Proven Approaches to Minimize Voiding under QFNs and other Bottom-Termination Components

Brook Sandy-Smith
Indium Corporation
Achieve over 50% reduction in voiding

- Prismark projects that by 2013, 32.6 billion QFNs will be assembled
- QFN Challenges:
  - Small form factors
  - Increased demand on solder paste performance
  - Large thermal pad is often the site for extensive voiding when using solder paste
- Voiding impedes thermal transfer, reducing the efficiency and lifetime of the package
- No one approach has proven to be the solution
- Solder preforms add solder volume to the paste and help to reduce voiding
- Important to reduce overall % voids and size of largest void
- Try combinations of proven approaches to achieve the best possible process
Solder paste is ~50% flux by volume

- Large paste deposit contains volatiles
- During reflow volatiles must escape to accomplish complete coalescence
- Low standoff leaves no exit for excess volatiles
- Large voids cause production failures and long term reliability risks
The Strategies

Add solder volume without adding volatiles, considering these approaches:

• Thermal pad and via design
  – Thermal Pad Design and Process for Voiding Control at QFN Assembly, Dr. Lee et al.
  – The Effect of Thermal Pad Patterning on QFN Voiding, Dr. Lee, Dr. Yan Liu, Derrick Herron

• Stencil design

• Preform design and placement
  – Minimizing Voiding in QFN Packages Using Solder Preforms, Seth Homer, Dr. Ron Lasky

• Reflow profile optimization
## Voiding Control for QFN Assembly

*Authored by: Derrick Herron, Dr. Yan Liu, and Dr. Ning-Cheng Lee*

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Sub parameter</th>
<th>Layers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermal Pad on PCB</td>
<td>Microvia number</td>
<td>0, 16, 32, 36</td>
</tr>
<tr>
<td></td>
<td>Peripheral venting for full thermal pad</td>
<td>With and without</td>
</tr>
<tr>
<td></td>
<td>Dividing method</td>
<td>Solder mask, venting channel</td>
</tr>
<tr>
<td></td>
<td>Thermal subpad shape</td>
<td>Square, triangle</td>
</tr>
<tr>
<td></td>
<td>Thermal subpad number</td>
<td>1, 4, 8, 9</td>
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<tr>
<td>Stencil</td>
<td>Aperture</td>
<td>85%, 100%</td>
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<tr>
<td>Heat History</td>
<td>Reflow profile</td>
<td>Short, long cool, long, long hot</td>
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<tr>
<td></td>
<td>Other heat treatment</td>
<td>Prebake, 1 reflow, 2 reflow</td>
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</tbody>
</table>

*Table 1. Parameters used in voiding study.*
Thermal Pad Design

<table>
<thead>
<tr>
<th>Description</th>
<th>Number of Vias</th>
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</thead>
<tbody>
<tr>
<td>Full, no vent, 36 via</td>
<td>36</td>
</tr>
<tr>
<td>Full, vented, 36 via</td>
<td>36</td>
</tr>
<tr>
<td>Full, no vent, 16 via</td>
<td>16</td>
</tr>
<tr>
<td>Full, vented, 16 via</td>
<td>16</td>
</tr>
<tr>
<td>Square 4, 16 via</td>
<td>16</td>
</tr>
<tr>
<td>Triangle 4, 16 via</td>
<td>16</td>
</tr>
<tr>
<td>Square 9, 36 via, NSMD</td>
<td>36</td>
</tr>
<tr>
<td>Square 9, 36 via, SMD</td>
<td>36</td>
</tr>
<tr>
<td>Triangle 8, 32 via</td>
<td>32</td>
</tr>
</tbody>
</table>

Table 2. Design of thermal pads on test board.

Herron, D., Liu, Y., and Lee, N.C.; Voiding Control at QFN Assembly; SMTAi 2011, Fort Worth
Notes on Thermal Pad Design

• “Window paning” creates pathways to vent volatiles
• Reduced pockets of volatiles cause smaller voids and less overall voiding
• Downside: Vent channels result in less solder joint continuity, although selectively
• Best results for few pathways away from the center

Herron, D., Liu, Y., and Lee, N.C.; Voiding Control at QFN Assembly; SMTAi 2011, Fort Worth
Results with Optimized Thermal Pads

- Venting reduces the size of voids, but does not significantly reduce the total voiding area.
- For thermal transfer, large voids are more disruptive. Smaller voids allow for more transfer.
- Solder mask defined pads offer further improvement.

