SWTEST

PROBE TODAY, FOR TOMORROW

2023 CONFERENCE

Optimization of thermo-mechanical characteristics of a probe card

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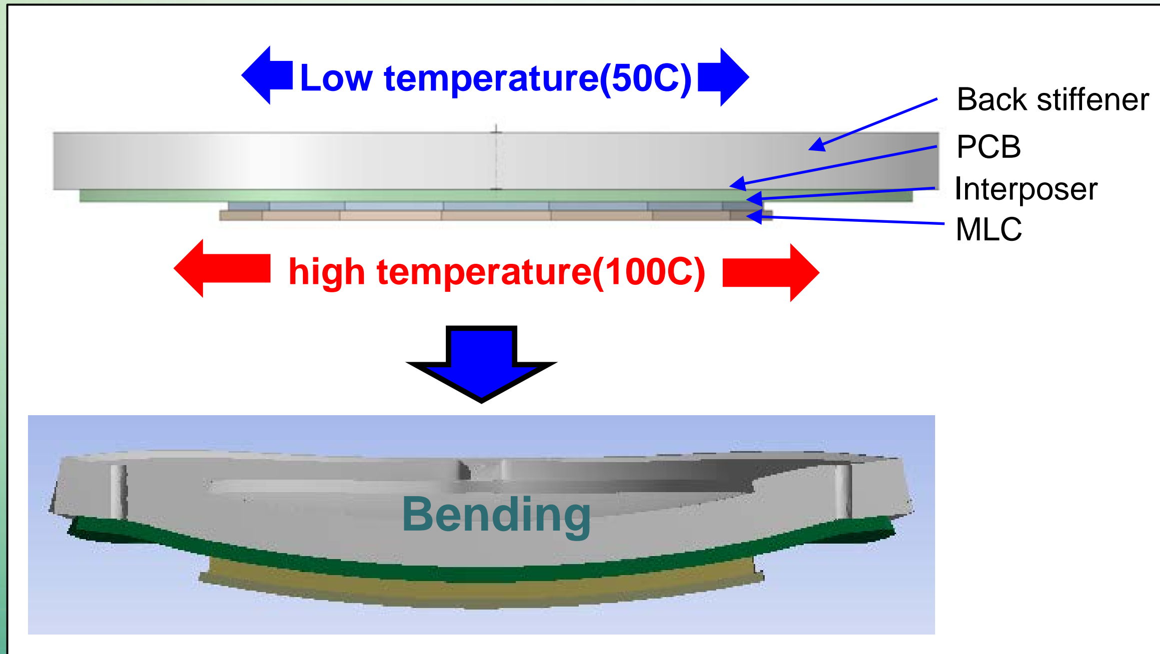
AGENDA

- INTRODUTION
- SOLUTION
- OPTIMIZATION OF THERMAL PLANARITY
- OPTIMIZATRION OF THERMAL ALIGNMENT
- SUMMARY

Introduction – 1

- **Thermal planarity**
  - Thermal bending : CTE and thermal expansion by temperature gradient
  - Main factor of thermal bending : Back-stiffener

