MULαS
CHALLENGE TO ZERO ALPHA

# *Development of Plating Process for Micro Bump Formation*

Takuma Katase, Koji Tastumi, Takeshi Hatta, Masayuki Ishikawa,
Akihiro Masuda
Mitsubishi Materials Corporation, Sanda Plant,
12-6, Technopark, Sanda-shi, Hyogo-ken, 669-1339, JAPAN
Phone: +81-79-568-2316, E-mail: katase@mmc.co.jp

MULαS
CHALLENGE TO ZERO ALPHA

# Contents

- *Introduction*
- *Characteristic Issues for Micro Bump Formation*
- *Introduction of Cu and Sn-Ag plating chemical*
- *Example of forming Cu/Sn-Ag micro bump and Cu pillar*
- *Summary*

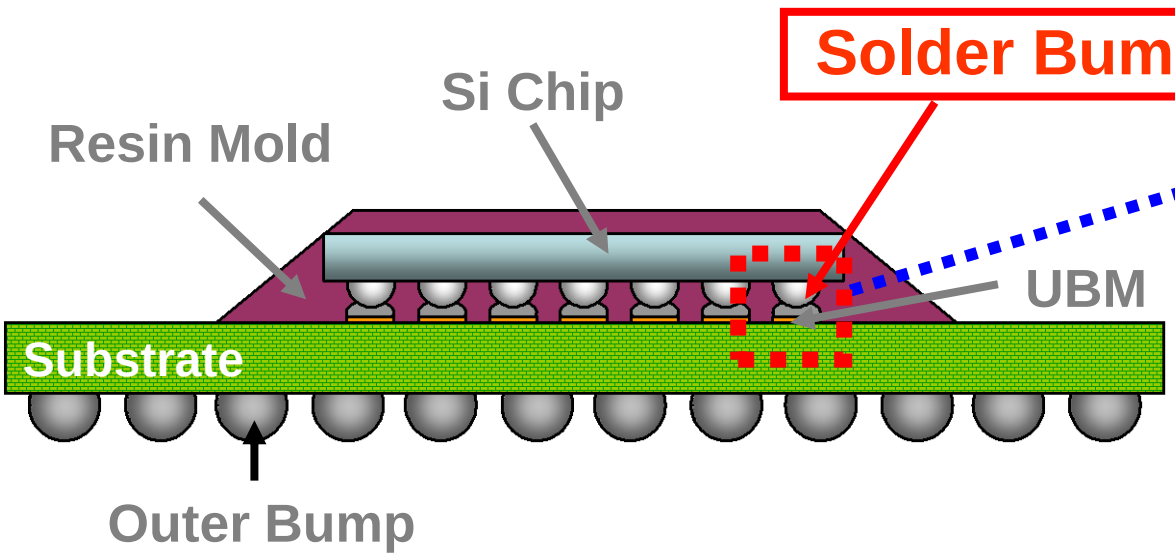
# *Introduction*

# Low Alpha Solder Materials in MMC

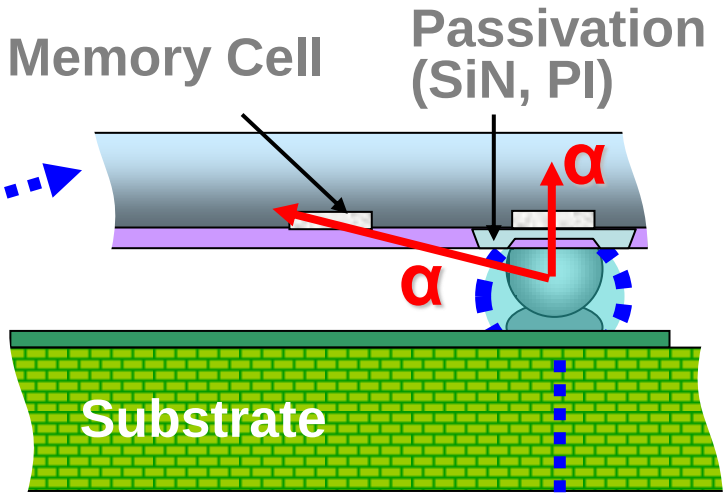
MULαS CHALLENGE TO ZERO ALPHA

- Main Application:PC (CPU, GPU, Chip-set), Game, Mobile Phone, etc

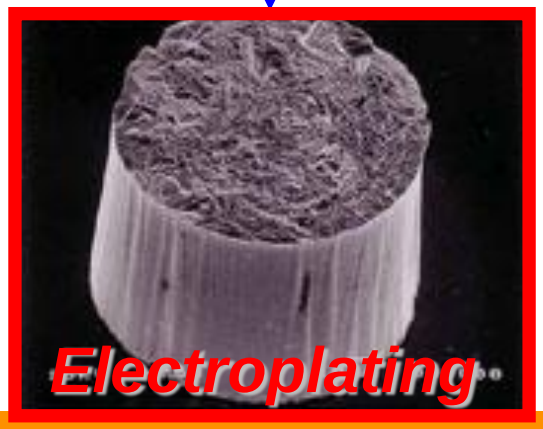
## FC-BGA

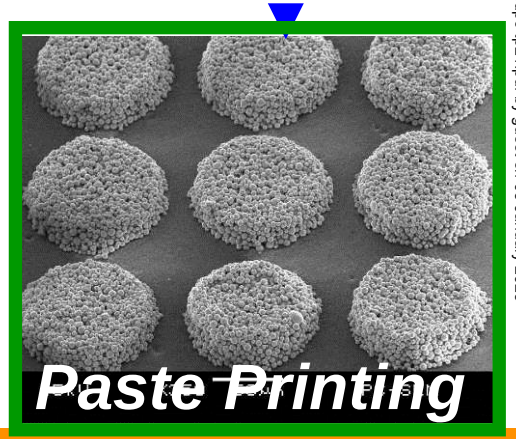



## Image of Soft Error







MULαS
CHALLENGE TO ZERO ALPHA

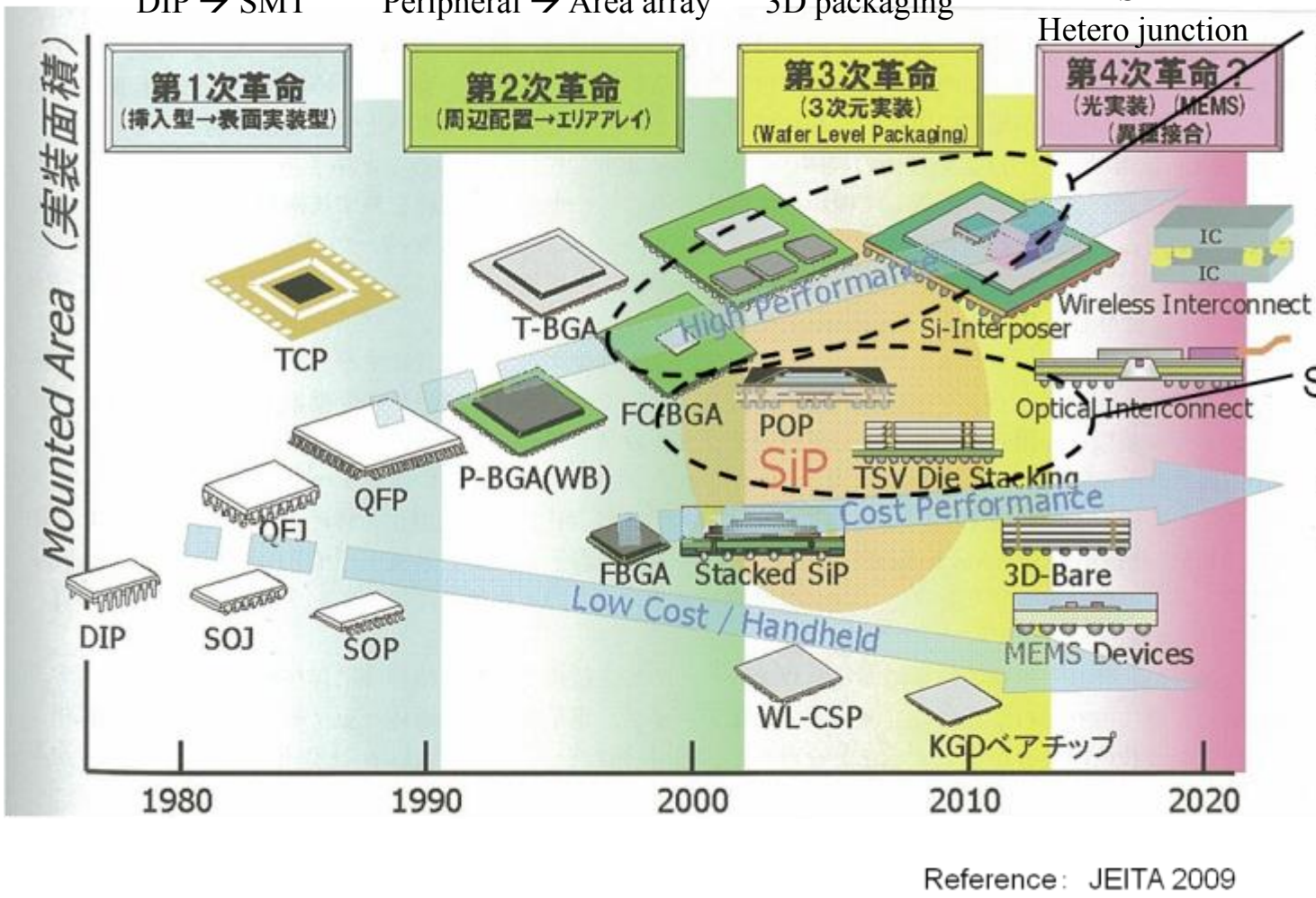
# Roadmap of Packaging Technology

1st generation
DIP → SMT

2nd generation
Peripheral → Area array

3rd generation
3D packaging

4th generation
Optical packaging
MEMS
Hetero junction




Reference: JEITA 2009

## High performance region

FC (Flip Chip) technology for fine pitch

- FC (Solder bump)
- FC (Cu pillar/solder)
- C2C (Si-interposer/solder)

