SW Test Workshop
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An probing evaluation of Cu-Pillar by using wire type Probe Card

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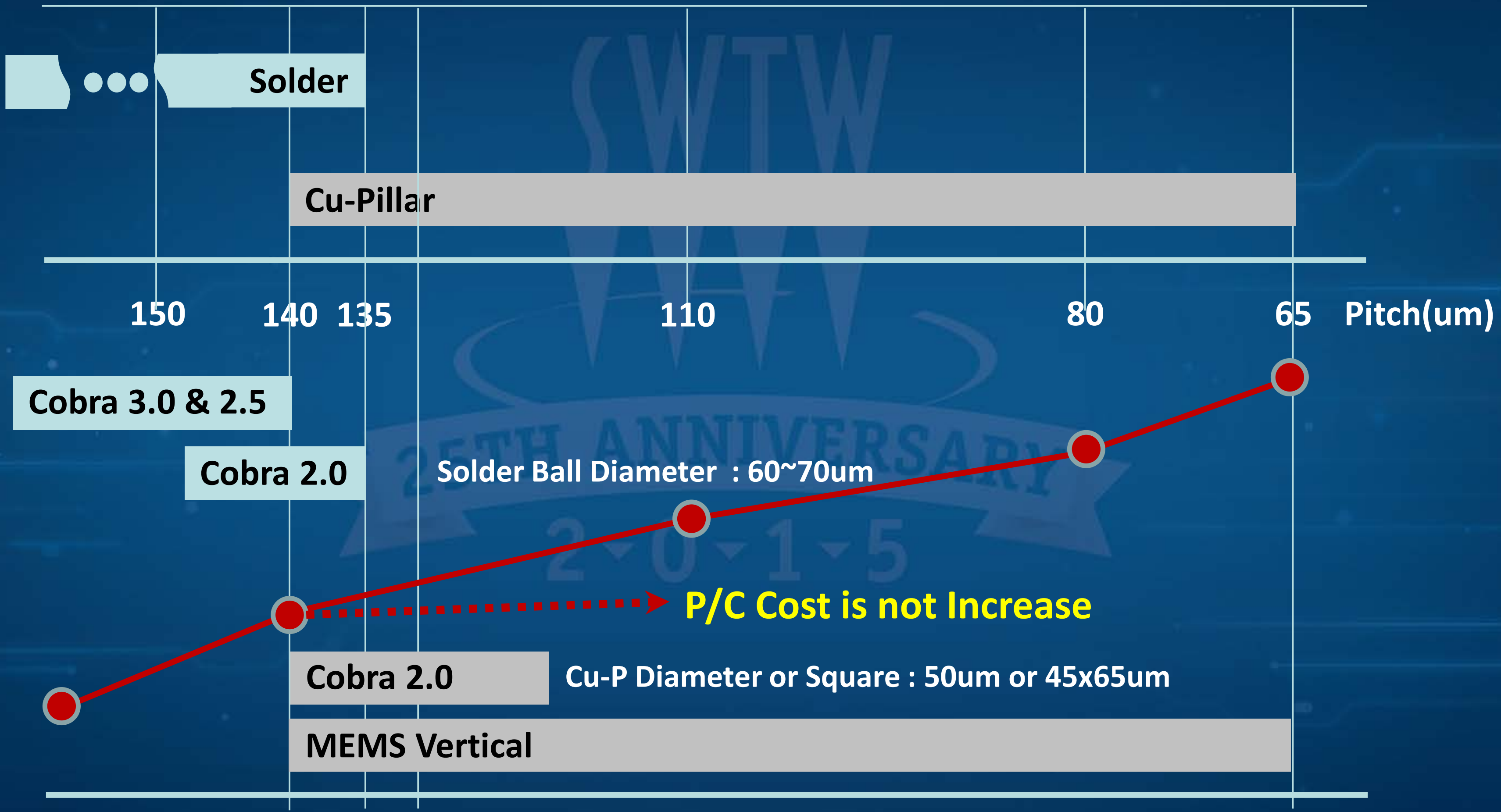
- Probe Card cost of Cu-Pillar probing
- Cases introduction of Cu-Pillar probing
  - Temperature & Pad structure
- An experience of Cu-Pillar probing by wire type
- Process change for cost reduction
- SEC Requirement of Cu-Pillar Flip-Chip Probing
- Probe Card long life (MEMS Vertical)
- Summary

Probe Card cost for Cu-P probing

※ Cu-Pillar = Cu-P



※ The using of Cu-P is increasing in the DTV controller & lower MoDAP chips

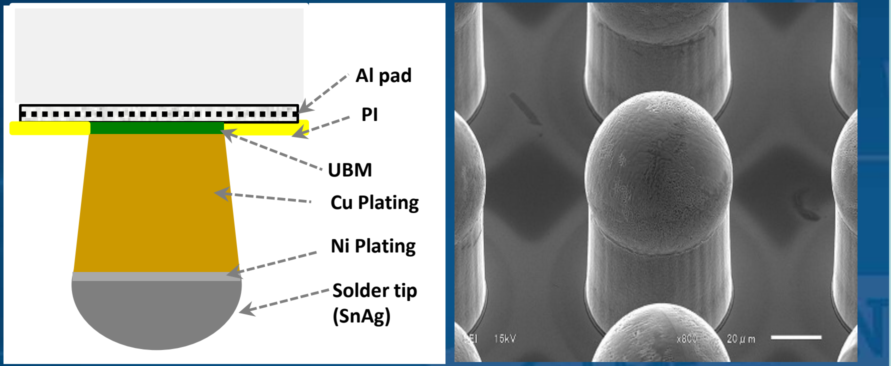
→ P/C cost is very important for higher margin of revenue

