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Accurate Probe Positioning by Using Low CTE Ceramic Substrate for 12 " Testing

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Overview

- 12” Test Trend and Challenge
- Goal of Study
- Selection of proper CTE and Temperature of Ceramic
- 12” accurate probing using LTCC ceramic
- Summary

Test Trend

- Higher pin count, smaller pad size, larger wafer test

2000 2005 2010 2015 2020

Process (D/R)

0.18 ㎛ 90 ㎚ 50 ㎚ 20 ㎚ ?? ㎚

PAD size (Memory test)

90 ㎛ × 100 ㎛ 70 ㎛ × 80 ㎛ 50 ㎛ × 60 ㎛ ?? ㎛ × ?? ㎛

Touch-down area

200mm
1 T/D

300mm (FLASH)
1 T/D

300mm (DRAM)
1 T/D

Accurate pin positioning Issue

- Hot/Cold electrical die sorting is needed
- There is expansion discrepancy between Si wafer and MEMS pin on ceramic of probe card
- And more, temperature difference exists
- So, accurate pin positioning becomes more difficult,

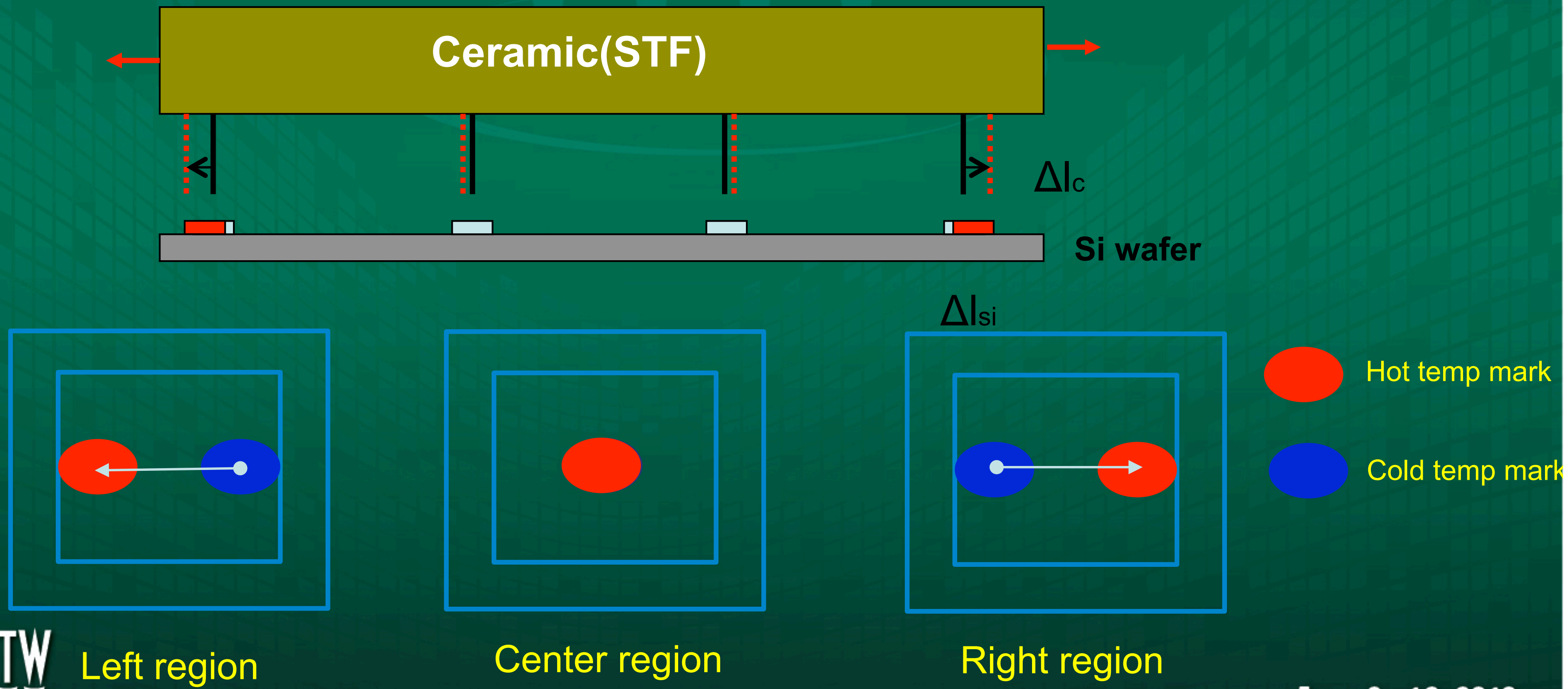
  as pad size decrease, hot/cold temperature differences increase, and wafer size increase
- Many probe card makers feels hurdle of it

Goal of Study

- Suggest the guideline to select CTE and temperature of ceramic STF to meet the need of small pad probing
- Consider the main parameters affecting temperature of ceramic
- Summarize various ceramics suitable for STF
- Show the field test result of the accurate pin positioning using low CTE LTCC ceramic

Scrub mark movement Analysis

- **MEMS Pin scrub mark moves as test temperature changes**
- **Almost ceramic has higher CTE than Si wafer, so hot temp mark moves out relative to cold scrub mark, generally.**

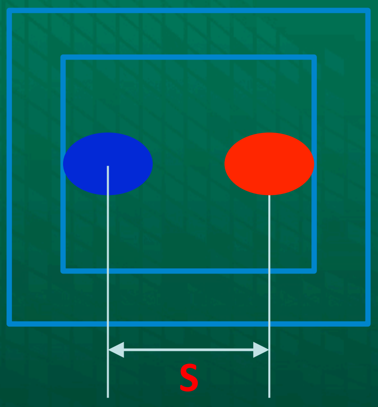


Moving Distance of Scrub Mark

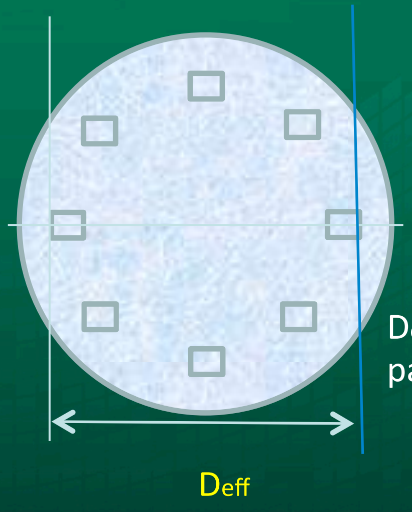
- **Scrub mark's moving distance(S) from cold to hot temp.**

$$
\begin{aligned}
S &= \Delta l_c - \Delta l_{si} \\
&= \underbrace{\frac{D_{eff}}{2}\cdot\alpha_c\cdot(T_c^h - T_c^c)}_{\text{Ceramic expansion}} - \underbrace{\frac{D_{eff}}{2}\cdot\alpha_{si}\cdot(T_{si}^h - T_{si}^c)}_{\text{Wafer expansion}}
\end{aligned}
\quad ①
$$

