Solder Material Technology for Embedded Package

Tetsuya Okuno/Senju Metal Industry Co., LTD
Solder materials for 2.5D, 3D, and Embedded Package
3D PKG Assembly solution (Solder materials)

- **Solvent cleaning Type5 Solder paste**
  - High-Temp solder paste
  - M10-LSC50

- **Spacer Ball**
  - Cu core ball

- **High TCT & Drop performance Alloy Ball for BGA/CSP**
  - M770

- **High Reliability alloy ball for WLP**
  - M758

- **Solder powder transfer PPS(Precoat bump)**

- **Micro solder ball /LAS ball**
  - M705/M200
  - Prevent HIP transfer Paste/Flux For POP/TMV
  - NSV320/NSV301

- **Epoxy paste**

- **Pre solder**
  - RAM
  - JPP
  - SPP
  - Pre solder • SMB • PPS

- **Prevent NWO type 5 NC paste**
  - S101-S4HF

- **Fine Pitch & no-HiP NC solder Paste**
  - RGS800HF Type5

- **PCB**

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Friday, Sept. 6, 2013

Senju Metal Industry Co., Ltd.
3D PKG Assembly Solution (Flux)

- Solder fusing flux
  - SPK-3400
  - Low volatile / Water soluble

- Micron Ball attach active Flux
  - MB-T100
  - Resin type / Solvent cleaning

- Flip chip attach flux
  - WF-6317
  - Low volatile / WS type

- JPK8
  - Epoxy harden / NC protect
  - Ultra low residue / NC

- Ball attach Flux
  - WF-6317
  - JPK8
  - GTN-68(HF)
  - Rosin type transfer

- PKG assembly Flux
  - WF-340
  - JPK8
  - NSV301HF
  - Transfer POP Flux
**ECO SOLDER Ball**

Solder ball requirements include high purity and roundness. ECO SOLDER ball is widely used for soldering microscopic sections of crystal oscillators and diodes, as an electrode bump for hybrid ICs or power diodes in addition to the micro-soldering of BGA, MCM, CSP and FLip Chips.

Our Lead-Free ECO SOLDER ball exhibits excellent wettability though it contains no lead.

*Micro balls less than 0.1 dia, are available on request*

<table>
<thead>
<tr>
<th>Diameter (mm)</th>
<th>Tolerance (µm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ø0.02 to ø0.08</td>
<td>+/-3</td>
</tr>
<tr>
<td>ø0.1 to ø0.25</td>
<td>+/-5</td>
</tr>
<tr>
<td>ø0.3 to ø0.45</td>
<td>+/-10</td>
</tr>
<tr>
<td>ø0.5 to ø0.76</td>
<td>+/-20</td>
</tr>
</tbody>
</table>

+/-10µm type is available on request.
Features

- Available in various compositions and sizes.
- LAS Micro-balls protect products from “soft errors”.

Table:

<table>
<thead>
<tr>
<th>Product</th>
<th>Alloy Product Number &amp; Composition</th>
<th>Melting Point (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Solid</td>
</tr>
<tr>
<td>M34</td>
<td>Sn-1.0Ag-0.5Cu</td>
<td>217</td>
</tr>
<tr>
<td>M35</td>
<td>Sn-0.3Ag-0.7Cu</td>
<td>217</td>
</tr>
<tr>
<td>M705</td>
<td>Sn-3.0Ag-0.5Cu</td>
<td>217</td>
</tr>
<tr>
<td>M52</td>
<td>Sn-1.0Ag-0.1Cu-0.05In-0.02Ni</td>
<td>218</td>
</tr>
<tr>
<td>M60</td>
<td>Sn-2.3Ag-0.08Ni-Co</td>
<td>221</td>
</tr>
<tr>
<td>M61</td>
<td>Sn-1.0Ag-0.75Cu</td>
<td>217</td>
</tr>
<tr>
<td>M20</td>
<td>Sn-0.75Cu</td>
<td></td>
</tr>
<tr>
<td>M30</td>
<td>Sn-3.5Cu</td>
<td></td>
</tr>
<tr>
<td>M706</td>
<td>Sn-3.0Ag-0.7Cu-1.0Bi-2.5In</td>
<td>204</td>
</tr>
<tr>
<td>L20</td>
<td>Sn-58Bi</td>
<td>139</td>
</tr>
</tbody>
</table>

Standard Specification Products
- Diameter and tolerance: 65 μm - 110 μm ± 3 μm
- Alpha count: 0.02 cph/cm² or less
- Composition: M705

Special Specification Products
- Available in various compositions.
- Please inquire with SMIC.
Eco Solder Ball
M758/M770 and other high reliability
**Need new alloy bump for WLP**

**New alloy technology development**

* Suitable solder ball materials for **Wafer Level Package**
  → **Eco Solder Ball M758**
  
  - Background
  - Joint Reliability [TCT, Drop]
  - Wettability Test
  - High Speed Shear Test
  - Summary
  - Reference [Test Method of TCT and Drop test]

* **How to enhance TCT and Drop of capability (PBGA, CSP)**
  → **Eco Solder Ball M770**

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**BGA/CSP**

- **Die**
- **Mold Package**
  - **Solder balls**
  - **Interposer**
Background Data from Semicon Taiwan 2012

Future Trends and Challenges - From Material Perspective

Tetsuya Okuno
Senju Metal Industry Co., LTD.