C.H Hyun

Test case of Cu-P probing

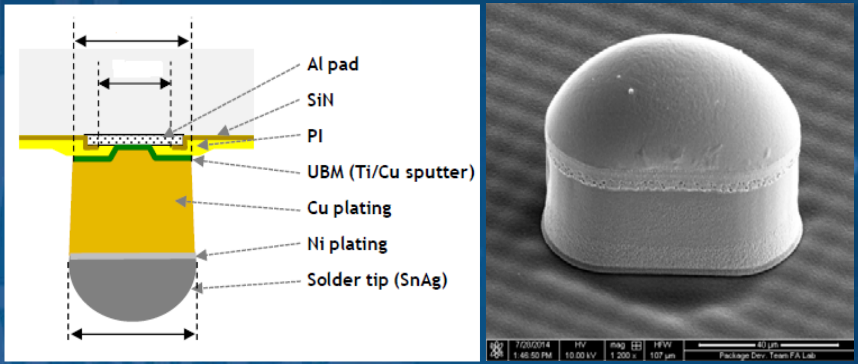
A. Cu-P Structure Introduction

TCFC : Thermal Compression Flip Chip



Source : DIPSOL Website Figure
http://www.dipsol-jp.com/wp-content/uploads/bump_reflow_sem200.png

CuBOL : Copper-column Bond on Lead



Source : Hamid Eslampour(STATSChipPAC)
"Low Cost Cu Colimn fcPOP Technology "
IEEE, EMTC, 2012

- The diameter limit of CuBol type is 40~45um → 100um under pitch will be used TCFC
- Cu-P is expected to grow at CAGR(2014~2018) of 10~15% (SEC Case)
  - 2014 ~ 2015 : 28nm Controller/Modem (Room Temp) & MoDAP (Hot Temp)
  - 2016 ~ 2018 : 10~14nm Premium AP & 28nm Product(~beyond)
  - Mobile Phone Price drop down → Improve PKG Cost → Applying of Cu-P will expand

Test case of Cu-P probing

B. Cu-P Products Table

Room : 77℉, Hot : 185℉

Type	Diameter (um)	Temperature (℉)	Product	Probe Card Type
CuBOL	45 x 65	Room	Controller , Modem	**Cobra - 2.0mil**
		Room/Hot	Premium AP, MoDAP	MEMS Vertical
TCFC	50	Room	Foundry	**Cobra - 2.0mil**
		Room/Hot	Premium AP, MoDAP	MEMS Vertical
	30	Room	Foundry	MEMS Vertical
		Room/Hot	Premium AP, MoDAP	

Probing Consideration

- In case of same tip force(O/D), impact on solder cap is different between Room and Hot temperature
- The key factors of our chip package process are **Height Variance and Stick Out** of Pillar

→ If Cu-P will be probing at room temperature, more higher force tip is able to use

Evaluation result by using wire type

A. Experiment Set-up

- **Test Wafer Descriptions**

  . Real Function Wafers of DV Controller : Peripheral Cu-Pillar

  . 135um Minimum Pitch

  . Cu-Pillar Type : Cu-BOL (45x65um)

- **Probe Card Used**

  . Will Technology Cobra 2.0 Probe Card (& developed MEMS Vertical)

  . Cobra 2.0mil / 3,908pins / 2 Para

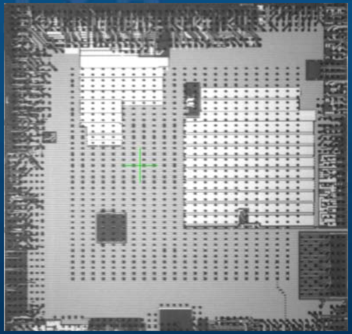
- **Measurement Condition**

  . Tester : T2K 8” Pogo Tower (ADVAN)

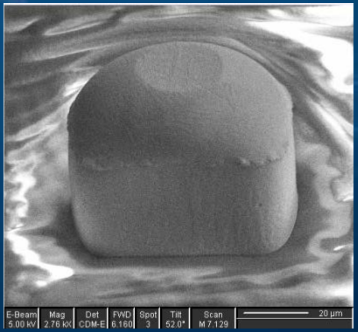
  . Prober : IP-300H (SECRON)

