300mm Wafer – Electroless Bumping

T. Teutsch, E. Zakel, T. Oppert

Internepcon 2005
January 19, 2005
Tokyo Big Sight, Japan

Pac Tech GmbH
Outline

- Short Company Profile
- Introduction
- Electroless Ni/Au Under Bump Metallization (UBM for Copper Devices)
- Solder Bumping: Stencil Printing & Ball Placement
- Wafer Level RDL
- Interface for Wirebonding Application
- Outlook: Stacking, Via Filling, Micro Ball Placement
- Summary
# Corporate Profile

PacTech GmbH & PacTech-USA Inc.

<table>
<thead>
<tr>
<th>Berlin (D)</th>
<th>Nauen (D)</th>
<th>Santa Clara, CA (USA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dept. Equipment Development &amp; Production</td>
<td>Dept. Bumping &amp; Redistribution Service</td>
<td>Bumping Service &amp; Equipment Sales Center</td>
</tr>
<tr>
<td>• Solder Ball Bumper: SB²-Jet, SB²-SM</td>
<td>• Electroless Ni/Au Bump</td>
<td>Equipment Sales &amp; Service</td>
</tr>
<tr>
<td>• Flip Chip Placer: LAPLACE, MAPLACE</td>
<td>• Solder Stencil Printing</td>
<td>• Laser Microassembly &amp; Equipment Demo Center</td>
</tr>
<tr>
<td>• Electroless Bumping Line PacLine 2000</td>
<td>• Solder Ball Placement</td>
<td></td>
</tr>
<tr>
<td>• Laser Wafer Marking System: LS²</td>
<td>• Wafer Sawing &amp; Scribing</td>
<td>Wafer Bumping Service</td>
</tr>
<tr>
<td></td>
<td>• Wafer Level RDL &amp; CSP</td>
<td>• Electroless Ni/Au</td>
</tr>
<tr>
<td></td>
<td>• FC-Assembly</td>
<td>• Solder Stencil Printing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Solder Ball Placement</td>
</tr>
</tbody>
</table>

- Equipment Sales & Service
- Laser Microassembly & Equipment Demo Center
- Wafer Bumping Service
- Electroless Ni/Au
- Solder Stencil Printing
- Solder Ball Placement
Pac Tech Germany – Production Site
Berlin (Equipment Manufacturing)
Pac Tech Germany – Production Site Nauen (HQ & Wafer Bumping Subcon. Service)
Pac Tech Germany Nauen - Cleanroom
PacTech-USA

- Bumping & Technology Services
- Equipment Sales: SB², Pacline, etc.
- Process Licensing & Technology Transfer
- Training & Support

- 10,000 ft² floorspace
- 2,000 ft² cleanroom
- class 10,000

328 Martin Avenue
Santa Clara, CA 95050
Phone: 408-588-1925
www.pactech-usa.com
Worldwide Use of Electroless Ni & Solder bumping

Distribution

- USA (30%)
- Europe (40%)
- Asia (30%)

Applications

- Memory 12.5%
- RFID 20%
- Pass. Comp./CSP's 20%
- MOSFET 10%
- LCD Driver 2.5%
- ASIC 22.5%
- Medical 12.5%

Implementation Status

- Production 50%
- Qualification 30%
- Prod. Ramp Up 20%

Main Customers
Introduction

• **Low K**
  - Dielectric Performance
  - Wafer Redistribution
  - Solder Bumping: Low Alpha, Lead-free
  - Wafer Size: 300mm, Tooling, Prototyping

• **Copper**
  - Under Bump Metallization
  - Wire Bondability
  - Wafer Size: 300mm, Tooling, Prototyping

• **Next Generation**
  - Stacking & Via Filling
  - High I/O count
Under Bump Metallization for 300mm

Challenges: Copper Pad Metallization, Organic Passivation, Homogeneity

Process: Electroless Ni/Au UBM
Electroless UBM Advantages

- Maskless Process (Simplicity)
- No Sputtering
- Low Initial Capital Investment
- Quality/Reliable/Proven Chemistries
- Suitable for Solder Bumping & Adhesives
- Half the Cost of Electrolytic Plating
- Wire bondable
- Fastest and Most Cost Effective Method
Under Bump Metal Process

Electroless Plating of Ni/Au Bumps

Backside Coating

Copper Cleaning (Oxides, CMP)

Paladium Pretreatment

Electroless Nickel

Immersion Gold

Coating Removal
Electroless UBM Advantages

- Maskless Process (Simplicity)
- No Sputtering
- Low Initial Capital Investment
- Quality/Reliable/Proven Chemistries
- Suitable for Solder Bumping & Adhesives
- Wire bondable Interface
- Less cost than Electrolytic Plating
- Fastest and Most Cost Effective Method

- 150 Wafers / hour
- 4” – 12” Capability
- SECS GEM
- 300mm Handling
- SPC Sofware
Ni/Au Bump height measurements on a 12” Wafer

**UBM Height Measurements:**
- 21 Areas
- Samples/Area: 10
- Sample Size: 210
- Mean Value (μm): 9.71
- 3 Sigma (μm): ±0.41

**Shear Force Values:**
- 21 Areas
- Samples/Area: 20
- Sample Size: 420
- Mean Value (g): 124
- Sigma (g): ±15
Distribution of Ni bump height on a 12” Wafer

- Mean Value: 9.71 μm
- 3 Sigma: 0.49 μm
**Fully automated 300mm Equipment Concept**