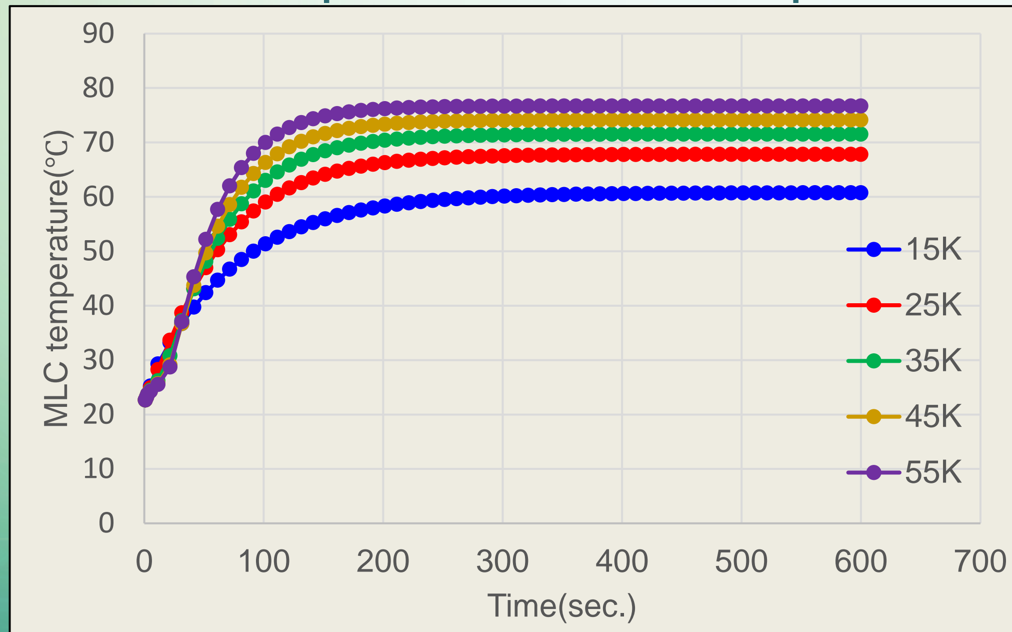


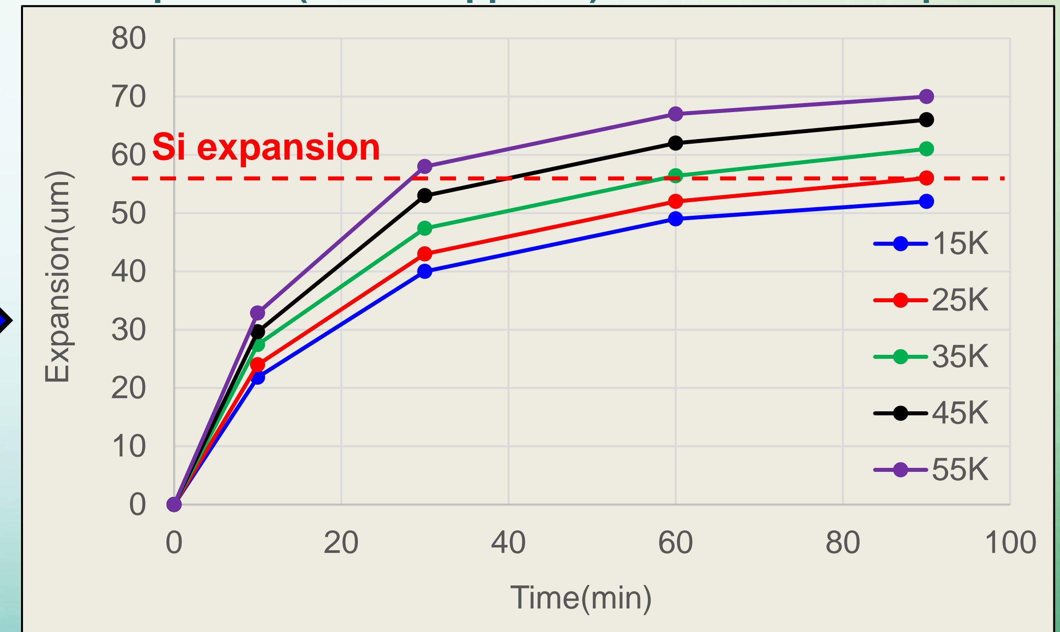
Configuration of Probe Card

Part	Elastic modulus (GPa)	Thickness (mm)	material	CTE (ppm/℃)	**bending contribution**
Back stiffener	**200**	**20~30**	**Based Steel**	**10~20**	**80% over**
PCB	20~30	6~7	FR4	20~30	4%
MLC	130	5.5	Ceramic	4~5	15%

Introduction - 2

- **Thermal alignment**
  - Thermal align miss-match : Difference of expansion between wafer and MLC
  - Number of probes : Important factor in selecting CTE of MLC





Solution

- **Optimization of thermal planarity**

  - Optimization of back-stiffener using FEA simulation

  1) Selection of material and CTE
  2) Shape and thickness
  3) Back-stiffener size

- **Optimization of thermal alignment**

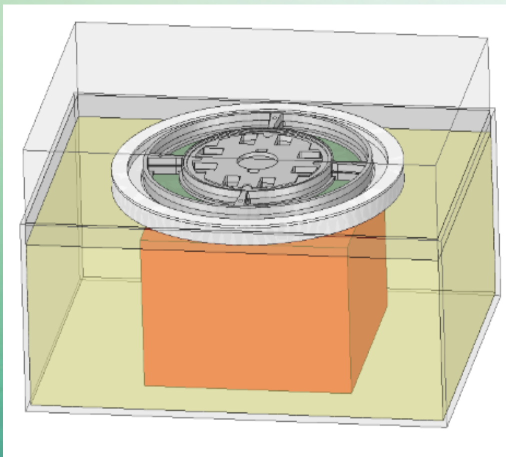
  - Lower CTE MLC

  1) Improvement of thermal alignment applied low CTE MLC
  2) Stable probe counts applied low CTE MLC

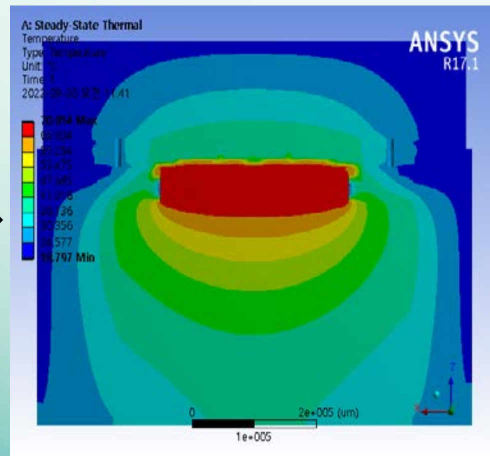
FEA system

- **Probe card simulation using FEA**
  - **FEA procedure**
    1) 3D full modeling
    2) Transient thermal analysis
    3) Import main part temperature
    4) Static structural analysis