  . Image Capture : 3D Scope & FIB

  . Pillar Profile : 3D Scope



Test Chip Map

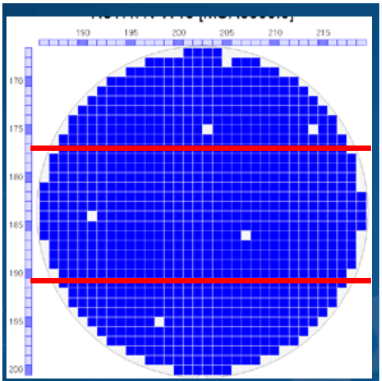
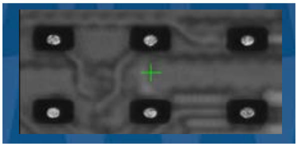
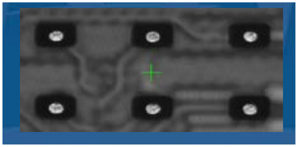
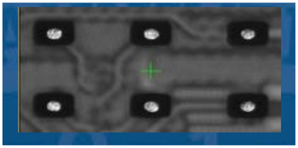
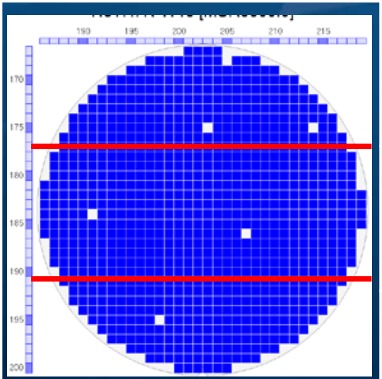
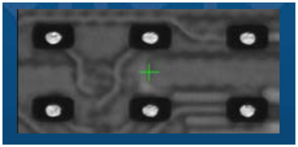
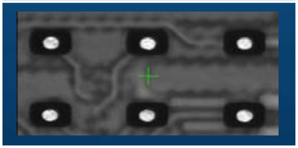
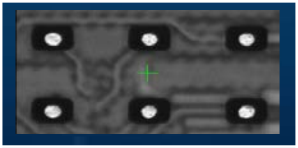


Cu-P With SnAg Caps

Evaluation result by using wire type

B. Probing DOE Result Table

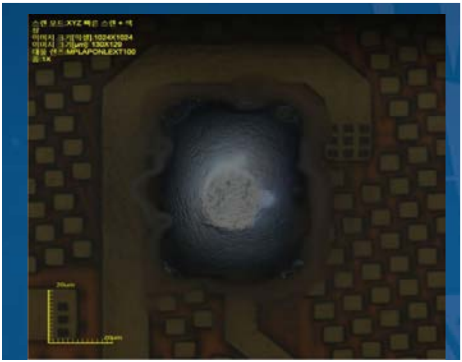
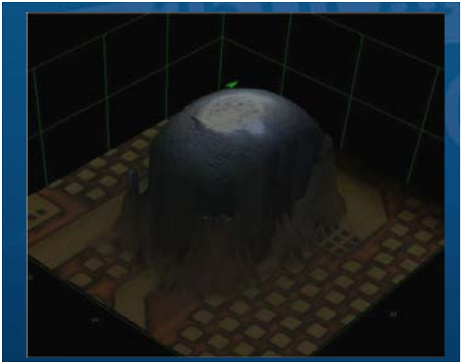
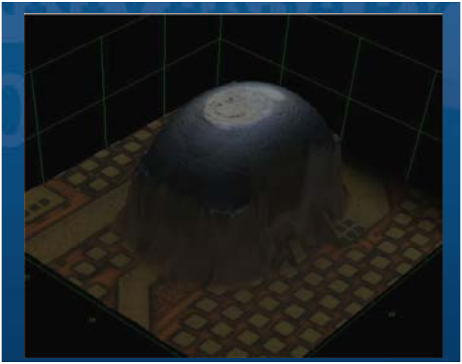
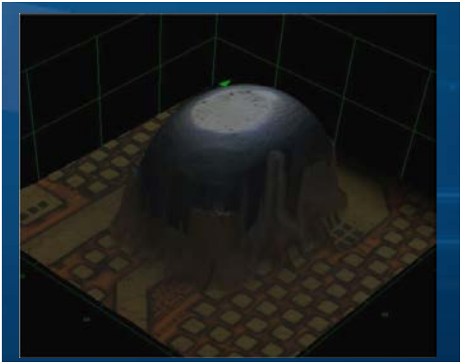
(Probing Condition : 6 Times Probing per 1 Cap)

Sample	DOE Map	Overdrive (um)	Image	Bump Height (um)		Mark Ratio (%)
				Before → After	Variance	
#1	 Operation Condition	70		61.7 → 60.2	1.5	10.7 ~ 13.0
		80		61.0 → 59.3	1.7	10.7 ~ 14.2
		90		61.8 → 59.8	2.0	**11.8 ~ 15.2**
#2	 Overdrive Margin	100		61.4 → 59.1	2.3	15.5 ~ 16.8
		110		61.2 → 58.6	2.6	15.5 ~ 18.1
		120		61.3 → 58.5	2.8	**15.5 ~ 18.3**

