Fill the Void

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Outline/Agenda

- Introduction
- Factors that Influence Voiding
- Voiding Results
- What Have We Learned About Voiding?
- Future Work
- Acknowledgements
- Q & A
Introduction

Do you have voids in your life?
Introduction

Good news! We have solutions!
Introduction

Void: (noun)

1. A completely empty space. “The black void of space.”
2. Gap in the solder joint where the solder does not fill the space completely.

Introduction

Void Limits

3.5.7 Voids in BGA  Many companies use X-ray, In-circuit Test (ICT) and Automatic Optical Inspection (AOI) in combination to improve their process control for BGA solder joints. Some look for voids through X-ray to determine accept/reject criteria. Some level of voiding in any kind of solder joint is inevitable, but there is still debate as to what is acceptable or an excessive void. The proponents of voids argue that it is not the void that is bad, but its location. The review of voiding has many considerations, and in order to assist in process improvement

**Void Limits**

<table>
<thead>
<tr>
<th>Void Type</th>
<th>Void Description</th>
<th>Corrective Action Indicator</th>
<th>Action Taken</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Voids in the solder ball (prior to assembly)</td>
<td><strong>Class 1</strong>&lt;br&gt;Up to 90% balls may have voids&lt;br&gt;Maximum Void size in any ball is 9% of Area (30% of the image diameter)</td>
<td>Investigate root cause in process &amp; take corrective action</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Class 2</strong>&lt;br&gt;Up to 70% balls may have voids&lt;br&gt;Maximum Void size in any ball is 4% of Area (20% of the image diameter)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Class 3</strong>&lt;br&gt;Up to 50% balls may have voids&lt;br&gt;Maximum Void size in any ball is 2% of Area (15% of the image diameter)</td>
<td></td>
</tr>
</tbody>
</table>

All balls with cumulative voids no matter what size are considered.

| B         | Voids at package interface (prior to assembly) | **Class 1**<br>Up to 80% balls may have voids<br>Maximum Void size in any ball is 6% of area (25% of the image diameter) | Investigate root cause in process & take corrective action |
|           |                  | **Class 2**<br>Up to 70% balls may have voids<br>Maximum Void size in any ball is 4% of Area (20% of the image diameter) |              |
|           |                  | **Class 3**<br>Up to 50% balls may have voids<br>Maximum Void size in any ball is 2% of Area (15% of the image diameter) |              |

All balls with cumulative voids no matter what size are considered.

| C         | Voids within the ball after PCA reflow | **Class 1**<br>Up to 100% balls may have voids<br>Maximum Void size in any ball is 25% of Area (50% of the image diameter) | Investigate root cause in process & incoming parts, take corrective action |
|           |                  | **Class 2**<br>Up to 70% balls may have voids<br>Maximum Void size in any ball is 10% of Area (22% of the image diameter) |              |
|           |                  | **Class 3**<br>Up to 60% balls may have voids<br>Maximum Void size in any ball is 5% of Area (15% of the image diameter) |              |

All balls with cumulative voids no matter what size are considered.

| D         | Voids at the package interface after PCA reflow | **Class 1**<br>Up to 100% balls may have voids<br>Maximum Void size in any ball is 15% of area (40% of the image diameter) | Investigate root cause in process & incoming parts, take corrective action |
|           |                  | **Class 2**<br>Up to 70% balls may have voids<br>Maximum Void size in any ball is 10% of Area (22% of the image diameter) |              |
|           |                  | **Class 3**<br>Up to 60% balls may have voids<br>Maximum Void size in any ball is 5% of Area (15% of the image diameter) |              |

All balls with cumulative voids no matter what size are considered.

| E         | Voids at the mounting surface interface after PCA reflow | **Class 1**<br>Up to 100% balls may have voids<br>Maximum Void size in any ball is 15% of area (40% of the image diameter) | Investigate root cause in process & incoming parts, take corrective action |
|           |                  | **Class 2**<br>Up to 70% balls may have voids<br>Maximum Void size in any ball is 10% of Area (22% of the image diameter) |              |
|           |                  | **Class 3**<br>Up to 60% balls may have voids<br>Maximum Void size in any ball is 5% of Area (15% of the image diameter) |              |

All balls with cumulative voids no matter what size are considered.