Δl_c	ceramic expansion
Δl_{si}	wafer expansion
α_c	CTE of ceramic
α_{si}	CTE of Si wafer
T_c^h	Ceramic temp @ hot test
T_c^c	Ceramic temp @ cold test
T_{si}^h	Wafer temp @ hot test
T_{si}^c	Wafer temp @ cold test



Bonding Pad



Deff : diameter of active test pad region

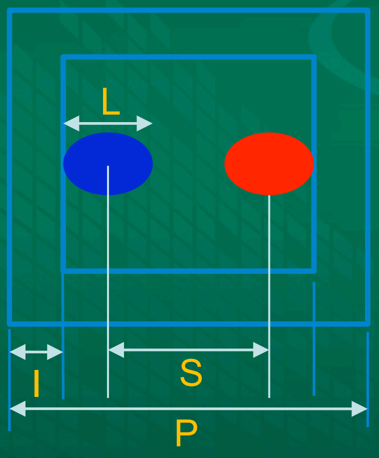
Wafer

Positioning Criteria

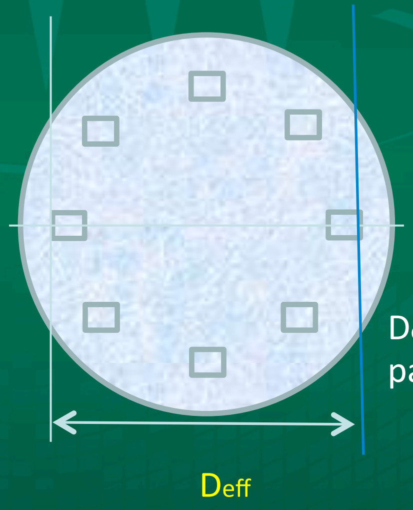
- To position hot and cold mark in bonding pad, following condition must be met

$$S \le (P - 2I - L)$$

②



Bonding Pad



Wafer

S : Scrub mark movement
P : Bonding pad size
I : Bonding margin
L : Scrub mark size

D_{eff} : diameter of active test pad region

For 60um pad with 15um bonding margin and 10um scrub mark size, moving distance(S) must be kept below 20um only !!

Positioning Criteria

- After summarizing above equations(1,2), following condition is derived for safe positioning.

$$\left(T_c^h - T_c^c\right) \le \frac{K}{\alpha_c}$$

where,

$$K = (P - 2I - L)\cdot\left(\frac{2}{D_{eff}}\right) + \alpha_{si}\cdot\Delta T_{si}$$

- There are two variables to control probe mark position for determined hot/cold test temperature

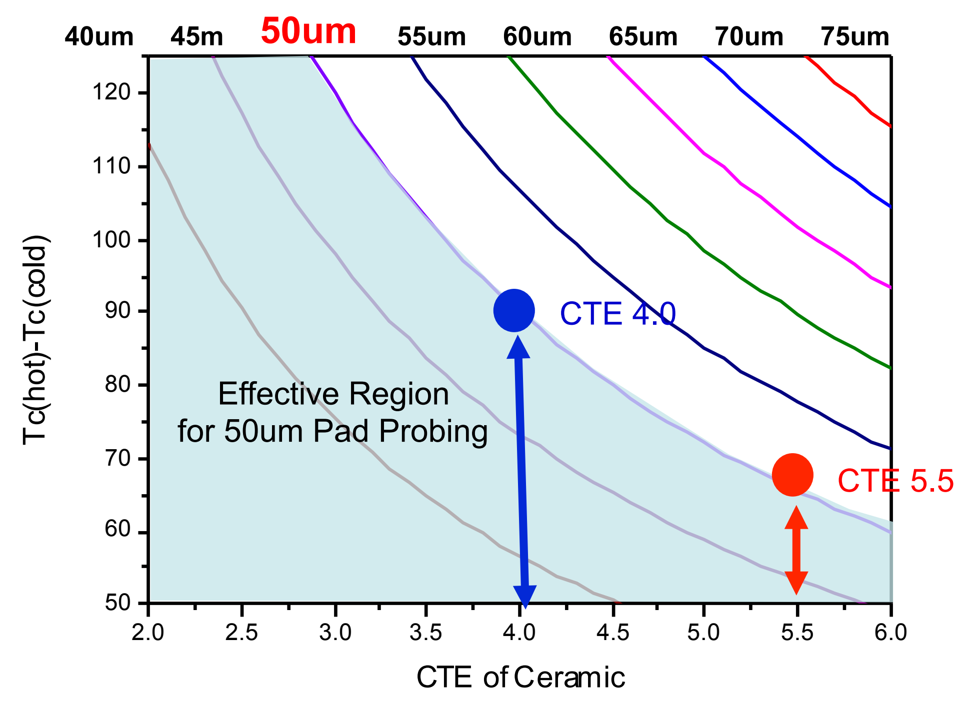
(1) Temperature of ceramic : T_c

(2) CTE of ceramic

Positioning Criteria

- For various bonding pad size, we can draw the line for safe positioning of probe mark as below

Condition
- T(cold) : -25 deg.C
- T(hot) : +95 deg.C
- I(Pad Margin) : 15um
- L(Scrub length) : 10um



$$\left(T_c^h - T_c^c\right) \le \frac{K}{\alpha_c}$$

1st Case : For 50um probing with ceramic CTE 5.5, ceramic temp difference below 65 deg.C is needed. But, for ceramic CTE 4.0, this number can be released to 90 deg.C → It is easier to be accomplished

