## Legs 1, 2 & 3: Olin 194 8lead SOIC Molded/Singulated

### Table

<table>
<thead>
<tr>
<th>Leg #</th>
<th>Test sequence</th>
<th>Sample</th>
<th>Whisker (yes/no)?</th>
<th>Max. length</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>500 -55C/85C TC</td>
<td>A</td>
<td>no</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>B</td>
<td>no</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>D</td>
<td>yes?</td>
<td>1µm</td>
<td>May be too short</td>
</tr>
<tr>
<td>2</td>
<td>4weeks 60C/95%RH Storage</td>
<td>A</td>
<td>no</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>B</td>
<td>no</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>D</td>
<td>no</td>
<td></td>
<td>Odd feature on D1</td>
</tr>
<tr>
<td>3</td>
<td>500 -55C/85C TC plus 4weeks 60C/95%RH Storage</td>
<td>A</td>
<td>yes?</td>
<td></td>
<td>Whisker clusters?</td>
</tr>
<tr>
<td></td>
<td></td>
<td>B</td>
<td>no</td>
<td></td>
<td>Corrosion</td>
</tr>
<tr>
<td></td>
<td></td>
<td>D</td>
<td>yes?</td>
<td>1µm</td>
<td>May be too short</td>
</tr>
</tbody>
</table>

### From Phase1 DOE

A = 50-100 µinches Bright Sn  
B=500-600 µinches Bright Sn  
D=500-600 µinches Sn/10Pb

---

**Connect with and Strengthen Your Supply Chain**
Sample Set A: 50-100 μinch Bright Sn, Olin 194
8 lead SOIC Molded/Singulated

Leg# 3, unit A2, lead 1: 500 –55C/85C
TC plus 4weeks 60C/95%RH Storage.
Possibly whisker clusters.

Leg# 3, unit A2, lead 2: 500 –55C/85C
TC plus 4weeks 60C/95%RH Storage.
Possibly whisker clusters.

• Set A did not show signs of whisker growth after 500 –55C/85C temp cycles or 4weeks 60C/95%RH storage.
• However, clusters, which could be whiskers, were present when Set A samples were subjected to 500 –55C/85C temp cycles followed by 4weeks 60C/95%RH storage.

Connect with and Strengthen Your Supply Chain
Connect with and Strengthen Your Supply Chain

Sample Set B: 500-600 μinch Bright Sn, Olin 194
8 lead SOIC Molded/Singulated

Plating cracks observed at time zero.

Leg# 3: 500–55C/85C TC plus 4 weeks 60C/95%RH Storage. Beginning to corrode.

• Whiskers were NOT observed in any of the legs.
• Cracking may have reduced or eliminated internal stress.

Connect with and Strengthen Your Supply Chain
Sample Set D: 500-600 μinch Sn/10Pb, Olin 194
8 lead SOIC Molded/Singulated

- Leg #1: 500–55°C/85°C TC. Onset of a possible whisker.
- Leg #2: 4 weeks 60°C/95%RH Storage. Not likely to be a whisker.

- Set D samples appear to form short whiskers after 500–55°C/85°C temp cycles.
- Odd shaped features were observed after 4 weeks 60°C/95%RH storage, however, although the features appear whisker-like, the lack of striations make it unlikely to be whiskers.

Connect with and Strengthen Your Supply Chain
Sample Set D: 500-600 μinch Sn/10Pb, Olin 194 8 lead SOIC Molded/Singulated

• Set D samples appear to form short whiskers after 500 –55C/85C temp cycles plus 4weeks 60C/95%RH storage.

Connect with and Strengthen Your Supply Chain
Whisker Growth Literature Research

Environment
- Temperature
  - 50º - 70ºC
  - > 150ºC
- High Humidity
- Temperature Cycling
- External mechanical stress

Methods
- Ni Underplating
- Annealing

Substrate Preparation
- Plating Process

Materials
- Plating thickness
  - > 10 µm
  - < 0.5 µm
- Plating grain size
  - 1 - 8 µm
  - < 1 µm
- Low Organic Additives
  (>2%)
- Alloying

Equipment
- Electroplating
  - Hot Dip
- High current density plating baths

Whisker Retardation
- Intermetallic formation (Cu₆Sn₅)
- Crystal Orientation
- Surface oxidation
- Physical imperfections caused in assembly

Equipment Methods Materials

Connect with and Strengthen Your Supply Chain
Whisker Types

Lump Whisker  Flower Whisker  Needle Whisker

Needle whiskers can potentially cause a short

Criteria: \[75\mu m\]

Connect with and Strengthen Your Supply Chain
### 64 LQFP Whisker Acceleration Study

<table>
<thead>
<tr>
<th>Plating Finish</th>
<th>60°C/95%RH 3 weeks</th>
<th>85°C/85%RH 500 hours</th>
<th>121°C/100%RH 576 hours</th>
<th>-55°C/85°C 500 cycles</th>
<th>-35°C/125°C 500 cycles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sn/2Bi</td>
<td>No whiskers</td>
<td>No whiskers</td>
<td>No whiskers</td>
<td>Whiskered</td>
<td>No whiskers</td>
</tr>
<tr>
<td>Sn/10Pb</td>
<td>Whiskered</td>
<td>No whiskers</td>
<td>No whiskers</td>
<td>Whiskered</td>
<td>No whiskers</td>
</tr>
</tbody>
</table>

Whiskers formed with either 60°C/95%RH storage or -55°C/85°C temperature cycling.