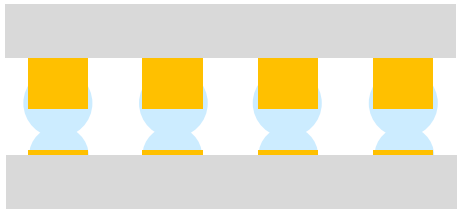
## SiP (System in Package) region

- PoP(FC+WB)
- TSV (Trough Silicon Via ··Cu)
- Built-in substrate (passive device/IC)

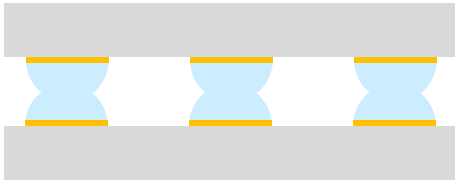
**Importance of Cu and solder bump technology is increasing more and more**

MULαS CHALLENGE TO ZERO ALPHA

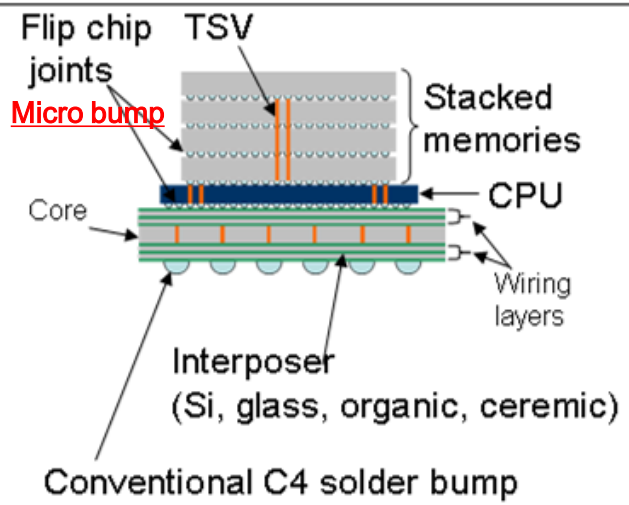
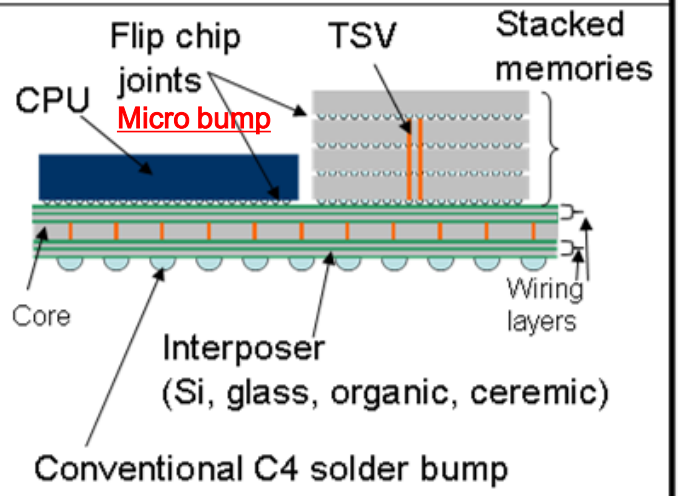
# 2.5D and 3D Packaging



Cu pillar connection



Micro bump connection

| | 3D | 2.5D |
|---|---|---|
| Structure example |   |   |
| Merit | High band width<br>Small package area | Thermal management<br>CPU thinning is not required<br>Restriction due to pad location of memory is small<br>Applicable the conventional technology |
| Demerit | Difficulty in thermal management<br>Stress in transistor due to CPU thinning<br>Consideration of CPU design for compatibility with memory | Limit of band width<br>Large package area |

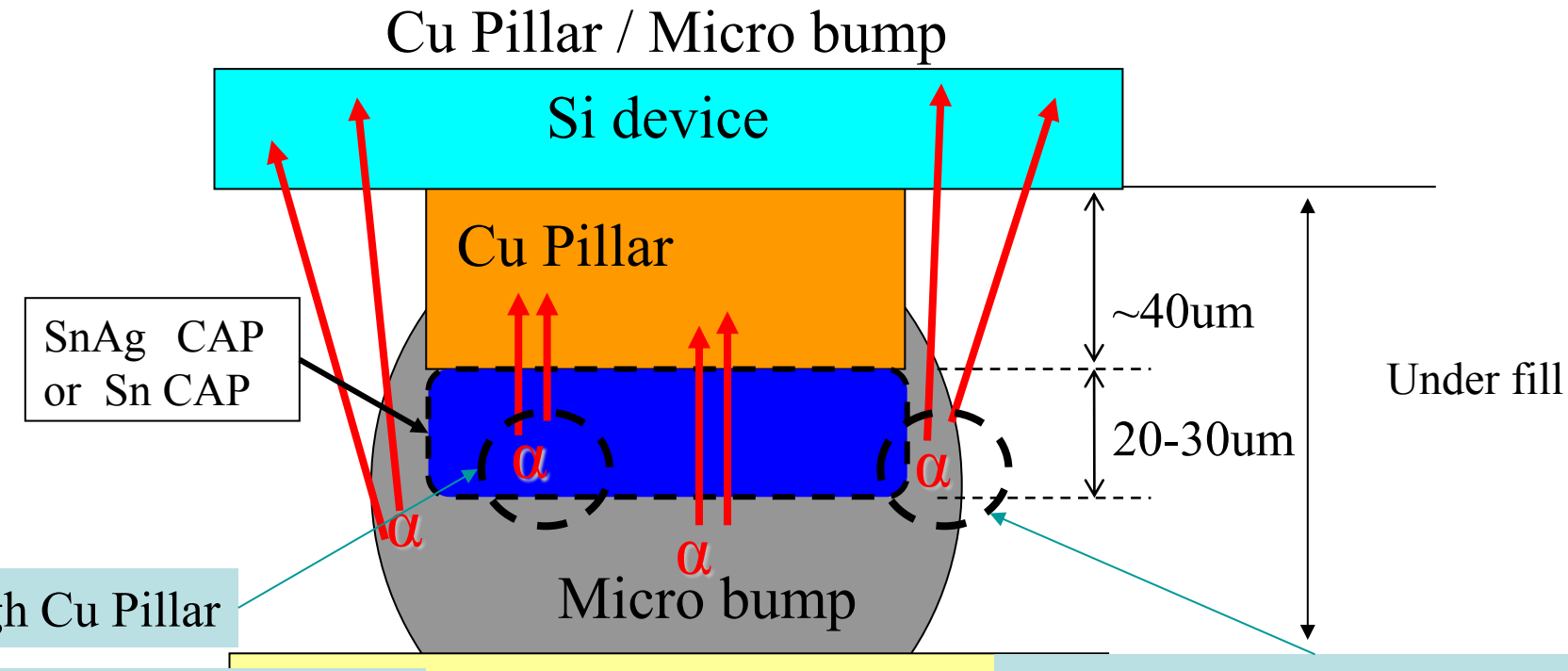


Reference: NIKKEI ELECTRONICS 2012.4.16, p.36

In the case of 2.5D/3D packaging, micro bumps will be applied to the stacked device connection.

# Alpha Particle Penetration Image and Depth into the Si Device

## Two penetration roots for α particles.




1. Directly through Cu Pillar

α particles can not reach the Si device.
(Shielded by Cu Pillar)

2. Over hanged solder bump

α particles can reach the Si device directly.

Even if the Cu pillar and/or TSV technology (micro bump connection) become mainstream, the importance of low alpha technology does not change

MULOS
CHALLENGE TO ZERO ALPHA

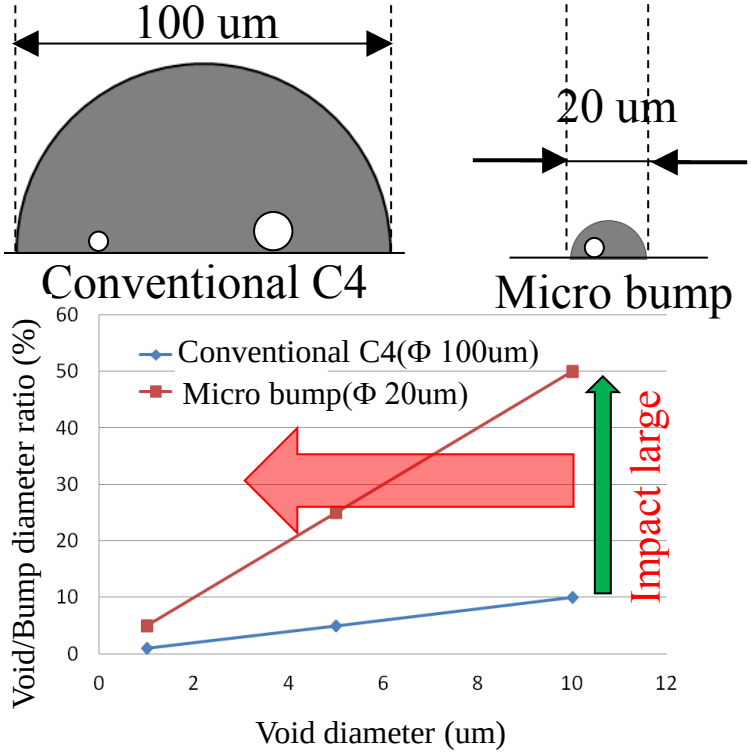
# *Characteristic Issues for Micro Bump Formation*