Evaluation result by using wire type

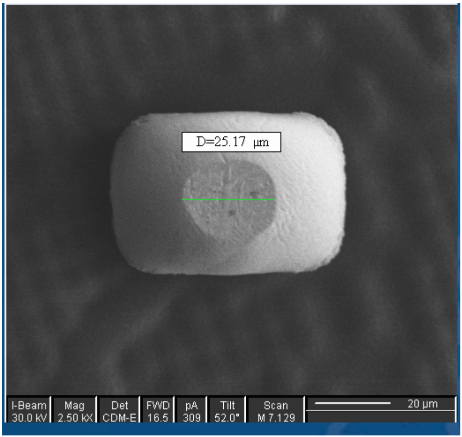
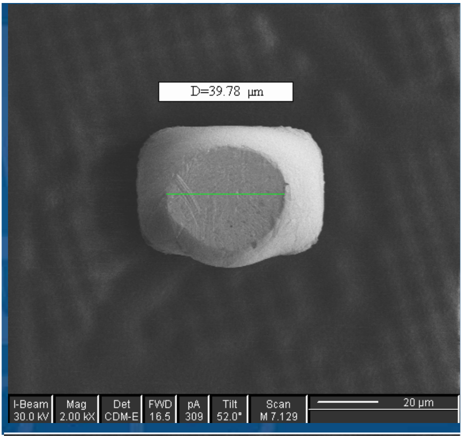
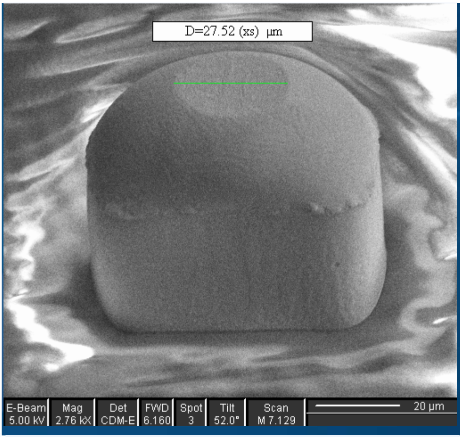
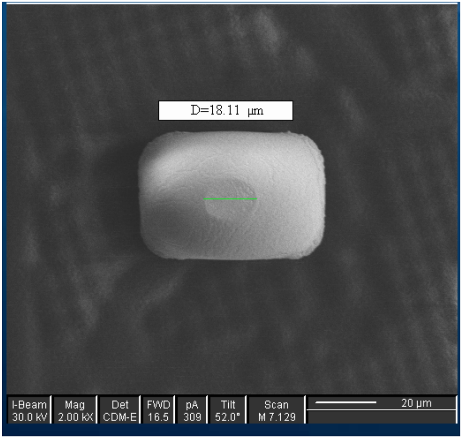
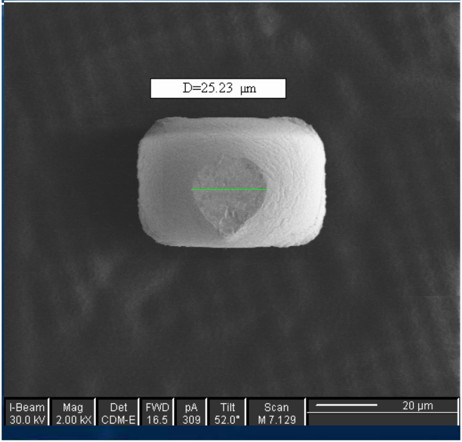
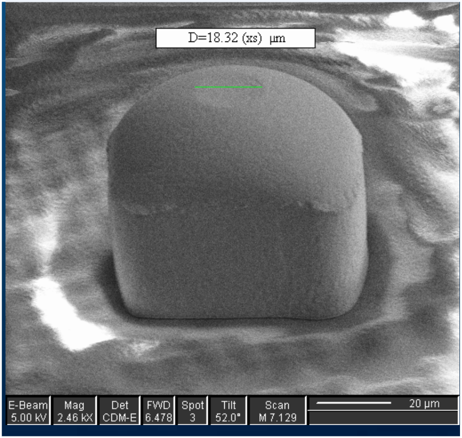
C. 3D Scope Image : Production Product

Room : 77°F

	80um	100um	120um
Top View			
Side View			
Measure	Probe X : 17.2um Probe Y : 22.9um Bump Z : 63.8um	Probe X : 20.3um Probe Y : 23.7um Bump Z : 61.3um	Probe X : 22.3um Probe Y : 27.4um Bump Z : 60.8um

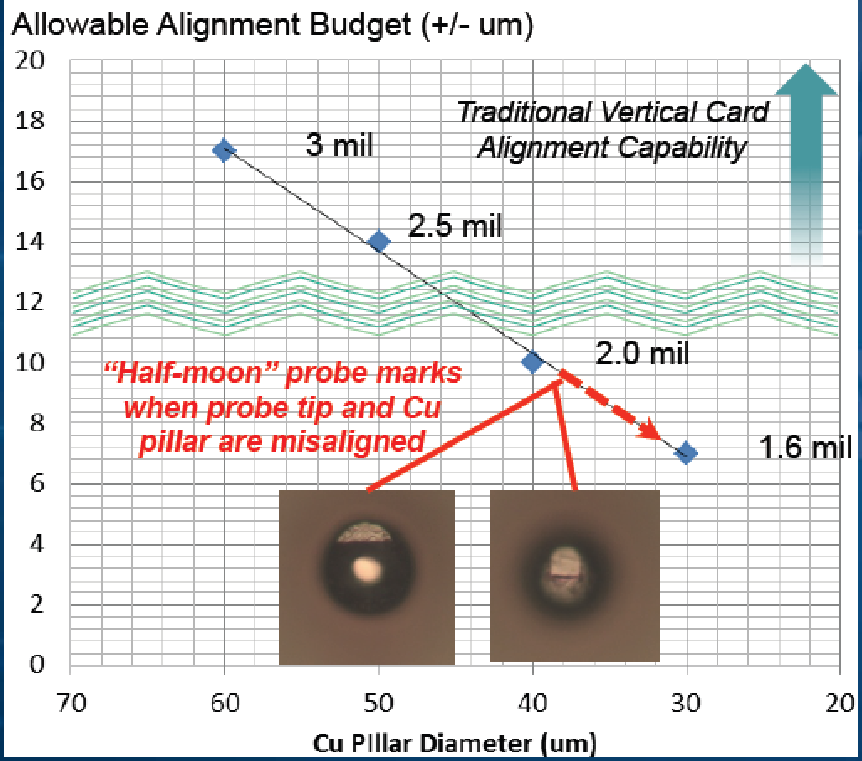
Evaluation result by using wire type

D. FIB Image : Cobra vs MEMS Vertical Probe

Overdrive (120um)	Temperature		Side View (77℉)
	77℉ (25℃)	257℉ (85℃)	
Cobra 2.0			
MEMS			

