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

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Contents

• 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**
  - **Cobra 3.0 & 2.5**
  - **Cobra 2.0**
  - **MEMS Vertical**

- **Solder**
  - **Solder Ball Diameter**: 60~70um

- **Cu-P Diameter or Square**: 50um or 45x65um

- **Pitch (um)**: 150, 140, 135, 110, 80, 65

- **P/C Cost is not Increase**

- **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**

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C.H Hyun

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A. Cu-P Structure Introduction

TCFC : Thermal Compression Flip Chip

CuBOL : Copper-column Bond on Lead

- The diameter limit of CuBol type is 40~45um $\rightarrow$ 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 $\rightarrow$ Improve PKG Cost $\rightarrow$ Applying of Cu-P will expand

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

Source : DIPSOL Website Figure
### Test case of Cu-P probing

#### B. Cu-P Products Table

<table>
<thead>
<tr>
<th>Type</th>
<th>Diameter (um)</th>
<th>Temperature (°F)</th>
<th>Product</th>
<th>Probe Card Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>CuBOL</td>
<td>45 x 65</td>
<td>Room</td>
<td>Controller, Modem</td>
<td>Cobra - 2.0mil</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Room/Hot</td>
<td>Premium AP, MoDAP</td>
<td>MEMS Vertical</td>
</tr>
<tr>
<td>TCFC</td>
<td>50</td>
<td>Room</td>
<td>Foundry</td>
<td>Cobra - 2.0mil</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Room/Hot</td>
<td>Premium AP, MoDAP</td>
<td>MEMS Vertical</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>Room</td>
<td>Foundry</td>
<td>MEMS Vertical</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Room/Hot</td>
<td>Premium AP, MoDAP</td>
<td>MEMS Vertical</td>
</tr>
</tbody>
</table>

#### 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
# Evaluation result by using wire type

## B. Probing DOE Result Table

(Probing Condition : 6 Times Probing per 1 Cap)

<table>
<thead>
<tr>
<th>Sample</th>
<th>DOE Map</th>
<th>Overdrive (um)</th>
<th>Image</th>
<th>Bump Height (um)</th>
<th>Mark Ratio (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Before → After</td>
<td>Variance</td>
</tr>
<tr>
<td>#1</td>
<td><img src="image" alt="DOE Map" /></td>
<td>70</td>
<td><img src="image" alt="Image" /></td>
<td>61.7 → 60.2</td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>80</td>
<td><img src="image" alt="Image" /></td>
<td>61.0 → 59.3</td>
<td>1.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>90</td>
<td><img src="image" alt="Image" /></td>
<td>61.8 → 59.8</td>
<td>2.0</td>
</tr>
<tr>
<td>#2</td>
<td><img src="image" alt="DOE Map" /></td>
<td>100</td>
<td><img src="image" alt="Image" /></td>
<td>61.4 → 59.1</td>
<td>2.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>110</td>
<td><img src="image" alt="Image" /></td>
<td>61.2 → 58.6</td>
<td>2.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>120</td>
<td><img src="image" alt="Image" /></td>
<td>61.3 → 58.5</td>
<td>2.8</td>
</tr>
</tbody>
</table>
Evaluation result by using wire type

C. 3D Scope Image : Production Product  
Room : 77°F

<table>
<thead>
<tr>
<th></th>
<th>80um</th>
<th>100um</th>
<th>120um</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top View</td>
<td><img src="image1" alt="Top View Image" /></td>
<td><img src="image2" alt="Top View Image" /></td>
<td><img src="image3" alt="Top View Image" /></td>
</tr>
<tr>
<td>Side View</td>
<td><img src="image1" alt="Side View Image" /></td>
<td><img src="image2" alt="Side View Image" /></td>
<td><img src="image3" alt="Side View Image" /></td>
</tr>
<tr>
<td>Measure</td>
<td>Probe X: 17.2um, Probe Y: 22.9um, Bump Z: 63.8um</td>
<td>Probe X: 20.3um, Probe Y: 23.7um, Bump Z: 61.3um</td>
<td>Probe X: 22.3um, Probe Y: 27.4um, Bump Z: 60.8um</td>
</tr>
</tbody>
</table>
### Evaluation result by using wire type

**D. FIB Image: Cobra vs MEMS Vertical Probe**

<table>
<thead>
<tr>
<th>Overdrive (120µm)</th>
<th>Temperature</th>
<th>Side View (77°F)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>77°F (25°C)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>257°F (85°C)</td>
<td></td>
</tr>
</tbody>
</table>

- **Cobra 2.0**
  - Diameter: 55.17 µm
  - Diameter: 39.78 µm
  - Diameter: 25.23 µm

- **MEMS**
  - Diameter: 10.11 µm
  - Diameter: 25.23 µm
  - Diameter: 18.32 (as) µm
E. Pin Alignment & Plate Hole Processing Improvement

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

Source: Alexander Wittig (Global Foundry)  
“Probing Study of Fine Pitch Copper Pillars”  SWTW 2013
Evaluation result by using wire type