# Characteristic Issues for Micro Bump

- **Due to the small size of micro bump, following items should be considered**

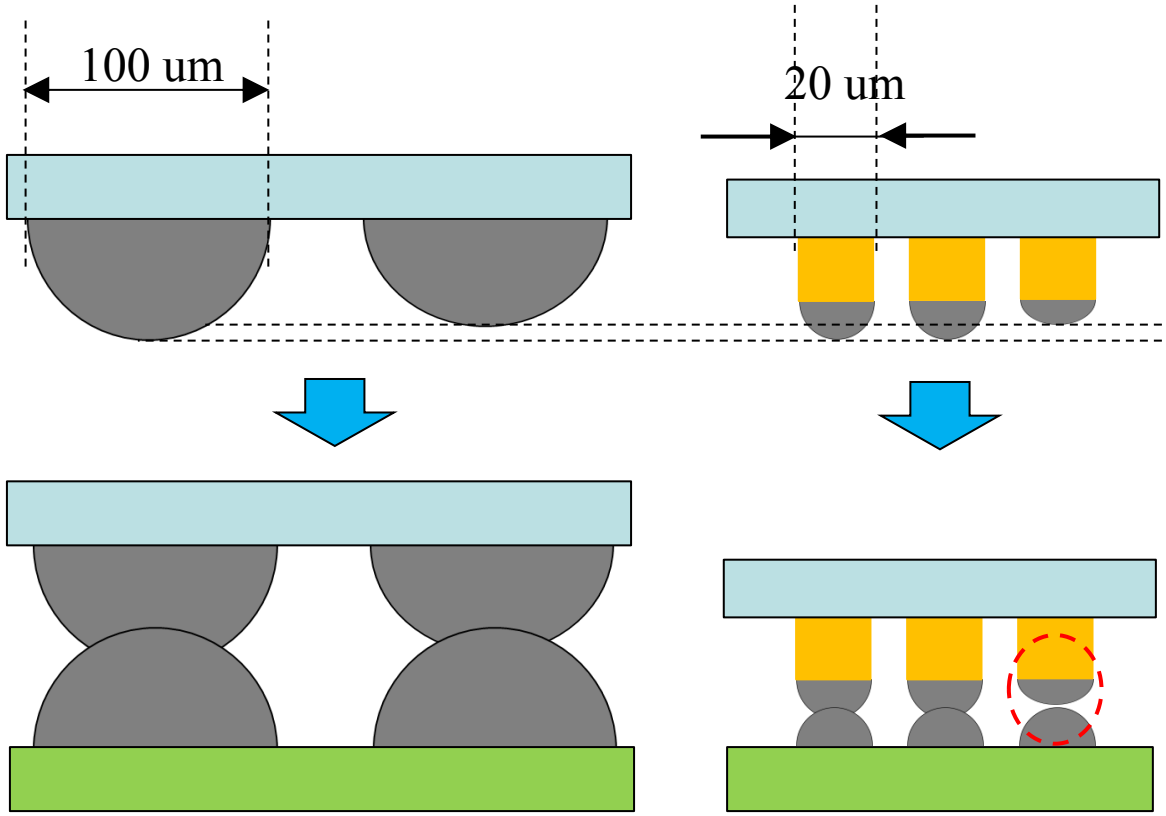
-Void generation

***Due to the size effect, the impact of "micro void" become large for micro bump***




-Coplanarity

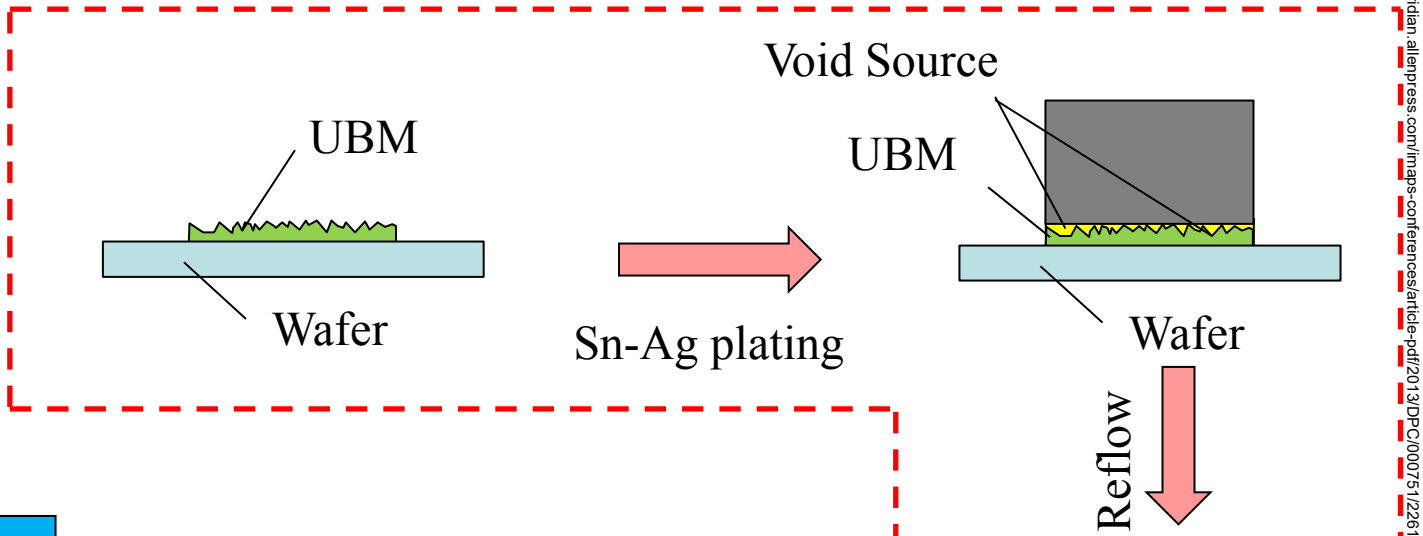
***Due to the size effect, excellent coplanarity should be needed***



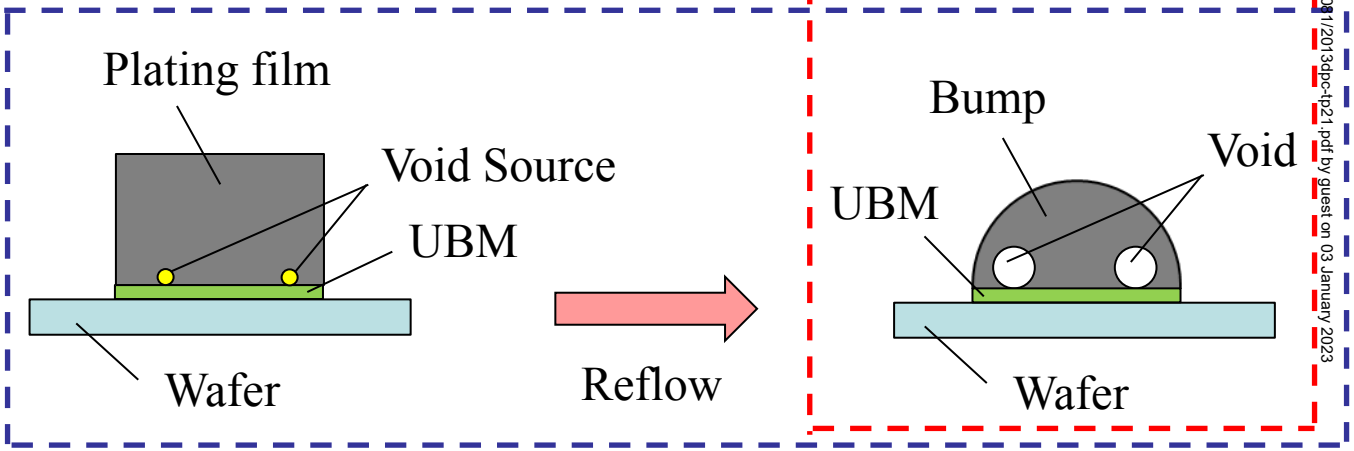
# Consideration of Void Generation

## Possible factor of micro void generation

- UBM condition
- UBM material
- **UBM roughness**
- UBM cleanness

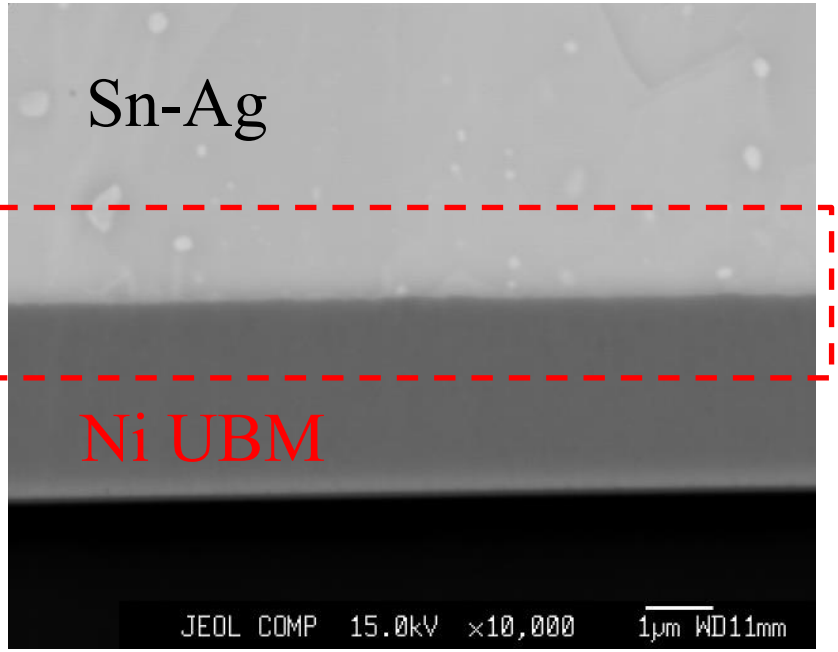



- Plating film layer around UBM Interface (early step of plating)
- **Plating film structure**
- Displacement