The Power of \( x \)

Thermal cycle and drop impact
Multifunctional type solder ball M770

Senju Metal Industry Co., Ltd.
Thermal cycle and drop impact Multifunctional type solder ball M770 from Semicon Taiwan 2012
PBGA/CSP reliability Test on Ni/Pd/Au, data from Semicon Taiwan 2012

Mold Resin Package

Cu-OSP  Electroless Ni/Pd/Au

Thermal cycle test

Drop test

Accumulation rate [%]

Cycle number

Drop number

SAC305 : Sn3.0Ag0.5Cu
SAC105 : Sn1.0Ag0.5Cu
M770 : SnAgCu+x

IMC layer ⇒ Very thin
Crack progress ⇒ Solder Bulk

Joint interface

After drop test
Crack point

Crack progress ⇒ Joint interface

M770

Drop number

Good

Good

Accumulation rate [%]
**PBGA/CSP reliability Test on Cu-OSP, data from Semicon Taiwan 2012**

**Mold Resin Package**

- Cu-OSP

**Thermal cycle test**

- SAC305 : Sn3.0Ag0.5Cu
- SAC105 : Sn1.0Ag0.5Cu
- M770 : SnAgCu+x

**Drop test**

- IMC layer ⇒ Fine grain
- Crack progress ⇒ Solder Bulk

**Joint interface**

**After drop test**

- Crack point
- Crack progress ⇒ Joint interface
Multifunctional type solder ball M770 for BGA/CSP
Summary data from Semicon Taiwan 2012

Excellent Performance for both TCT and DROP in one.
✓ Thermal cycle: Equal to 3Ag solder or better
✓ Drop impact performance: Equal to 1Ag solder or better

- Works excellent on any surface finish.

- Applies to a wide field, From PC(CPU) to a mobile

<table>
<thead>
<tr>
<th>Solder Name</th>
<th>Melting point [°C]</th>
<th>TCT</th>
<th>Drop</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Solidus</td>
<td>Peak</td>
<td>Liquidus</td>
</tr>
<tr>
<td>M60</td>
<td>221</td>
<td>222</td>
<td>225</td>
</tr>
<tr>
<td>M61</td>
<td>217</td>
<td>220</td>
<td>227</td>
</tr>
<tr>
<td>M770</td>
<td>217</td>
<td>225</td>
<td>225</td>
</tr>
</tbody>
</table>

*Please contact Senju-Taiwan for more detailed information*
However, why need to change solder alloy for WLP?

PBGA, CSP

WLCSP – Wafer Level CSP

SAC 305/405, or even M770 may not survive TCT >1,000 cycle on WLP

TCT – Thermal Cycle Test

SAC305 on WLP shows much shorter life
Huge CTE Mis-match on WLP soldering!

WLP – Wafer Level Package

![WLP Image]

CTE – Coefficient of Thermal Expansion

<table>
<thead>
<tr>
<th>Parts</th>
<th>CTE [ppm/C]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Si</td>
<td>3</td>
</tr>
<tr>
<td>Solder</td>
<td>20</td>
</tr>
<tr>
<td>Board</td>
<td>60</td>
</tr>
</tbody>
</table>

Characteristics that require mainly → Thermal Cycle Reliability

Difference in CTE is very large [Si/Board]

Generated distortion is large

And More…

【JJTR2013(Japan Jisso Technology Roadmap)】
Approach to improve TCT reliability for WLP

* Solid solution strengthening improvement
* strength improvement by solute Sn phase of etc.

* Precipitation strengthening improvement
* dispersion hardening by intermetallic compound
  (Cu₆Sn₅, Ag₃Sn, etc.)

Solid solution is distributed at an atomic size.

When different atoms enter homogeneous atom lattice, it prevents transformation.

Intermetallic compounds lie between grain boundary, pin Sn grains. It prevents slip deformation.
Excellent Performance for Thermal cycle reliability on WLP
New Alloy: Eco Solder Ball M758

WLCSP: Size 7 x 7mm
S/S: Cu

Table:

<table>
<thead>
<tr>
<th>Product Name</th>
<th>Composition</th>
<th>Melting Point(℃)</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>M705</td>
<td>SAC305</td>
<td>217-220</td>
<td>Pb-free Standard</td>
</tr>
<tr>
<td>M710</td>
<td>SAC405</td>
<td>217-229</td>
<td></td>
</tr>
<tr>
<td>M758</td>
<td>SAC+Z</td>
<td>205-215</td>
<td>Suitable material for WLP</td>
</tr>
</tbody>
</table>

Graphs:
- **TCT**: Significantly improved from SAC305 & SAC405
- **M758 TCT**: Good
- **Drop Test**: Drop Performance is equivalent with the SAC305 & SAC405
- **M758 Drop Test**: Good
WLP Ball Alloy: M758 Wettability test

- Plating: Cu
- Solder: M705 (SAC305)  
  M710 (SAC405)  
  M758
- Flux: WF-6317
- Reflow: 245°C Peak
- Atmosphere: O2 < 200ppm

Solder wetting wide length is measured.