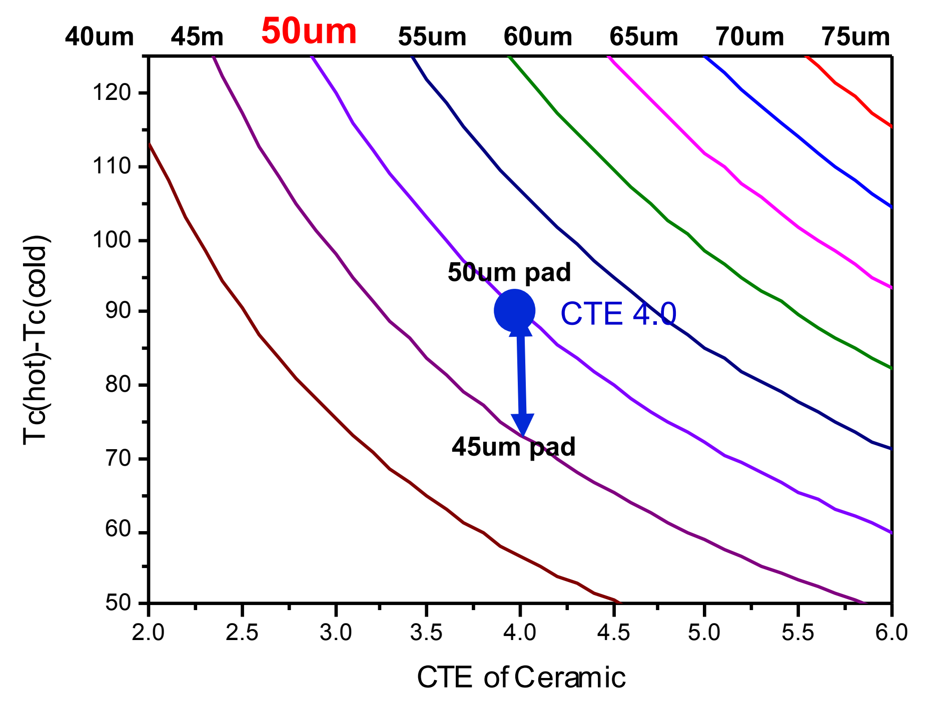
Positioning Criteria

- ***2^nd^ Case*** **: For determined CTE of ceramic, we can adjust probe position by changing temperature of ceramic**

→ For ceramic with CTE 4.0ppm/k, 45um pad probing is possible by reducing ceramic temperature difference from 90 to 70deg.C

→ Important point for controlling scrub mark positioning

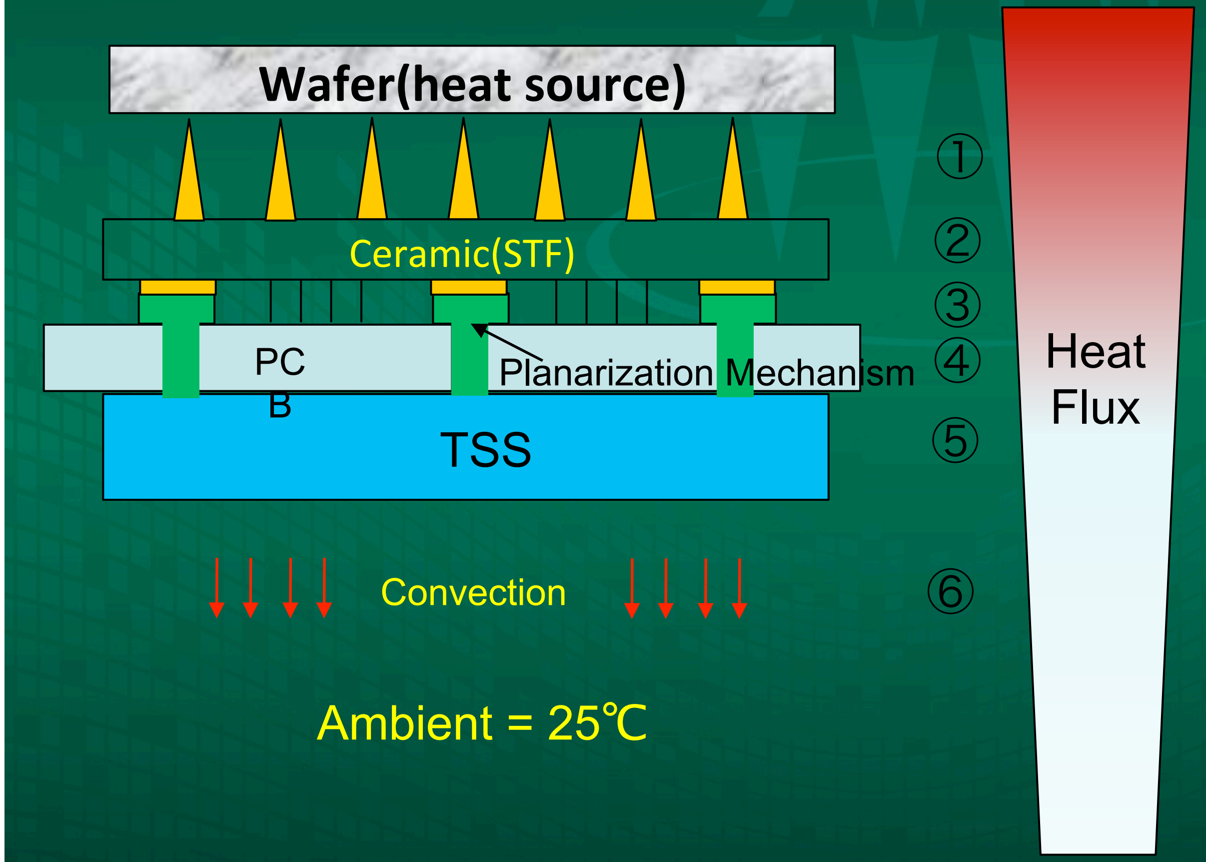
Condition
- T(cold) : -25 deg.C
- T(hot) : +95 deg.C
- l(Pad Margin) : 15um
- L(Scrub length) : 10um



$$\left(T_c^h - T_c^c\right) \leq \frac{K}{\alpha_c}$$

How we can control ceramic temp??

- **System overview**



Constant Temp(Wafer)

① Air/MEMS Pin

② Ceramic Substrate

③ Bond/Solder/Interposer

④ PCB/Planarization Mech.

⑤ TSS

⑥ TSS to Chamber

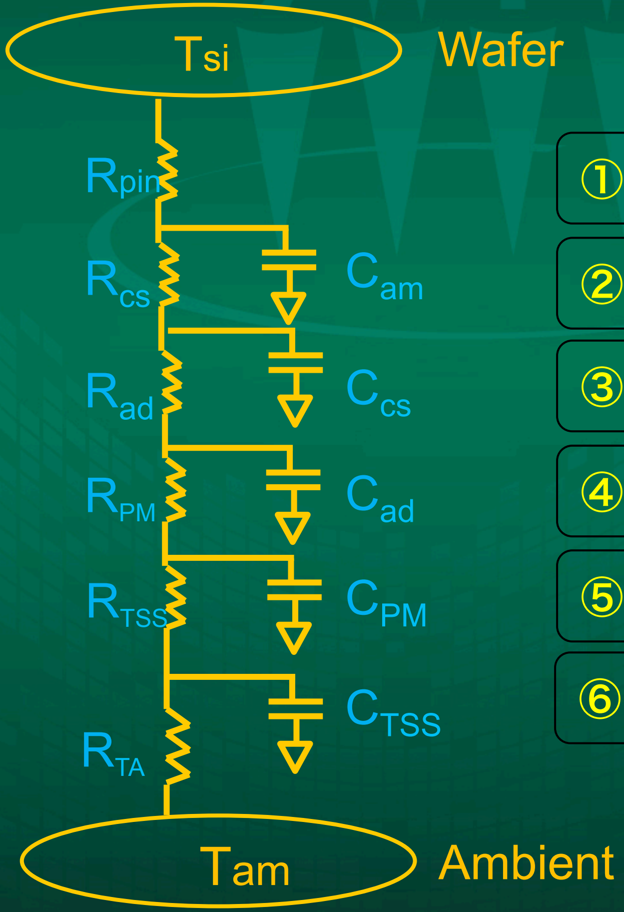
Const. Temp(Ambient)