MULαS
CHALLENGE TO ZERO ALPHA

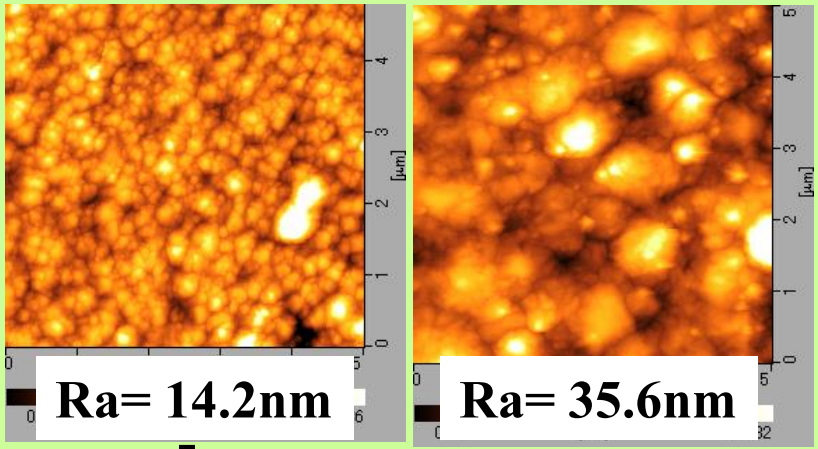
# Consideration of Micro Voids



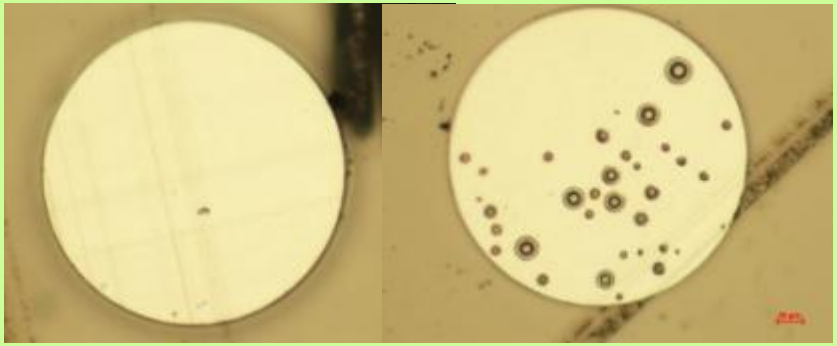

**No micro voids!!**

**It's important to adjust suitable Ni UBM surface**

Ni UBM image by AFM




Cross-sectional image of bump



***Micro voids has correlation with UBM condition.***

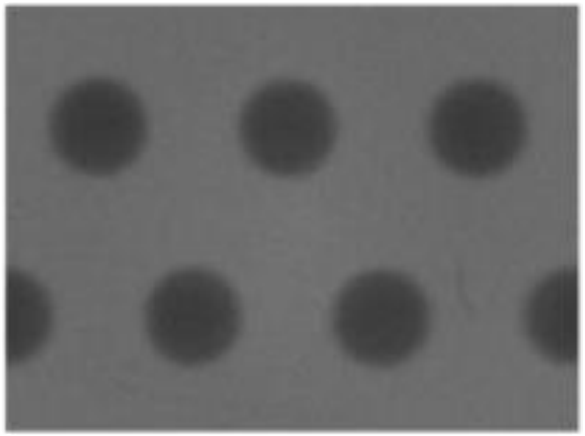
MULαS CHALLENGE TO ZERO ALPHA

# Consideration of Void Generation

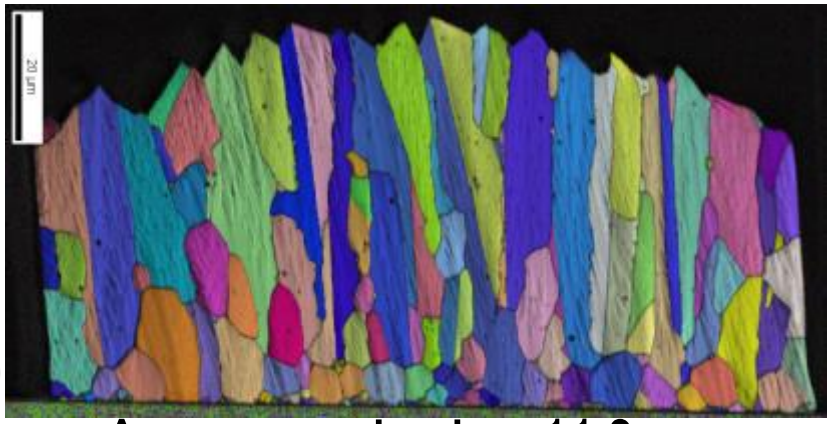
15ASD

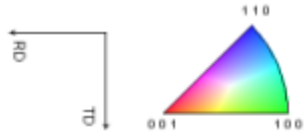
TS-507


Average grain size: 6.7um

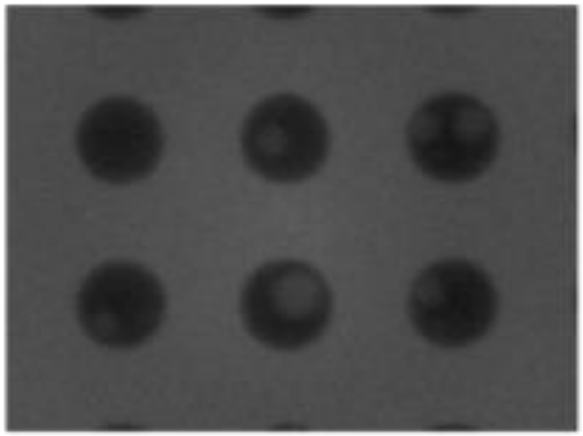


Conventional




Average grain size: 11.9um



## TS-507

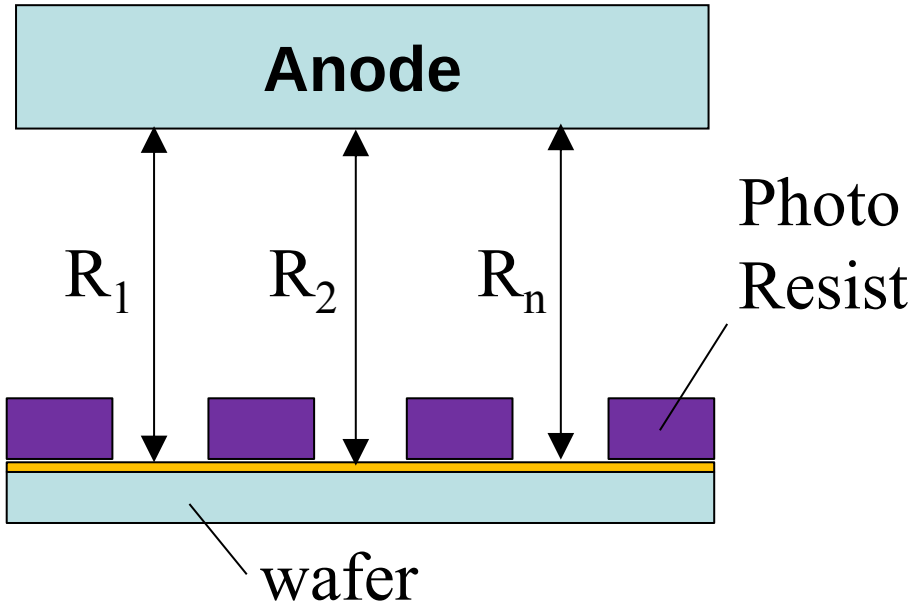
- Fine grain
- Good morphology

**TS-507 will achieve the good void performance**

MULαS CHALLENGE TO ZERO ALPHA

# Consideration of Coplanality

## Model of Bump Plating




$I_1=V/R_1 \quad I_2=V/R_2 \quad \cdots \quad I_n=V/R_n$

## Polarization resistance; Rp

$I_1=V/(R_1+Rp) \quad \cdots \quad I_n=V/(R_n+Rp)$

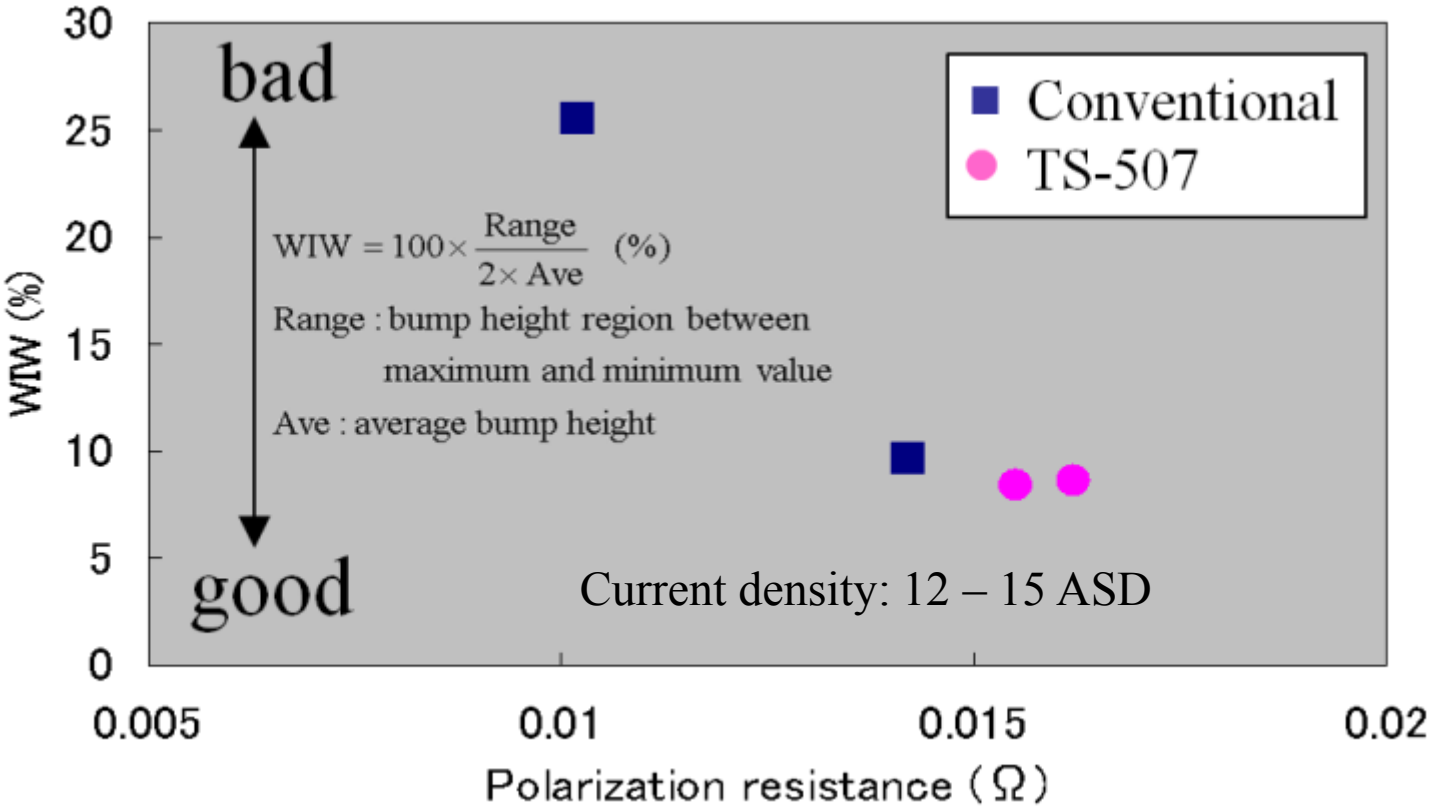
Relative current density among these bump hole

$\mathbf{J_1/J_n=(R_n+Rp)/(R_1+Rp)}$

$J_1/J_n$ approaches to 1 with increasing Rp