M758 has better wettability
WLP Ball Alloy: M758 High Speed Shear Test

Test machine: Dage Bond Tester 4000HS
Shear speed: 4,000,000um/sec (4,000mm/sec)
Shear height: 10um
S/F: Cu

Reflow Peak: 245°C

Content of Evaluation
* Shear Strength
* Failure Mode

Shear tool Shear height

M758 shows Higher Shear Strength,
Failure mode shows equivalent
Suitable solder ball materials for **Wafer Level Package**

⇒ Eco Solder Ball M758

### Solder property

<table>
<thead>
<tr>
<th>Solder</th>
<th>Composition</th>
<th>Melting Temperature [°C]</th>
<th>Tensile Strength [MPa]</th>
<th>Elongation [%]</th>
<th>Young’s Modulus [GPa]</th>
<th>Thermal Conductivity [W/m · K]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Solidus</td>
<td>Liquidus</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SAC305</td>
<td>Sn-3.0Ag-Cu</td>
<td>217</td>
<td>220</td>
<td>53.3</td>
<td>56</td>
<td>47</td>
</tr>
<tr>
<td>SAC405</td>
<td>Sn-4.0Ag-Cu</td>
<td>217</td>
<td>229</td>
<td>47.9</td>
<td>49</td>
<td>49</td>
</tr>
<tr>
<td>M758</td>
<td>Sn-3.0Ag-Cu-Bi-Ni</td>
<td>205</td>
<td>215</td>
<td>80.7</td>
<td>24</td>
<td>53</td>
</tr>
</tbody>
</table>

**M758 TCT** : Significantly improved from SAC305 & SAC405

**M758 Drop Test** : Drop Performance is equivalent with the SAC305 & SAC405
[Reference] Thermal cycle test

PKG
S/F : Cu
Size : 7 x 7mm
Ball Size : 0.3mm dia.
Pitch : 0.5mm
SRO : 0.24mm (SMD)

PCB
Board : FR-4
Thickness : 0.6mm
S/F : Cu+ OSP
SRO : 0.24mm (SMD)

Assembly
Paste : S70G (SAC305 Rosin type paste)
Stencil Thickness : 100um

Test condition
Impact acceleration : -40°C/+125°C each 10min
Test number : N=15

The resistance of the Daisy Chain is measured. Initial resistance is 3-5Ω. When 15Ω is exceeded, it is judged as the breaks down.
[Reference] Drop test

The resistance of the Daisy Chain is measured. If the resistance exceeds 1.5 times of the initial one, cracking is assumed.

Test reflow profile

<table>
<thead>
<tr>
<th>Ball Attachment</th>
<th>Assembly</th>
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<tr>
<td>140~160°C[sec.]</td>
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</tr>
<tr>
<td>Over 220°C [sec]</td>
<td>40</td>
</tr>
<tr>
<td>Peak temperature [C]</td>
<td>245</td>
</tr>
<tr>
<td>Cooling Rate[C/sec.]</td>
<td>2~3</td>
</tr>
<tr>
<td>240°C → 220°C</td>
<td></td>
</tr>
<tr>
<td>Atmosphere</td>
<td>N2 Air</td>
</tr>
</tbody>
</table>

PKG: 7 x 7 mm SRO:0.25mm (SMD)
Ball Dia.: φ0.3mm
Board: 30 x 120 x 0.8 t mm
Board plating: Cu+OSP (NSMD)
Assembly paste: Sn-3.0Ag-0.5Cu-S70G
Impact acceleration: 1500G

PKG S/F: Cu

Reflow profile

Ball Attachment Assembly

Table

Drop

Impact acceleration: 1500G

Reflow profile

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</tr>
<tr>
<td>Atmosphere</td>
<td>N2 Air</td>
</tr>
</tbody>
</table>
Cu-Core Ball
SMIC “Cu core solder ball” has possibility that is used same solder ball process. The melting point of copper core is over 1,000°C, so it keeps the shape (stand off) after reflow.

