Introduction of Low Temperature Au-to-Au Submicron Bonding Material
Characteristics of Sub-micron Au Particles

- **High Purity Au Particles**

  ![X-ray diffraction pattern]

  - Intensity (a.u.)
  - 2θ (degree)
  - Peaks: Au (111), Au (200), Au (222), Au (311), Au (222)

- **Particle Size Control**

  ![Particle size distribution]

  - D10: 0.18μm
  - D50: 0.30μm
  - D90: 0.48μm

- **Surface Preparation of Au Particles**

  - **Sub-micron particles**
    - Surface active agent (Physically bonded)
    - Can be removed at low temp > 100°C

  - **Nano-particles**
    - Organic shell (Chemically bonded)
    - Need to heat up to higher temp. to remove
Low-temperature Bonding material

AuRoFUSE™

- AuRoFUSE™ TR-191R
- 200Pa·s, 95mass%Au
- Distribution 0.2-0.5 μm

- Screen printing
- Halogen free solvent
- No cleaning process
- RT. storage for 3 month
## Typical Properties of AuRoFUSE™

<table>
<thead>
<tr>
<th>PASTE PROPERTIES</th>
<th>TR-191R</th>
<th>80Au20Sn (mass%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Viscosity</td>
<td>200 Pa·s (Shear rate 20/s)</td>
<td>—</td>
</tr>
<tr>
<td>Au content</td>
<td>95 mass%</td>
<td>—</td>
</tr>
<tr>
<td>Au diameter</td>
<td>0.2-0.5 μm</td>
<td>—</td>
</tr>
<tr>
<td>Shelf life</td>
<td>3 Month (Jars, &lt;25°C)</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>3 Month (Syringes, &lt;25°C)</td>
<td>—</td>
</tr>
<tr>
<td>Ionic impurities</td>
<td>Cl&lt;sup&gt;-&lt;/sup&gt; &lt; 10ppm, K&lt;sup&gt;+&lt;/sup&gt; &lt; 10ppm, Br&lt;sup&gt;-&lt;/sup&gt; &lt; 10ppm</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>Na&lt;sup&gt;+&lt;/sup&gt;, F&lt;sup&gt;-&lt;/sup&gt; : under investigation</td>
<td>—</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>BONDED PROPERTIES</th>
<th>230°C heating in air (No pressure)</th>
<th>300°C soldering with Flux (No pressure)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrical resistivity</td>
<td>5.4 μ Ω cm (25°C)</td>
<td>27.6 μ Ω cm (25°C)</td>
</tr>
<tr>
<td>Thermal conductivity</td>
<td>150 W / mK</td>
<td>57.3 W / mK</td>
</tr>
<tr>
<td>Heat-resistant</td>
<td>1064 °C (melting point)</td>
<td>278 °C (melting point)</td>
</tr>
<tr>
<td>Young’s modulus</td>
<td>9.5 GPa (25°C)</td>
<td>60 GPa (25°C)</td>
</tr>
<tr>
<td>Shear strength</td>
<td>40 MPa ※1</td>
<td>100 MPa</td>
</tr>
<tr>
<td>Au content</td>
<td>99.95 mass%</td>
<td>80 mass%</td>
</tr>
<tr>
<td>UBM</td>
<td>Au finish</td>
<td>Au / Ni</td>
</tr>
</tbody>
</table>

※1) “Ar plasma cleaning” against bonding surface of Au finish is recommended to eliminate the surface contamination such as some oxidations of under barrier metals Ni, Cu, Ti etc., resulting in the increment of shear strength.
Motivation of Sub-micron Au Particles to Interconnections of Functional Device