TSS: Tester Side Stiffner

Ceramic Temp. Control

- **Heat transfer can be analyzed by RC thermal equivalent circuit**

  - Constant voltage(temperature) condition



① Air/MEMS Pin

② Ceramic Substrate

③ Bond/Solder/Interposer

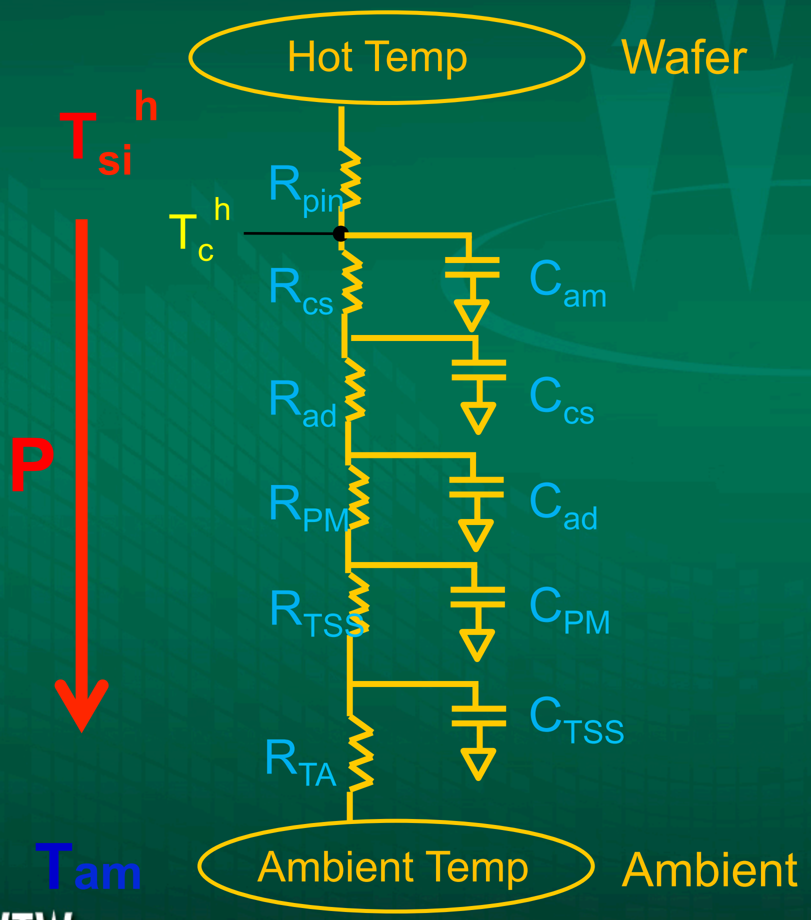
④ PCB/Planarization Mech.

⑤ TSS

⑥ TSS to Chamber

Ceramic Temp. Control

Derivation of equation for ceramic temperature at hot test condition



Heat flux(P)
= (Temp. Difference) / (Thermal Resistance)

$$P = \frac{T_{si} - T_{am}}{R_{th}}$$

$$R_{th} = R_{pin} + R_{cs} + R_{ad} + R_{PM} + R_{TSS} + R_{TA}$$
$$= R_{pin} + R_{other}$$

Ceramic Temp(Tc)

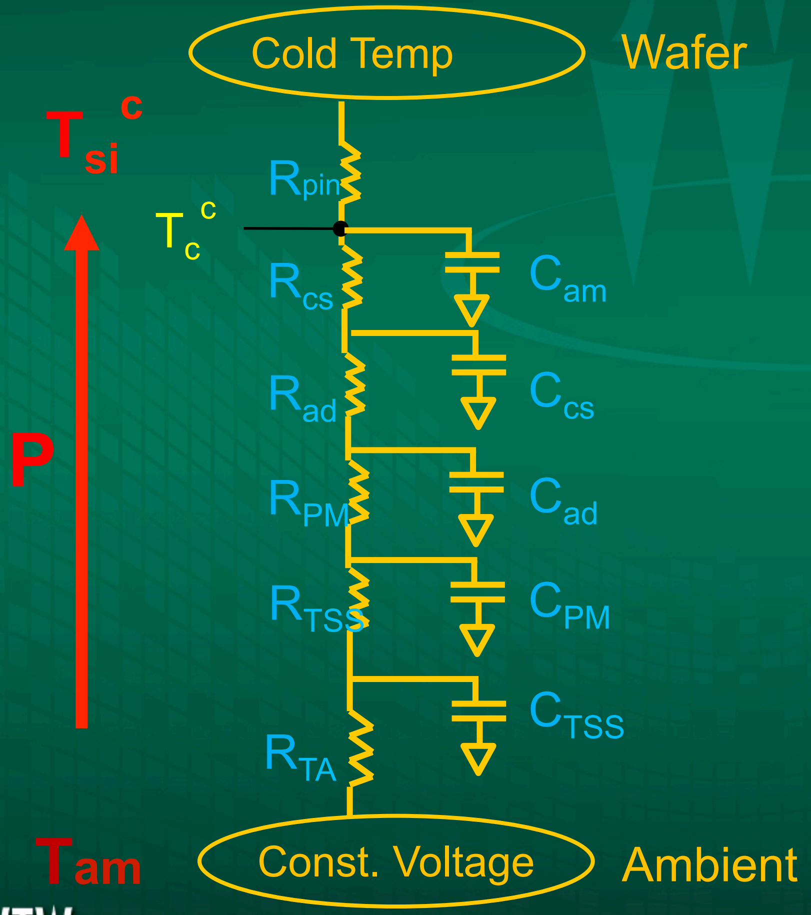
$$T_{c}^{h} = T_{si}^{h} - \frac{R_{pin}}{R_{th}} \cdot (T_{si}^{h} - T_{am})$$

→ T_{c}^{h} = f'n(Rpin, Rth)