This is a new solution for future bump development!
# Cu-Core Ball Features

<table>
<thead>
<tr>
<th>Normal bump</th>
<th>Electro Migration</th>
<th>Stand off space</th>
<th>Conductivity and heat dissipation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chip</td>
<td>Chip</td>
<td>Chip</td>
<td>Chip</td>
</tr>
<tr>
<td>Substrate</td>
<td>Substrate</td>
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</table>

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<tr>
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<td>Substrate</td>
<td>Substrate</td>
<td>Substrate</td>
</tr>
</tbody>
</table>

**Sn=10, Cu=64.5, Au=49, Bi=1 x10^-6 S/m (0 deg.C)**
Solder Volume, Pitch, Space

Solution..

3D packaging (CoC, TSV, PoP, TMV..)

Ball diameter = 1.25a

Pitch = 2a

SRO = a

Reflow

Bump bridge

Height ≤ a

Standard soldering

Stand off keeping

Cu core proposal

Friday, Sept. 6, 2013  Senju Metal Industry Co., Ltd.
Cu-Core Product Component

We can try φ0.03mm Cu ball.

<table>
<thead>
<tr>
<th>Part</th>
<th>Size or Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cu core</td>
<td>0.03~0.6mm</td>
</tr>
<tr>
<td>Ni Barrier</td>
<td>2um</td>
</tr>
<tr>
<td>Solder</td>
<td>Consult to us</td>
</tr>
</tbody>
</table>

ECO
- Sn, SAC, SA, SC

Low Temp
- Sn-Bi

Try
- others

The tolerance of Cu core ball is as same as that of solder ball.
Reliability Evaluation

M90 Plating
(Sn-3.0Ag-0.5Cu)
Test Sample Specification

C-Cu M90 (Cu-Cored Ball)

<table>
<thead>
<tr>
<th>Core (Cu)</th>
<th>Ni Plating-μm</th>
<th>Solder Plating-μm</th>
<th>Alloy Type</th>
<th>Total Size-μm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dia:250μm</td>
<td>2μm</td>
<td>23μm</td>
<td>Sn-3.0Ag-0.5Cu</td>
<td>300μm</td>
</tr>
</tbody>
</table>

M705 (Solid Solder Ball)

<table>
<thead>
<tr>
<th>Alloy Type</th>
<th>Total Size-μm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sn-3.0Ag-0.5Cu</td>
<td>300μm</td>
</tr>
</tbody>
</table>

※SAC305 plating on the Cu-Cored ball is called M90 in Senju brand. However, in the solid solder products name (include BGA Ball) of SAC305 is M705.
Drop Test Condition

PKG: 12 x 12 mm
   192pin 0.5mm pitch
Ball Dia.: φ0.3mm
Board: 30 x 120 x 0.8 t mm
Board plating: Cu+OSP (NSMD, SRO 0.24mm)
Assembly paste: Sn-3.0Ag-0.5Cu-S70G
Impact acceleration: 1500G

PKG Plating
- Cu-OSP
- Electrolysis Ni/Au (SMD, SRO 0.24mm)

The resistance of the Daisy Chain is measured. If resistance exceeds 1.5 times of the initial one, cracking is assumed.

Test reflow profile

<table>
<thead>
<tr>
<th>Ball Attachmente</th>
<th>Assembly</th>
</tr>
</thead>
<tbody>
<tr>
<td>140～160C[sec.]</td>
<td>20</td>
</tr>
<tr>
<td>Over 220C [sec]</td>
<td>40</td>
</tr>
<tr>
<td>Peak temperature [C]</td>
<td>245</td>
</tr>
<tr>
<td>Cooling Rate[C/sec.]</td>
<td>2~3</td>
</tr>
<tr>
<td>Atmosphere</td>
<td>N₂</td>
</tr>
</tbody>
</table>

Reflow profile

Impact acceleration: 1500G
Ball Attachment: 140～160C[sec.]
Assembly: 70

Reference: Senju Metal Industry Co., Ltd.
Drop Test Results (Comparison of Cu-Cored vs Solid Solder)

Cu-OSP: Cu-cored ball has better drop reliability than solid solder ball.

Electrolytic Ni/Au: Cu-cored ball has better drop reliability than solid solder ball.

PKG Plating: Cu-OSP

PKG Plating: Electrolysis Ni/Au

M90 (Sn-3.0Ag-0.5Cu)
### Drop Test Results

<table>
<thead>
<tr>
<th>PKG Plating</th>
<th>Cu-OSP</th>
<th>Electrolytic Ni/Au</th>
</tr>
</thead>
<tbody>
<tr>
<td>PCB Plating</td>
<td>Cu-OSP</td>
<td>Cu-OSP</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Pad</th>
<th>Crack Point</th>
<th>Pad</th>
<th>Crack Point</th>
<th>Pad</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cu-Cored Ball</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C-Cu M90</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Pad</th>
<th>Crack Point</th>
<th>Pad</th>
<th>Crack Point</th>
<th>Pad</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Solid Solder Ball</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M705</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

After Drop test, the crack point of Cu Core Ball is solder bulk. However, that of solid solder ball is joint interface. It is considered that the joint strength of Cu Core Ball raise up.
Thermal Cycle Test Condition