Evaluation result by using wire type

E. Pin Alignment & Plate Hole Processing Improvement

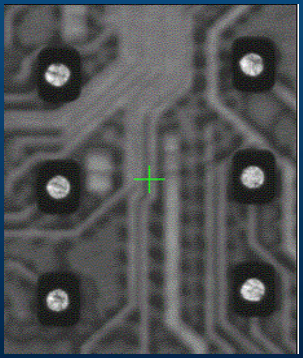


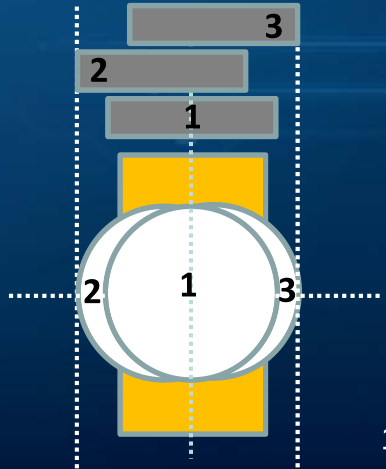
Source : Alexander Wittig(Global Foundry)
"Probing Study of Fine Pitch Copper Pillars " SWTW 2013

A. The key Items of Probe tip Alignment
1. Guide Plate Hole diameter & alignment
2. The range of Alignment fluctuation

B. 45x65um CuBOL probing
1. Alignment Budget Target : ± 10um
2. Hole diameter : Target ± 4um
3. Hole alignment : Target ± 2um
4. Probe tip alignment : ± 6um

Cobra2.0 – OD 5mil

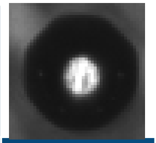
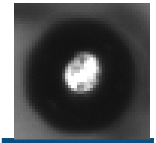
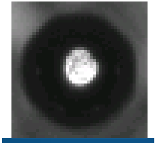
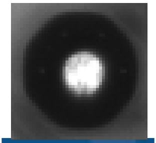
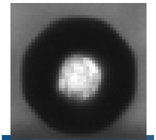
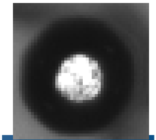
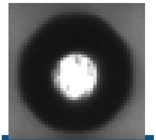
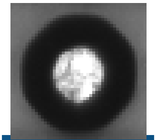
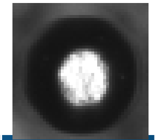
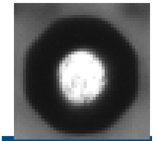
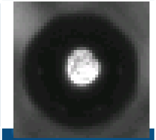
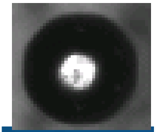
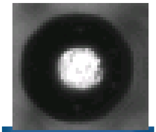
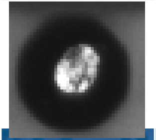
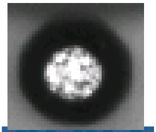
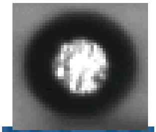
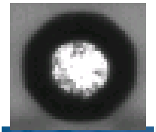
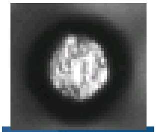
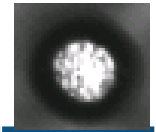
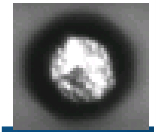