**Increasing Rp, improving uniformity**

# Polarization Resistance vs. Coplanarity

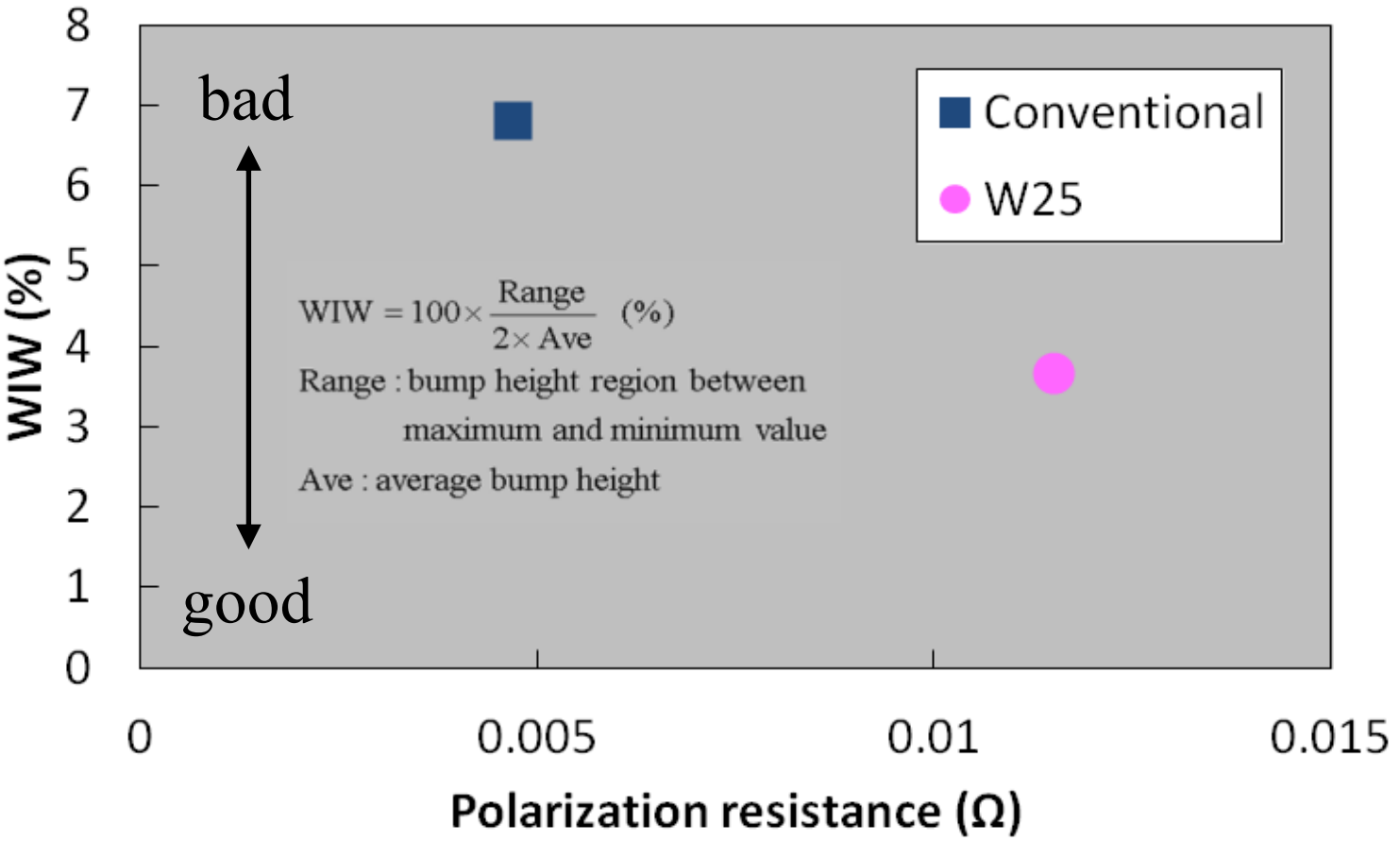



Polarization resistance
Conventional<TS-507

Coplanarity
Conventional: poor
**TS-507: good!**

**Large polarization resistance generates the good coplanarity.**
**TS-507 is one of the ideal chemicals for micro bumps.**

# Consideration of Coplanarity for Cu Plating Chemical




Polarization resistance
Conventional<W25

Coplanarity
Conventional: poor
**W25: good!**

**In the case of Sn-Ag plating, increasing the polarization resistance makes the good coplanarity**

**These concept can be applied to the Cu plating**

MULαS
CHALLENGE TO ZERO ALPHA

# *Introduction of Cu and Sn-Ag Plating Chemical*

# Introduction of our Cu, Sn-Ag plating chemical

MULαS CHALLENGE TO ZERO ALPHA

## TS-507 (Sn-Ag)

| Items | Standard | Control Range |
|---|---|---|
| $Sn^{2+}$(g/L) | 85.0 | 75 to 95 |
| $Ag^{+}$(g/L) | 1.5* | 1.0 to 2.0 |
| Free Acid(g/L) | 100 | 80 to 350 |
| TS-SLG(g/L) [complex agent for Ag] | 220 | 200 to 300 |
| TS-507AD(ml/L) [additive] | 60.0 | 50 to 80 |
| Optimum Current Density (ASD) | 13 | 8 to 15 |

※Ag concentration should be adjusted depending on plater and resist thickness.

