Tin Whisker Test - Phase II
Passives
Keith Spalding
PASSIVE COMPONENT
TIN WHISKERING TEST PLAN - Phase II

Original Plan

• Perform all tests on 1206 size fuses with a Nickel and 100% Matte Tin Plating.

• Vary the plating parameters to produce different lots with different stress levels and surface finishes.

• Minimize the changes to one or two variables per lot.
PASSIVE COMPONENT
General Fuse Construction

1. Termination Pads
2. Ceramic Substrate (Alumina)
3. Printed Glass Amp Mark
4. Silver Thick film Termination (Silver with glass frit.)
   - Nickel Plated Barrier
   - Tin or Tin/Lead Final Plate
5. Printed Fuse Element
6. Stenciled Glass Layers
# PASSIVE COMPONENT
## TIN WHISKERING TEST PLAN - Phase II

<table>
<thead>
<tr>
<th>Plating Lot #</th>
<th>SEM Puck #’s</th>
<th>500 Temp Cycles</th>
<th>SEM Insp</th>
<th>4 wks @ Temp &amp; Humidity</th>
<th>SEM Insp</th>
<th>Fuse Type</th>
<th>Sample Size</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1 - 2</td>
<td>-40 to 90C</td>
<td>X</td>
<td>60C/90% RH</td>
<td>X</td>
<td>1206FA</td>
<td>10 Fuses</td>
<td>Only run Puck 2 at Temp/Humidity</td>
</tr>
<tr>
<td>1</td>
<td>3 - 4</td>
<td>None</td>
<td>60C/90% RH</td>
<td>X</td>
<td>1206FA</td>
<td>10 Fuses</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>5 - 6</td>
<td>None</td>
<td>X</td>
<td>Ambient</td>
<td>X</td>
<td>1206FA</td>
<td>10 Fuses</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>7 - 8</td>
<td>-40 to 90C</td>
<td>X</td>
<td>60C/90% RH</td>
<td>X</td>
<td>1206FA</td>
<td>10 Fuses</td>
<td>Only run Puck 8 at Temp/Humidity</td>
</tr>
<tr>
<td>2</td>
<td>9 - 10</td>
<td>None</td>
<td>60C/90% RH</td>
<td>X</td>
<td>1206FA</td>
<td>10 Fuses</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>11 - 12</td>
<td>None</td>
<td>X</td>
<td>Ambient</td>
<td>X</td>
<td>1206FA</td>
<td>10 Fuses</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>13 - 14</td>
<td>-40 to 90C</td>
<td>X</td>
<td>60C/90% RH</td>
<td>X</td>
<td>1206FA</td>
<td>10 Fuses</td>
<td>Only run Puck 14 at Temp/Humidity</td>
</tr>
<tr>
<td>3</td>
<td>15 - 16</td>
<td>None</td>
<td>60C/90% RH</td>
<td>X</td>
<td>1206FA</td>
<td>10 Fuses</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>17 - 18</td>
<td>None</td>
<td>X</td>
<td>Ambient</td>
<td>X</td>
<td>1206FA</td>
<td>10 Fuses</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>19 - 20</td>
<td>-40 to 90C</td>
<td>X</td>
<td>60C/90% RH</td>
<td>X</td>
<td>1206FA</td>
<td>10 Fuses</td>
<td>Only run Puck 20 at Temp/Humidity</td>
</tr>
<tr>
<td>4</td>
<td>21 - 22</td>
<td>None</td>
<td>60C/90% RH</td>
<td>X</td>
<td>1206FA</td>
<td>10 Fuses</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>23 - 24</td>
<td>None</td>
<td>X</td>
<td>Ambient</td>
<td>X</td>
<td>1206FA</td>
<td>10 Fuses</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>25 - 26</td>
<td>-40 to 90C</td>
<td>X</td>
<td>60C/90% RH</td>
<td>X</td>
<td>0603FA</td>
<td>10 Fuses</td>
<td>Only run Puck 26 at Temp/Humidity</td>
</tr>
<tr>
<td>5</td>
<td>27 - 28</td>
<td>None</td>
<td>60C/90% RH</td>
<td>X</td>
<td>0603FA</td>
<td>10 Fuses</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>29 - 30</td>
<td>None</td>
<td>X</td>
<td>Ambient</td>
<td>X</td>
<td>0603FA</td>
<td>10 Fuses</td>
<td></td>
</tr>
</tbody>
</table>

Temp Cycles = 10 min @ Each Temp & 5 sec to shift
# Tin Whiskering Study Phase 2 Plating Log

