Micro Ball Bumping for Wafer Level & 3-Dimensional Applications using Solder Sphere Transfer and Solder Jetting

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6th June 2013
Outline

- Solder Bumping/Balling Processes
  - Wafer Level Solder Sphere Transfer (WLSST)
    - Flip Chip Test Vehicle
    - Flip Chip Assembly
    - Reliability Results
  - Solder Jetting (SB²)
    - Stacked Chips
    - Camera Modules
    - Hard Disk Drives (HGA, HSA, Hook-Up)
- Summary
Wafer Level Solder Sphere Transfer 1/3

Vacuum picking of solder spheres from reservoir to stencil

Removal of excess balls by US & optical inspection of balls in stencil

Vacuum

Solder Ball

Bond Tool

Mask

Vibration

Floating Solder Balls by US

Jumping Solder Balls by Air knife

Air knife

Wafer Level Solder Sphere Transfer 1/3

Vacuum picking of solder spheres from reservoir to stencil

Removal of excess balls by US & optical inspection of balls in stencil

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Floating Solder Balls by US

Jumping Solder Balls by Air knife

Air knife
Wafer Level Solder Sphere Transfer 2/3

Placement of solder spheres & optical inspection of balls on wafer

Per robot back to cassette

Next step: Reflow

Solder Ball

Bond Tool

Mask

Flux

Wafer

UBM
Ultra-SB² 200/300

Dual endeffector & Prealigner

200/300mm wafer chuck

Stencil mounted on vacuum transfer head
# Flip Chip Test Vehicle

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Die Thickness</td>
<td>0.8 mm</td>
</tr>
<tr>
<td>Die Size</td>
<td>10 mm x 10 mm</td>
</tr>
<tr>
<td>Pitch</td>
<td>100 µm</td>
</tr>
<tr>
<td>UBM / Solder-Alloy</td>
<td>NiAu / SAC305</td>
</tr>
<tr>
<td>Bump Count (Chip / Wafer)</td>
<td>360 / 99,720</td>
</tr>
<tr>
<td></td>
<td>354 / 98,058</td>
</tr>
<tr>
<td>Bump Array</td>
<td>Peripheral</td>
</tr>
<tr>
<td>Daisy Chain</td>
<td>Yes</td>
</tr>
<tr>
<td>Dies per Wafer</td>
<td>277</td>
</tr>
</tbody>
</table>

Substrates: FR4 and thin film ceramic with Au finish

- Pad for 60µm spheres
- Pad for 50µm spheres
- Pad for 40µm spheres
- Pad for 30µm spheres
## Solder Bumping Processes

<table>
<thead>
<tr>
<th>WLSST</th>
<th>SB²</th>
</tr>
</thead>
<tbody>
<tr>
<td>60µm solder spheres</td>
<td>30µm solder spheres</td>
</tr>
<tr>
<td>50µm solder spheres</td>
<td></td>
</tr>
<tr>
<td>40µm solder spheres</td>
<td></td>
</tr>
</tbody>
</table>

- Lead-free solder spheres (SAC305)
- 60, 50 & 40µm solder spheres placed with WLSST technology
- SB² process successfully proven for 30µm solder bumps
- SB² process suitable for 3-dimensional packages/applications
Flip Chip Assembly

All flip chips were mounted using an automated assembly process in an industrial environment

Flip Chip on FR4 after placement
FC Assembly on FR4

Limitations of PCB technology below 50µm bumps:

- Thickness of the solder mask (about 15µm)
- Tolerances of the openings in the solder mask
- Solder mask registration tolerances

Misalignment and irregular shape of the solder bumps
FC Assembly on Thin Film Ceramic

40µm solder spheres after reflow and underfill

- Low tolerances of thin film structures
- Not wettable metal oxide instead of solder mask

very high yield achieved with 40µm solder bumps on TFC
FC Assembly on Thin Film Ceramic

30µm solder spheres after reflow and underfill

30µm solder spheres, Initial state (0 hours)

Assembly of 30µm solder bumps on Thin Film Ceramic with high yield possible
## Reliability Test Procedures

<table>
<thead>
<tr>
<th>Test #</th>
<th>Method</th>
<th>Description</th>
<th>Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>EIA/JESD22-A101-B</td>
<td>Voltage between two daisy chains</td>
<td>85 °C/85 % r. humidity, 3 V</td>
</tr>
<tr>
<td>2</td>
<td>EIA/JESD22-A101-B</td>
<td>Life test, with current through the daisy chain</td>
<td>85 °C/85 % r. humidity, 100 mA</td>
</tr>
<tr>
<td>3</td>
<td>MIL-STD 883G, meth. 1010.8, c. B</td>
<td>Temperature cycling</td>
<td>-55 °C/ +125 °C</td>
</tr>
<tr>
<td>4</td>
<td>MIL-STD 883G, meth. 1005.8</td>
<td>Dry heat storage</td>
<td>+125 °C, 1000 hours</td>
</tr>
</tbody>
</table>
SEM Analysis of Flip Chips – 40µm