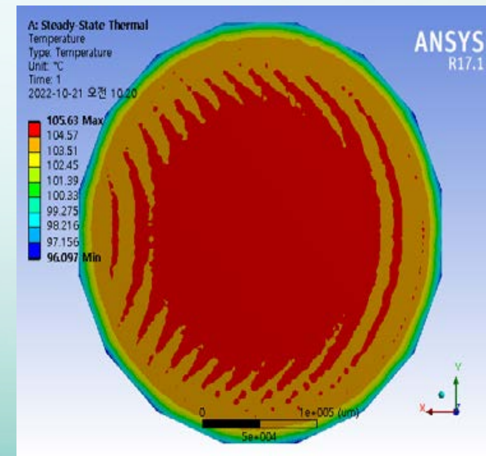
3D full modeling



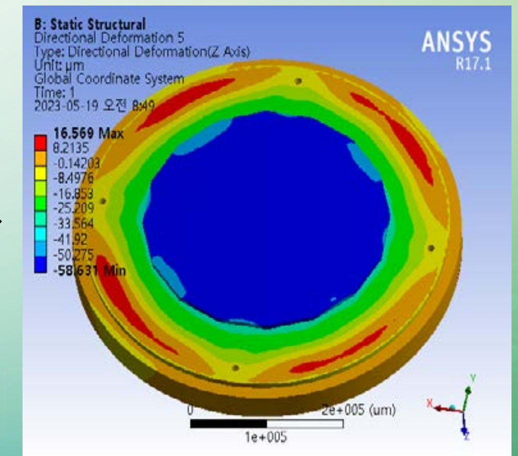
Transient thermal



Import main part



Static structural



Optimization of thermal planarity

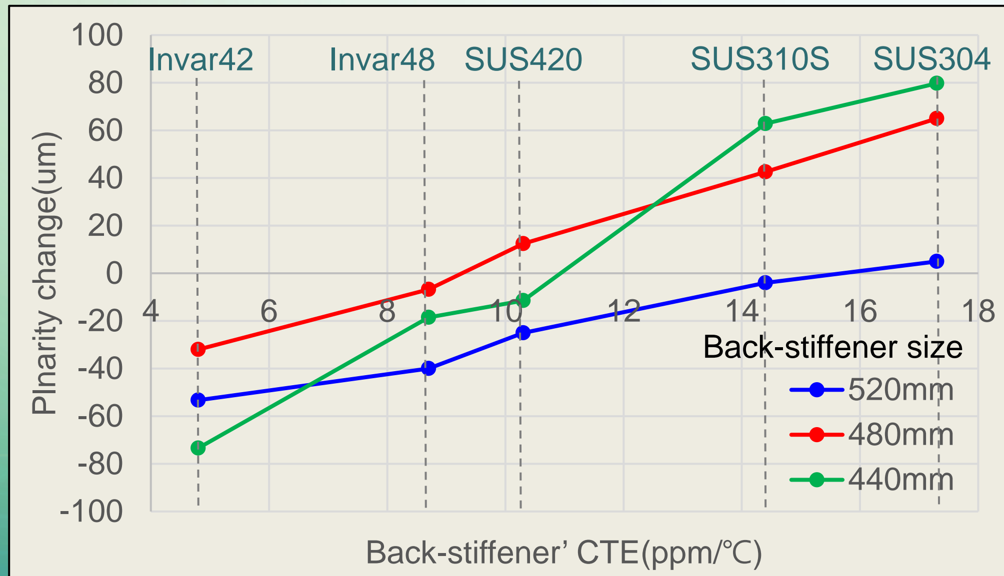
- **Effect of back-stiffener's CTE(material)**

  - Increasing size of back-stiffener : Suitable for material with higher CTE

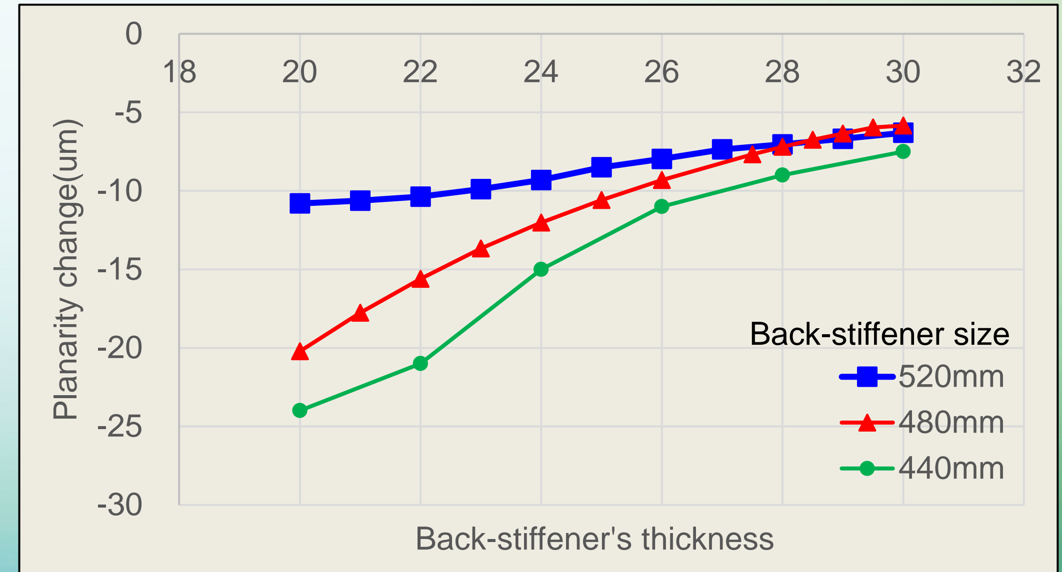
- **Effect of back-stiffener's thickness**

