Eless NiPd and NiPdAu OPM: A Low Cost, High Throughput Solution for Enhanced Gold and Copper Wire Bond Reliability

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Pac Tech – Packaging Technologies
Outline:

• Overview of the Electroless Ni/Au and Ni/Pd/Au Process
• Electroless Ni/Au and Ni/Pd/Au for Wirebonding
• Summary
High Temperature/Power Electronics

Business Sectors:
- Defense & Aerospace
- Automotive
- Oil Well & Geothermal
- Solid State Lighting
- Motor Control

Interconnect Technologies:
- Wirebonding
- Solder Bumping
- Clip Attach

Interface:
- e-NiAu
- e-NiPdAu
**Electroless Nickel Process**

**e-Ni/Au Process on Aluminum:**

1) Passivation Clean  
2) Al Etch  
3) Zincate  
4) Zn stripper  
5) Zincate  
6) Electroless Ni  
7) Electroless Pd  
7) Immersion Au

**e-Ni/Au Process on Copper:**

1) Passivation Clean  
2) Copper Clean  
3) Catalysis  
4) Electroless Nickel  
5) Electroless Pd  
5) Immersion Gold

**Wet Chemical Process**

Sequential Steps  
Robotic Control  
Chemistry Control  
>50 wafers/hour
Electroless Nickel and Immersion Gold (or Pd) Process on Aluminum

1) Pass Clean
2) Al Etch
3) Zincate
4) Zn Strip
5) Zincate II
6) Ni Plate
7) Gold (Pd) Plate

Ni/P Autocatalytic Reaction

Zn - Al Replacement

Au or Pd

Ni – Zn Replacement

Si, Organics

Incoming
Electroless Nickel and Immersion Gold (or Pd) Process on Copper

1) Pass Clean
2) Cu Etch
3) Pd Catalyst
4) Ni Plate
5) Ni Plate Cont.
6) Ni Plate Cont.
7) Gold (Pd) Plate

Ni/P Autocatalytic Reaction

Au or Pd

Au/Ni replacement reaction
Advantages of Electroless Nickel

- **Low Capital Investment Cost**
  - Sputtering or ElectroPlating: 10-20 Mio US$
  - Electroless UBM + Solder Print/Ball: 3-5 Mio US$

- **High Throughput** (single plating line)
  - 600,000 wafers per year 8" or 312,000 wafers 12" per year

- **Maskless Process**
  - No tooling, No high vacuum, No lithography

- **Suitable for Al and Cu pad metallization**

- **Compatible for wafers from 4" to 12"**
  - no additional invest for different wafer sizes

- **Proven Reliability and Production History**

- **NiAu and NiPdAu for Optimized IMC Growth**

- **Compatibility with all FC and WLCSP-Assembly processes**
  - Solder (lead, lead free, AuSn,.....)
  - ACF
  - NCP

- **Compatible with Clip Attach**

- **Compatibility with Au and Cu Wire Bonding**

- **Performance**

- **Applications**
Wirebonding
### Example 1: Engine Control Module

<table>
<thead>
<tr>
<th>OPM</th>
<th>Test</th>
<th>Conditions</th>
<th>Time Point</th>
<th>Ref. AlCu</th>
<th>NiPdAu</th>
</tr>
</thead>
<tbody>
<tr>
<td>TMCL</td>
<td>-65 °C ~ 175 °C (15-0-15-0, 2 cyc/hr)</td>
<td>Precon</td>
<td>Pass</td>
<td>Pass</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>500 cyc</td>
<td>Pass</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>1000 cyc</td>
<td>1 fail</td>
<td></td>
<td>Pass</td>
</tr>
<tr>
<td>HAST</td>
<td>130 °C, 85 % RH, 264 hrs</td>
<td>Precon</td>
<td>Pass</td>
<td>Pass</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>264 hrs</td>
<td>Pass</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPL</td>
<td>150 °C, 5 Volts</td>
<td>500 hrs</td>
<td>Pass</td>
<td>Pass</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>1000 hrs</td>
<td>Pass</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPL+HTSL</td>
<td>175 °C</td>
<td>+1000 hrs</td>
<td>1 fail</td>
<td>Pass</td>
<td></td>
</tr>
<tr>
<td>OPL+HTSL</td>
<td>200 °C</td>
<td>+1000 hrs</td>
<td>1 fail</td>
<td>Pass</td>
<td></td>
</tr>
<tr>
<td>HTSL</td>
<td>175 °C</td>
<td>500 hrs</td>
<td>Pass</td>
<td>Pass</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>1000 hrs</td>
<td>Pass</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2000 hrs</td>
<td>Pass</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Example 1: Engine Control Module

