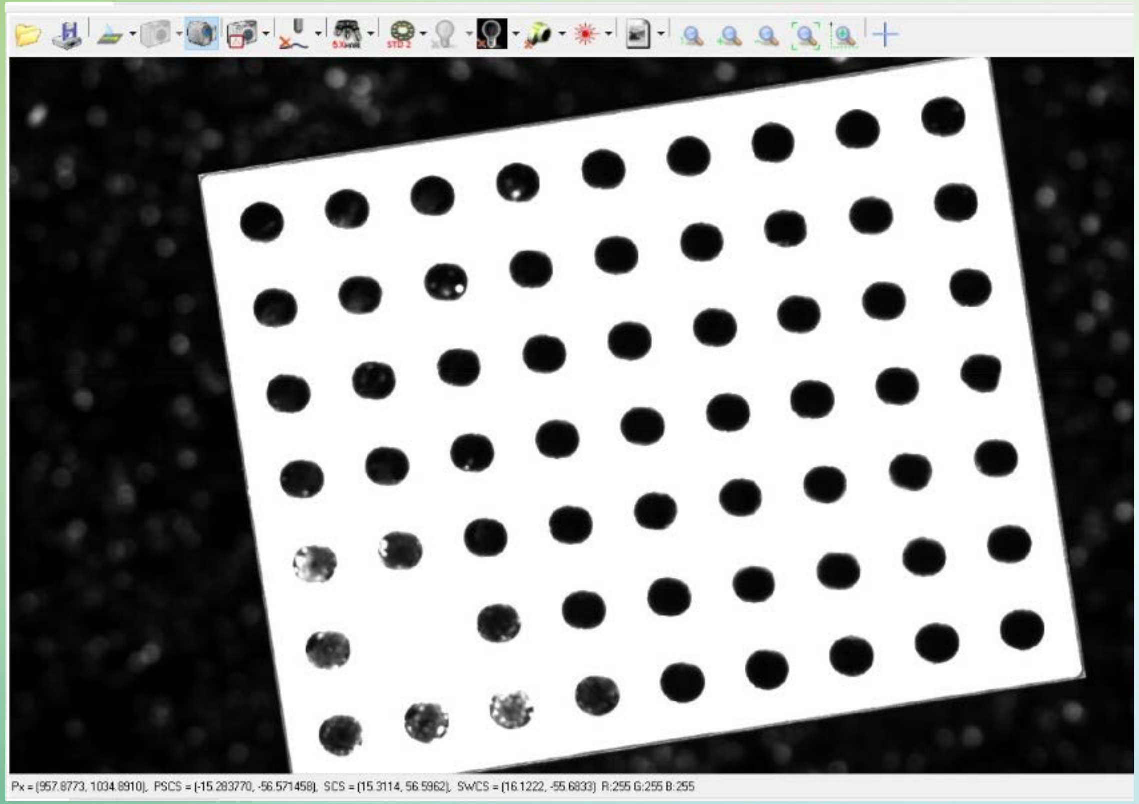


Organic residue under fluorescent illumination

Problem Statement:
OSAT customers having yield issue and probes getting damaged after testing.
But normal microscope inspection is not showing any defects.

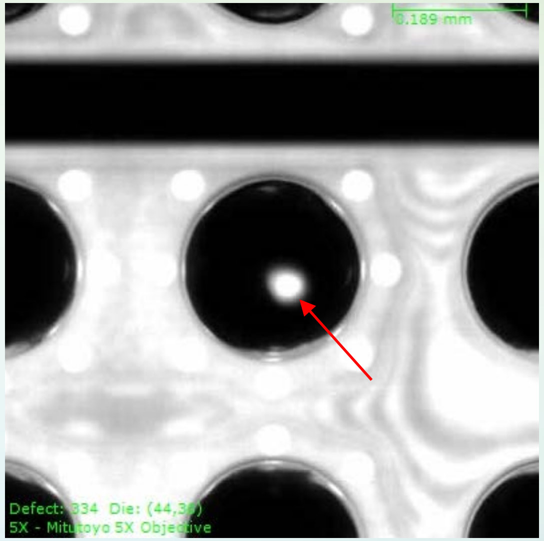
Root Cause Analysis:
Invisible organic residues on bumps were adding resistance and damaging probes.
Organic residue is not visible using traditional BF & DF illumination due to their transparent nature.
Need fluorescent illumination to visualize organic defects.

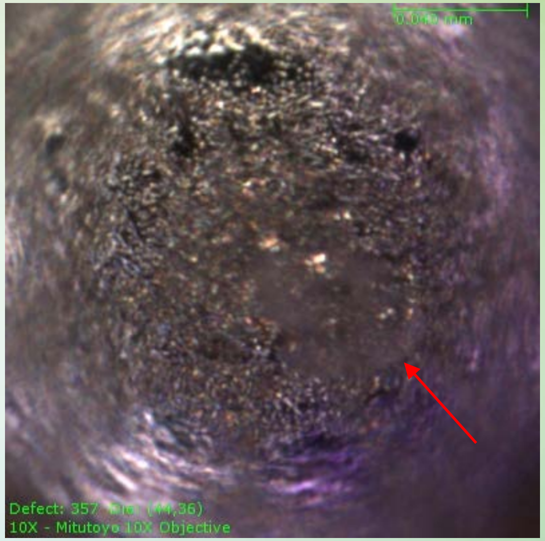
Case 5: Invisible Yield Killer – Organic Residue



```
Px = (957.8773, 1034.8910),  PSCS = (-15.283770, -56.571458),  SCS = (15.3114, 56.5962),  SWCS = (16.1222, -55.6833)  R:255 G:255 B:255
```

Die Image with fluorescent illumination





Organic residue on bump, difficult to visualize with microscope

Full Wafer Probing Process Analysis

- 2D probe mark "analysis"
- Quantify wafer/card thermal effects
- Probe-to-pad alignment analysis
- Probe card performance assessment
- Prober stage performance assessment
- Process shrink assessment
- Pre-silicon process set-up & optimization
- New prober & probe card product assessment