Initial state after reflow soldering

After 1,000 hours dry heat storage at 125 °C

Still ductile solder in solder joint
Reliability with 40µm Solder Bumps

Cross sections after temperature cycles according to MIL-STD883 (-55 °C/+125 °C):

- Flip Chip Thin film ceramic
  - after 2,000 hours
- Flip Chip Thin film ceramic
  - after 6,000 hours
- Flip Chip Thin film ceramic
  - after 10,000 hours

No cracks could be found
Flip Chip with 30µm Solder Bumps

Initial state after reflow soldering

Bumps after 1,000 cycles (-55 °C/+125 °C)

No cracks could be found
Solder Jetting (SB²) 1/2

Schematic diagram of **Solder Ball Bumping (SB²)** process:

- **Ball Reservoir**
- Optical sensor
- Laser
- Singulation Disk
- Optical sensors
- **N₂ gas**
- **Reflowed solder balls**
- Capillary
- **N₂**
- **Pressure sensor**
- Search level
- Bond level
- Semiconductor wafer
- Bond pad
Solder Jetting (SB²) 2/2

Process video for solder jetting and solder stacking

Movie starts with mouse click
Soldering of stacked chips

Pin soldering of two stacked chips
PIN-Soldering

Pin soldering onto organic substrate
3D-HGA Soldering for HDD

Soldering Read-Write Head of a Hard Disk Drive (HDD)
CMOS Camera Market

Mobile phone camera evolution

The evolution of the mobile phone camera has experienced a rapid decrease in size and cost.

Where CMOS Image Sensor Sales Are Going

2009 Market ($3.9B)
- Optical Mouses 3%
- Toys & Video Games 1%
- Industrial 3%
- Medical & Scientific 2%
- Other 2%
- Security Cameras 2%
- Digital Cameras (Still & Video) 6%
- Camera Phones & PDAs 74%

2014 Market ($8.3B, Fcst)
- Optical Mouses 2%
- Toys & Video Games 3%
- Industrial 4%
- Medical & Scientific 3%
- Automotive 17%
- Other 5%
- Camera Phones & PDAs 47%

Source: IC Insights

In M units

- EDoF
- Reflow
- with A/F
- Total camera
- VGA
- 1.3M
- 2.0M
- 3.0M
- 5.0M
- 8.0M
- 12M

Source TSR

2009
- 976
- 1150
- 1344
- 1542
- 1745

2010
- 303
- 455
- 555
- 628

2011
- 370
- 455
- 555
- 628

2012
- 230
- 368
- 510

2013
- 70
- 90

Source TSR
Camera Module – Terminal Soldering

VCM Terminal Contacts
Camera Module – Terminal Soldering

Camera Module before solder jetting

Camera module after solder jetting

Movie starts with mouse click
Camera Module Bonding with 600µm solder ball

Reliable wetting on the pre-soldered ground pad as well as on the titanium pin.

No burnings or discoloration of the epoxy material around the solder connection, pad or pin.

Minimized influence of alternating quality of the pre-soldered ground pad, with 600µm solder spheres.
Camera Module Bonding with 2x 300µm solder ball
Hook-Up-Soldering for HDD (1/5)

- Solder jetting with 2x 760µm
- Solder alloy SAC305

- Solder jetting with 1x 760µm
- Solder alloy SAC305
Hook-Up-Soldering for HDD (2/5)

- Solder jetting with 2x 760µm
- Solder alloy SAC305
Hook-Up-Soldering for HDD (3/5)

Solder Jetting FPC

- Solder jetting with 1x 760µm
- Solder alloy SAC305
Hook-Up-Soldering for HDD (4/5)

- Middle pad with 3x solder ball stacking, each 760µm
- Wire soldering left and right with 1x 760µm
- Solder alloy SAC305
Solder Jetting VCM

- Middle pad with 3x solder ball stacking, each 760µm
- Wire soldering left and right with 1x 760µm
- Solder alloy SAC305
Summary

• Solder Balling Processes for solder spheres down to 30µm have been introduced

• Wafer Level as well as 3-Dimensional Applications can be processed by either WLSST or Solder Jetting

• Results of assembled flip chips on FR4 and thin film ceramic were presented

• Flip chip assemblies have passed reliability tests according MIL-STD883G

• Various applications for 3D-Solder Jetting using different solder ball sizes have been shown
Thanks for your attention.