## W25 (Cu)

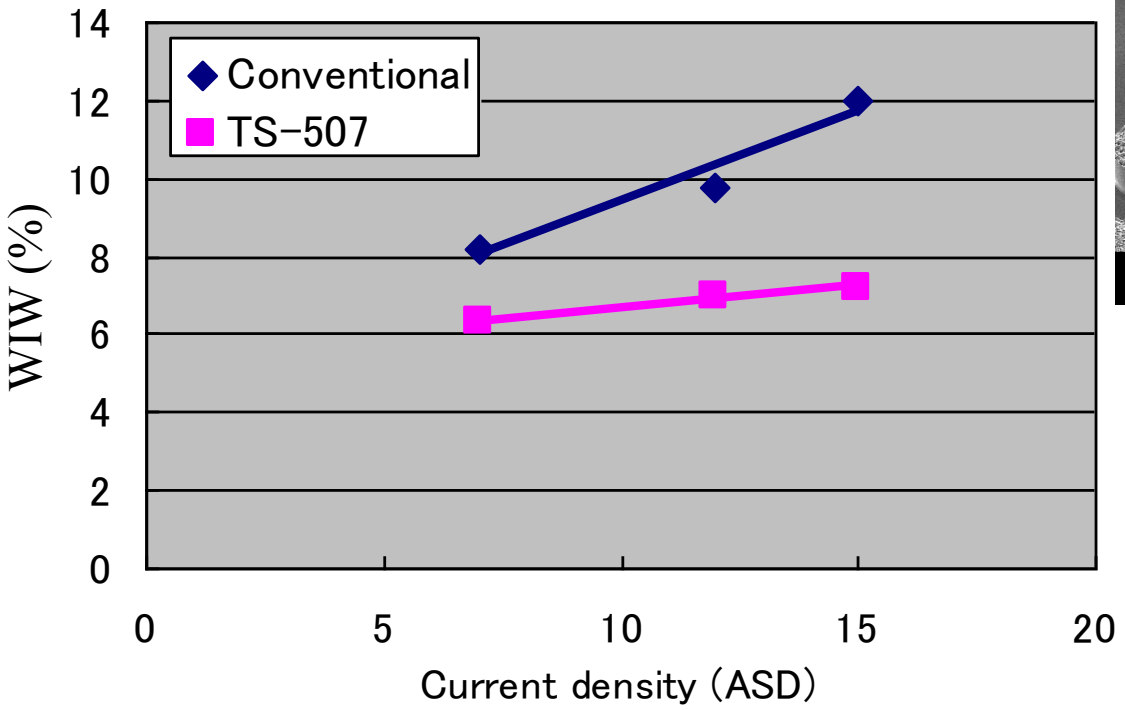
| Items | Standard | Control Range |
|---|---|---|
| $Cu^{2+}$ (g/L) | 55 | 55 to 60 |
| $H_2SO_4$ (g/L) | 110 | 90 to 130 |
| $Cl^{-}$ (ppm) | 80 | 60 to 100 |
| W25-A (mL/L) [additive] | 5 | 2 to 8 |
| W25-B (mL/L) [additive] | 10 | 7 to 13 |
| Optimum Current Density (ASD) | 15 | 10 to 20 |

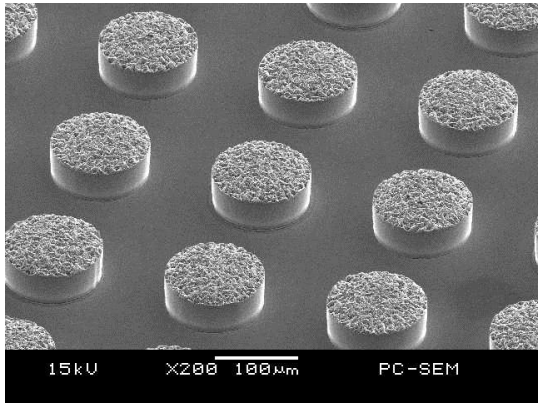
**Our new Cu and Sn-Ag plating chemical can achieve high speed plating process**

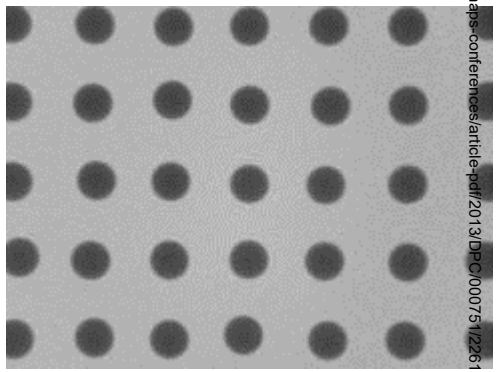
MULαS
CHALLENGE TO ZERO ALPHA

# Feature of Sn-Ag Plating Chemical

- High rate plating (8-15ASD)
- Excellent coplanarity
- Excellent Ag content variation



| Current Density | Ag% σ |
|---|---|
| 11ASD | 0.26 |
| 13ASD | 0.23 |
| 15ASD | 0.17 |

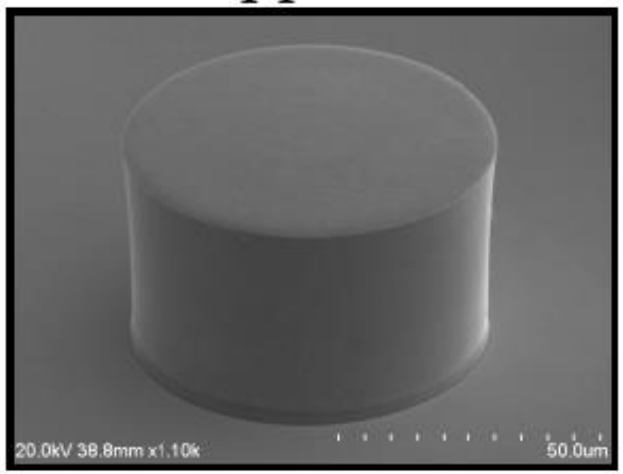
MULαS
CHALLENGE TO ZERO ALPHA

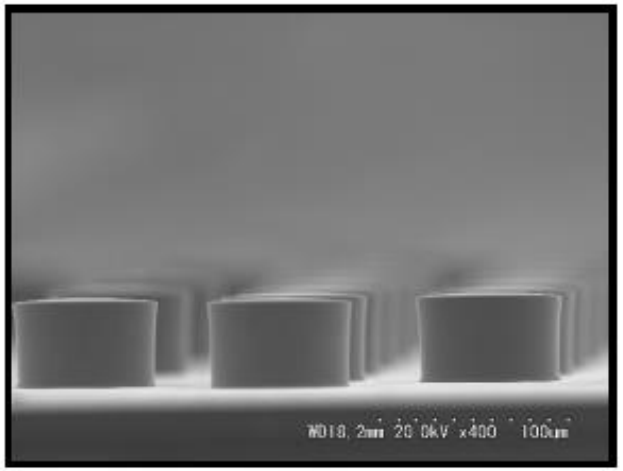
# Features of Cu Plating Chemical (W25)

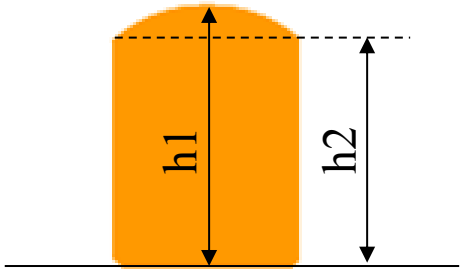
High speed (conventional: < 10 A/dm$^2$)

- High Throughput : 15A/dm$^2$(10 ~ 20A/dm$^2$)
  (2.2 to 4.4 um/min)
- Thickness Uniformity : WID 1 ~ 3%
- Flatness : Doming Ratio 3 ~ 5%

Pillar Appearance at 15A/dm$^2$ (3.3 $\mu$ m/min)

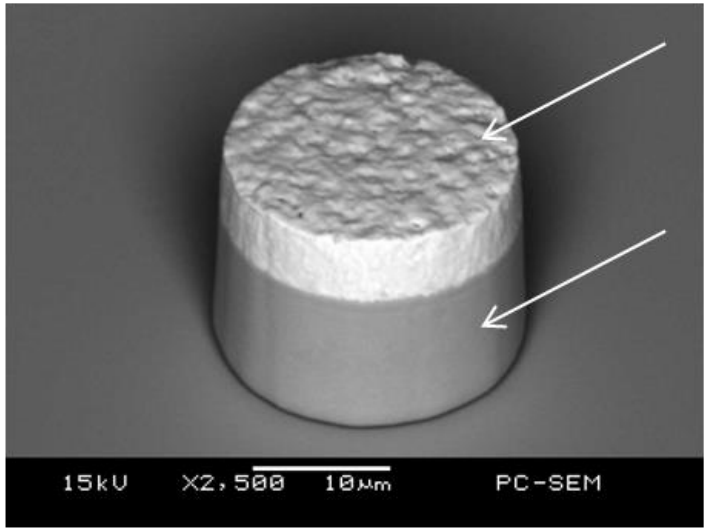





$$\text{Doming Ratio} = \frac{h1 - h2}{h1} \times 100\,(\%)$$

# Consideration of Cu Pillar Forming (TS-507)




Cu pillar and Sn-Ag cap structure

| | Conventional | Novel |
|---|---|---|
| Cu Plating rate | 1.1 um/min | 3.3 um/min |
| Sn-Ag plating rate | 2.5 um/min | 6.5 um/min |

**> 2 times faster**

Cu plating rate is slower than that of Sn-Ag plating at the same current density
→ Cu pillar process might be the bottleneck

