SWTEST
PROBE TODAY, FOR TOMORROW
2024 CONFERENCE

300mm Probe card for Logic device with wide temperature range

AMST Co. Ltd. Dongil Kim
Jinhyang Heo
Choongsik Kim
Ildu Kim
Infineon Technology AG. Mark Ojeda
Phuc Do

Overview

- 300mm Rainbow Layout for Logic Devices
- TD Reduction with 300mm Probe Card
- Wide Temperature Range (-40°C to 150°C) with a Single Probe Card
- Thermal Expansion Control
- Zero-Scrub Possibilities
- Probe Tip and Probe Depth Control
- Summary

300mm Rainbow Layout PC

- Today, Rainbow layout in Probe cards are widely used in memory devices, DRAM, and Flash
- Rainbow layout:
  - Pro
    - Lower price vs vertical probe cards with similar pin count
    - Simple structure which allows easier issue identification and faster repair
    - Edge die solution possible
    - TD reduction for better throughput
  - Con
    - Limitation on the possible pad layout
    - Thermal expansion control is difficult

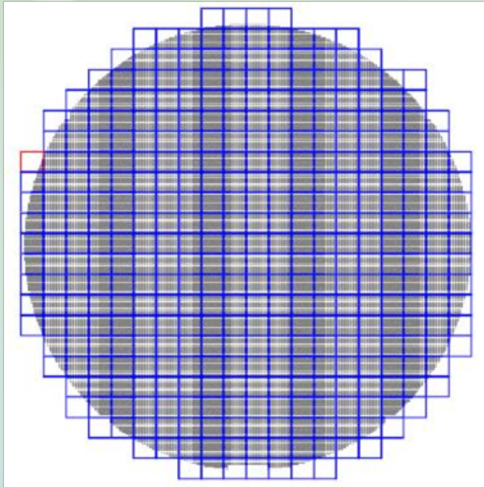
Logic devices testing with Square Layout

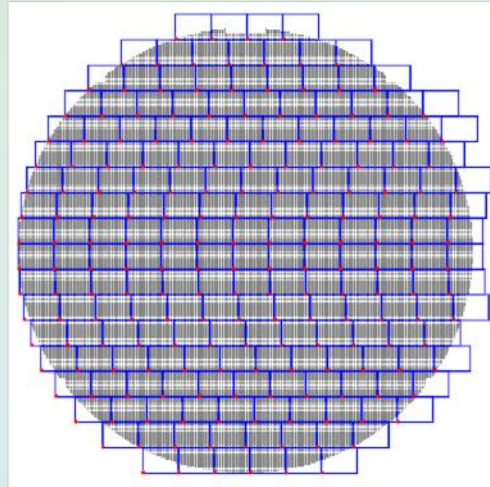
- Usually, logic device testing is performed using probe cards that have a square layout
- Square layout:
  - Pro
    - Small probe head size (lower cost)
    - Vertical Probe possible
    - Less restrictions on pad layout
  - Con
    - High price if pin count increases (high cost per pin)
    - Temperature non-uniformity issue
- 300mm Rainbow layout is another option for Logic device testing

