The Solder Ball Joint Reliability of Electroless Ni-P/Pd/Au Plating

Key points
(1) Issue of the solder ball joint reliability on BGA
(2) High speed shear test
(3) Low reliability of electroless Ni-P/Au plating (ENIGEG)
(4) Good reliability of electroless Ni-P/Pd/Au plating (ENEPIGEG)

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Increasing Density
Decreasing Size

TSOP
(Thin Small Outline Package)

CSP
(Chip Scale Package)

Metal Lead
FeNi Arroy

Assembly Area ⇒ Below 1/2

Plastic Package Substrate
Epoxy Polyimide
Structure of BGA Assembly

- Gold Wire
- Semiconductor Chip
- Die Bonding Material
- Molding Material
- Package Substrate
- Solder Joint
- Solder Ball
- Printed Circuit Board

- Wire Bonding
Wire bonding

Copper Line

Aluminum Electrode

Gold Wire

Resist

LSI

Die Bonding Material

Package Substrate

Gold Plated Terminal
Solder Ball Joint

Copper Pad

Package Substrate

Resist

Solder Ball

Gold Plated Terminal
## Characterization of Gold Plating

<table>
<thead>
<tr>
<th>Item</th>
<th>Electrolytic Ni/Au (5/0.5µm)</th>
<th>Electroless Ni-P/Au (5/0.5µm)</th>
<th>Electroless Ni-P/Pd/Au (5/0.2/0.3µm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wire Bondability</td>
<td>OK</td>
<td>OK</td>
<td>OK</td>
</tr>
<tr>
<td>Wire Bondability after Aging *</td>
<td>OK</td>
<td>NG</td>
<td>OK</td>
</tr>
<tr>
<td>Wire Bondability after Aging * and Plasma **</td>
<td>OK</td>
<td>OK</td>
<td>OK</td>
</tr>
<tr>
<td>Solder Joint Reliability</td>
<td>OK</td>
<td>NG</td>
<td>OK</td>
</tr>
</tbody>
</table>

* Aging : 150°C, 50 hours  ** Plasma : O₂ plasma
Issues of Solder Ball Joint-1

- Thermal Stress (Mismatch of CLE: $\beta$)
  - Silicon=3.5 ppm, Solder=24 ppm, G/Epoxy=15 ppm
- External Force (Dropping Impact)

TSOP・QFP

- Leads Absorb Stresses
- Large Areas

BGA・CSP

- Concentration of Stresses at Solder Ball and Interfaces
- Solder Balls Absorb Stresses
Issues of Solder Ball Joint-2

Mobile Phone

Mobile PC

Mobile e-device (Small, Light)

Drop Frequency Increase

Mechanical Shock Strong Vibration
Shear Test

Shear Speed
(1 to 10,000mm/min)

Solder Ball

Resist   Ball Pad

Package Substrate

Shear Tool
Solder Fracture

Comparison with Shear Strength
Solder < Interface

Fracture Mode
Solder Ball

Solder Strength

Interfacial Strength

Resist  Ball Pad

Package Substrate
Interfacial Fracture

Comparison with Shear Strength

Interface < Solder

Fracture mode Interface

Interfacial Strength

Solder Ball Sn/Pd

Solder Strength

Resist

Ball Pad

Package Substrate
Fracture Mode with Shear Test

Relationship between Shear Strength and Fracture Mode

1. Solder Strength < Interfacial Strength
   = Solder Ball Fracture
2. Solder Strength > Interfacial Strength
   = Interfacial Fracture
Relationship between Shear Speed and Solder Strength

- **Solder Strength** (kgf/mm²)
  - 0.01
  - 0.1
  - 1
  - 10
  - 100
  - 1000

- **Shear Speed** (mm/min)
  - 0.01
  - 0.1
  - 1
  - 10
  - 100
  - 1000

- **Eutectic Solder Wire** (63Sn-37Pb)
  - 0.6mm φ

- **Tests**:
  - **Drop Test**
  - **Thermal Stress**
  - **Conventional Shear Test**
Solder Ball Joint Reliability

- Thermal Stress
- Conventional Shear Test
- Drop Test
- High Speed Shear Test
- Dage 4000HS Bond Tester

![Graph showing Solder Ball Fracture Rate vs. Shear Speed for different materials and tests.](image_url)
Interfacial Fracture of Electroless Ni-P/Au

Electroless Ni-P/Immersion Au/Electroless Au
Electroless Ni-P Surface after Au or Pd Dissolution

Electroless Ni-P/Au
Corrosion of Ni-P Boundary

Electroless Ni-P/Pd/Au
No Corrosion

Electroless Ni-P/Pd/Au Immersion Au
Electroless Ni-P/Pd/Au Immersion Au
Electroless Ni-P/Pd/Au Immersion Au
FIB/SIM Observation of Electroless Gold Plating

Electroless Ni-P/Pd/Au | No Dissolution
Electroless Ni-P/Au | Localized dissolution
Immersion Au | Electroless Pd
Electroless Au | Immersion Au

Localized dissolution

0.5 μm
TEM Observation of Electroless Gold Plating

Evenly Corrosion

Electroless Ni-P Immersion Au Electroless Au

Electroless Ni-P Electroless Pd Immersion Au Electroless Au
Electric Potential Change in Immersion Gold Plating

Immersion Reaction:

\[ \text{Ni} + 2\text{Au}^+ = \text{Ni}^{2+} + 2\text{Au} \]

Localized Dissolution

Electric Potential Change in Immersion Gold Plating
Model for Electroless Ni-P/Au Plating Reaction

**Immersion Gold**

- 

**Electroless Gold**

- 

Localized Dissolution and Evenly Corrosion

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Fracture Model of Electroless Ni-P/Au

Solder Sn/Pb

Localized Dissolution Ni-P

Reflow

Solder Sn/Pb/Au

Localized Dissolution Ni-P

Shear Test

Solder Sn/Pb/Au

Localized Dissolution Ni-P

Interfacial Fracture

Localized Dissolution Ni-P

Au
Electric Potential Change in Electroless Pd Plating

Electroless Pd Reaction

\[
\text{Pd}^{2+} + \text{Reductant} = \text{Pd}
\]

Electric Potential (mV vs. Pd)

Immersion Time (min)
Model for Electroless Ni-P/Pd/Au Plating Reaction

Electroless Pd (Reduction)

\[ \text{Pd}^{2+} \rightarrow \text{Pd} \]

Reductant

\[ e^- \]

Immersion Gold (Immersion)

\[ \text{Au}^+ \rightarrow \text{Au} \]

\[ \text{Pd}^{2+} \rightarrow \text{Pd} \]

Electroless Gold (Reduction)

\[ \text{Au}^+ \rightarrow \text{Au} \]

\[ e^- \]

No Corrosion
Fracture Model of Electroless Ni-P/Pd/Au

Solder Sn/Pb

Reflow

Solder Sn/Pb Au/Pd

Shear Test

Solder Ball Fracture

Au

Pd

Ni-P

Ni-P
(1) The solder strength is affected by shear speed.

(2) The reliability of the electroless Ni-P/Pd/Au is higher than that of the electroless Ni-P/Au, and is equivalent to those of OSP and electrolytic Ni/Au on the high speed shear test.

(3) The reason for the low reliability of the electroless Ni-P/Au is that minute pits are formed in the electroless Ni-P, caused by Ni dissolution resulting from immersion Au.