PKG
S/F : Cu-OSP
Ball Size : 0.3mm dia.
Pitch : 0.5mm
SRO : 0.24mm
Bump# : 192

PCB
Board : FR-4
Thickness : 0.6mmt
S/F : Cu-OSP

Assembly
Paste : M705-GRN360 K2-V (SAC305 Rosin type paste)
Stencil Thickness : 100um

Test condition
Impact acceleration : -40°C/+125°C each 10min
Test number : N=15

The resistance of Daisy Chain is measured. Initial resistance is 3-5Ω. When 15Ω is exceeded, it is judged as the breaks down.
TCT Results (Comparison of Cu-Cored vs Solid Solder)

**PKG Plating: Cu-OSP**
Cu-cored ball has equivalent TCT reliability to solid solder ball.

**PKG Plating: Electrolysis Ni/Au**
Cu-cored ball has equivalent TCT reliability to solid solder ball.

M90 (Sn-3.0Ag-0.5Cu)
After TCT, the crack point of Cu Core Ball is the edge of solder resist, and same as that of solid solder ball. Therefore, TCT reliability of Cu Core Ball is same as that of solid solder ball.
### TCT Result (PCB Side)

<table>
<thead>
<tr>
<th>PKG Plating</th>
<th>Cu-OSP</th>
<th>Electrolytic Ni/Au</th>
</tr>
</thead>
<tbody>
<tr>
<td>PCB Plating</td>
<td>Cu-OSP</td>
<td>Cu-OSP</td>
</tr>
</tbody>
</table>

#### Cu-Cored Ball
- **C-Cu M90**
  - Crack Point
  - Pad

#### Solid Solder Ball
- **M705**
  - Crack Point
  - Pad

---

After TCT, the crack point of Cu Core Ball is the edge of solder resist, and same as that of solid solder ball. Therefore, TCT reliability of Cu Core Ball is same as that of solid solder ball.
HnP Issue VS.
Solder Plating Thickness on Cu-Core
HnP Evaluation Condition

**Sample Spec.**

<table>
<thead>
<tr>
<th>Cu Ball Dia. [μm]</th>
<th>Ni Plating-t [μm]</th>
<th>Solder Plating-t [μm]</th>
<th>Composition</th>
<th>Cu Core Ball Dia. [μm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>250</td>
<td>2</td>
<td>20.5</td>
<td>Sn100%</td>
<td>295</td>
</tr>
<tr>
<td></td>
<td></td>
<td>25.5</td>
<td></td>
<td>305</td>
</tr>
</tbody>
</table>

**Reflow Condition**

**1st Reflow**
- Peak: 245°C
- 220°C over retention: 50 sec
- S/F: Cu-OSP
- SRO: 240μm
- Resist Thickness: 15μm

**2nd Reflow**
- Preheat: 180°C 150 sec
- Peak: 235°C
- Assembly Paste: M705 GRN360 K2-V
- S/F: Cu-OSP
- SRO: 240μm
- Resist Thickness: 15μm

1st Reflow Profile: SAC305 Ball Attach Profile
2nd Reflow Profile: HnP Evaluation Profile (Hard Preheat)

To evaluate HnP due to presence or absence of solder above the top of Cu-core bump.
### Results of HnP Evaluation

<table>
<thead>
<tr>
<th>Solder Plating-t</th>
<th>20.5μm</th>
<th>25.5μm</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Top</strong></td>
<td><img src="image1.png" alt="Image" /></td>
<td><img src="image2.png" alt="Image" /></td>
</tr>
<tr>
<td><strong>Side</strong></td>
<td><img src="image3.png" alt="Image" /></td>
<td><img src="image4.png" alt="Image" /></td>
</tr>
<tr>
<td><strong>1st Reflow Bump</strong></td>
<td><img src="image5.png" alt="Image" /></td>
<td><img src="image6.png" alt="Image" /></td>
</tr>
<tr>
<td>1st Reflow Bump</td>
<td><strong>Lack of Solder at Cu-Core bump top</strong></td>
<td><strong>Enough Solder at Cu-Core bump top</strong></td>
</tr>
<tr>
<td><strong>2nd Reflow Bump</strong></td>
<td><img src="image7.png" alt="Image" /></td>
<td><img src="image8.png" alt="Image" /></td>
</tr>
<tr>
<td><strong>Results</strong></td>
<td><strong>HnP</strong></td>
<td><strong>No HnP</strong></td>
</tr>
</tbody>
</table>
The flux reflow of Cu core ball shows good coplanarity. When the solder quantity increases, coplanarity of the bump height is the same as the case of the solder ball reflow.
• Joint Protect Solder Paste/Flux
• Paste/Flux for POP/TMV
JPP/JPK Joint Protect Paste/Paste

Concept

Flux is consist of Epoxy resin
Residue after Reflow(cure) improves,,,,

✓ Joint strength
✓ Perfect adhesion with under-fill materials
✓ SAC or SnBi alloy is available for JP paste
✓ Halogen Free and meet RoHS and REACH
Dippable paste for PoP/TMV process

- Stretchable solder paste/flux Rheology
- Eliminate POP/TMV non-wet and HiP issue
- Halogen Free and meet RoHS and REACH
Thank you very much!!!