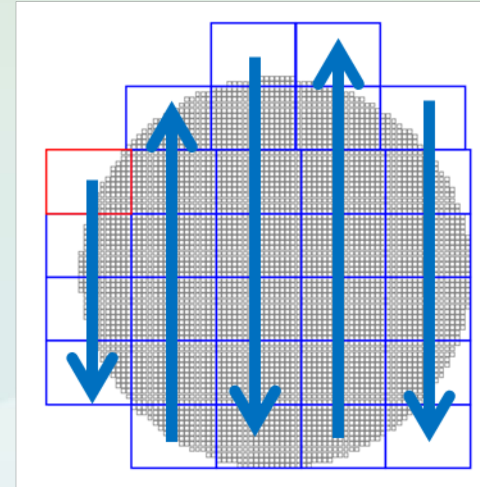
Layout Comparison Samples

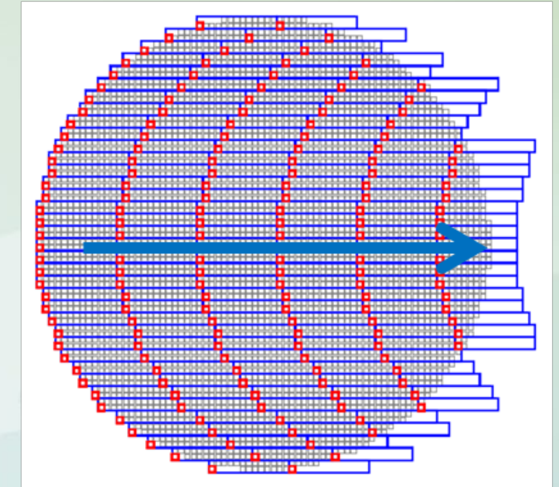
Chip size : 1,000㎛ x 1,000㎛

Chip size : 4,000㎛ x 4,000㎛







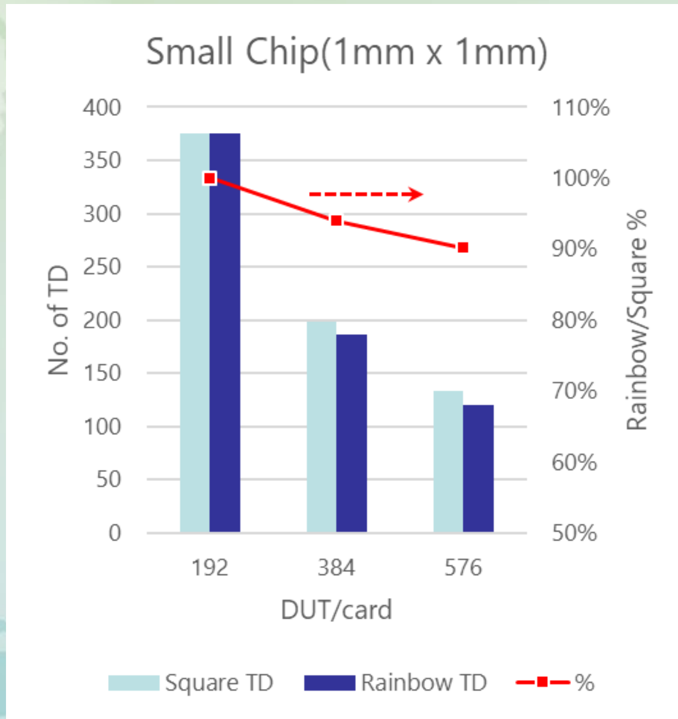


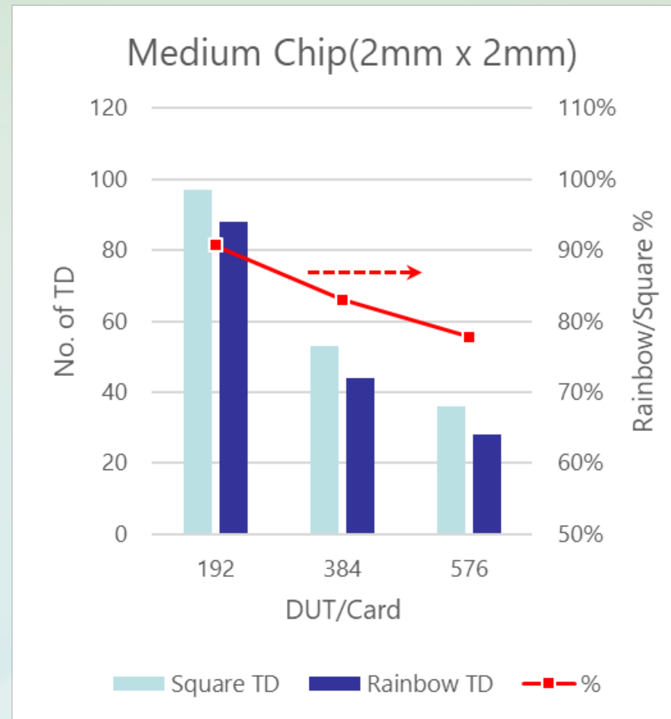
Square	Rainbow	Square layout	Rainbow layout
192(16*12) DUT / 375TD	192 DUT / 375(25*15)TD	Used 192(16*12) DUT / 30TD	Used 184 DUT / 26(13*2)TD

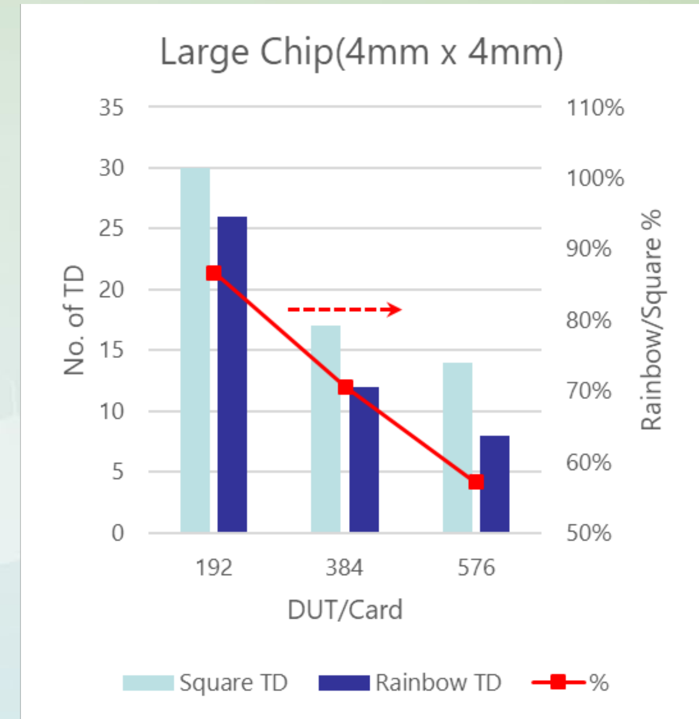
TD of Square = TD of Rainbow

13% TD Reduction with Rainbow layout

Chip size and TD: Square vs. Rainbow







- As the chip size becomes larger or more DUTs/card are possible, the number of touchdowns for a Rainbow layout becomes fewer than that of a Square layout.

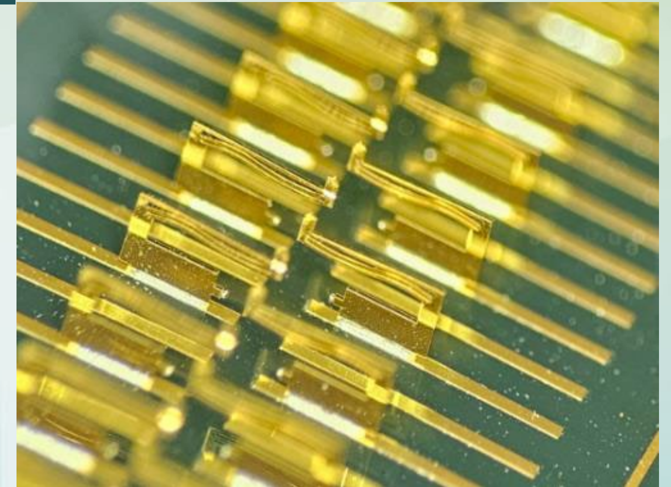
Logic Design for Test (DFT)

- A long time ago we had 8 DUT probe cards, now we have 3000 DUT probe cards.
- What Changed?
  - New testers came out with more resources
  - Main thing that changed was DFT
- DFT: optimize for test
  - Design the chip so you don't need as much tester resources, meaning you put more DUTs per Card
- In the future, better testers with more resources will appear
- As the number of tested DUT sites go up, the benefit of rainbow testing increases.

300mm MEMS Probe card

- 300mm MEMS Probe card for logic device
  - Vertical probe cards can be replaced in many scenarios

- 2D MEMS rainbow probe cards are a good, low cost, fast-delivery alternative
  - Multi-Layer Ceramic(MLC) is used for probe head material
  - Simple and easy to design and manufacture
  - More controllable probing properties
  - Short delivery time (New design to delivery is 8~12 weeks)



- Complexity of 300mm full wafer probe card design increases because many applications now requires a wide temperature range testing

Solving for
a Wide Temperature Range (-40°C to 150 °C)
with a Single Probe card

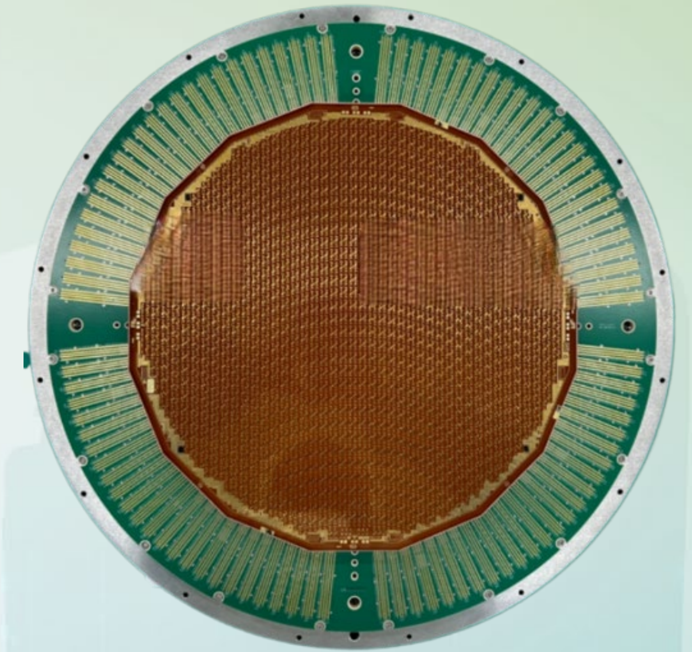
Wide temperature range card

- Now possible: One probe card for -40°C ~ 150°C

- Advantages of wide temperature range card
  - Versatility in card deployment
  - Fewer total cards needed