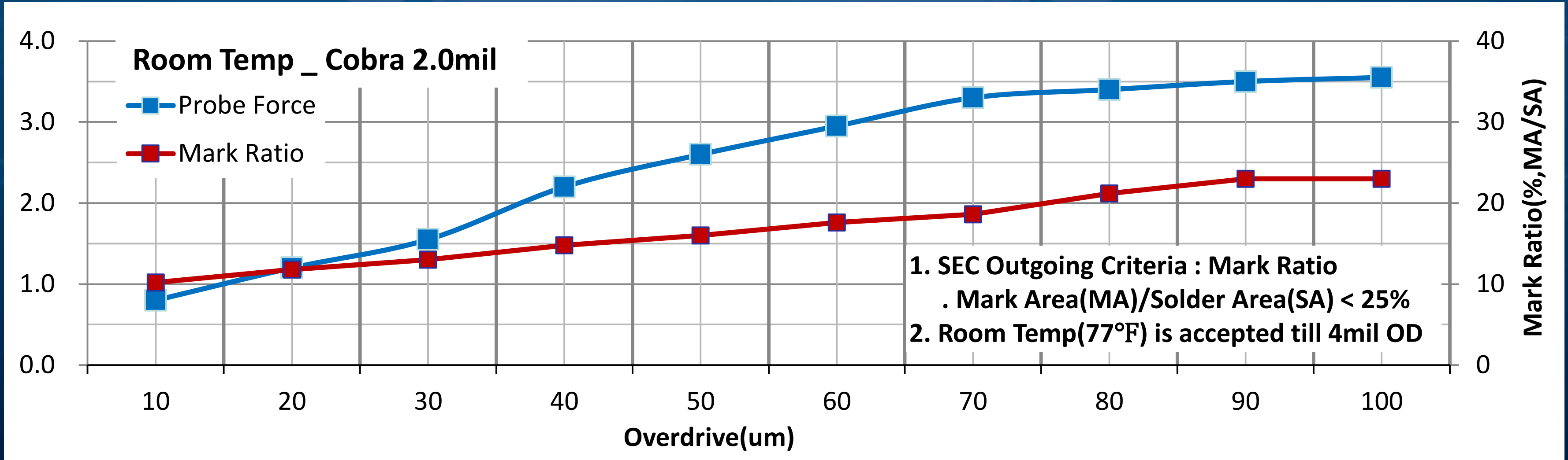


Evaluation result by using wire type

F. Tip Force & Optical Mark Image(For TCFC Type)

Cu-P Diameter : 50um

Temp	10um	20um	30um	40um	50um	60um	70um	80um	90um	100um
Room	 10.2%	 11.8%	 13.0%	 14.8	 16.0%	 17.6%	 18.6%	 21.2%	 23.0%	 23.0%
Hot	 10.2%	 12.5%	 14.4%	 19.4%	 21.2%	 23.0%	 27.0%	 31.4%	 33.6%	 36.0%



1. SEC Outgoing Criteria : Mark Ratio
   . Mark Area(MA)/Solder Area(SA) < 25%
2. Room Temp(77°F) is accepted till 4mil OD

Evaluation result by using wire type

G. Cobra 2.0 Achievement

- **Cobra 2.0 vertical probe cards are more longer life time than MEMS vertical probe cards**

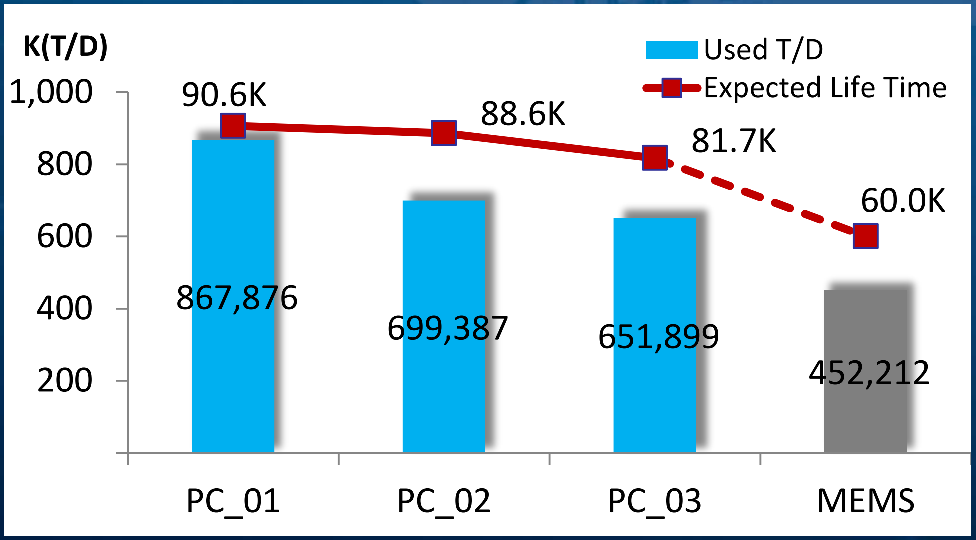
  . Test Environment - 45um Over Diameter Solder Cap, Room Temperature – Can use Cobra 2.0

  . **7~8$/pin Cost Reduction** : Needle Cost + Extension Life time (SEC Case)

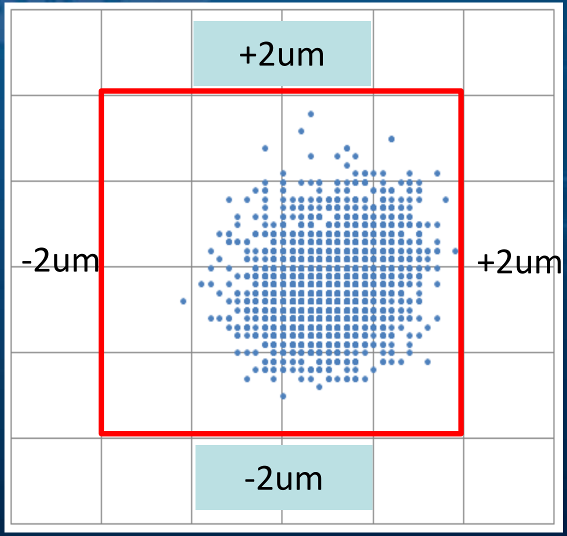
- **Cobra style vertical probe card challenges needle alignment**

  . By improvement of plate processing, **in less than ±6um Alignment achievement**

Life Time Improve (vs MEMS – 1.5~2.0x)