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Factors that Influence Voiding

Factors that were Studied
Factors that were Studied

PRINT / DISPENSE
Stencil Design was Varied on QFN Thermal Pads:

QFN 68 lead
10 mm body
0.5 mm pitch
Tin finish
Factors that were Studied

PRINT / DISPENSE
Printed paste on QFN Thermal Pads (65% Area Covered):
Factors that were Studied

REFLOW - Reflow Profile was Varied:

- **RTS (Ramp to Spike)**
  - TAL 53 – 59 sec
  - Peak 245 – 249 °C

- Both
  - Ramp 1.1 °C/sec
  - Length 4.5 – 4.6 min

- **RTS-HT (High Temperature)**
  - TAL 68 – 75 sec
  - Peak 255 – 259 °C
Factors that were Studied

SOLDER PASTE

Two lead-free water soluble solder pastes were used:

- Paste A = 88.0% SAC305 Type 3. Moderate Activity.
- Paste B = 88.5% SAC305 Type 3. High Activity.
Equipment

Printer: 30 mm/sec, 1.0 lb/in, 1.5 mm/sec separation

Pick and Place
Equipment

Reflow Oven: simulates 10 zone, reflow in air

X-Ray: voltage 70 kV, current 400 µA
Box and Whisker Plot

- **Minimum**
- **First Quartile**
- **Median**
- **Third Quartile**
- **IQR**
- **Maximum**

- **Outliers**
- **Suspected Outliers**
- **Inner Fence**
- **Outer Fence**

- **1.5 IQR**
- **Third Quartile**
- **First Quartile**
Voiding Results – Solder Paste

- Solder Paste A
- Solder Paste B
Tukey-Kramer HSD Testing

Data sets represented by circles

95% confidence level

Connecting letters shows differences

Tukey-Kramer HSD Testing

Oneway Analysis of Void area % By Solder paste

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q* Alpha
1.96494 0.05

LSD Threshold Matrix
Abs(Dif)-HSD

Paste B WS SAC T3 Paste A WS SAC T3
Paste B WS SAC T3 -2.376 32.208
Paste A WS SAC T3 32.208 -2.376

Positive values show pairs of means that are significantly different.

Connecting Letters Report

<table>
<thead>
<tr>
<th>Level</th>
<th>Paste B WS SAC T3 A Mean</th>
<th>Paste A WS SAC T3 B Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level</td>
<td>39.825417</td>
<td>5.242083</td>
</tr>
</tbody>
</table>

Levels not connected by same letter are significantly different.
Voiding Results – Solder Paste

![Graph showing voiding results for solder pastes A and B.](image)

**Means Comparisons**

Comparisons for all pairs using Tukey-Kramer HSD

<table>
<thead>
<tr>
<th>Confidence Quantile</th>
<th>Alpha</th>
</tr>
</thead>
<tbody>
<tr>
<td>$q^*$</td>
<td>0.05</td>
</tr>
</tbody>
</table>

LSD Threshold Matrix

<table>
<thead>
<tr>
<th>Paste B WS SAC T3</th>
<th>Paste A WS SAC T3</th>
<th>Paste B WS SAC T3 Paste A WS SAC T3</th>
</tr>
</thead>
<tbody>
<tr>
<td>-2.376</td>
<td>32.208</td>
<td>32.208 - 2.376</td>
</tr>
</tbody>
</table>

Positive values show pairs of means that are significantly different.