## Nickel Plating Parameters

<table>
<thead>
<tr>
<th>SEM Puck Number</th>
<th>Part Number</th>
<th>Lot Number</th>
<th>Lot Volume 1/8 or 1/16 ml</th>
<th>Ball Volume ml</th>
<th>Total Volume ml</th>
<th>Ball Size 1/8 / 1/16</th>
<th>Plate Date</th>
<th>Nickel Current</th>
<th>Nickel Voltage</th>
<th>Amp-Hrs/Ft²</th>
<th>Nickel Thickness u in</th>
<th>pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - 6</td>
<td>1206FA-4A</td>
<td>J189</td>
<td>120</td>
<td>130</td>
<td>250</td>
<td>1/8</td>
<td>7/18/02</td>
<td>25</td>
<td>9</td>
<td>20</td>
<td>48</td>
<td>5.647</td>
</tr>
<tr>
<td>7 - 12</td>
<td>1206FA-1.5A</td>
<td>J184A</td>
<td>137</td>
<td>113</td>
<td>250</td>
<td>3/32</td>
<td>7/17/02</td>
<td>25</td>
<td>9</td>
<td>17</td>
<td>41</td>
<td>4.261</td>
</tr>
<tr>
<td>13 - 18</td>
<td>1206FA-4A</td>
<td>J189</td>
<td>120</td>
<td>130</td>
<td>250</td>
<td>1/16</td>
<td>7/18/02</td>
<td>25</td>
<td>10</td>
<td>12</td>
<td>29</td>
<td>2.428</td>
</tr>
<tr>
<td>19 - 24</td>
<td>1206FA-1.5A</td>
<td>J184A</td>
<td>137</td>
<td>113</td>
<td>250</td>
<td>3/32</td>
<td>7/17/02</td>
<td>25</td>
<td>9</td>
<td>17</td>
<td>41</td>
<td>4.261</td>
</tr>
<tr>
<td>25 - 30</td>
<td>0603FA-2A</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
</tbody>
</table>

## 100% Tin Plating Parameters

<table>
<thead>
<tr>
<th>SEM Puck Number</th>
<th>Part Number</th>
<th>Sn Number</th>
<th>Sn Current</th>
<th>Sn Voltage</th>
<th>Sn Amp-Hr Setting</th>
<th>Actual Plating Time (min)</th>
<th>Thickness u in</th>
<th>Sn Amp-Hrs/Ft²</th>
<th>Sn %</th>
<th>Sn pH</th>
<th>Tilt</th>
<th>Immr</th>
<th>Barrel Dia x Length</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - 6</td>
<td>1206FA-4A</td>
<td>10</td>
<td>5</td>
<td>10</td>
<td>60</td>
<td>420 - 526</td>
<td>2.8235</td>
<td>100%</td>
<td>3.1</td>
<td>0</td>
<td>1</td>
<td>4&quot; dia x 4&quot;</td>
<td>Rod style dangler in barrel #8.</td>
<td></td>
</tr>
<tr>
<td>7 - 12</td>
<td>1206FA-1.5A</td>
<td>10</td>
<td>5</td>
<td>8</td>
<td>48</td>
<td>377 - 450</td>
<td>1.9953</td>
<td>100%</td>
<td>3.5</td>
<td>0</td>
<td>1</td>
<td>4&quot; dia x 4&quot;</td>
<td>Rod style dangler in barrel #8.</td>
<td></td>
</tr>
<tr>
<td>13 - 18</td>
<td>1206FA-4A</td>
<td>10</td>
<td>5</td>
<td>6</td>
<td>36</td>
<td>418 - 534</td>
<td>1.2094</td>
<td>100%</td>
<td>3.1</td>
<td>0</td>
<td>1</td>
<td>4&quot; dia x 4&quot;</td>
<td>Rod style dangler in barrel #4.</td>
<td></td>
</tr>
<tr>
<td>19 - 24</td>
<td>1206FA-1.5A</td>
<td>15</td>
<td>7.5</td>
<td>8</td>
<td>32</td>
<td>302 - 388</td>
<td>1.9953</td>
<td>100%</td>
<td>3.5</td>
<td>0</td>
<td>1</td>
<td>4&quot; dia x 4&quot;</td>
<td>Rod style dangler in barrel #8.</td>
<td></td>
</tr>
<tr>
<td>25 - 30</td>
<td>0603FA-2A</td>
<td>7.5</td>
<td>5</td>
<td>302 - 388</td>
<td>1.9953</td>
<td>100%</td>
<td>N/A</td>
<td>N/A</td>
<td>35mm</td>
<td>Plated on GET machine.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

## Notes:
1. The first 4 barrel plated groups were burnished for 1 - 2 minutes in the Tin bath. (Tumbled without current.)
2. The last group was plated in an automated plating system from GET Systems without any media.
3. The plating chemicals used in both systems was Nickel Sulfate and Solderon LG.
PASSIVE COMPONENT

Plating Bath Analysis

Barrel Plating Analysis by Shipley

Tin Solution Contaminants
• Copper - 1 ppm
• Lead - 16 ppm
• Zinc - 1 ppm
• Iron - 3 ppm
• Nickel 70 ppm

Automated Pulse Plating Machine
• Test was not done.
PASSIVE COMPONENT
TIN WHISKERING TEST PLAN - Phase II

Barrel Plating Line
PASSIVE COMPONENT
TIN WHISKERING TEST PLAN - Phase II

Pulse Plating Without Media

GET Systems, Inc.