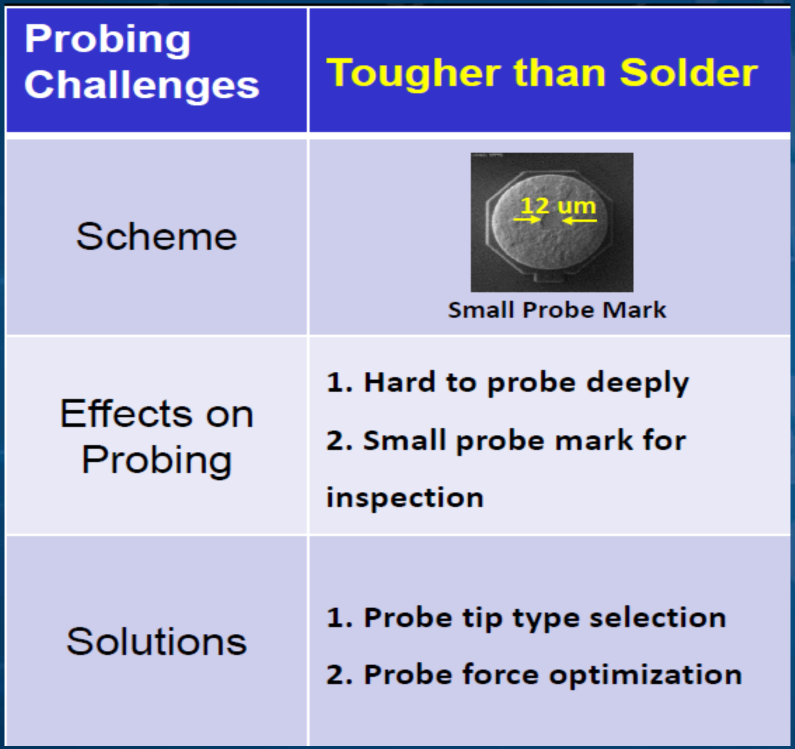


X/Y Plate Hole Alignment (Target ±2um)



Process change for cost reduction

A. Cu-Pillar without Solder Cap



Probing Challenges	**Tougher than Solder**
Scheme	12 um Small Probe Mark
Effects on Probing	**1. Hard to probe deeply** **2. Small probe mark for inspection**
Solutions	**1. Probe tip type selection** **2. Probe force optimization**

Source : Hao Chen(TSMC)
"Wafer Level Chip Scale Package Copper Pillar Probing"
International Test Conference 2014, Seattle, Washington

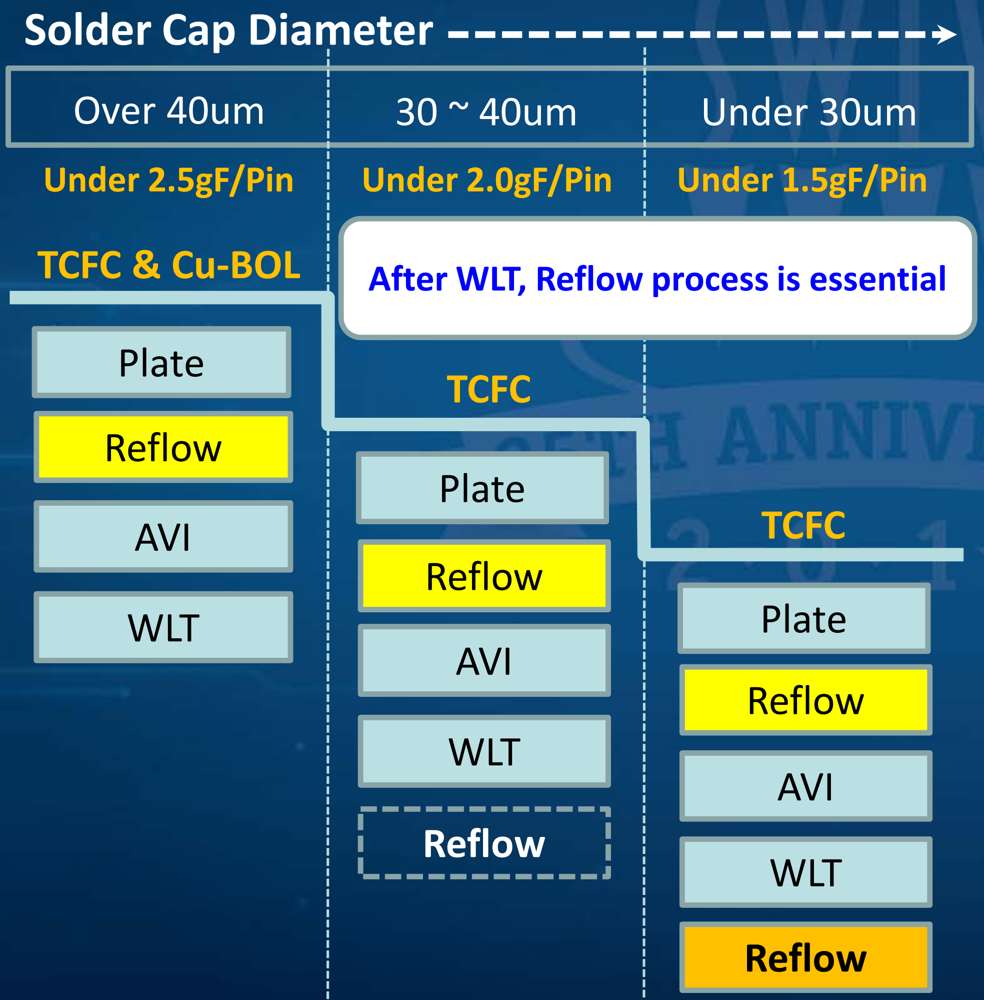
Cu Pillar without solder cap is a cheaper contact interface for InFO-PoP!