- Requirements to achieve wide temp card
  - Good thermal expansion control:
    - Thermal Expansion matching
    - Minimize soak time
    - Stable Z movement
  - Small probe mark size
    - Small scrub action
    - Controlled probe tip size

- Especially true if the pad size is small, e.g. below 50µm x 50µm



~2,000DUT probe card (T5830)
for ~60,000die wafer

Thermal Expansion Problem

- Thermal expansion problem
  - Coefficient of Thermal Expansion(CTE) mismatch between the wafer and the ceramic probe head exists which will cause alignment error if not handled correctly
- CTE mismatch
  - Silicon wafer CTE is ~2.6 ppm/°C
  - MLC CTE is usually between 3.7~4.5 ppm/°C
  - CTE of 0.1 ppm/°C cause about 5.7μm expansion for a 300mm probe head if heated from -40°C to 150°C
- There also is the temperature difference between wafer and probe head

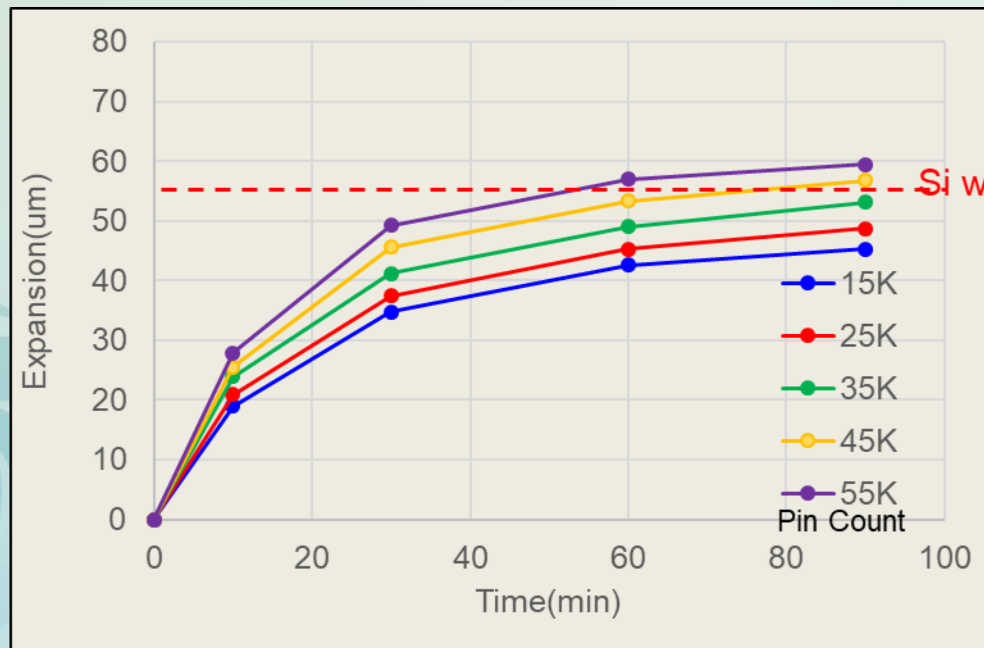
Thermal Expansion Problem

- Temperature difference between wafer and probe head happens because the heat source is usually only the prober chuck
- The probe head's main heat source is the heat transfer through probes from wafer
    - Number of probes is important in the amount of heat transferred
- CTE value of Probe head need to be selected in relation to No. of Probes especially for small pads (<50µm x 50µm)