Graph showing Bump Shear Strength [g] for different conditions:
- As-molded
- HAST (175°C @ 1000 hrs)
- TMCL (200°C @ 1000 hrs)
- OPL

Legend:
- Reference AlCu pad
- Degrade due to thermal aging
- No degrade post thermal aging

Comparison of Bump Shear Strength:
- As-molded:
  - Max: 79.37
  - Min: 48.02

- +175°C 1000 hr:
  - Max: 55.62
  - Min: 30.56

- +200°C 1000 hr:
  - Max: 36.5
  - Min: 3.35

- +175°C 1000 hr +1000 hrs:
  - Max: 58.59
  - Min: 28.56

- +200°C 1000 hr +1000 hrs:
  - Max: 58.93
  - Min: 45.24
Example 1: Engine Control Module

**Al Interface**
- Pad alloy AlCu(0.5%)
- Pad Thickness 0.905 μm

**NiPdAu Interface**
- E'less Ni: 3 ± 0.3 μm
- E'less Pd: 0.3 ± 0.1 μm
- Immr Au: 0.03 ~ 0.05 μm
Example 2: Reliability

4000h/150°C HTOL

Al/Ni/Au Bond Pad

<table>
<thead>
<tr>
<th>MIN</th>
<th>MAX</th>
<th>AVG</th>
<th>STD</th>
<th>CPK</th>
</tr>
</thead>
<tbody>
<tr>
<td>11.6</td>
<td>14.2</td>
<td>12.87</td>
<td>0.54</td>
<td>6.08</td>
</tr>
</tbody>
</table>

break mode: broken at neck

• Increased void generation on Al-Au interface is weakening the bond adhesion
• Al/Ni/Au-Au interface does not show any signs of aging!

Al Bond Pad

<table>
<thead>
<tr>
<th>MIN</th>
<th>MAX</th>
<th>AVG</th>
<th>STD</th>
<th>CPK</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>6.4</td>
<td>3.38</td>
<td>1.72</td>
<td>0.07</td>
</tr>
</tbody>
</table>

break mode: lifted ball, broken at neck

• Increased void generation on Al-Au interface is weakening the bond adhesion
• Al/Ni/Au-Au interface does not show any signs of aging!
Example 3: Al vs Ni/Au vs NiPdAu

\[ \Phi \text{ 25um, 99\% Au wire} \]

**Pad Metallization vs Bond Shear Strength**  N=15pcs/type

- **Ref. (Al)**: Ave. 23.84g, STD. 1.51
- **EL-Ni/Au**: Ave. 20.24g, STD. 2.61
- **EL-Ni/Pd/Au**: Ave. 37.68g, STD. 2.39

\[ \phi \text{ 25um, 99\% Au wire} \]
Solder Bumping
Clip Attach

- Passivated die
- Copper 'drain' clip
- Die attach material
- Gate connection
- Copper track on board
- Source connection
Wafer Level Clip Attach MOSFET

<table>
<thead>
<tr>
<th>Solder voids:</th>
<th>NiPdAu</th>
<th>NiAu</th>
<th>NiPd</th>
</tr>
</thead>
<tbody>
<tr>
<td>Without clip (spec 10% max)</td>
<td>0.29%</td>
<td>0.85%</td>
<td>0.35%</td>
</tr>
<tr>
<td>With clip (spec 10% max)</td>
<td>10.29% (fail)</td>
<td>1.12%</td>
<td>2.40%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Wire bond:</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>wire Pull test</td>
<td>ok</td>
<td>ok</td>
<td>ok</td>
</tr>
<tr>
<td>Ball Shear Test (spec 80.5g min)</td>
<td>135 g</td>
<td>95 g</td>
<td>16.2 g (fail)</td>
</tr>
</tbody>
</table>

Warp h (in.)

Temperature (°C)

- No thermal anneal
- Thermal Anneal
- Wafer with no e-less and thermal anneal (control)
Summary

• Pac Tech has developed and implemented an automotive standard process for Ni/Pd and Ni/Pd/Au OPM.
• Au- and Cu-Wire bonding is qualified at different automotive and consumer customers. A new improved chemistry for smooth Ni/Pd Plating has been qualified and implemented.
• Pac Tech offers subcontractor service from its facilities in Santa Clara (USA), Penang (Malaysia) and Berlin (Germany). We offer equipment solutions and turnkey solutions for customers, who want to implement process and technology for inhouse manufacturing.