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

Cu-P Diameter : 50um

<table>
<thead>
<tr>
<th>Temp</th>
<th>10um</th>
<th>20um</th>
<th>30um</th>
<th>40um</th>
<th>50um</th>
<th>60um</th>
<th>70um</th>
<th>80um</th>
<th>90um</th>
<th>100um</th>
</tr>
</thead>
<tbody>
<tr>
<td>Room</td>
<td><img src="10um.png" alt="Image" /></td>
<td><img src="20um.png" alt="Image" /></td>
<td><img src="30um.png" alt="Image" /></td>
<td><img src="40um.png" alt="Image" /></td>
<td><img src="50um.png" alt="Image" /></td>
<td><img src="60um.png" alt="Image" /></td>
<td><img src="70um.png" alt="Image" /></td>
<td><img src="80um.png" alt="Image" /></td>
<td><img src="90um.png" alt="Image" /></td>
<td><img src="100um.png" alt="Image" /></td>
</tr>
<tr>
<td></td>
<td>10.2%</td>
<td>11.8%</td>
<td>13.0%</td>
<td>14.8</td>
<td>16.0%</td>
<td>17.6%</td>
<td>18.6%</td>
<td>21.2%</td>
<td>23.0%</td>
<td>23.0%</td>
</tr>
<tr>
<td>Hot</td>
<td><img src="10um.png" alt="Image" /></td>
<td><img src="20um.png" alt="Image" /></td>
<td><img src="30um.png" alt="Image" /></td>
<td><img src="40um.png" alt="Image" /></td>
<td><img src="50um.png" alt="Image" /></td>
<td><img src="60um.png" alt="Image" /></td>
<td><img src="70um.png" alt="Image" /></td>
<td><img src="80um.png" alt="Image" /></td>
<td><img src="90um.png" alt="Image" /></td>
<td><img src="100um.png" alt="Image" /></td>
</tr>
<tr>
<td></td>
<td>10.2%</td>
<td>12.5%</td>
<td>14.4%</td>
<td>19.4%</td>
<td>21.2%</td>
<td>23.0%</td>
<td>27.0%</td>
<td>31.4%</td>
<td>33.6%</td>
<td>36.0%</td>
</tr>
</tbody>
</table>

Room Temp _ Cobra 2.0mil

![Graph](https://example.com/graph.png)

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

<table>
<thead>
<tr>
<th>Probing Challenges</th>
<th>Tougher than Solder</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scheme</td>
<td>12 um Small Probe Mark</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Effects on Probing</td>
<td>1. Hard to probe deeply</td>
</tr>
<tr>
<td></td>
<td>2. Small probe mark for inspection</td>
</tr>
<tr>
<td>Solutions</td>
<td>1. Probe tip type selection</td>
</tr>
<tr>
<td></td>
<td>2. Probe force optimization</td>
</tr>
</tbody>
</table>

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

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

Solder Cap Diameter

<table>
<thead>
<tr>
<th></th>
<th>Over 40um</th>
<th>30 ~ 40um</th>
<th>Under 30um</th>
</tr>
</thead>
<tbody>
<tr>
<td>TCFC &amp; Cu-BOL</td>
<td>Under 2.5gF/Pin</td>
<td>Under 2.0gF/Pin</td>
<td>Under 1.5gF/Pin</td>
</tr>
</tbody>
</table>

- **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
- AVI
- Reflow

Before Reflow
After Reflow

Source: DIPSOL Website Figure

<table>
<thead>
<tr>
<th>Type</th>
<th>Cres</th>
<th>Tip Force</th>
<th>Life Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>MEMS Flat</td>
<td>Bad</td>
<td>Good</td>
<td>Good</td>
</tr>
<tr>
<td>MEMS Point</td>
<td>Good</td>
<td>Good</td>
<td>Bad</td>
</tr>
<tr>
<td>Wire Point</td>
<td>Good</td>
<td>Middle</td>
<td>Bad</td>
</tr>
<tr>
<td>Cobra Flat</td>
<td>Bad</td>
<td>Bad</td>
<td>Good</td>
</tr>
</tbody>
</table>

• Table data is expectation grade (SEC Simulation)
→ Next Step Study
## SEC Requirement of Flip-Chip Probing

<table>
<thead>
<tr>
<th>Items</th>
<th>SOLDER</th>
<th>Cu-Pillar</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pitch</strong></td>
<td>150um ↑</td>
<td>140-149um</td>
</tr>
<tr>
<td></td>
<td>135um ↑</td>
<td>110-135um</td>
</tr>
<tr>
<td></td>
<td>135um ↑</td>
<td>65-80um</td>
</tr>
<tr>
<td><strong>Solder Diameter</strong></td>
<td>90um ↑</td>
<td>80um</td>
</tr>
<tr>
<td></td>
<td>50um</td>
<td>45um</td>
</tr>
<tr>
<td></td>
<td>30um</td>
<td>25um</td>
</tr>
<tr>
<td><strong>Needle Diameter</strong></td>
<td>60~75Φ</td>
<td>60-75Φ</td>
</tr>
<tr>
<td></td>
<td>45*45um ↓</td>
<td>50Φ</td>
</tr>
<tr>
<td></td>
<td>30*30um ↓</td>
<td>45Φ</td>
</tr>
<tr>
<td><strong>Needle Type</strong></td>
<td>Wire</td>
<td>Wire</td>
</tr>
<tr>
<td></td>
<td>Wire (Only Room Temp)</td>
<td>MEMS &amp; Etc</td>
</tr>
<tr>
<td></td>
<td>Only MEMS</td>
<td>Only MEMS</td>
</tr>
<tr>
<td><strong>Needle Shape</strong></td>
<td>Flat</td>
<td>Flat</td>
</tr>
<tr>
<td></td>
<td>Flat (Point)</td>
<td>Flat (Point)</td>
</tr>
<tr>
<td><strong>Tip Force (3mil)</strong></td>
<td>7g ↓</td>
<td>6g ↓</td>
</tr>
<tr>
<td></td>
<td>2.5g ↓</td>
<td>2g ↓</td>
</tr>
<tr>
<td></td>
<td>1.5g ↓</td>
<td></td>
</tr>
<tr>
<td><strong>C.C.C</strong></td>
<td>800[mA] ↑</td>
<td>800[mA] ↑</td>
</tr>
</tbody>
</table>

- 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.