→ To decrease T_{c}^{h}, Rpin ↑ or Rth ↓

Ceramic Temp. Control

Derivation of equation for ceramic temperature : (2) cold test condition



$$P = \frac{T_{am} - T_{si}}{R_{th}}$$

$$\begin{aligned} R_{th} &= R_{pin} + R_{cs} + R_{ad} + R_{PM} + R_{TSS} + R_{TA} \\ &= R_{pin} + R_{other} \end{aligned}$$

$$\boxed{T_c^c = T_{si}^c - \frac{R_{pin}}{R_{th}} \cdot (T_{si}^c - T_{am})}$$

→ To increase T_c^c, Rpin ↑ or Rth ↓

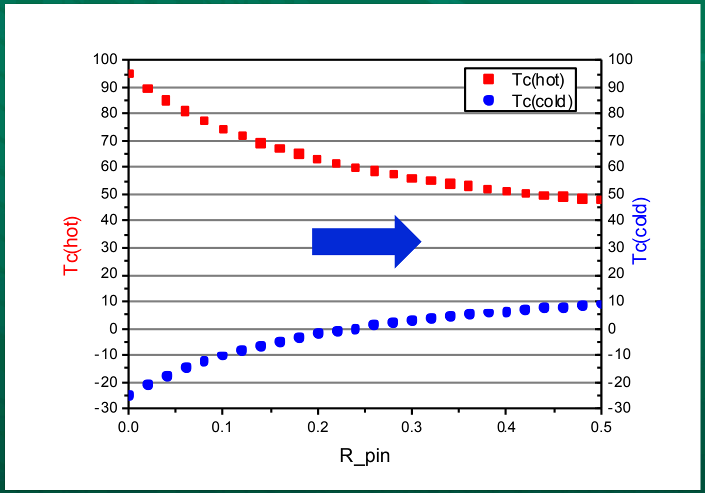
Ceramic Temp. Control

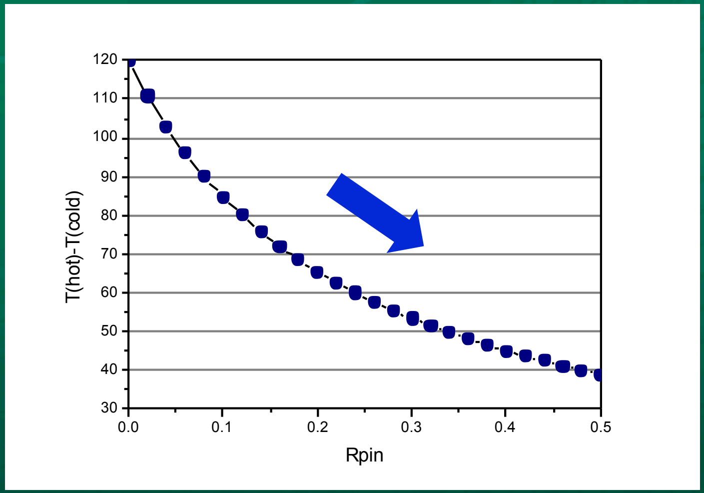
- 1st Method to control the ceramic temperature - pin height increasing

Hot temp $$T_c^h = T_{si}^h - \frac{R_{pin}}{R_{th}} \cdot (T_{si}^h - T_{am}) = T_{am} + \frac{\Delta T \cdot R_{other}}{R_{pin} + R_{other}}$$

Cold temp $$T_c^c = T_{si}^c + \frac{R_{pin}}{R_{th}} \cdot (T_{am} - T_{si}^c) = T_{am} - \frac{\Delta T \cdot R_{other}}{R_{pin} + R_{other}}$$

$$R_{other} = R_{cs} + R_{ad} + R_{PM} + R_{TSS} + R_{TA}$$





→ **As pin height increases, ceramic temperature difference is decreased**

→ **1st way to get a accurate positioning for finer bonding pad**

Ceramic Temp. Control

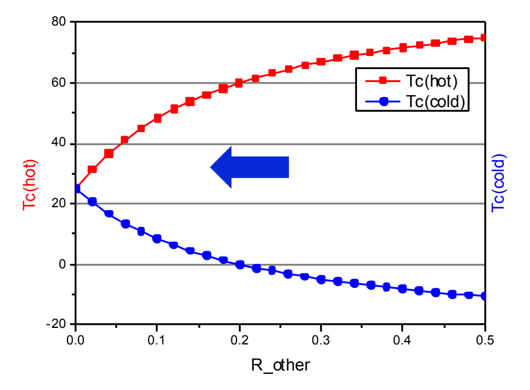
- 2nd method to control the ceramic temperature – reducing thermal resistance of system from ceramic to TSS

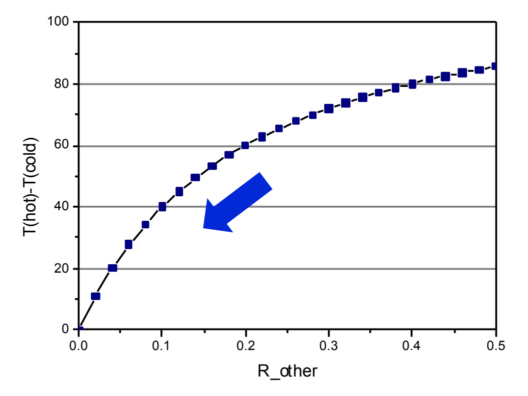
Hot temp

$$T_c^h = T_{si}^h - \frac{R_{pin}}{R_{th}} \cdot (T_{si}^h - T_{am}) = T_{si}^h - \frac{\Delta T \cdot R_{pin}}{R_{other} + R_{pin}}$$

Cold temp

$$T_c^c = T_{si}^c + \frac{R_{pin}}{R_{th}} \cdot (T_{am} - T_{si}^c) = T_{si}^c + \frac{\Delta T \cdot R_{pin}}{R_{other} + R_{pin}}$$





→ As R_{other} decreases, ceramic temperature difference is decreased

; high thermal conductivity material, # of PM increase, etc.

