New bonding Cu ink by using low temperature sinterable Cu particles

Dr. Jung Lae Jo, Mitsui Mining & Smelting Co.,Ltd.

Company profile

<table>
<thead>
<tr>
<th>Company Name</th>
<th>MITSUI MINING &amp; SMELTING CO., LTD. [Common name: MITSUI KINZOKU]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Established</td>
<td>May 1, 1950</td>
</tr>
<tr>
<td>President and Representative Director</td>
<td>Keiji Nishida</td>
</tr>
<tr>
<td>Paid-in capital</td>
<td>42,129 millions of yen (As of March 31, 2018)</td>
</tr>
<tr>
<td>Sales</td>
<td>Consolidated: 519,215 millions of yen (As of March 31, 2018)</td>
</tr>
<tr>
<td></td>
<td>Non-consolidated: 260,719 millions of yen (As of March 31, 2018)</td>
</tr>
<tr>
<td>Location</td>
<td>1-11-1, Osaki, Shinagawa-ku, Tokyo, Japan</td>
</tr>
<tr>
<td>Number of employees</td>
<td>Consolidated: 12,276</td>
</tr>
<tr>
<td></td>
<td>Non-consolidated: 1,840</td>
</tr>
<tr>
<td></td>
<td>(As of March 31, 2018)</td>
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</tbody>
</table>
Business segments of MITSUI KINZOKU

We have a wide variety of techniques for powder (metal/oxide) materials!!
(One of Mitsui’s core techniques)

Powder manufacturing technologies of MITSUI KINZOKU

Core Technologies

Size control
Shape control
Surface treatment
- Wettability control
- Anti-oxidation etc.

Alloying
Coating

Others

Ni
Cu
Ag

Zinc
Lead
Cu
Recycle
Mineral resource development
Automotive Parts & Components
Perlite
Rolled Cu
Die casting parts
Product line up of Cu Powder

We have an extensive lineup of copper powder products for various applications!!

Today’s Agenda

1. Background & Target

2. Experiment
   2-1 Screening of Cu particles
   2-2 Reliability evaluation of Cu substrate and Cu ink sintering layer
   2-3 Reliability evaluation of SiC-SBD/TO-247 package

3. Conclusions & Future plans
Today’s Agenda

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3. Conclusions & Future plans

Affordable Cu can be recommended as a bonding material for wide application

High operation temperature (> 200°C)

<table>
<thead>
<tr>
<th>Bonding materials</th>
<th>Melting temp. (°C)</th>
<th>Thermal conductivity (W/m·K)</th>
<th>Concern</th>
</tr>
</thead>
<tbody>
<tr>
<td>Au-Sn</td>
<td>&gt; 280</td>
<td>50-60</td>
<td>Cost</td>
</tr>
<tr>
<td>Cu-Sn</td>
<td>&gt; 400</td>
<td>40-50</td>
<td>Thermal conductivity</td>
</tr>
<tr>
<td>Ag</td>
<td>963 (bulk)</td>
<td>420 (bulk)</td>
<td>Cost Migration</td>
</tr>
<tr>
<td>Cu</td>
<td>1083 (bulk)</td>
<td>396 (bulk)</td>
<td>Oxidation</td>
</tr>
</tbody>
</table>

Higher output & Higher power density

Power electronics for EV

Ag sintering material is expensive

Affordable Cu can be recommended as a bonding material for wide application

Needs for high thermal conductivity & high reliability as a bonding material
Objectives

- To study availability of submicron Cu particles as sintering material
- Evaluation of reliability of Cu sintering layer by some method

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3. Conclusions & Future plans
2-1 Screening of Cu particles

Screening of Cu submicron particles

<Cu ink composition>
- Filler: Submicron particle (3 types) / micron (2 μm)*
- Solvent: Triethanol amine
- Binder: Inorganic type
  *2 μm particle adding for prevention over shrinkage after sintering