  - Amount of planarity change : Stable of back-stiffener with increasing size

Planarity change as back-stiffener's CTE

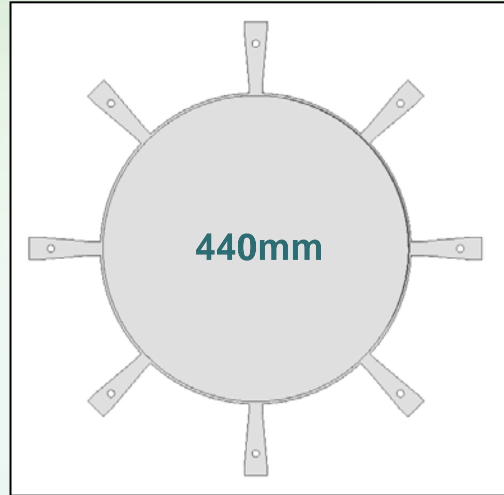


Planarity change as the Back-stiffener's thickness

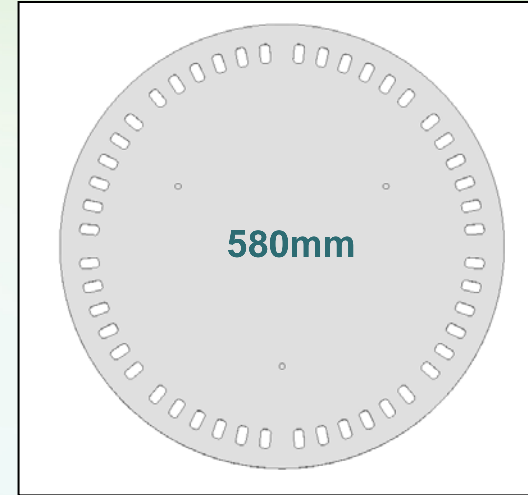


Type of Back-stiffener

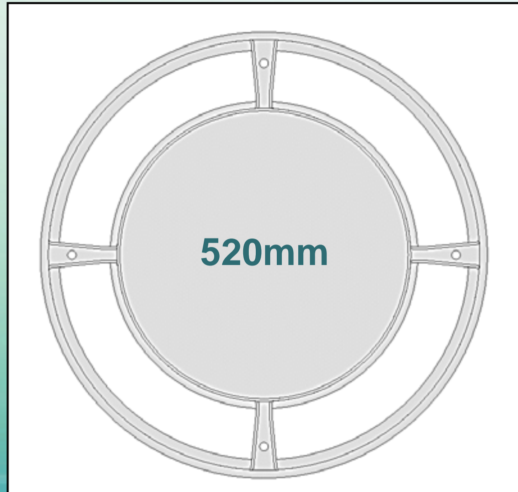
Volume type back-stiffener



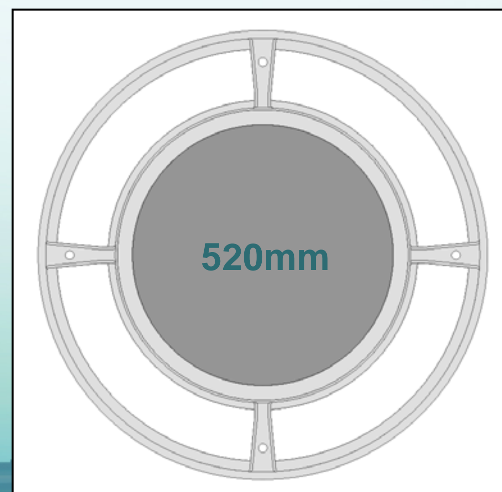
Large area type back-stiffener



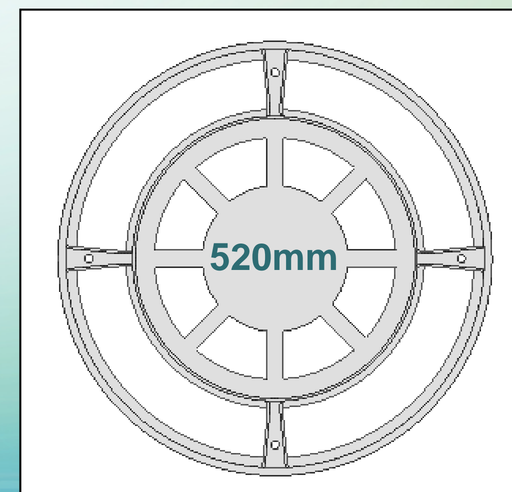
Volume type back-stiffener 1



Volume type back-stiffener 2



Relay board type back-stiffener

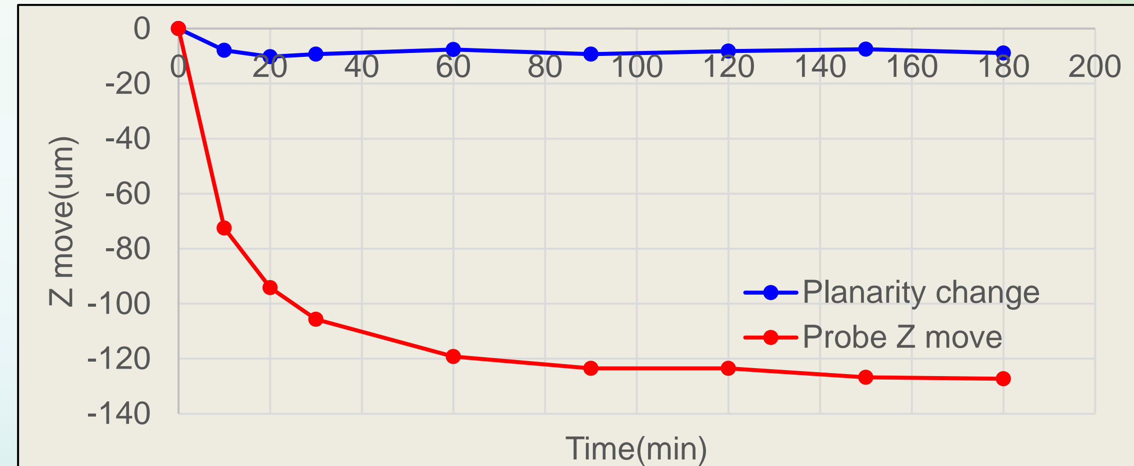


Experiment of thermal planarity

PROBER system

Temperature	Value
Test temperature(℃)	100
Ambient temperature(℃)	25

Probe Z move and planarity change



Time(min)	0	10	20	30	60	90	120	150	180
Z move (um)	0.0	-72.5	-94.2	-105.7	-119.2	-123.5	-123.5	-126.8	-127.3
Planarity change(um)	0.0	-7.9	-10.2	-9.3	-7.6	-9.3	-8.2	-7.5	-8.9