SMIC-HQ
Technical center
A New Embedded Package Structure and Technology for Next Generation of WLP, The Wafer Level Fun-out Package - WFOP™

J-DEVICES CORPORATION
Packaging Research & Development Center
Akio Katsumata
Contents

1. J-DEVICES’ Semiconductor Packaging Roadmap
2. J-DEVICES’ FO-WLP Development Concept
3. WFOP™ Characteristics
4. Design Rule
5. Target Applications
6. Conclusion
J-DEVICES’ Semiconductor Packaging Roadmap
• The technology requirements for semiconductor packages for example higher data transfer, lower thermal resistance and higher reliability are increasing.
• Bump connection and RDL are key technologies to realize the next generation semiconductor packages.
J-DEVICES’ FO-WLP Development Concept
Validity of FO-WLP Technology

✓ Package design of FO-WLP is INDEPENDENT from chip size
  ➔ Fan-In WLPs are chip size package. All balls must fit UNDER chip shadow.

✓ Large panel assembly
  ➔ Larger throughput

  The pin unit price of a package falls drastically with enlargement of the panel size.

✓ Design flexibility
  ➔ Redistribution layer easily forms 2D & 3D design.

✓ Suitable for low package profile demand
  ➔ No need for wire bonding height and substrate thickness.
J-DEVICES’ FO-WLP Development Concept

- Connect to Finer Pad Pitch
  50um Pad Pitch is achievable

- Higher density RDL
  L/S=20/20(um) is achievable

- Better thermal performance than molded BGA

- Better EMI Shielding effect

- 3D Packaging capability
  Die stack structure is achievable
J-DEVICES’ WFOP Technology

**Package Structure**

- **Backside view**
- **Top view of chip area (Line width: 20 um)**
- **Pad interconnection**
- **SEM image**
- **Panel appearance**

- **Redistribution layer**
- **Metal Base Plate**
- **Resin**
- **Die**
- **Adhesive**
- **Solder Ball**

**J-DEVICES’ Advantage**

- RDL is directly connected to the pad.
- RDL technology is based on PCB technology which makes it cost-competitive.
- Manufacturing work uses large panel.
- 50um pad pitch interconnection technology is already developed.
J-DEVICES’ WFOP™ Technology
WFOP™ has two kinds of interconnection methods. (Lead-finger type and Via type)

- The purpose of developing Lead-finger type is to realize finer connection to device pad.
- The purpose of developing Via type is selection flexibility to dielectric resin.
WFOP™: Redistribution layer for 50um Pad pitch
# Comparison table of WFOP™ and Other FO-WLP

<table>
<thead>
<tr>
<th>Package Cross-section</th>
<th>Other FO-WLP</th>
<th>WFOP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Influence of die shift problem caused by mold resin shrinkage</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Other FO-WLP</th>
<th>WFOP</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Thermal</td>
<td>-</td>
<td>much better</td>
</tr>
<tr>
<td>2) EMI Shielding</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Work Size</th>
<th>Φ200mm, Φ300mm</th>
<th>320mm x 320mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>RDL Technology</td>
<td>Semiconductor photolithography</td>
<td>PCB Technology</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Application</th>
<th>Only Side by side</th>
<th>Not only side by side</th>
</tr>
</thead>
</table>
WFOP™ Characteristic
The thermal resistance of WFOP™ is decreased because metal plate effectively functions as a heat-spreader.
WFOP™: “EMI shielding” Effect of Metal Plate

Simulation results (Magnetic field)

Package size: 12 x 18mm
Die size: 1.4 x 4.5mm
Frequency: 1GHz

- The better shielding effect of WFOP™ is verified by simulation.
WFOP™: “EMI shielding” Effect of Metal Plate

Simulation results (Electric field)

- Package size: 12 x 18mm
- Die size: 1.4 x 4.5mm
- Frequency: 1GHz

![Graph showing electric field comparison between WFOP and FBGA](image)

- The better shielding effect of WFOP™ is verified by simulation.
**Solder Joint Reliability**

Warpage problem of current BGA Package

- Warpage direction is different because of environment temperature.
- Shape of solder joint is affected by warpage.
  → Even solder joint get higher reliability.

The relationship between environment temperature and package warpage.
**Solder Joint Reliability**

**Advantage of WFOP™**

1) The package warpage caused by the environment temperature change is small because the metal plate has high elasticity.
2) C.T.E of the metal plate is adjustable to that of the mother board.

WFOP™ achieves improved solder joint reliability by optimizing the material property of metal plate.