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<tr>
<th>Features of Au particles</th>
<th>Features of interconnections</th>
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<tr>
<td>Low temperature bonding due to the sintering behavior of Au particles.</td>
<td>• Reduced heat damage of components</td>
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<td>• Lower residual stress to devices</td>
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<td>• Small pitch and multiple bonding with no pressure</td>
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<tr>
<td>Sintered compact consists of a number of Au/Au metal joints.</td>
<td>• Low electrical resistance (&lt; $5 \times 10^{-6}$ Ω cm)</td>
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<td>• High thermal conductance (&gt; 150W/m·K)</td>
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<td></td>
<td>• Heat resistance of joint (mp:1063°C)</td>
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<td></td>
<td>⇒ <strong>Die-bonding application</strong></td>
</tr>
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<td>Compressive deformation of sintered compact leads to a densely structure</td>
<td>• Hermetic sealing (leak rate &lt; 1x10^{-13} Pa·m3/s)</td>
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<td>• Tolerance of surface roughness (&lt;±3μm)</td>
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<td>⇒ <strong>Hermetic sealing application</strong></td>
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# Sintering Behavior of Sub-micron Au Particles

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Duration</th>
<th>Image (distribution)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100°C</td>
<td>5min</td>
<td><img src="image1.png" alt="" /></td>
</tr>
<tr>
<td>150°C</td>
<td>5min</td>
<td><img src="image2.png" alt="" /></td>
</tr>
<tr>
<td>200°C</td>
<td>5min</td>
<td><img src="image3.png" alt="" /></td>
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Necking of Au particles is observed above 150°C in air with no pressure.
# Motivation of Sub-micron Au Particles to Interconnections of Functional Device

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| *Low temperature bonding* due to the sintering behavior of Au particles. | • Reduced heat damage of components  
• Lower residual stress to devices  
• Small pitch and multiple bonding with no pressure |
| Sintered compact consists of a number of *Au/Au metal joints.* | • Low electrical resistance (< $5 \times 10^{-6} \, \Omega \, \text{cm}$)  
• High thermal conductance (> 150 W/m·K)  
• Heat resistance of joint (mp:1063°C)  
⇒ *Die-bonding application* |
| Compressive deformation of sintered compact leads to a densely structure | • Hermetic sealing (leak rate< $1 \times 10^{-13}$Pa·m3/s)  
• Tolerance of surface roughness (±3μm)  
⇒ *Hermetic sealing application* |
Development of Die-bonding for LED
High-precision Screen Printing (LS-150, NEWLONG)

**Film Printing**
- AuRoFUSE
- Screen Mask (Taiyo Chemical)
- Sub. Au/Pd/Ni

**Bump Printing**
- AuRoFUSE
- J-Squeegee (350mm/s)
- Additive Metal-Mask (SONOCOM)
- Sub. Au/Pd/Ni

**Ring Printing**
- AuRoFUSE
- Screen Mask (Taiyo Chemical)
- Sub. Au/Pt/Ti

Die-bond joint for LED, P/D
FC joint for LED
Hermetic sealing for MEMS
Assemble of Flip-Chip LED

Reliability Tests

<table>
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<tr>
<th>Test</th>
<th>Items</th>
</tr>
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<tbody>
<tr>
<td>Die Shear Strength (MPa)</td>
<td>4</td>
</tr>
<tr>
<td>Thermal Transient (K/W)</td>
<td>2</td>
</tr>
<tr>
<td>Electric Resistance (Ω)</td>
<td>3</td>
</tr>
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Film Printing of TR-191R for Die-bonding

1. Printing (off-contact)
   - AuRoFUSE
   - Screen Mask (Taiyo Chemical)
   - Sub. Au/Pd/Ni

2. Alignment
   - Electroless Au/Pt/Ti
   - LED
   - 10μm

3. Mounting (RT)
   - Loading > 0.5 N
   - LED
   - Less than 5μm

4. Heating
   - without pressure
   - 2 min ~ 10 min
   - 0.5 °C/s
   - 0.5 °C/s
   - Time

Before (a) and after (b) mounting of LED electrode size and pitch
Dispensing of TR-191R for FC joints having Ag finished electrodes