- Sn-Pb Needle Whisker
- Sn-Bi Needle Whisker
- Sn-Pb Needle Whisker

Connect with and Strengthen Your Supply Chain
**Whisker Growth Test Flow**

<table>
<thead>
<tr>
<th>Sample size 3 units. Die &amp; wirebond required.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Initial Inspection</strong></td>
</tr>
<tr>
<td><em>Handle units with vacuum wand or tweezers.</em></td>
</tr>
<tr>
<td>1) Attach the package (live bug) to the SEM work holder using double-sided carbon tape.</td>
</tr>
<tr>
<td>2) Use air or N2 to blow off debris (optional).</td>
</tr>
<tr>
<td>3) At 300X magnification, inspect 3 random leads per package for whiskers.</td>
</tr>
<tr>
<td><strong>Temperature Cycle (air-air)</strong></td>
</tr>
<tr>
<td>-55±5°C/85±5°C, 500cyc; 7minute hold; 5minute ramp; 24minutes/cycle</td>
</tr>
<tr>
<td><strong>Temperature &amp; Humidity Storage</strong></td>
</tr>
<tr>
<td>60°C/95%RH, 500hrs</td>
</tr>
<tr>
<td><strong>Post Inspection</strong></td>
</tr>
<tr>
<td><em>Attach the package to the SEM work holder according to “Initial Inspection” steps 1 and 2.</em></td>
</tr>
<tr>
<td>1) At 300X magnification, inspect 3 random leads per package for whisker.</td>
</tr>
<tr>
<td>2) Record the length and location (unit#, lead#) of the longest whisker on each lead.</td>
</tr>
<tr>
<td>3) Take a picture of the longest whisker on each lead for later review.</td>
</tr>
</tbody>
</table>

**Criteria:** For information only; length [75µm].

*Connect with and Strengthen Your Supply Chain*
• Surface mount does not inhibit whisker growth.
• Whiskers formed on both the plating finish and solder.
• Solder alone does not appear to be prone to whisker growth.
Whisker Prior to FIB Cross-Sectioning

EDS Dot Mapping – red is Sn, green is Ni, and blue is Cu

Focused Ion Beam (FIB) of Whisker, Sn with Ni Barrier

- Whisker appears to form from surface grains.
- Whiskers appear to be made up of only Sn.
- Intermetallics formed between grain boundaries.
### -55°C/85°C Temperature Cycle versus Ambient Storage

<table>
<thead>
<tr>
<th>Package</th>
<th>Plating</th>
<th>Avg. Quantity</th>
<th>Avg. Max. Length</th>
<th>Ambient, ~23°C &amp; ~60%RH (1 Year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>64 LQFP</td>
<td>Sn</td>
<td>72</td>
<td>15µm</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>Sn/2Bi</td>
<td>56</td>
<td>10µm</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>Sn/15Pb</td>
<td>1</td>
<td>1µm</td>
<td>None</td>
</tr>
<tr>
<td>132 PQFP</td>
<td>Sn</td>
<td>Not usable</td>
<td>Not usable</td>
<td>Not usable</td>
</tr>
<tr>
<td></td>
<td>Sn/2Bi</td>
<td>9</td>
<td>5µm</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>Sn/15Pb</td>
<td>None</td>
<td>N/A</td>
<td>None</td>
</tr>
</tbody>
</table>

- Temperature cycling at –55°C/85°C in general grows more whiskers than storage at ambient (~23°C, ~60%RH).
- Based on the 132PQFP data, whisker growth may be dependent on the plating finish (chemistry, process, composition,…).
Summary of Findings

- $-55^\circ C / 85^\circ C$ temp cycling and $60^\circ C / 95\%$RH storage accelerated whisker growth.
- Whiskers form on Sn-based finishes including SnPb.
- Having a Ni barrier did not retard whisker growth.
- Whiskers appear to form from surface grains.
- SnCu intermetallics formed between grain boundaries and may be a source of internal stress.
- Whiskers formed even after surface mount on both package and solder.
- Solder itself does not appear to be prone to whisker growth.
- 500 $-55^\circ C / 85^\circ C$ temp cycles is more severe than one year of storage at ambient.