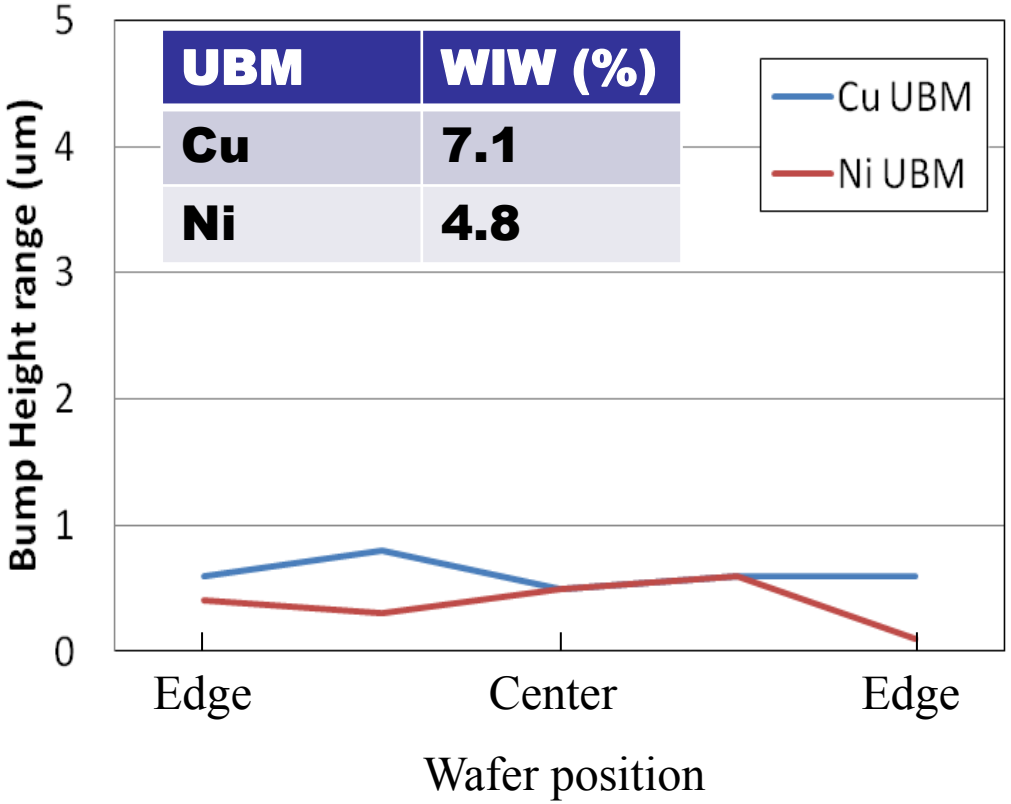
**Applying the high speed chemical to the Cu pillar structure makes high throughput**

# *Example of Forming Micro Bump*

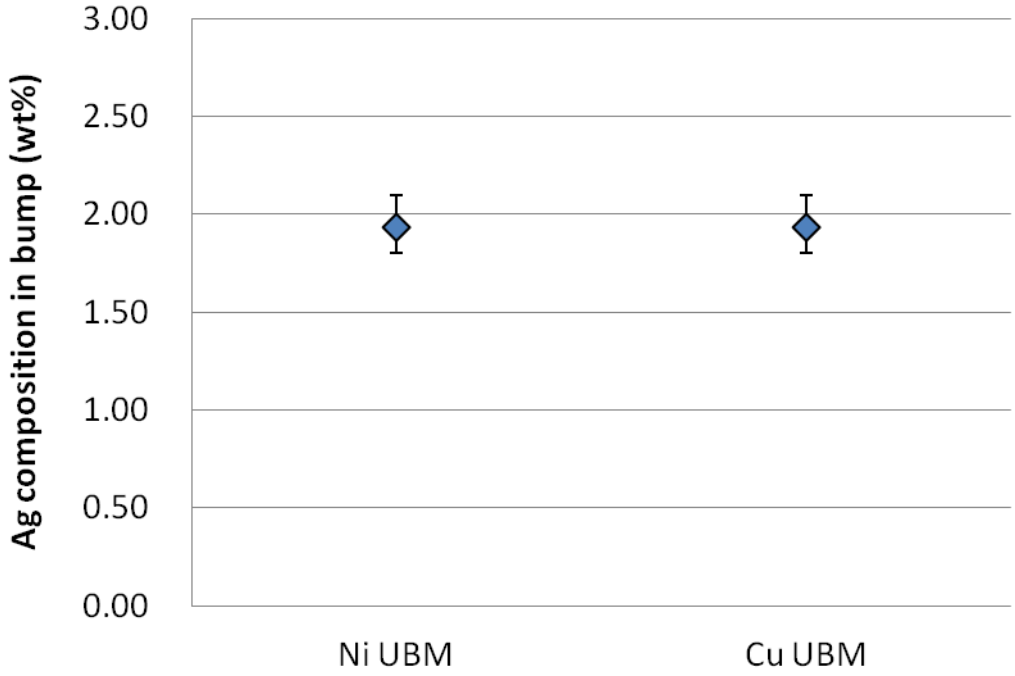
MULαS CHALLENGE TO ZERO ALPHA

# Plating Performance (micro bump)

| UBM | WIW (%) |
|---|---|
| Cu | 7.1 |
| Ni | 4.8 |




Cu:W25 (10 ASD) Ni: NPL-110 (5 ASD)
Sn-Ag:TS-507 (8 ASD)
Plater: vertical
Target height: Cu, Ni: 3 um, Sn-Ag: 15 um

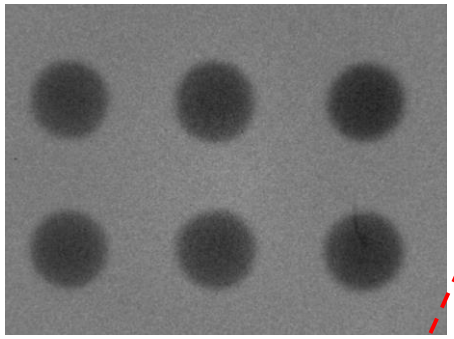



Our plating chemical can achieve the excellent coplanarity and bump composition uniformity

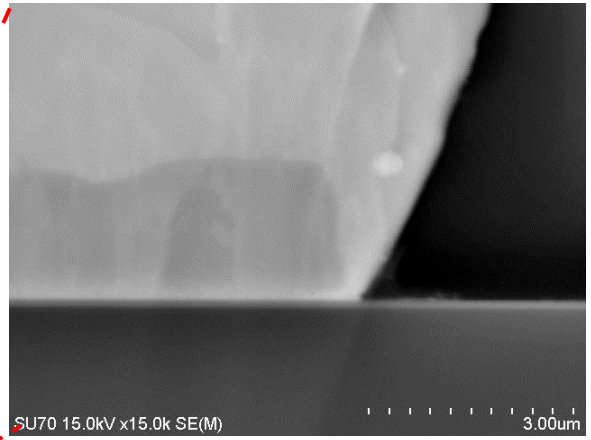
MULαS
CHALLENGE TO ZERO ALPHA

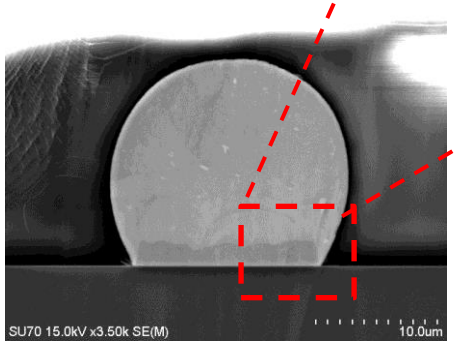
# Plating Performance (micro bump)