Comparison with FEA and Experiment

ITEM	Target	FEA	Experiment
Planarity change	+/- 5um	**-5 ~ 3um**	**-4 ~ 2um**

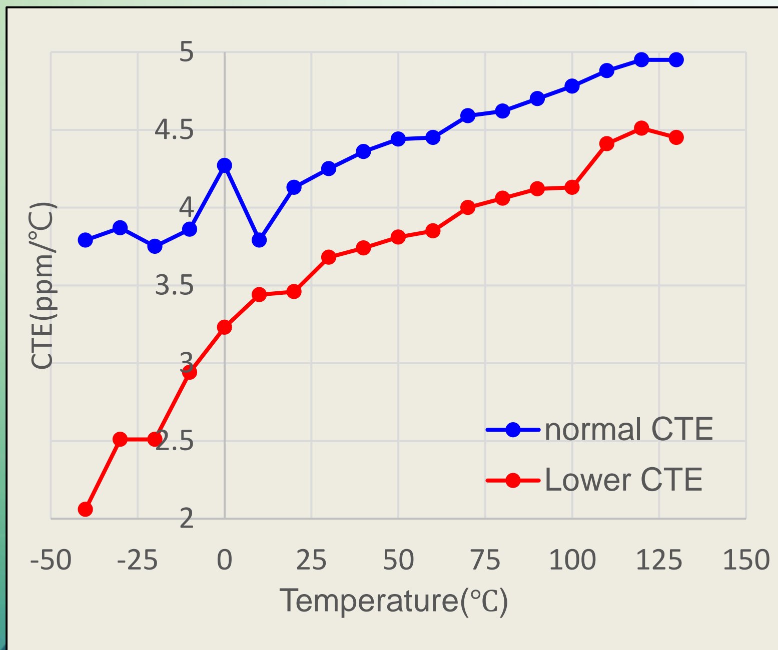
Tester	Back-stiffener size	Material	Temperature(℃)	Planarity change FEA	Planarity change Experiment	Error (FEA-Experiment)
A	**440**	**SUS420**	**100℃**	-5um	-4um	-1um
B	**480**	**SUS420**	**85℃**	-5um	-4um	-1um
C	**520**	**SUS310S**	**110℃**	-5um	-4um	-1um
	580	**SUS304**	**110℃**	-4um	-3um	-1um
	520	**SUS310S**	**150℃**	3um	2um	1um

Mainly SUS420 and SUS310S are used and a planarity change of less than +/-5μm is achieved.

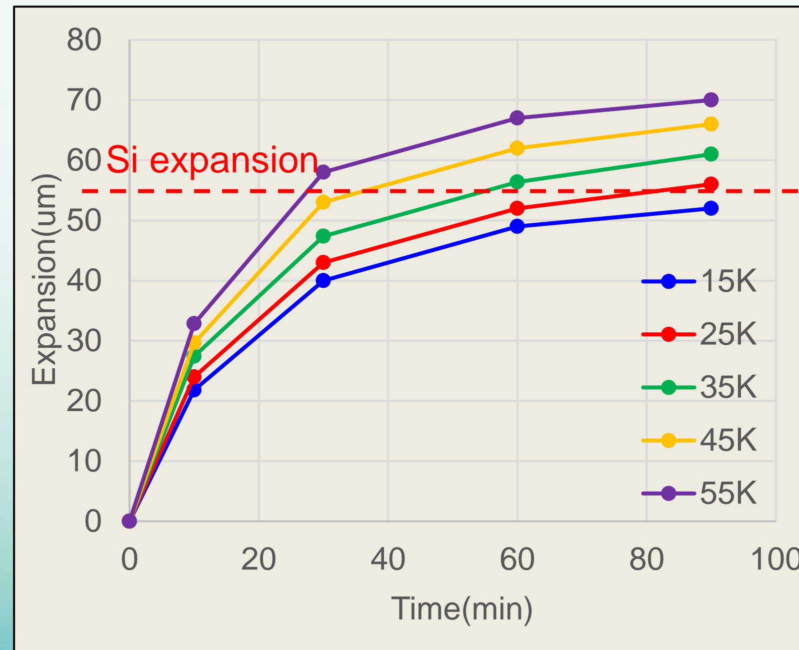
Optimization of thermal alignment

- **Lower CTE MLC**
  1) Manufacturer of lower CTE MLC : SEMCNS
  2) Lower CTE value : 3.87 ppm/℃ (normal CTE 4.46 ppm/℃, at 25~100℃)
  3) Higher probe counts : Suitable for lower CTE MLC