<Evaluation>

<table>
<thead>
<tr>
<th>Submicron particle</th>
<th>Particle A (New type)</th>
<th>Particle B</th>
<th>Particle C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface treatment</td>
<td>○</td>
<td>○</td>
<td>-</td>
</tr>
<tr>
<td>Crystallite size (nm)</td>
<td>34</td>
<td>44</td>
<td>&gt;100</td>
</tr>
<tr>
<td>Particle size (D50;nm)</td>
<td>0.16</td>
<td>0.29</td>
<td>0.39</td>
</tr>
<tr>
<td>Impurity (%)</td>
<td>C 0.23</td>
<td>0.23</td>
<td>0.04</td>
</tr>
<tr>
<td></td>
<td>O 0.66</td>
<td>0.61</td>
<td>0.95</td>
</tr>
<tr>
<td>Remarks</td>
<td>Small size particle</td>
<td>Medium size particle</td>
<td>Medium size particle</td>
</tr>
<tr>
<td></td>
<td>Small crystalline</td>
<td>Small crystalline</td>
<td>Large crystalline</td>
</tr>
<tr>
<td></td>
<td>Low oxygen</td>
<td>Low oxygen</td>
<td>High oxygen</td>
</tr>
</tbody>
</table>

Properties of Cu submicron particles
2-1 Screening of Cu particles

Screening test

<table>
<thead>
<tr>
<th>RUN-1 (micron/particle A)</th>
<th>RUN-2 (micron/particle B)</th>
<th>RUN-3 (micron/particle C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shear strength (MPa)</td>
<td>Shear strength (MPa)</td>
<td>Shear strength (MPa)</td>
</tr>
<tr>
<td>25~30</td>
<td>&lt;10</td>
<td>&lt;10</td>
</tr>
</tbody>
</table>

Cross-sectional Image after sintering

Sinterability: Particle A > Particle B = Particle C
Shear Strength: RUN-1 >> RUN-2 = RUN-3

Small size & Small crystallite & Low oxygen are keys to improving low temperature sinterability

2-2 Reliability evaluation

Cu substrate and Cu ink sintering layer

<Evaluation>

Cu substrate and Cu ink sintering layer

Drying profile
A: RT ~ 150℃ / 4 min
B: 150℃ × 3 min
C: 150℃ ~ 60℃ / 3 min.

Sintering profile
A: RT ~ 260 ℃ / 8 min
B: 260℃ × 9 min
C: 260 ~ 60 ℃ / 3 min.
2-2 Reliability evaluation

**HTS test**

No significant change of shear strength/SAT image at 200 °C aging

**TC test**

No significant change of shear strength/SAT image at TC
2-2 Reliability evaluation

Why can Cu joint structure sustain high shear strength?

It is possible to block intrusion of air at TCT & HTS since the binder is filled in Cu joint.

Binder plays role of oxygen intrusion inhibitor

2-3 Reliability evaluation

Packaging evaluation

<Filler> Submicron particle A / micron (2 μm)
<Solvent> Triethanol amine
<Binder> Inorganic type

<Sample fabrication>
Package type: TO-247
- Substrate: Cu lead frame
- Chip: SiC-Schottky barrier diode (SBD)
  (1.85 mm, 0.235 mmt, Cu metalize)
- Wire bonding: Al (350 μmφ)
- Sealing: Mold resin

<Packaging process>
Cu ink printing on LF → SiC chip mounting → Sintering → Wire bonding → Molding → Singulation → Reliability evaluation (HTS, TC)
2-3 Reliability evaluation

Results of HTS test

<Thermal resistance>

Time (hours at 250 °C in air)

THERMAL RESISTANCE (K / W)

Initial 1000 h

3 mm

Chip A

Chip B

No significant change of thermal resistance/SAT image at 250 °C aging

Results of TC test

<Thermal resistance>

Condition: -50 ~ 250 °C (Dwell time 30 min)

Number of cycle (times)

THERMAL RESISTANCE (K / W)

Initial 1000 cycles

3 mm

Chip A

Chip B

No significant change of thermal resistance but edge delamination is occurred after 1000 cycles
Conclusions

➢ Cu ink of specified submicron particles is suitable as a sinter joining material

➢ Cu sinter joining material has great potential for high temperature operation over 200 °C

➢ SiC-SBD/TO247 with the Cu ink has excellent heat resistance

Future plans

➢ Packaging evaluation with larger size SiC chip

➢ Improvement of sintering density

Acknowledgements

➢ This research was partially collaborated with Prof. Suganuma of ISIR, Osaka University.

➢ This research was partially supported by Clean device promotion project of NEDO, Japan.
Thank you for your attention!!