---

**Warpage Variation on TCT Condition (125°C⇔-25°C)**

<table>
<thead>
<tr>
<th>Motif</th>
<th>FBGA</th>
<th>WFOP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Package size : 12x18</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Die size : 10x16mm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Solder ball : 132pin</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Deformed Shape at -25°C (Corner Ball)

<table>
<thead>
<tr>
<th>Temp.</th>
<th>FBGA</th>
<th>WFOP</th>
</tr>
</thead>
<tbody>
<tr>
<td>125°C</td>
<td><img src="image" alt="FBGA_125°C" /></td>
<td><img src="image" alt="WFOP_125°C" /></td>
</tr>
<tr>
<td>-25°C</td>
<td><img src="image" alt="FBGA_-25°C" /></td>
<td><img src="image" alt="WFOP_-25°C" /></td>
</tr>
</tbody>
</table>

*Comparison with original shape*
Design Rule
Cross-section Design Rule

<table>
<thead>
<tr>
<th>Parts</th>
<th>Nominal (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>Base Plate</td>
</tr>
<tr>
<td>b</td>
<td>DAF</td>
</tr>
<tr>
<td>c</td>
<td>Die</td>
</tr>
<tr>
<td>d1</td>
<td>Resin 1</td>
</tr>
<tr>
<td>d2</td>
<td>Resin 2</td>
</tr>
<tr>
<td>e</td>
<td>Solder resist</td>
</tr>
<tr>
<td>f</td>
<td>Cu layer</td>
</tr>
<tr>
<td>g</td>
<td>Stand off</td>
</tr>
<tr>
<td></td>
<td>Pakcage height</td>
</tr>
</tbody>
</table>
## Design Rule to connect Peripheral Pad

<table>
<thead>
<tr>
<th>Current Design Rule</th>
<th>Next generation</th>
</tr>
</thead>
<tbody>
<tr>
<td>50um pitch</td>
<td>45um pitch</td>
</tr>
</tbody>
</table>

### Current Design Rule
- **Die**
- **Die pad**
- **Pad opening (opening collectively)**
- **L1 Copper pattern**
  - L/S = 20um/20um
- **Via land [80um dia.]** (adjacent solder ball)

### Next generation
- **Die**
- **Die pad**
- **Pad opening (opening collectively)**
- **L1 Copper pattern**
  - L/S 15um/15um\(^*1\)
  - 18um/18um\(^*2\)
- **Via land [70um\(^*1\)/65um\(^*2\) dia.]** (adjacent solder ball)

*\(^1\): option-1, \(^2\): option-2
Design Rule to connect Area Pad

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Item</th>
<th>Design value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Current</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Option-1</td>
</tr>
<tr>
<td>Line width</td>
<td>20um</td>
<td>20um</td>
</tr>
<tr>
<td>Line space</td>
<td>20um</td>
<td>20um</td>
</tr>
<tr>
<td>C</td>
<td>Die pad opening diameter</td>
<td>50um</td>
</tr>
<tr>
<td>D</td>
<td>Via land diameter</td>
<td>80um</td>
</tr>
<tr>
<td>E</td>
<td>Via land diameter</td>
<td>80um</td>
</tr>
<tr>
<td>F</td>
<td>Via diameter</td>
<td>50um</td>
</tr>
<tr>
<td>G</td>
<td>Via land - line space</td>
<td>20um</td>
</tr>
<tr>
<td>H</td>
<td>Via pitch</td>
<td>100um</td>
</tr>
<tr>
<td>I</td>
<td>Ball land diameter</td>
<td>Refer other page</td>
</tr>
<tr>
<td>J</td>
<td>Ball land - line space</td>
<td>20um</td>
</tr>
<tr>
<td>K</td>
<td>Ball land – via land space</td>
<td>0um</td>
</tr>
<tr>
<td>K’</td>
<td>Ball land – via land space</td>
<td>20um</td>
</tr>
</tbody>
</table>

Pad connect (Area pad)  Via (Interlayer connect)  Ball land

Die pad

Pad opening (opening separately)
Target Applications
<table>
<thead>
<tr>
<th><strong>J-DEVICES’ WFOP™ Package Structure</strong></th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Application</th>
<th>Logic</th>
<th>Memory</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>F CBGA</strong></td>
<td><strong>PoP</strong></td>
<td></td>
</tr>
<tr>
<td>Replace Package</td>
<td><img src="image1.png" alt="Image" /></td>
<td><img src="image2.png" alt="Image" /></td>
</tr>
<tr>
<td>Cross-section</td>
<td><img src="image3.png" alt="Image" /></td>
<td><img src="image4.png" alt="Image" /></td>
</tr>
<tr>
<td><strong>Advantage</strong></td>
<td>• Thinner</td>
<td>• Multi-Channel</td>
</tr>
<tr>
<td></td>
<td>• Better Electrical Performance</td>
<td>• Reduce Thermal Resistance</td>
</tr>
<tr>
<td></td>
<td>• Design Flexibility</td>
<td>• Better Electrical Performance</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• EMI shielding effect</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Thinner/Smaller</td>
</tr>
</tbody>
</table>
WFOP™ for High Performance Logic

- No need for bump and package substrate.
- Like core-less substrate structure. Reduced capacitance and inductance of wiring.