→ 2nd way to get a accurate positioning for finer bonding pad

Condition for Zero Movement

Let's remind the scrub mark movement equation

$$S = \frac{D_{eff}}{2} \cdot \alpha_c \cdot (T_c^h - T_c^c) - \frac{D_{eff}}{2} \cdot \alpha_{si} \cdot (T_{si}^h - T_{si}^c)$$

If S = 0, there is no mark movement during hot/cold test

$$\Rightarrow \quad \boxed{T_c^h - T_c^c = \frac{\alpha_{si}}{\alpha_c}(T_{si}^h - T_{si}^c)}$$

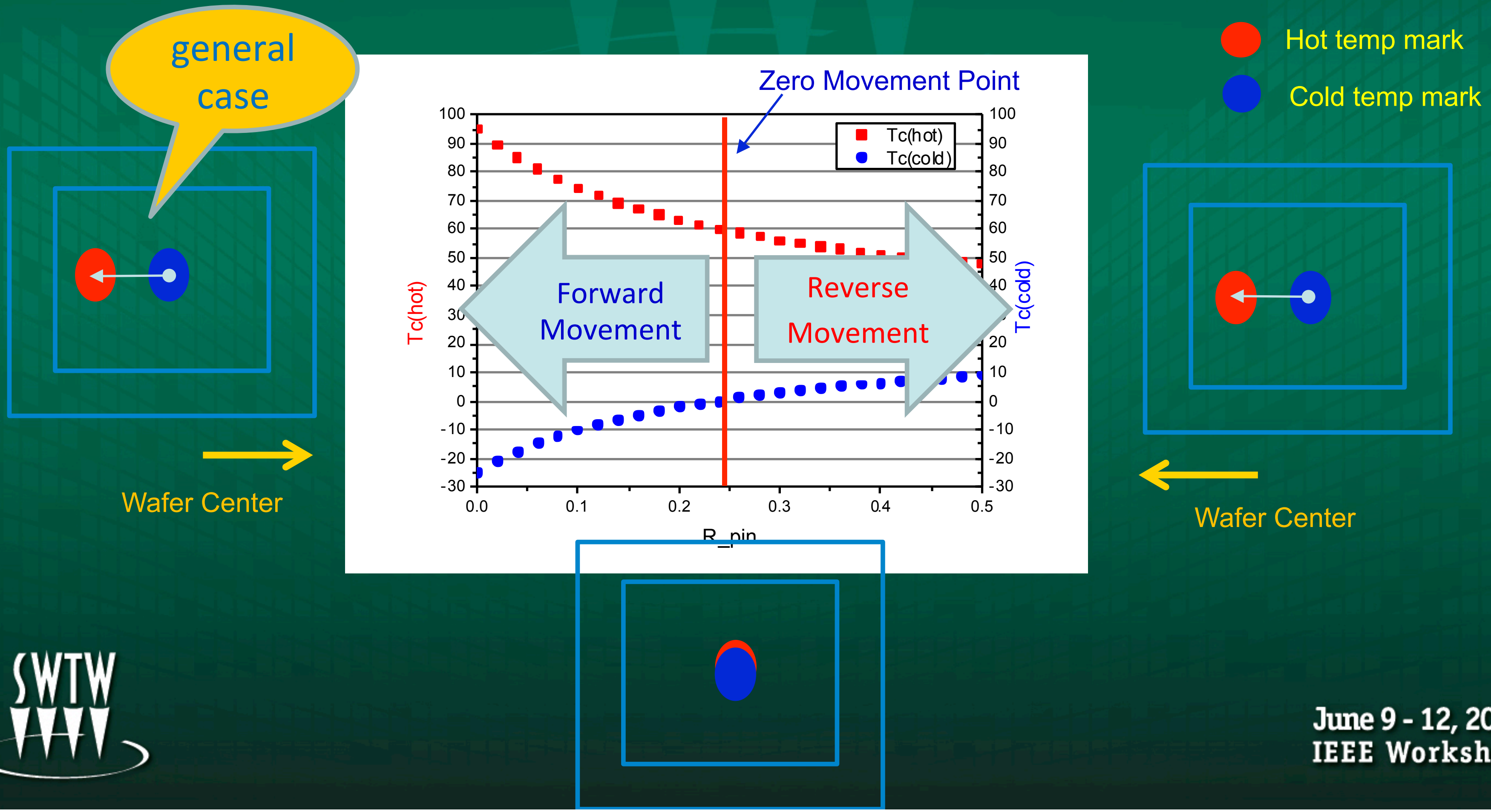
Ex) CTE(ceramic) = 4.3 ppm/K, CTE(Si) = 3.0 ppm/K,
T_{si}(hot) = 95 deg.C, T_{si}(cold) = -25 deg.C

→ Tc(h) – Tc(c) = (3/4.3) * (95 + 25) = 83 deg.C

Movement Direction

We can look strange behavior of probe mark movement ,
if ceramic temperature difference is decreased over “0” movement point

→ S < 0 : reverse movement of scrub mark between cold & hot condition



Ceramic for STF

- Ceramic for STF must have following properties

  - low CTE, via position accuracy, strength, chemical endurance etc
- LTCC may be good candidate material for its low CTE and accurate via position

	LTCC	HTCC	
		Alumina	Mullite
Composition	Glass+Al2O3	Al2O3	3Al2O3-2SiO2
CTE(ppm/K)	3.5~5.0	5.5~6.0	2.5~4.0
Thermal conductivity(W/mK)	3	15	6
Heat capacity(J/gK)	0.96	0.88	0.98
Bending Strength(Mpa)	200	350	300
Young's Modulus(GPa)	130	300	230
Conductor	Ag	W/Mo	W/Mo
Via position Accuracy(%)	0.05% (Non-Shrinkage)	0.2%	0.2%

Probe Card using LTCC

- Test condition is
  - Hot temp =100℃. Cold temp = -25℃
  - CTE_{wafer} =3.0 ppm/K , CTE_{LTCC} = 4.3 ppm/K

- “Zero movement” condition is as follows

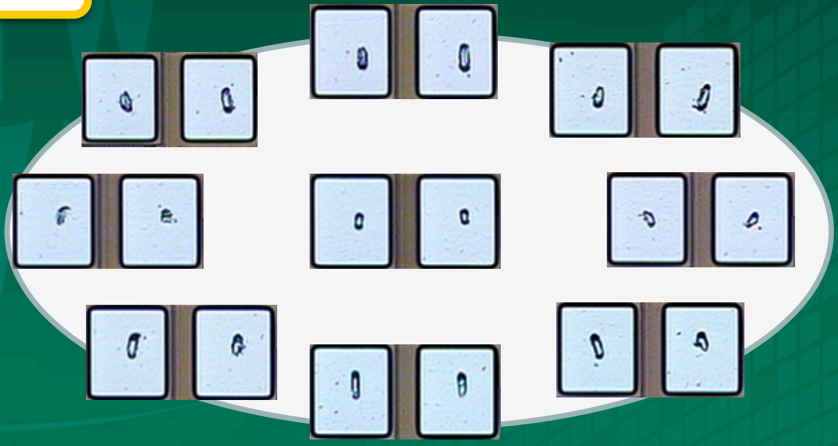
$$T_c^h - T_c^c = \frac{\alpha_{si}}{\alpha_c}(T_{si}^h - T_{si}^c) = \frac{3.0}{4.3}(100-(-25)) = 87^o C$$