**PacLine 300 A50**

- High Troughput: 75 wafers/h
- Automated Cassette to Cassette Wafer Handling
- Wafer Drying
- SECS GEM
- Improved Wafer DI Water Rinse by US Activation
- High Speed Profibus Internal Communication
Paceline 300 - A 50

6 Bumpng Systems in the Field
Solder Bumping

Challenges:
- Low Alpha
- Lead-Free
- High I/0 Count

Process:
- Stencil Printing
- Solder Ball Placement
Comparison of Solder Bumping Technologies

- **Evaporated Solder Bump**
  - C4 Solder
  - Solder
  - Au

- **Sputtered UBM + Plating**
  - Solder
  - Au

- **Sputtered UBM + Print (FCT)**
  - Solder

- **Electroless UBM (+) Print or Ball Attach**
  - Solder
  - Ni/Au
New Solder Bump Material Requirements

- **Lead-Free Solders**
  - Ternary & Quaternary Alloy Systems
    - stencil printing or ball placement
  - Type 6 & 7
  - Availability
  - Design & Assembly
  - Reflow & Flux Cleaning

- **(Ultra) Low Alpha**
  - Availability
  - Price
  - Qualification / Certification

SnAgCu Bumps
Certified DIN EN ISO 9001
Internepcon 2005
Tokyo, Japan

Stencil Solder Printing or Gang Solder Ball Placement
Process Flow

Electroless Ni/Au Bumping

Solder Paste (Flux) Printing
(Solder Ball Attach)

Reflow

Wafer Cleaning

Wafer Inspection

Pack & Ship

300 mm Capability!
PbSn 63/37 vs. Lead-free Solders
A Feasibility Study under Production Conditions

Bump Yield (8” Wafer)

<table>
<thead>
<tr>
<th>Bump Yield Loss [ppm]</th>
<th>SnAg4Cu0.5</th>
<th>Sn37Pb63</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wafer Type I</td>
<td></td>
<td></td>
</tr>
<tr>
<td>250um Pitch</td>
<td>0 - 55</td>
<td>0 - 110</td>
</tr>
<tr>
<td>I/0 count: 30,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wafer Type II</td>
<td>120 - 150</td>
<td>95 - 120</td>
</tr>
<tr>
<td>225um Pitch</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I/0 count: 30,000</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Bump Height Distribution:

typ. +/- 10µm @ 3 Sigma
slightly better for lead-free
Solder Bumping Roadmap

Main Challenge: High Pad Count / Pad Density

- **Stencil Printing**
  - Paste Material
  - Stencil Technology
  - Printer Accuracy
  - Stencil Cleaning
  - Solder Paste Transfer
  - Yield

- **Gang Ball Placement**
  - Micro Ball Placement
  - Cost
  - Equipment Availability
  - Yield / Repair
  - Inspection
Wafer Level Redistribution

Challenges:
- Low-K Dielectric Layer
- Throughput / Speed
- Tooling
- => Low Cost

Processes:
- (BCB) / Al / BCB
- Epoxy / Electroless Cu/ Epoxy
- Electroless Ni/Au UBM
Process Flow Overview - ElastoPAC

Epoxy / Cu / Epoxy

- Ni/Au - Bumping of Bond Pads
- Spinning of Dielectric Layer
- Photo Imaging: Opening of Ni/Au Bond Pads
- Formation of Seed Layer
- Full Area Copper Deposition
- Resist Spinning and Photo Structuring
- Copper Etching
- Solder Mask Spinning and Photo Imaging
- Ni/Au - Bumping of Redistributed Pads
- Solder Stencil Printing or Ball Placement
2nd Ni/Au-Bumping
Cu Wire Bonding

Challenges:

Wire Bondability of Copper Pad

Other Solutions:

Cu Wire Bonding
  => feasibility, reliability
Al sputtering on Cu Pad
  => Cost

Best Solution:

Wire Bondable Low Cost Interface
  => Electroless Ni/Au
Au Wire Bonding on Electroless Ni/Au Layer

• Surface Treatment
  – Ni/Au UBM
  – Ar Plasma Cleaning/Activation
  – Lowest Cost
  – Acceptable Bond Window
  – Process has to be optimized for thin Au layer

• Thick Au Finish
  – Ni/Au UBM
  – High Chemistry Cost
  – Chemistry Performance
  – Longer Processing Time
  – Broad Bond Window
  – Good Reliability

• Pd Layer
  – Ni/Pd/Au UBM
  – Broad Bond Window
  – Reasonable Cost / Reliability Ratio
  – Prototyping Status on Wafer-level
Thick Au Finish

Shear modes of Au Stud Bumps

Au: 0.1µm - 0.2µm

Bond Parameter:
- US-Time: 140 ms
- US-Power: 150 mW
- Bond Force: 30 cN
- Stage Temperature: 100 °C
Outlook

New Applications: e.g. Die Stacking

Requirements:
• Electroless Ni/Au UBM for Via Filling
  => Na free, low Phosphorous
  => Small Structure Plating Capability
Summary

300mm Capability
already in production,
cost effective bumping process & equipment
Excellent UBM Quality (height distribution)

Copper Pad Metalization
low cost process, no tooling, easy transferable (Al)

Bumping Process for low K
UBM and Solder (stencil printing or ball placement)

Redistribution
low cost, less tooling

Wire Bonding
cost, flexibility