<table>
<thead>
<tr>
<th>Material</th>
<th>Thickness (Height)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metal base plate</td>
<td>300um</td>
</tr>
<tr>
<td>Ball Stand-off (1mm pitch)</td>
<td>500um</td>
</tr>
<tr>
<td>Die</td>
<td>50um</td>
</tr>
<tr>
<td>Cu wiring</td>
<td>12um</td>
</tr>
<tr>
<td>Interlayer insulator</td>
<td>18um</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>RDL 2layers</th>
<th>RDL 3layers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Package Total Height</td>
<td>935um</td>
<td>965um</td>
</tr>
</tbody>
</table>
WFOP™ for High Performance Logic

WFOP™
- Base plate
- Die
- RDL
- Solder ball

FC-BGA
- LID
- TIM
- Die
- Solder bump
- Substrate
- Solder ball

1mm
Method: Shadow Moire
Temperature: 30 degC – 260 degC (Reflow top) -40 degC

Resin’s Tg =130 degC and 150deg. So the profile changes so much here.
**WFOP™ for High Performance Memory Module**

- Enables “Die stack module” without TSV structure.
- Enables higher multi-channel memory module without custom memory devices.
- Lower Thermal Resistance and high EMI shielding performance.

### Material Thickness (Height)

<table>
<thead>
<tr>
<th>Material</th>
<th>Thickness (Height)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metal base plate</td>
<td>300um</td>
</tr>
<tr>
<td>Ball Stand-off (1.0mm pitch)</td>
<td>320um</td>
</tr>
<tr>
<td>Die</td>
<td>50um</td>
</tr>
<tr>
<td>Cu wiring</td>
<td>15um</td>
</tr>
<tr>
<td>Interlayer insulator</td>
<td>15um</td>
</tr>
</tbody>
</table>

| Package Total Height            | 1055um             |
| RDL 3layers                     |                    |
Method: Shadow Moire
Temperature: 30 degC – 260 degC (Reflow top) –40 degC

Shadow Moire

Heating

Cooling

N = 9p

Temperature [°C]

Warpage [μm]

30 degC

260 degC

125 degC

40 degC

Cry (+)

Smile (−)
Package Reliability Test Result

Test Vehicle

<table>
<thead>
<tr>
<th>Item</th>
<th>Test Conditions</th>
<th>Test Result(NG)</th>
<th>100cyc /168h</th>
<th>300cyc /312h</th>
<th>500cyc /500h</th>
<th>700cyc/712h</th>
<th>1000cyc/1000h</th>
</tr>
</thead>
<tbody>
<tr>
<td>TCT</td>
<td>MRT1+TCT</td>
<td>-55degC/125degC</td>
<td>0NG/22</td>
<td>0NG/22</td>
<td><strong>0NG/22</strong></td>
<td>0NG/22</td>
<td>0NG/22</td>
</tr>
<tr>
<td></td>
<td>MRT2+TCT</td>
<td>-55degC/125degC</td>
<td>0NG/11</td>
<td>0NG/11</td>
<td><strong>0NG/11</strong></td>
<td>0NG/11</td>
<td>0NG/11</td>
</tr>
<tr>
<td>PCT</td>
<td>MRT1+PCT</td>
<td>110degC/85%/1.2atm</td>
<td>0NG/22</td>
<td>0NG/22</td>
<td><strong>0NG/22</strong></td>
<td>0NG/22</td>
<td>0NG/22</td>
</tr>
<tr>
<td></td>
<td>MRT2+PCT</td>
<td>110degC/85%/1.2atm</td>
<td>0NG/10</td>
<td>0NG/10</td>
<td><strong>0NG/10</strong></td>
<td>0NG/10</td>
<td>0NG/10</td>
</tr>
<tr>
<td>HTS</td>
<td>MRT1+HTS</td>
<td>150degC</td>
<td>0NG/22</td>
<td>0NG/22</td>
<td>0NG/22</td>
<td>0NG/22</td>
<td><strong>0NG/22</strong></td>
</tr>
</tbody>
</table>

MRT1:30degC/70%/216h+Reflow4times
MRT2:30degC/70%/144h+Reflow+30degC/70%/96h+Reflow

No failure was observed under these test conditions.
Conclusion

- The technology requirements for semiconductor packages for example higher data transfer, lower thermal resistance and higher reliability are increasing. Bump connection and RDL are key technologies to realize next generation packages.

- Panel scale assembly is a new solution to change the packaging manufacture style. (from One by One to Batch Processing)

- The development concept of WFOPTM is connect to finer pad pitch, better thermal performance, better EMI shielding and 3D packaging capability.

- Internal reliability test was already finished. J-DEVICES is promoting this technology for next generation devices.
END