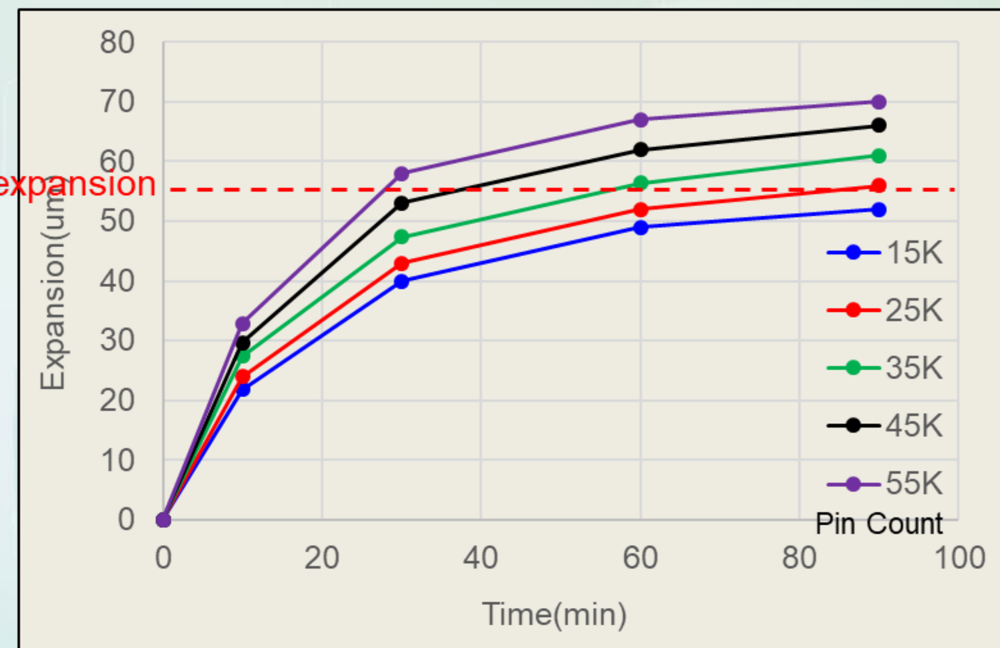
Effect of Pin count

- Number of probes is an important factor in selecting CTE of MLC

Simulation results of MLC expansion at 90°C



MLC CTE 3.87ppm/℃

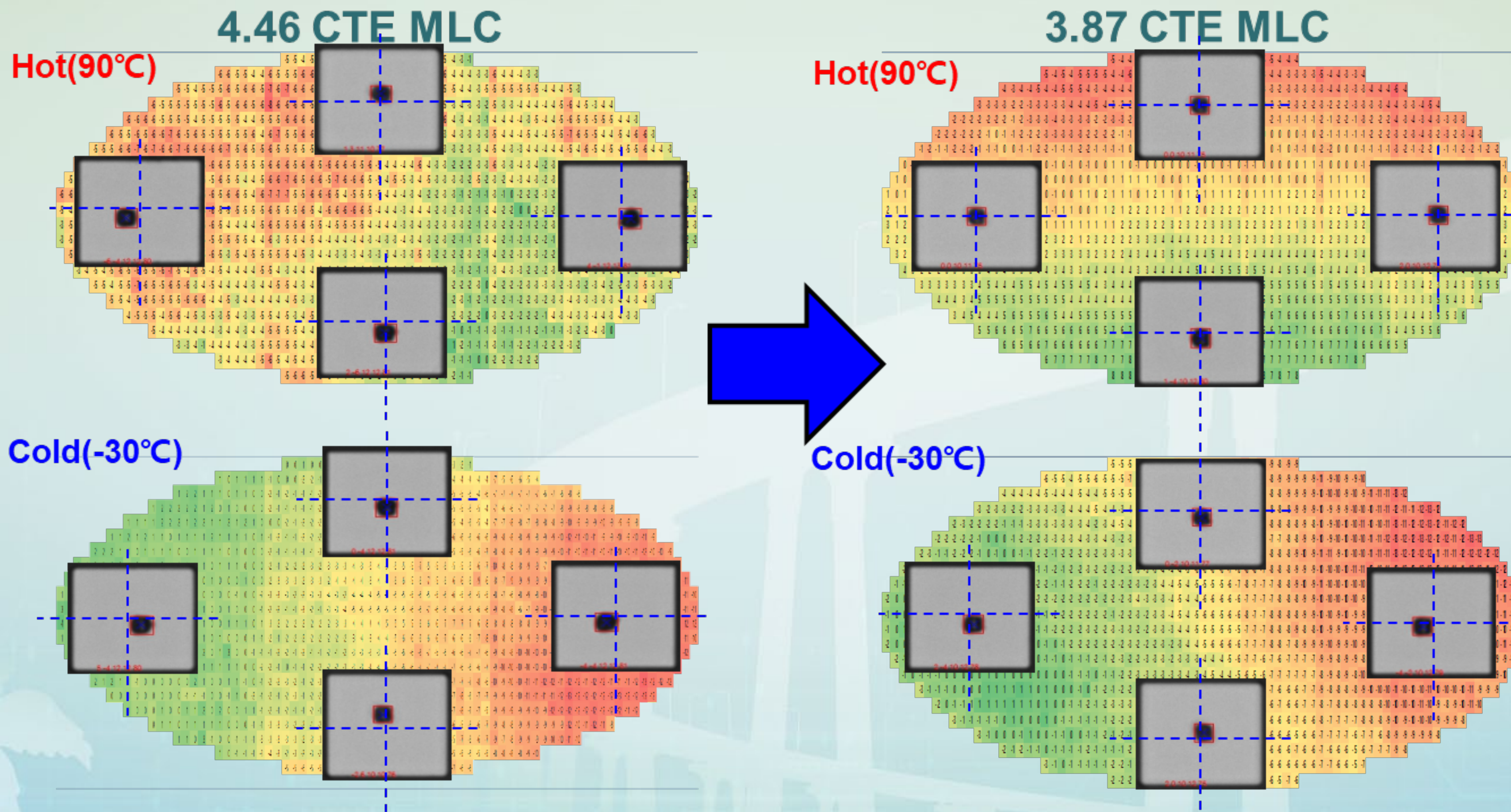


MLC CTE 4.46ppm/℃

*Data previously presented in SWTest2023 by authors

Probe mark with different CTE MLC

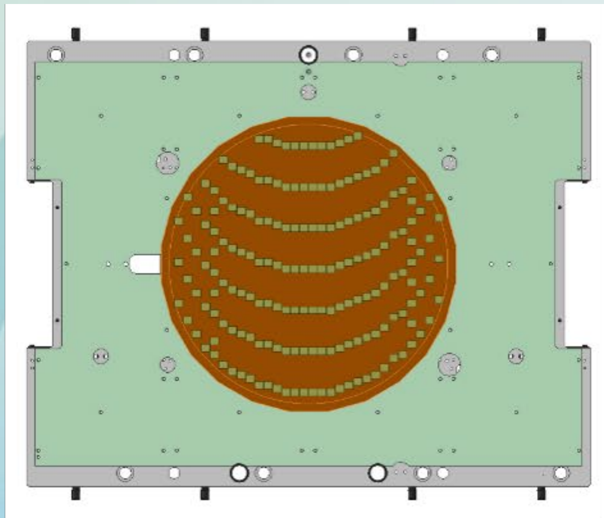
- Probe marks using MEMS Probe card (~43K pins)



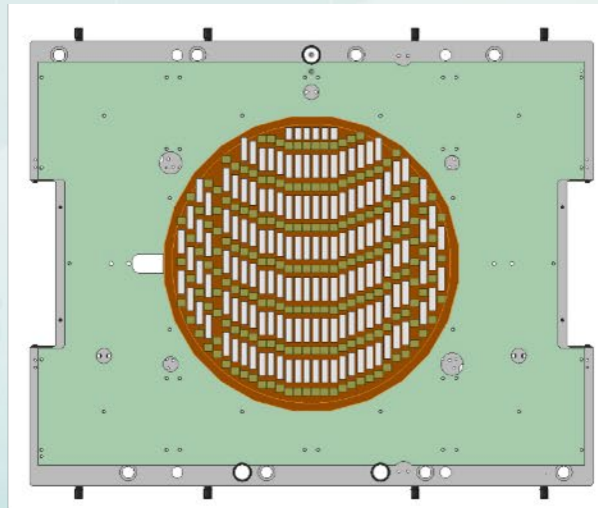
*Data previously presented in SWTest2023 by authors

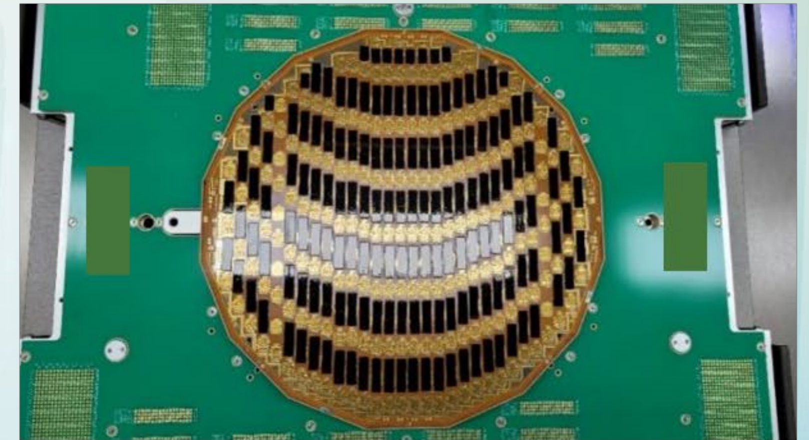
Importance of Heat Transfer Block(HTB)