## Cu UBM

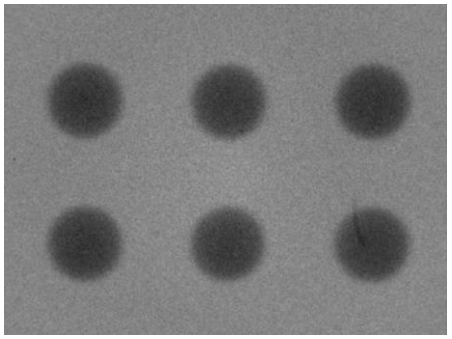


Cu:W25 (10 ASD)
Sn-Ag:TS-507 (8 ASD)
Plater: vertical

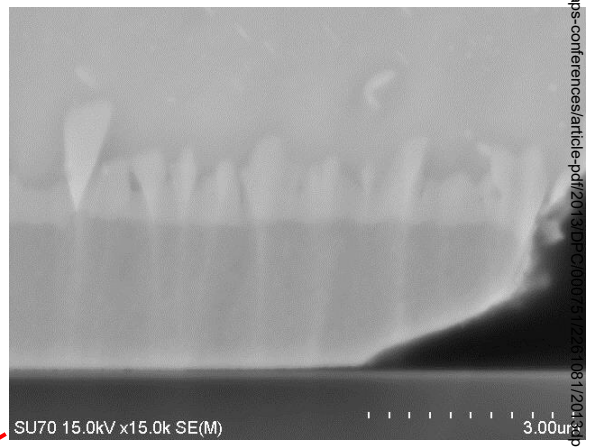


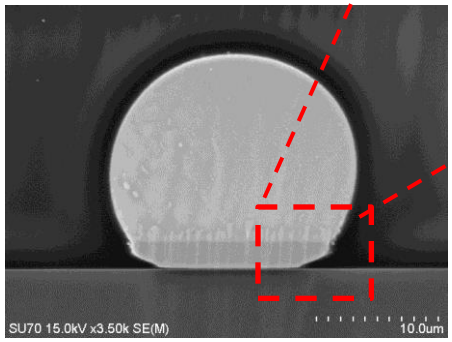




## Ni UBM



Ni:NPL-110 (5 ASD)
Sn-Ag:TS-507 (8 ASD)
Plater: vertical



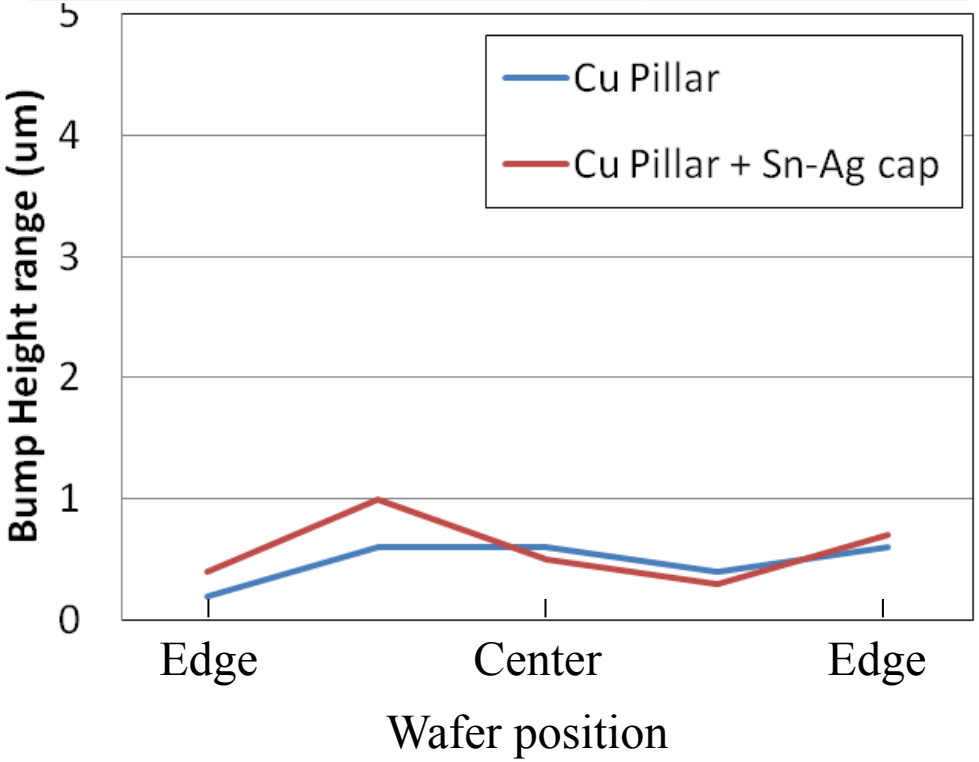




By applying our Cu, Ni, and Sn-Ag plating chemcial, we can obtain the void free micro bumps.

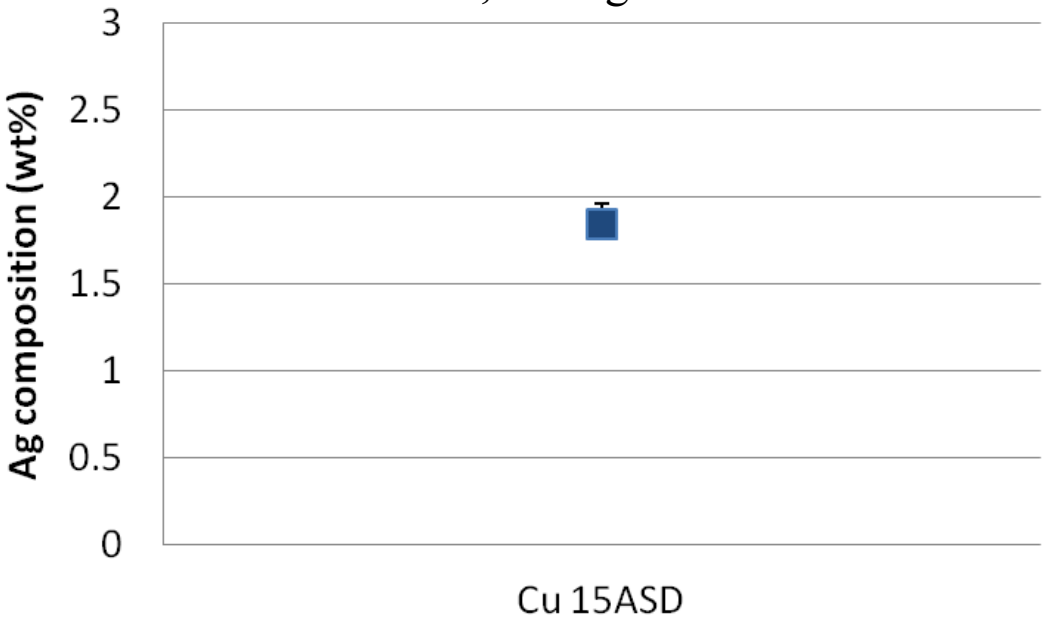
MULαS
CHALLENGE TO ZERO ALPHA

# Plating Performance (Cu pillar + Sn-Ag micro bump)

| Item | WIW (%) |
|---|---|
| Cu Pillar | 7.0 |
| Cu Pillar + Sn-Ag cap | 5.4 |



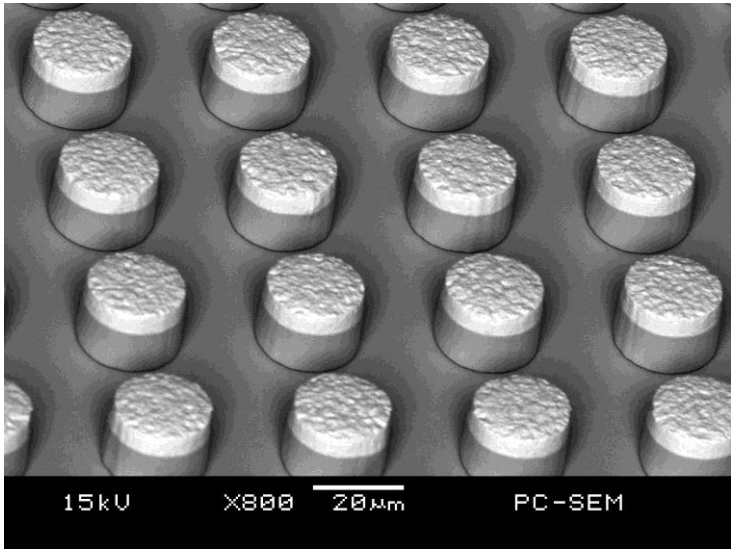

Cu:W25 (15 ASD)
Sn-Ag:TS-507 (8 ASD)
Plater: vertical
Target height
Cu:10 um, Sn-Ag:5 um



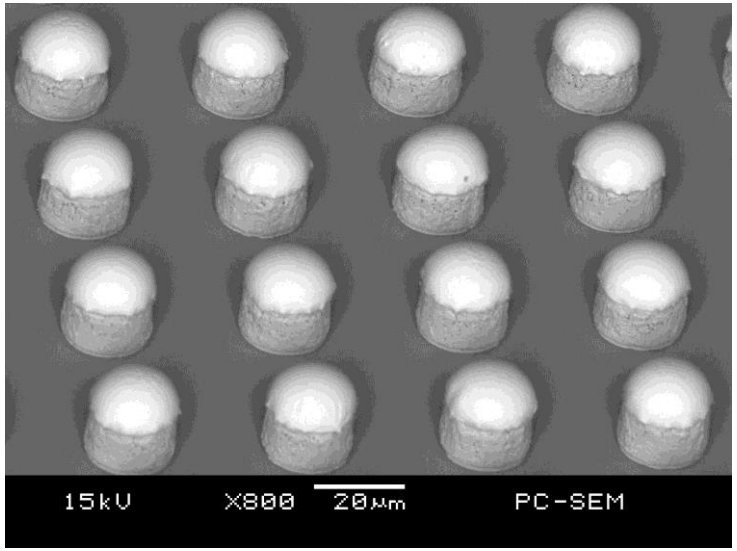

Our plating chemical can achieve the excellent coplanarity and bump composition uniformity even in Cu pillar structure

MULαS
CHALLENGE TO ZERO ALPHA

# Plating Performance (Cu pillar + Sn-Ag micro bump)

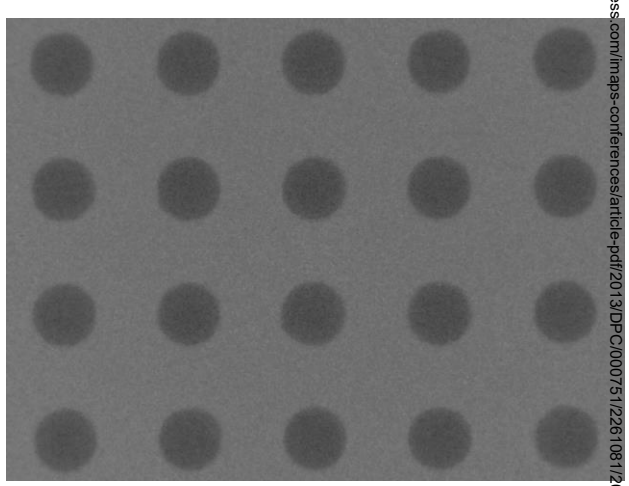



As plated




Reflowed

Cu:W25 (15 ASD)
Sn-Ag:TS-507 (8 ASD)
Plater: vertical
Target height
Cu:10 um, Sn-Ag:5 um



- Cu pillar and Sn-Ag cap structure have a good morphology, void performance even in high speed plating.
- Our Cu and Sn-Ag plating chemical are the potential candidates for micro bump formation with Cu pillar structure.

MULαS
CHALLENGE TO ZERO ALPHA

# Summary

- **Along with the development of packaging technologies, the requirement for bump forming process have been advanced.**

- **To correspond these requirement, we have established the high speed and high quality Cu and Sn-Ag plating chemical as W25 and TS-507**

- **Feature**

**void performance: optimize the UBM condition, fine grain Sn-Ag bump**

**Coplanarity: improvement of basic performance**

- **By using these chemical, we can achieve the good performance for micro bump with Cu pillar structure.**

- **We are convinced that the W25 and TS-507 are the ideal candidate for Cu pillar/ micro bump technologies.**


# Thank you!!

*If you are interested, please feel free to visit our booth.*