Contact Interface	**Aluminum Pad**	**Cu Pillar without Solder Cap**
Figure		
Design Cost	High (extra area overhead)	Low
Probing Decision	✗	✓

- **Essential Item**
  → Cu-P of under 30um diameter need to Reflow process after probing
- **Idea : without Solder Cap = Cu-P before Reflow**
- **Cost Improve(Bump ~ WLT)**
  → Reflow step change

Process change for cost reduction

B. Cu-P Process & Small Diameter Cu-P



Solder Cap Diameter ---------------------→

Over 40um	30 ~ 40um	Under 30um
Under 2.5gF/Pin	Under 2.0gF/Pin	Under 1.5gF/Pin
TCFC & Cu-BOL	TCFC	TCFC
Plate	Plate	Plate
Reflow	Reflow	Reflow
AVI	AVI	AVI
WLT	WLT	WLT
	Reflow	Reflow

After WLT, Reflow process is essential

- **Smaller Solder Cap Challenge**

  . Cap Disturbance

  . Solder Stick-Out

  . Heavy Probing → Height shortfall

  . Low Force Tip Development
  (~Keep on C.C.C)

- **2’nd Reflow Process**

  . Back End (Bump ~ WLT) Cost Increase

  . Daily Productivity Drop

  . After 2’nd Reflow Process, Inspection Step

Process change for cost reduction

Present Process

Plate

Reflow

AVI

WLT

New Process

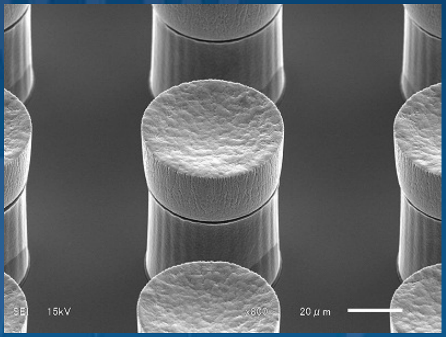
Plate

WLT

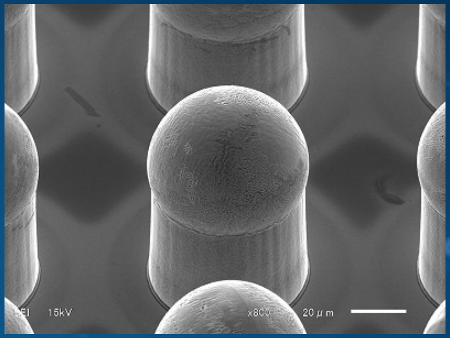
Reflow

AVI

Before Reflow



After Reflow



Source : DIPSOL Website Figure
http://www.dipsol-jp.com/wp-content/uploads/

Type	Cres	Tip Force	Life Time
MEMS Flat	Bad	Good	Good
MEMS Point	Good	Good	Bad
Wire Point	Good	Middle	Bad
Cobra Flat	Bad	Bad	Good

- **Table data is expectation grade (SEC Simulation)**
  → Next Step Study

SEC Requirement of Flip-Chip Probing

Items	SOLDER			Cu-Pillar				
Pitch	150um ↑	140-149um	135um ↓	135um ↑		110-135um	80-100um	65-80um
Solder Diameter	90um ↑	80um	70um	50um	45um	45um	30um	25um
Needle Diameter	60~75Φ	60-75Φ	50~65Φ	50Φ ↓		45*45um ↓	30*30um ↓	25*25um ↓
Needle Type	Wire	Wire	Wire	Wire (Only Room Temp)		MEMS & Etc	Only MEMS	Only MEMS
Needle Shape	Flat	Flat	Flat	Flat		Flat	Flat (Point)	Flat (Point)
Tip Force (3mil)	7g ↓	6g ↓	4.5g ↓	2.5g ↓		2g ↓	1.5g ↓	1.5g ↓
C.C.C	800[mA] ↑			800[mA] ↑				

- **In Solder Ball type, SEC will be using wire type Probe Card for long life realization**
  - **SEC Case : 2.0 ~ 2.5 Million Touch Down per 1 Probe Card**
- **Under 100um Cu-P product will be considering process change and MEMS point type**

MEMS vertical probe - long life challenge

- Usable Budget extension of Probe tip Length
  - Present Level : 300K ~ 500K T/D → Goal : 1,000K T/D (~ 2016.03)
  - Usable Budget of Tip Length : 250 ~ 270um → Goal : 350um (~ 2016.06)

- Probe tip Cleaning Optimization
  - Cleaning Methodology : Polishing Pattern change (~ 2x Improved)
  - Cleaning Sheet : 1um Lapping Film & Abrasive Material change (~ 2x Improved)
  - Minimal Side Length : Tip Diameter 90% (~ 1.5x Improved)

- Probe tip Geometry & Materials Improvement
  - SEC Goal : 1.5 ~ 2.0 Million Touch Down per 1 Probe Card (~ 2017.01)
  - SEC will consistently try to collaborate of Probe Card Maker for new materials & new concept

Summary

- Probe card cost for Cu-P probing is higher than Solder Ball type and is increasing continued by small pitch & small diameter

  . 130um pitch (cost 20% ↑/pin) → 80um (20~30% ↑/pin) → 65um (?)

- Cu-P product of over 45um diameter can use Cobra 2.0 & reduction cost

  . 7~8$/pin Cost Reduction : Needle Cost + Extension Life time (SEC Case)

  . Depends on Factors : Test Temperature, Solder Cap Diameter

- For more longer life time & more lower cost,

  Cu-P process change & tip material development should be evaluation

Next Step

- By change of Cu-P process, 2'nd reflow process can skip and probe card type flexibility is able to raise (Challenge Subject)

Thank You.