- If temp difference is near 87℃, scrub movement is minimized
- If temp difference is smaller than 87℃, reverse movement occurs

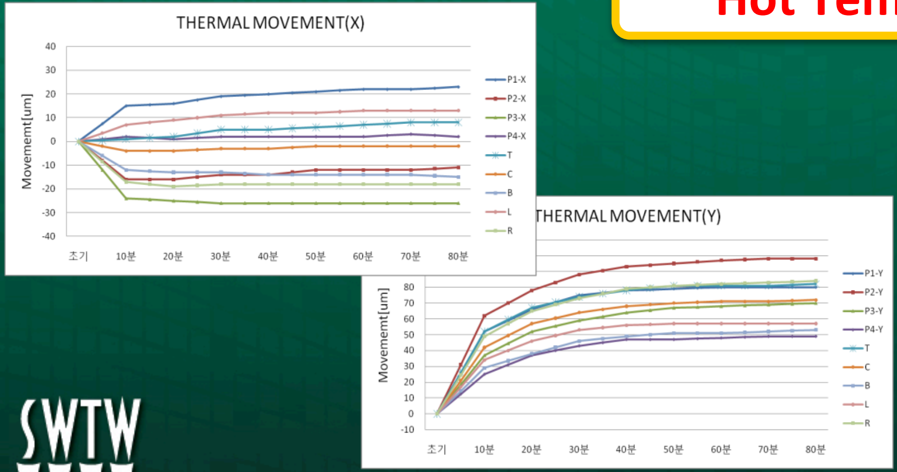
- 2 kind of probe card were fabricated and tested
- First card shows very small scrub mark movement during hot/cold test
- Second card shows reverse movement

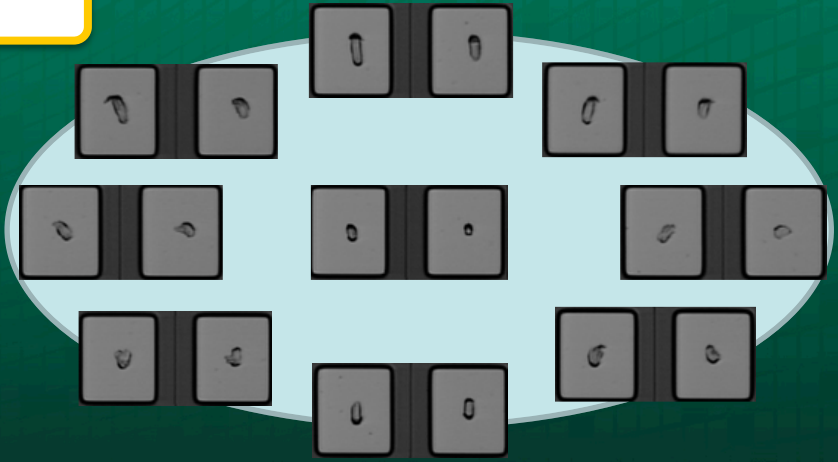
Scrub Mark Test (Probe type 1)

Cold Temp



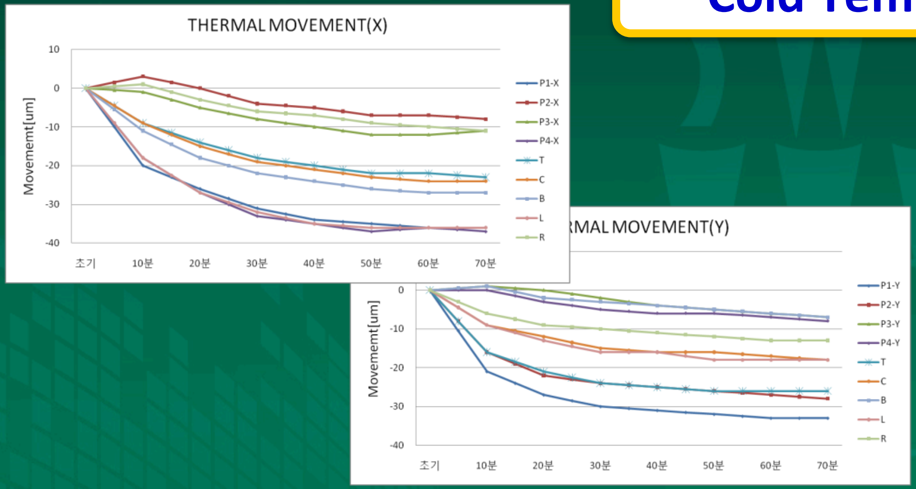
Hot Temp



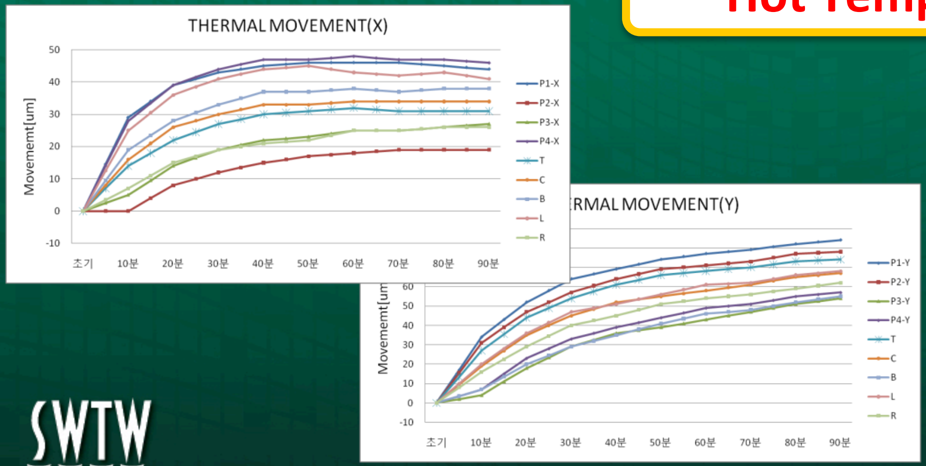


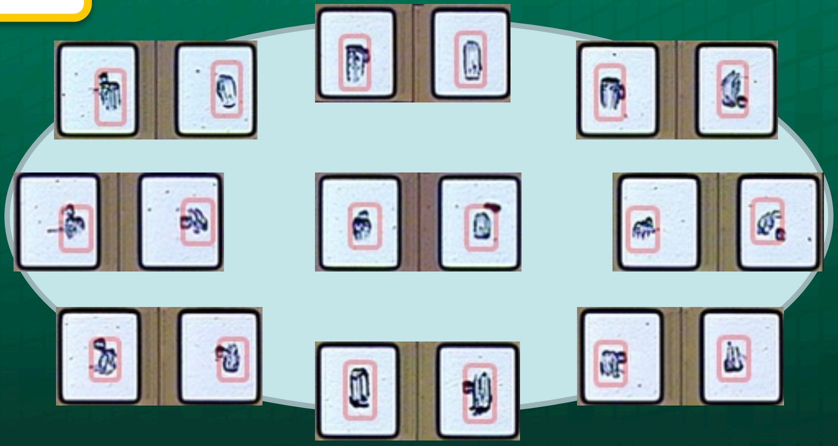
Scrub Mark Test (Probe type 2)