- It is difficult to get perfect thermal expansion matching with CTE control only
- Heat Transfer Blocks attached on empty spaces between the DUTs of an MLC increase the amount and speed of heat transferred, reducing total test time
- HTB application is possible with skip style rainbow layout probe heads



Block attach

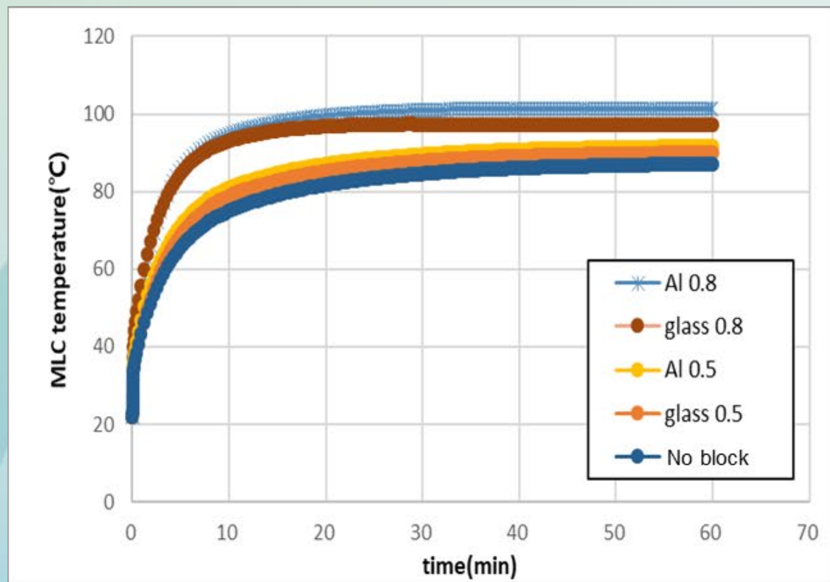


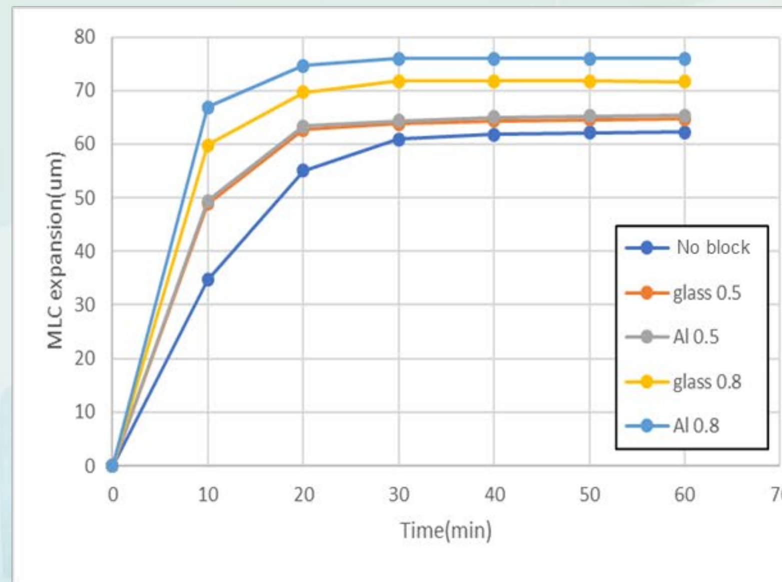


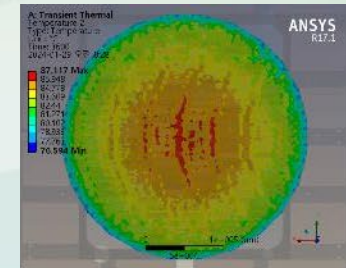
Real sample (V93K)

MLC temperature and HTB

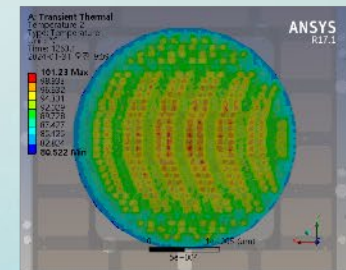
- Attaching block affect MLC temperature and saturation speed
- Metal and thicker material showed more expansion and faster saturation compared to glass and thinner material