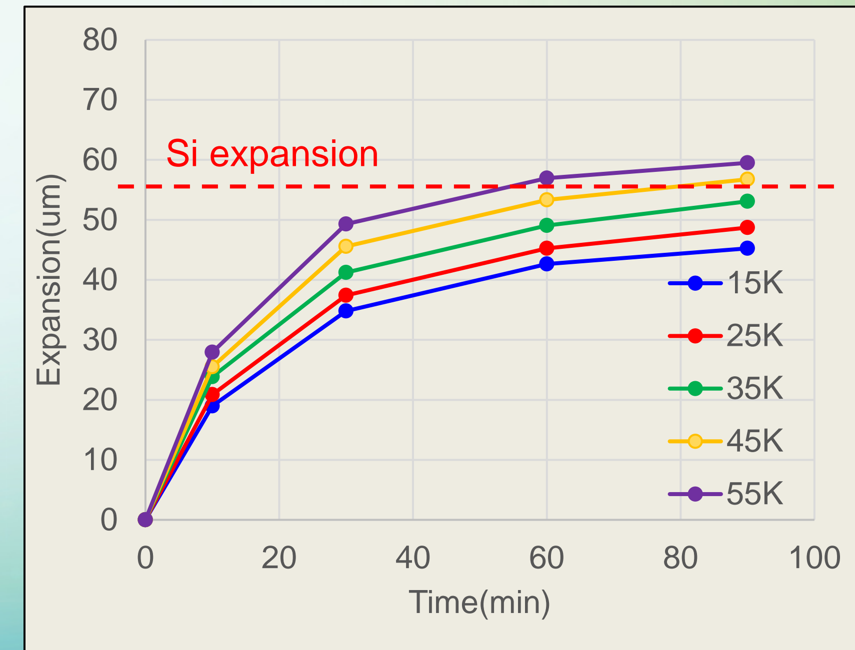
TMA



Normal CTE(4.46ppm/℃) MLC



Lower CTE(3.87ppm/℃) MLC



Measurement of lower CTE MLC

- **Thermal expansion measuring condition**
  - Test temperature : 100℃
  - Test sample : 300mm MLC
  - Test time : expansion measured after 2hours(full heating)
  - Test equipment : Auto 3D scope
  - Test data

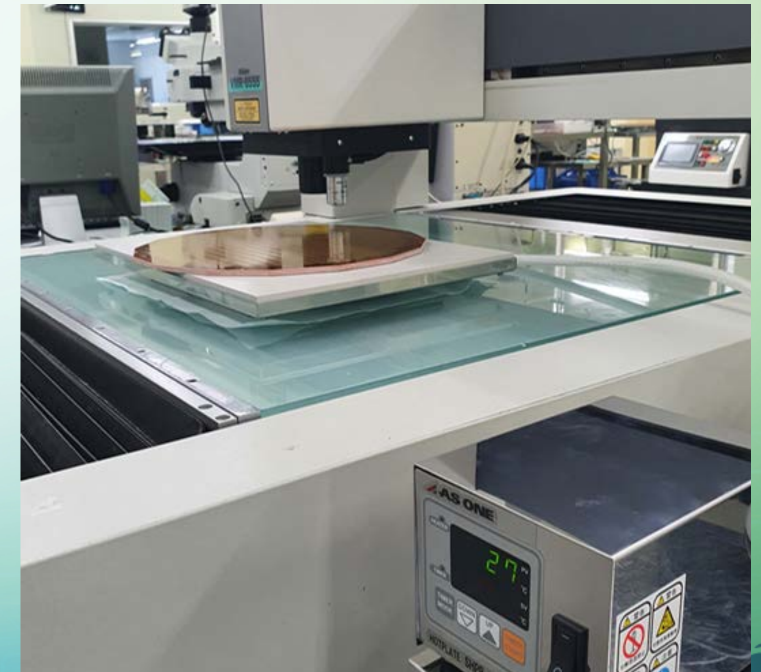
Sample	25℃		100℃		Expansion (um)
	Initial Temperature(℃)	Measuring Distance(um)	Initial Temperature(℃)	Measuring Distance(um)	
Normal CTE A	27.0	291640.4	99.8	291734.0	96.3
Normal CTE B	26.3	291637.3	99.8	291728.5	93.7
Lower CTE A	26.3	305825.1	99	305913.6	86.7
Lower CTE B	27.2	305825.0	99	305913.2	86.4

Decrease 8.4um thermal expansion compared with normal CTE

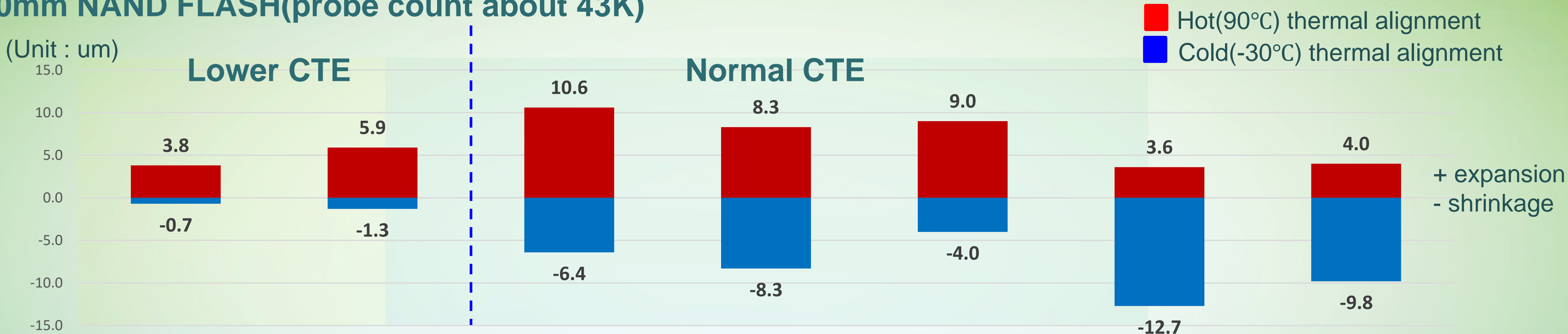
SEMCNS specification

TMA	Normal CTE	Lower CTE
25~100℃	4.46 ppm/℃	3.87 ppm/℃
-40~120℃	4.29 ppm/℃	3.81 ppm/℃