1. Ar plasma cleaning
   - Device
   - Au/Pd/Ni
   - Ag oxide
   - Substrate
   - Ag/Pd/Ni

2. Dispensing
   - AuRoFUSE

3. Leveling & Heating (200°C)
   - Loading (10MPa)※1)
   - Levering jig

4. Dispensing

5. Mounting & Heating
   - Loading > 0.5N
   - Device

※1) depend on Ag surface cleanliness

Graph:
- Temp. (°C)
  - 200
  - 150
  - 100
  - 50
  - 0
- Time
  - 10min～
  - 2min～
  - 0.5 °C/s
  - in air
  - 0.5 °C/s

without pressure

The Future is Precious.
TANAKA
Film Printing of TR-191R for die-bonding

3. Printing (off-contact)

4. Alignment by flip-chip bonder

5. Mounting (RT) & pre-sintering (200°C)

1. Printing (off-contact)

2. Pre-sintering (200°C) & levering

6. Sintering (250°C 2h) by oven furnace
Structure of Double-Side Bonded Power Module

Cu ‘Drain’ clip

“SiC” Die

Die attach (85Au15Ge)

SiN substrate

Gate (AuRoFUSE)

40um gap

Source (AuRoFUSE)
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• Heat resistance of joint (mp: 1063°C)  
⇒ *Die-bonding application* |
| Compressive deformation of sintered compact leads to a densely structure | • Hermetic sealing (leak rate < $1 \times 10^{-13} \text{Pa}\cdot\text{m}^3/\text{s}$)  
• Tolerance of surface roughness ($<\pm 3 \mu\text{m}$)  
⇒ *Hermetic sealing application* |
Development of Hermetic Sealing MEMS
What’s Hermetic Sealing by Au Sintered Compacts?

(a) 100MPa at R.T

(b) 100MPa at 150°C

To get a densely structure changing from open pore state to closed pore state by thermo-compression bonding.
High-precision screen printing
( LS-150, NEWLONG )

**Film Printing**
- AuRoFUSE
- Screen Mask (Taiyo Chemical)
- Sub.
- Au/Pd/Ni

**Bump Printing**
- AuRoFUSE
- J-Squeegee (350mm/s)
- Additive Metal-Mask (SONOCOM)
- Sub.
- Au/Pd/Ni
- 30μm

**Ring Printing**
- AuRoFUSE
- Screen Mask (Taiyo Chemical)
- Sub.
- Au/Pt/Ti

**Images**
- Die-bond joint for LED, P/D
- FC joint for LED
- Hermetic sealing for MEMS
Ring Printing of TR-191R for Hermetic Sealing

1. Printing (off-contact)

   AuRoFUSE
   Screen Mask (Taiyo Chemical)

   Cap wafer
   Au/Pt/Ti

2. Pre-sintering & outgas reduction (200°C, Ar-4%H₂, cycle purge)

3. Alignment (RT) & bonding (200°C)

   Ar plasma
   Loading in vacuum
   Device

4. Bonding profile for hermetic sealing

   Temp. (°C)
   150 MPa
   200
   30 min
   30 °C/min

   in vacuum

Printed network structure

15.0kV x300 SE(M)

0.3mm

100μm
Ring Patterns of Au sintered Compacts by Screen Printing on 4 in. wafer
Wafer level Au pattern transfer for hermetic seal rings

Initial Transfer Wafer (before transfer)

Transfer

After Transfer
Transferred Pattern Result:
Sealing Lines and Bumps onto Ceramic Substrate
Surface-Compliant Behavior of Sub-Micron Au Particle Patterns

ϕ2” bonded pair (glass + alumina) at 200°C, 200MPa, 30min. Blade-dicing was successfully done. He leak rate < 1x10-13 Pa·m3/s

Cross-section SEM images of a 20μm-wide seal ring
Conclusions

1. **Low temperature sintering** of sub-micron Au particles is suited to low temperature bonding with no pressure leading to less damage of functional devices.

2. **Au/Au metal joint** of sub-micron Au particles showing a low electrical resistance, high thermal conductance is applied to LED and P/D assembly.

3. Wafer-level packaging was successfully performed due to easy deformation of porous structure, and He leak rate of $< 1 \times 10^{-13}$ Pa·m$^3$/s was obtained for the bonded pairs between glass and Al2O3 wafers even if it has a surface irregularity.
Thank You For Your Attention!