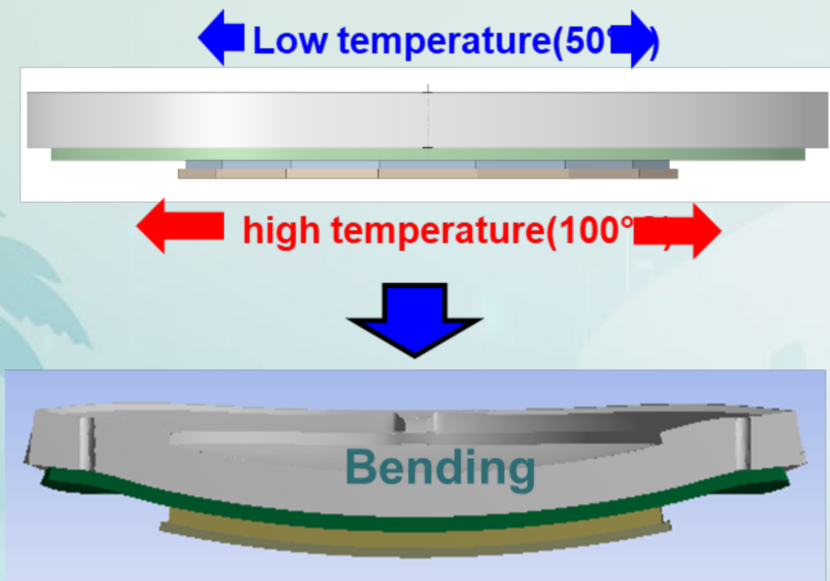
Without HTB

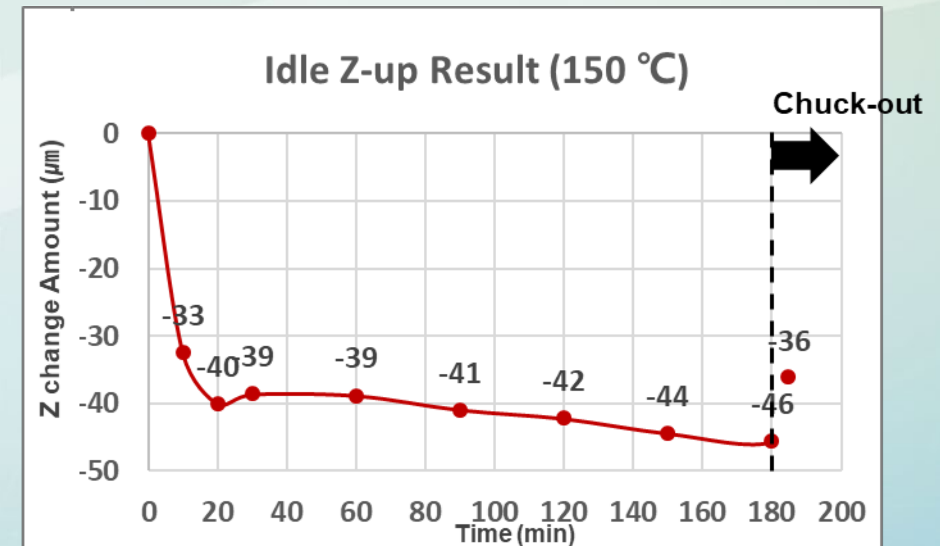


With HTB

Z movement control

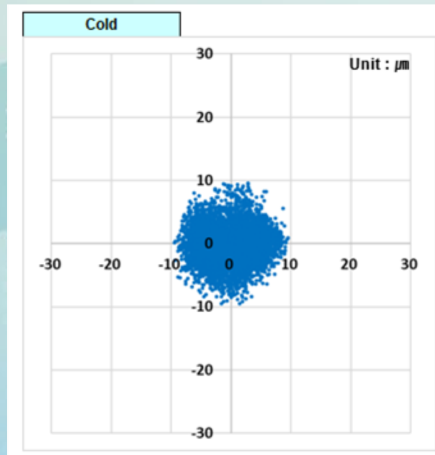
- For high temp usage, the chuck Z movement is a important factor
  - Z movement must be small during wafer change, probe card cleaning or lot change
- Target: Z-movement less than 10 ㎛ in up to 5 min after chuck out
- Simulation and manufacturing experience enabled the Z movement control

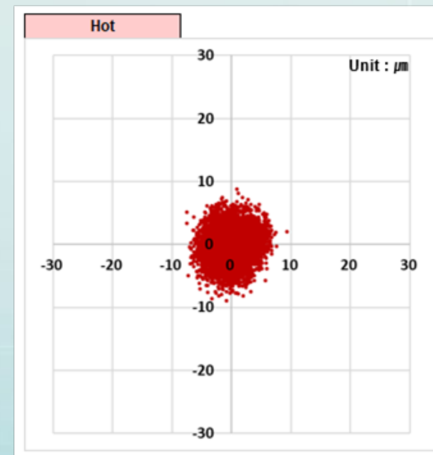


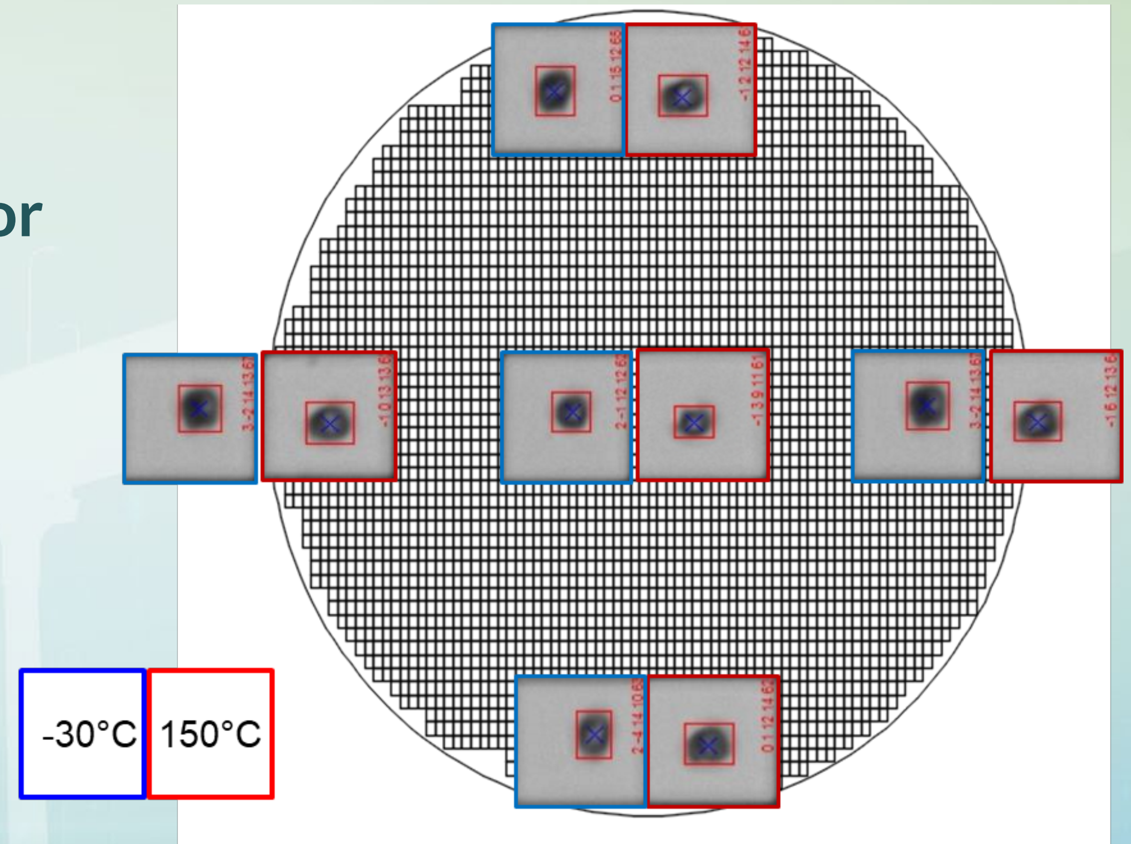


Sample Probe mark at HT and CT

- Probe marks from one card for -30 and 150°C
  - 300mm wafer, ~20K probes Probe Card
  - Pad size: 40 μm x 40 μm
- All probe marks formed inside the pad for both cold and hot well within margin







DI Kim, JH Heo, CS Kim, ID Kim, M Ojeda, P Do

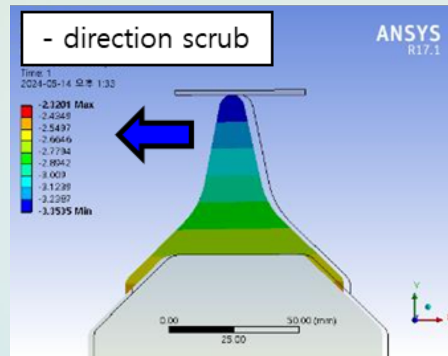
Zero-Scrub Possibilities

°C

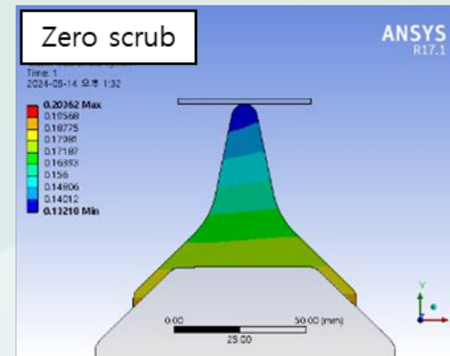
Scrub control by Probe design

- 2D MEMS probes has high freedom of design, which allow control over the probe scrub length
- To accommodate the scrub mark within the allowed area, the mark size must be kept at minimum