Measurement system



Thermal alignment applied probe card

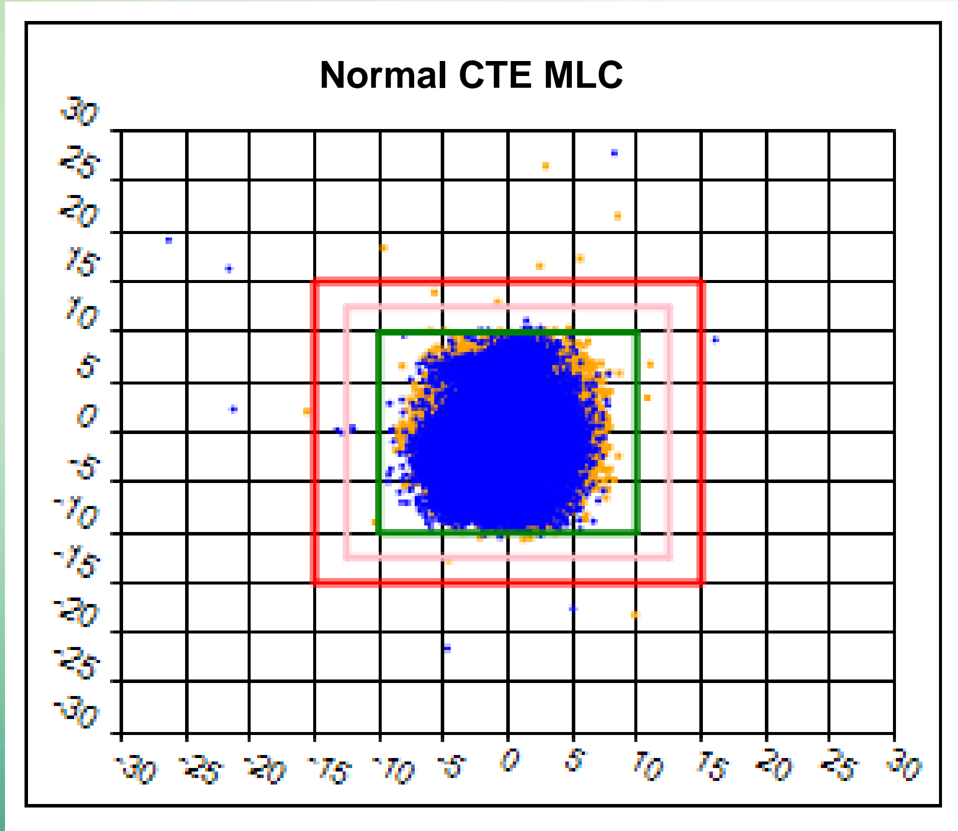


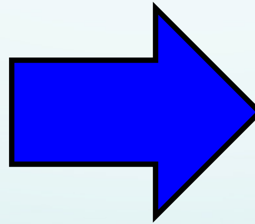
Probe card	MLC	CTE	Hot expansion direction	Cold expansion direction	Symmetry
Same device	**A**	**Lower**	**3.8**	**-0.7**	**4.5**
	B		**5.9**	**-1.3**	**7.2**
	C	**Normal**	10.6	-6.4	17.0
	D		8.3	-8.3	16.6
	E		9.0	-4.0	13.0
	F		3.6	-12.7	16.3
	G		4.0	-9.8	13.8
	Avg	**Low**	**4.9**	**-1.0**	**5.9**
		Normal	**7.1**	**-8.2**	**15.3**

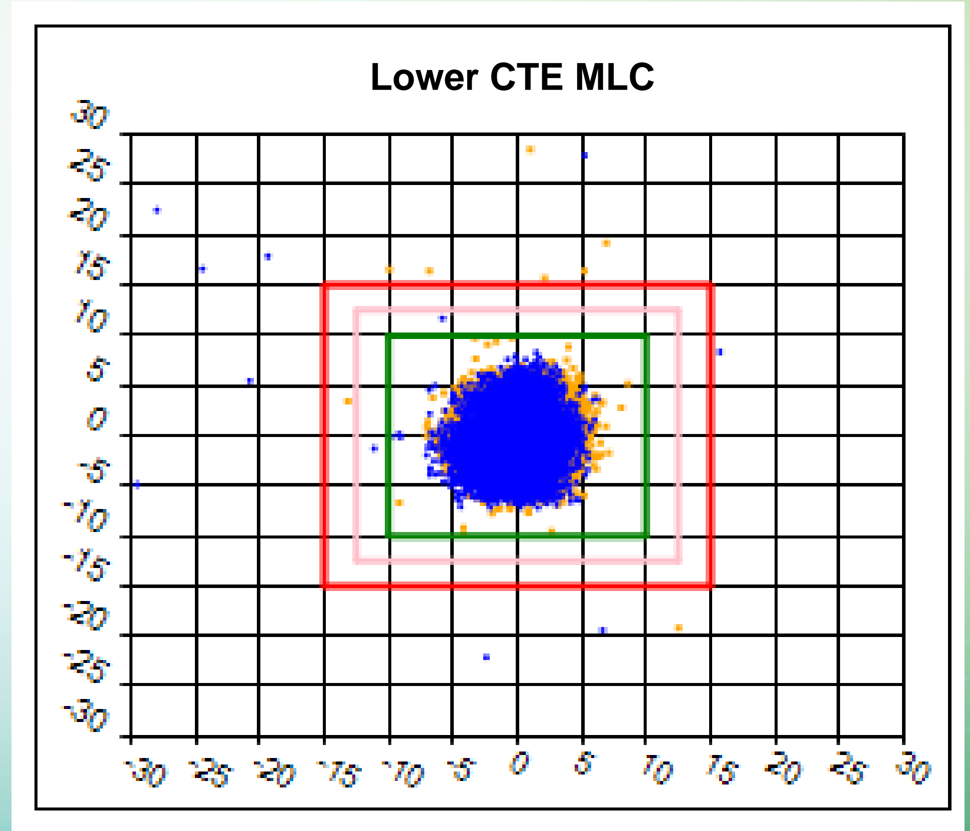
Improvement thermal alignment 9.4um compared with normal CTE