**Connecting Letters Report**

<table>
<thead>
<tr>
<th>Level</th>
<th>Mean</th>
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<tbody>
<tr>
<td>Paste B WS SAC T3 A</td>
<td>39.825417</td>
</tr>
<tr>
<td>Paste A WS SAC T3 B</td>
<td>5.242083</td>
</tr>
</tbody>
</table>

Levels not connected by same letter are significantly different.
Voiding Results – Stencil Design
Voiding Results – Stencil Design

5-Dot (U11) has Higher Voiding

Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

Connecting Letters Report

<table>
<thead>
<tr>
<th>Level</th>
<th>Mean</th>
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</thead>
<tbody>
<tr>
<td>U11</td>
<td>28.481667</td>
</tr>
<tr>
<td>U12</td>
<td>21.196667</td>
</tr>
<tr>
<td>U09</td>
<td>21.186667</td>
</tr>
<tr>
<td>U10</td>
<td>19.270000</td>
</tr>
</tbody>
</table>

Levels not connected by same letter are significantly different.
Voiding Results – Reflow Profile

![Graph Builder](Graph Builder)

- RTS
- RTS-HT
Voiding Results – Reflow Profile

Oneway Analysis of Void area % By Profile

Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

Connecting Letters Report

<table>
<thead>
<tr>
<th>Level</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>RTS-HT</td>
<td>23.230417</td>
</tr>
<tr>
<td>RTS</td>
<td>21.837083</td>
</tr>
</tbody>
</table>

Levels not connected by same letter are significantly different.

No Significant Difference
Voiding Results – Stencil Design by Solder Paste

Graph Builder

Void area % vs. Location

Solder paste

Paste A WS SAC T3

Paste B WS SAC T3

SOLDER PASTE A

SOLDER PASTE B
Voiding Results – Stencil Design by Solder Paste

- **SOLDER PASTE A**
- **SOLDER PASTE B**
Voiding Results – Reflow Profile by Solder Paste

Graph Builder

Void area % vs. Profile

Solder paste

Paste A WS SAC T3

Paste B WS SAC T3

SOLDER PASTE A

SOLDER PASTE B
Voiding Results – Reflow Profile by Solder Paste

**SOLDER PASTE A**

**SOLDER PASTE B**
Void Size
Voiding Results – Largest Void
Voiding Results – Largest Void by Solder Paste

Larger Voids with Paste B
Voiding Results – Largest Void by Stencil Design

Larger Voids with 5-Dot (U11)
Voiding Results – Largest Void by Reflow Profile

Profile - No Significant Difference
Previews of Coming Attractions

- Voiding with vapor phase reflow and vacuum
- Using vapor phase with vacuum to rework voids
Vapor Phase Reflow

- No vacuum
- Main Vac – during liquidus
- Prevac 1 – before heating
- Prevac 2 – during heating before liquidus
Voiding Results – Vapor Phase

- Solder Paste B SAC305 T3
- Linear ramp profile in vapor phase
Voiding Results – Vapor Phase

Vapor phase with vacuum lowers voiding dramatically.
Voiding Results – Vapor Phase as a Rework Method

- Solder Paste B SAC305 T3
- 1\textsuperscript{st} convection reflow – 2\textsuperscript{nd} vapor phase with vacuum
Voiding Results – Vapor Phase as a Rework Method

Vapor phase with vacuum can rework voids
What Have We Learned About Voiding?

- Solder paste B generated higher voiding and larger voids than solder paste A.

- The 5-Dot stencil pattern generated higher voiding and larger voids than the other designs.

- The RTS profile generated higher voiding with solder paste A, while the RTS-HT profile generated higher voiding with solder paste B.

- As total void area increases, the largest void size increases.
How to Fill the Void

✔ Use a solder paste that generates low voiding in your process.

✔ Optimize the stencil design to minimize voiding.

✔ Optimize the reflow profile for your solder paste to minimize voiding.
Future Work

Voiding mitigation work is ongoing and results will be presented in future papers. Some of the variables being studied are as follows:

- Vapor phase reflow with vacuum
- Convection reflow using nitrogen
- No clean vs. water soluble solder pastes
- Particle size of the solder powder used (T3, T4, T5)
- Manufacturer of the solder powder
- Additional stencil designs are being tested
Acknowledgements

Many thanks to McKennah Repasky, a summer intern with FCT Assembly, for all of her hard work running the testing for this paper.

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