Cold Temp

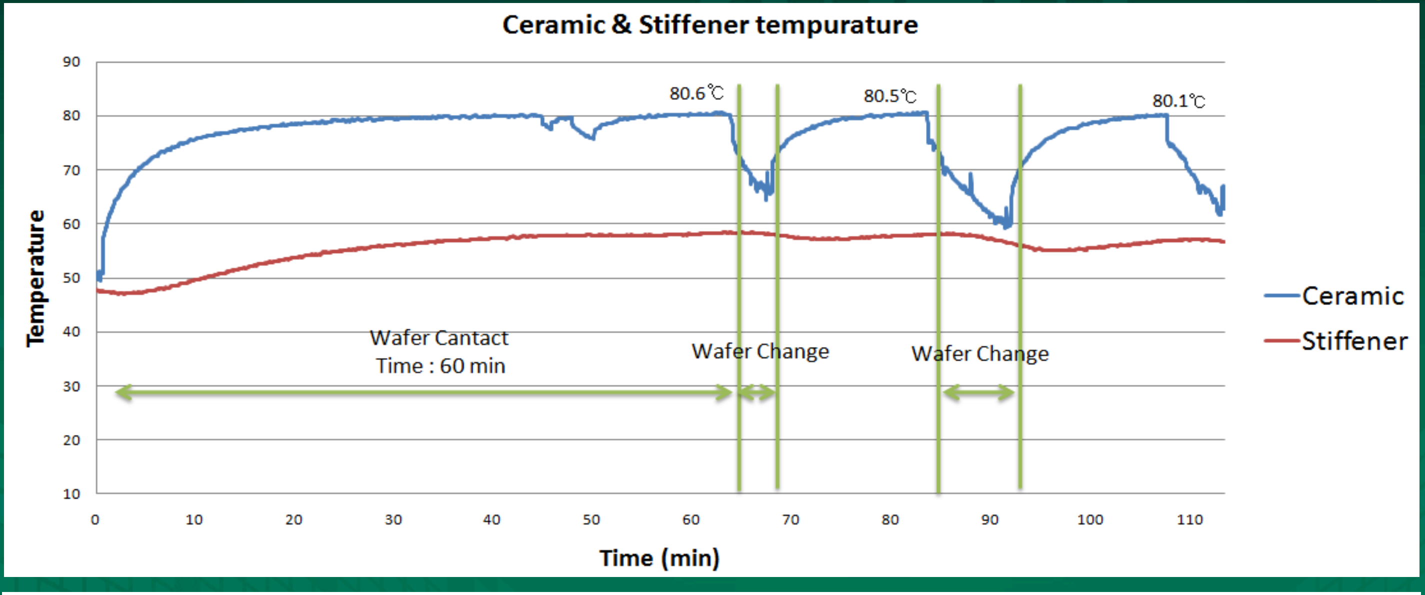


Hot Temp

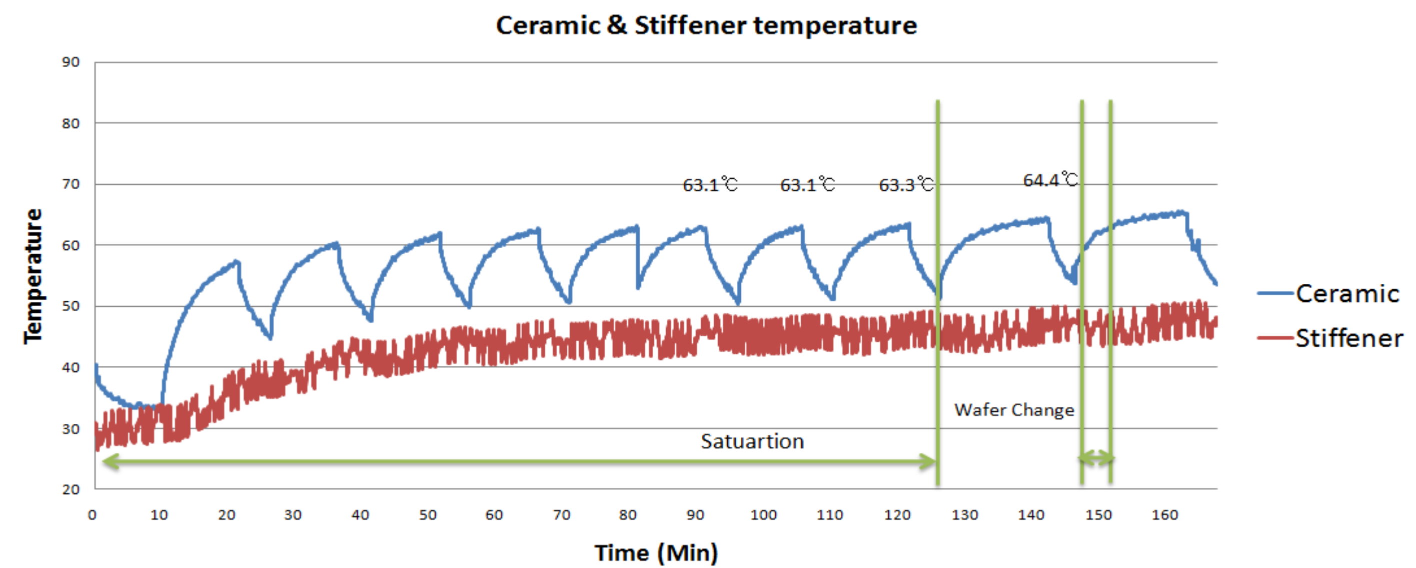




Probe substrate temp


Ceramic & Stiffener tempurature

Probe type1


Ceramic & Stiffener temperature

Probe type2

Summary

- Probe mark position can be controlled by CTE and temperature of ceramic STF
- Guide line to select proper CTE and temperature for various pad size was derived
- Main factors to control ceramic temperature and its effects was analyzed
- Probe mark movement direction can be estimated by ceramic temperature
- Probe card for 60um pad test was fabricated using LTCC, and its performance is presented

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