Thermal alignment diagram

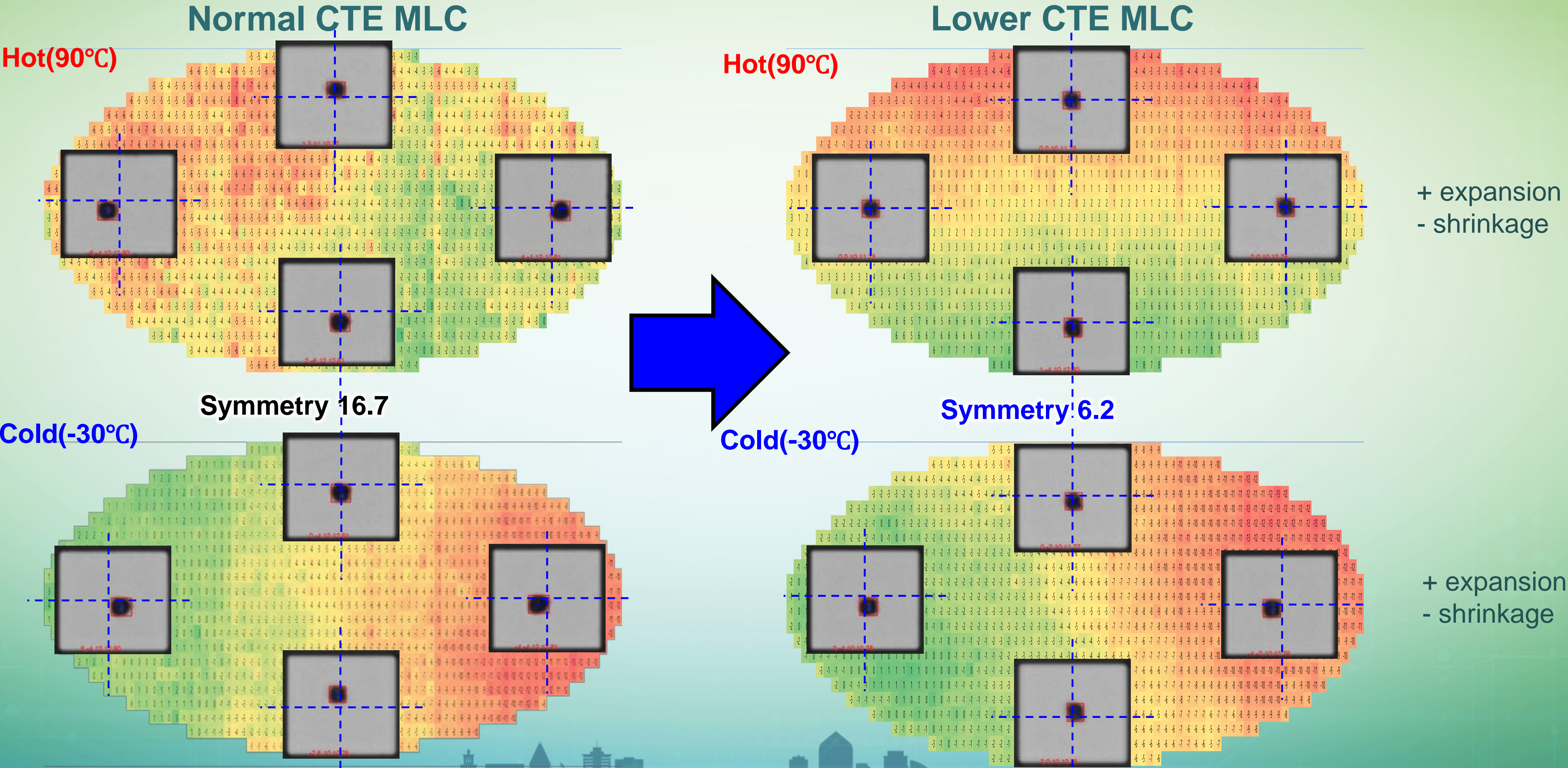
300mm NAND FLASH(probe count about 43K) One shot thermal alignment diagram(90℃)







Probe mark inspection applied lower CTE MLC



Summary

- **Thermo-mechanical properties of probe card**
  - **Thermal planarity**

    1) Main factor of thermal planarity : Back-stiffener
       - Size of back-stiffener : Large impact in the thermal Z movement of the probe card
       - Larger size of back-stiffener : Suitable for material with higher CTE, stable for planarity change

    2) Planarity change(target : +/-5um)
       - FEA : - 5 ~ 3um
       - Experiment : - 4 ~ 2um

  - **Thermal alignment**

    1) Number of probes : Important factor in selecting CTE of MLC
       - Lower CTE(3.87ppm/℃) MLC : Improvement of thermal alignment 9.4um compared with normal CTE (4.46ppm/℃)MLC with 43K probe card

    2) Probe counts for stable alignment(300mm probe card)
       - Normal CTE(4.46ppm/℃) MLC : From 20K to 30K probe counts
       - Lower CTE(3.87ppm/℃) MLC : From 35K to 55K probe counts