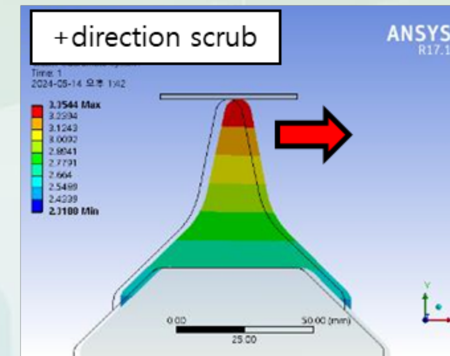
Over drive : 100μm



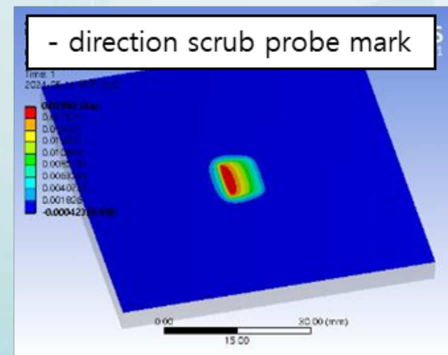
scrub length : about -3um



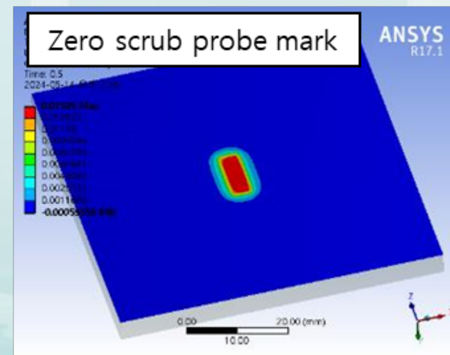
scrub length : 0um



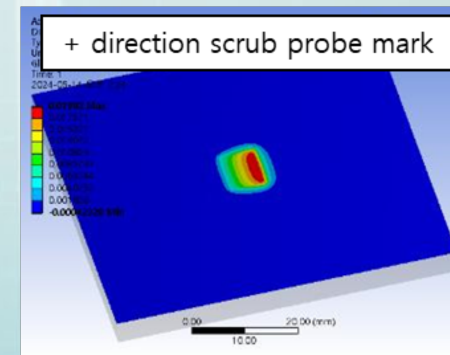
scrub length : about 3um



probe depth : 0.2um



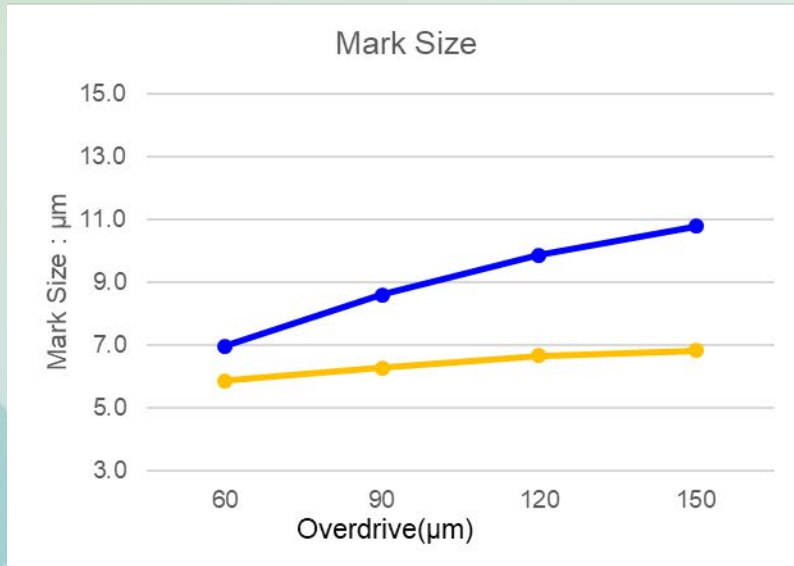
probe depth : 0.15um

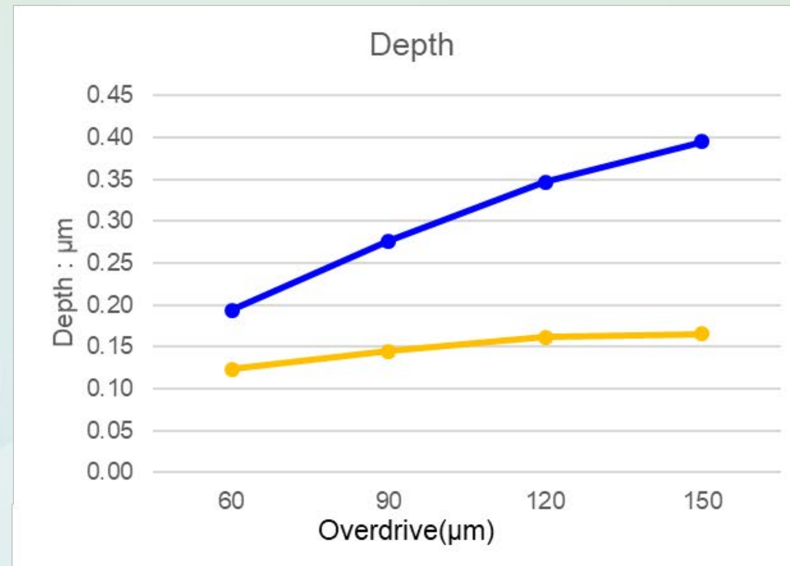


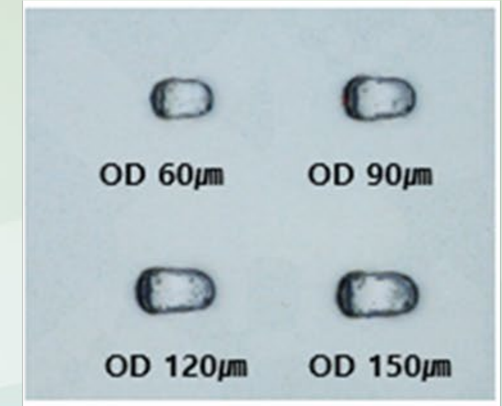
probe depth : 0.2um

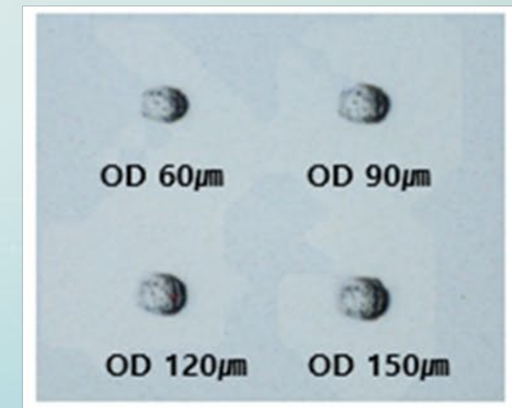
Near-Zero Scrub Probe

- Actual test results for small scrub probes



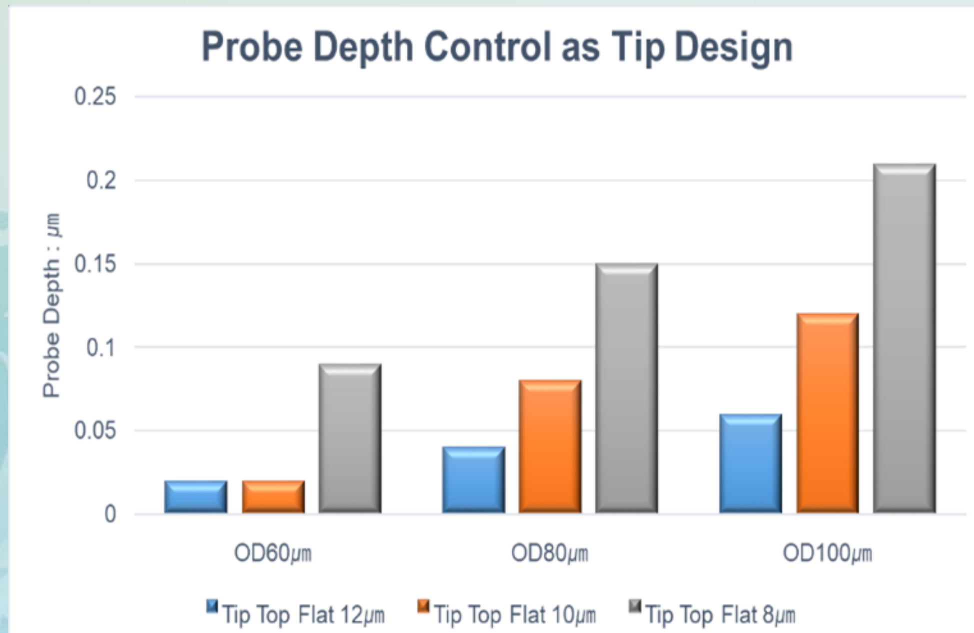


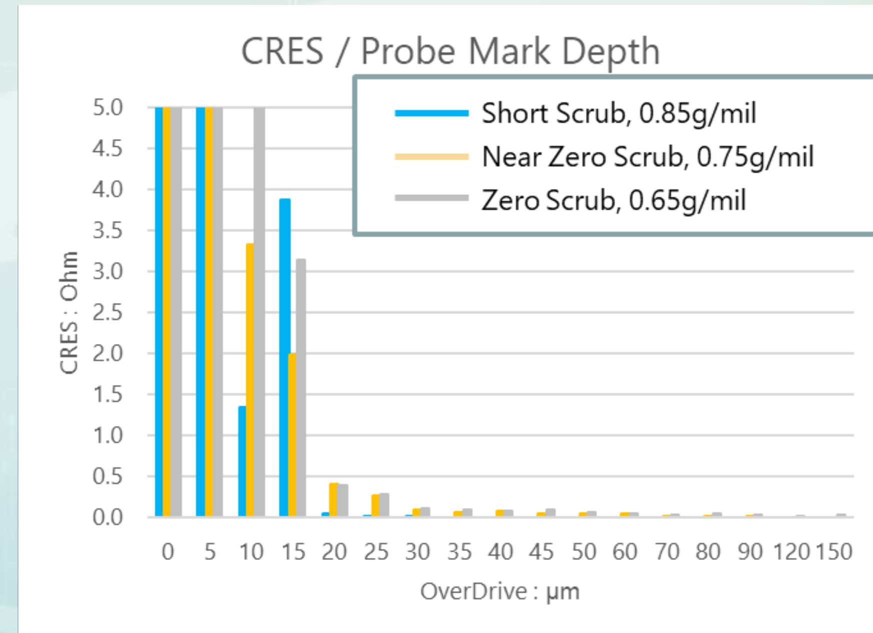




Tip Size design and Probe depth

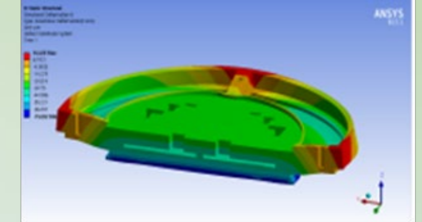
- Contact resistance(CRES) is related to the probe mark depth
- The mark depth is determined by tip size, scrub length and probe force
- Appropriate selection of probe force and tip size is important
- Tip size control is done by design and cleaning sequence management
- Constant monitoring is needed to prevent pad punch through due to small probe tip size

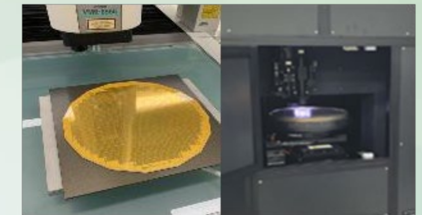


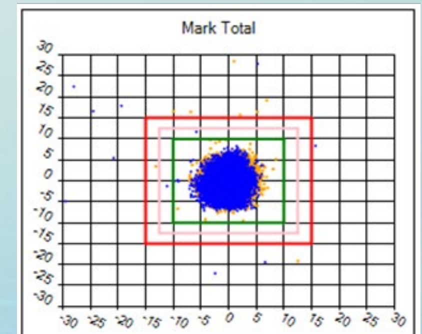


Fabrication process

Design	Probe Head / PCB / Stiffener	Design / Simulation
Material Check	Probe Head CTE Thermal Align Offset Pin Type selection	Material CTE Measurement Thermal offset calculation Force, scrub, tip size
Manufact-uring	Pin bonding 1st Align Inspection	±4㎛ Spec Optical Inspection system
Assembly	Assembly/2nd Align Inspection Thermal align check	Probe Mark at used temp Decision on Heat transfer block
Final QC Process	3rd Align Inspection	Final Inspection







Summary

- 300mm rainbow layout probe cards are now being used for logic devices with a TD reduction of more than 30%, meaning higher throughput
- It is now possible to have a single wide temperature range probe card (-40°C to 150°C), meaning fewer probe cards needed
- To enable 2D MEMS 300mm wide temp card
  - CTE of the Probe head must be selected in relation to pin count
  - The scrub size must be minimized for small pad and to partially compensate any alignment error caused by the thermal effect
  - Tip size and pin force are important factors to consider to keep CRes low with small scrub
- Careful control of the fabrication process is necessary to manufacture 300mm wide range logic device probe cards