COOPER Electronic Technologies
PASSIVE COMPONENT
Plating Group 1 - Barrel, 1/8” balls, Tin Plated @ 5V & 10A, 2.82 amp-hrs/ft²

After 500 Temp Cycles
P2-1A

After 500 Temp Cycles & 4 wks @ Temp/Humidity
P2-1A

Initial
P5-1A

After 4 wks @ Temp/Humidity
P3-1A

Scale:
Large Picture - 500 μm
Inset Picture - 100 μm
PASSIVE COMPONENT

Plating Group 2 - Barrel, 3/32” balls, Tin Plated @ 5V & 10A, 1.99 amp-hrs/ft²

Initial

After 500 Temp Cycles

After 500 Temp Cycles & 4 wks @ Temp/Humidity

Scale:
Large Picture - 500 μm
Inset Picture - 100 μm
PASSIVE COMPONENT
Plating Group 3 - Barrel, 1/16” balls, Tin Plated @ 5V & 10A, 1.20 amp-hrs/ft²

Initial

After 500 Temp Cycles

After 4 wks @ Temp/Humidity

After 500 Temp Cycles & 4 wks @ Temp/Humidity

Scale:
Large Picture - 500 μm
Inset Picture - 100 μm
PASSIVE COMPONENT
Plating Group 4 - Barrel, 3/32” balls, Tin Plated @ 7.5V & 15A, 1.99 amp-hrs/ft²

After 500 Temp Cycles

After 500 Temp Cycles & 4 wks @ Temp/Humidity

Initial

After 4 wks @ Temp/Humidity

Scale:
Large Picture - 500 μm
Inset Picture - 100 μm
PASSIVE COMPONENT
Plating Group 5 - GET Systems, No Media, Pulse Plated, Minimal Tumbling

After 500 Temp Cycles
P25-1A

After 500 Temp Cycles & 4 wks @ Temp/Humidity
P25-1A

Initial
P29-1A

After 4 wks @ Temp/Humidity
P28-1A

Scale:
Large Picture - 500 μm
Inset Picture - 100 μm
PASSIVE COMPONENT
Plating Groups vs Max Whisker Length

After 500 Temp Cycles

<table>
<thead>
<tr>
<th>Group 1</th>
<th>Group 2</th>
<th>Group 3</th>
<th>Group 4</th>
<th>Group 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1L-1D</td>
<td>P7L-4B</td>
<td>P14L-5B</td>
<td>P20L-3C</td>
<td>P25L-5</td>
</tr>
<tr>
<td>31 µm</td>
<td>44 µm</td>
<td>28 µm</td>
<td>34 µm</td>
<td>9 µm</td>
</tr>
</tbody>
</table>

After 500 Temp Cycles & 4 wks of Temp/Humidity

<table>
<thead>
<tr>
<th>Group 1</th>
<th>Group 2</th>
<th>Group 3</th>
<th>Group 4</th>
<th>Group 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>P2L-1D</td>
<td>P8L-4C</td>
<td>P14L-5B</td>
<td>P20L-3C</td>
<td>P26L-5B</td>
</tr>
<tr>
<td>22 µm</td>
<td>25 µm</td>
<td>38 µm</td>
<td>34 µm</td>
<td>9 µm</td>
</tr>
</tbody>
</table>

Scale: Each bar length is 50 µm
# PASSIVE COMPONENT

## Summary - Whisker Count & Size

<table>
<thead>
<tr>
<th>Plating Group #</th>
<th>After 500 Temp Cycles @ -40C to 90C</th>
<th>After 500 Temp Cycles @ -40C to 90C &amp; 4 wks @ 60C/90% RH</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Whisker Frequency</td>
<td>Max Size</td>
</tr>
<tr>
<td></td>
<td>200μm x 260μm Area</td>
<td>μm</td>
</tr>
<tr>
<td>1</td>
<td>223</td>
<td>31</td>
</tr>
<tr>
<td>2</td>
<td>54</td>
<td>44</td>
</tr>
<tr>
<td>3</td>
<td>137</td>
<td>28</td>
</tr>
<tr>
<td>4</td>
<td>66</td>
<td>34</td>
</tr>
<tr>
<td>5</td>
<td>6</td>
<td>9</td>
</tr>
</tbody>
</table>
PASSIVE COMPONENT

Summary Conclusions

• The automated pulse plating system imparted less surface stresses to the tin plating, which resulted in fewer whiskers and shorter whisker lengths. The system does not use media and uses a mild agitation versus the heavy impact the parts see from the tumbling action in the barrel plating process. (More studies are required for verification.)

• The 3/32” dia media, 1.99 Amp-Hrs/Ft² current density and 3.5 pH level produced less whiskers than the other barrel plated groups. The whisker lengths were similar in all four barrel plating groups.

• Ambient or Temp/Humidity exposure alone over a 4 wk period does not grow whiskers on this type of device.

• 500 Temp Cycles easily generates whiskers on this type of device. The addition of Temp/Humidity exposure did not add to the whisker length or frequency.
PASSIVE COMPONENT

Acknowledgments

All SEM pictures provided by Kemet

Rudy Wagner - Kemet Mgr, Microscopy and Failure Analysis