*Figure 5. X-ray images of QFN solder joints for designs with a 0.33mm wide channel reflowed with a long cool profile.*
Thermal Pad Patterning with Solder Mask

- Results better than with “broken up” pads, because exposed board between pads can outgas and contribute to voiding
- Same pattern shows best results
- Tested via placement under solder mask channels vs. next to channels or scattered
- Little impact to via placement, vias will often collect a void but there is promise to select via placement to reduce voiding
Reduce QFN Voiding Through Stencil Design

- Instead of printing one large square at the center of QFNs:
  - With greater paste volume, voiding increases, so aperture designs that limit paste volume will reduce voiding
  - Break up this square into smaller apertures
  - Spaces between printed areas leave paths for volatiles to escape
  - Larger aperture separations will further reduce voiding

For additional information refer to paper: “Influence of Reflow Profile and Pb-free Solder Paste in Minimizing Voids for QFN Assembly” by T. Jensen, E. Briggs et al.
Stencil Design
How effective are these process changes?

- Plating thermal vias with solderable materials minimizes voiding.
- Even with an optimized process and favorable venting, voiding is rarely below 30%, and often 40%.
- In order to reduce voiding to less than 20%, another process improvement is required.
- **Placing a solder preform is a viable solution**.
Definition: Solder Preforms

- Same alloys and metallic properties as solder paste
- Specified dimensions
- Offers predictable solder volume optimized for your process
Preform dimensions

Typically 80% of the QFM ground pad area is appropriate starting point for preform design.

<table>
<thead>
<tr>
<th>Freescale Semiconductor Application Note</th>
<th>Preform design:</th>
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<tbody>
<tr>
<td><strong>QFN</strong></td>
<td><strong>PCB Land Pattern</strong></td>
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<tr>
<td></td>
<td><strong>4 x 4</strong></td>
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<tr>
<td>Version</td>
<td>E</td>
</tr>
<tr>
<td>Lead pad width (mm)</td>
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<tr>
<td>Lead pad length (mm)</td>
<td>0.92</td>
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<tr>
<td>Pitch (mm)</td>
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<tr>
<td>Thermal pad width (mm)</td>
<td>2.15</td>
</tr>
<tr>
<td>Thermal pad length (mm)</td>
<td>2.15</td>
</tr>
<tr>
<td>Aspect ratio</td>
<td>—</td>
</tr>
<tr>
<td>Area ratio</td>
<td>—</td>
</tr>
</tbody>
</table>

Preform design:

- **QFN**
  - 4 x 4
  - 9 x 9
- **Thermal Pad**
  - 2.15 x 2.15
  - 7.25 x 7.25
- **Preform**
  - 1.83 x 1.83
  - 6.16 x 6.16
  - .002"
Flux-coated Preforms

- Flux coating is necessary to facilitate wetting at the interface with the QFN’s pad
  - Composed of predominantly solids, and will not add volatiles under the QFN
  - Promotes wetting, discouraging void propagation
Preform Thickness vs. Paste Depth

Preform thickness should be ~50-70% of paste depth
Tape and Reel Design

- Tape selection: pocket dimensions must be adjusted to minimize travel in the pocket during transport and on the line to minimize “mis-picks”
- Special attention to:
  - pitch
  - pocket depth
  - cover tape
Pick and Place Parameters

- Placed preform must be as flat as possible after being placed into the paste
- **Placement force is critical**
- Placement pressure should be increased more than normal levels to insure that the component forms good contact with paste perimeter around the preform
- Nozzle should be large enough to occupy as much of the surface as possible

<table>
<thead>
<tr>
<th>Placement Pressure</th>
<th>Placement Pressure</th>
<th>Placement Performance</th>
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<tbody>
<tr>
<td>Preform</td>
<td>Component</td>
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<tr>
<td>2n</td>
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<td>5n</td>
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<td>Fair</td>
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<tr>
<td>4n</td>
<td>3n</td>
<td>Good</td>
</tr>
</tbody>
</table>
Reflow Profile Optimization

- Generally, start out with current profile
- When using a preform, the best profile is ramp to peak
- Considering the thermal mass of an assembly, ramp to peak is often not the best option
- Balance soak to thermal mass, and minimize time to peak
- Current profile can be optimized toward this goal
Process Overview

- Print paste over entire ground pad
- Preform sized ~80% of paste area
- Paste perimeter will provide tack and keep the assembly together before reflow
- Preform thickness 50-70% of paste depth
- No-clean flux coating 1.5% by wt.
- Flux compatibility is required
- Placement parameters can be optimized for high-volume production
- Reflow profile allows large window for optimization
Parameters for Collaborative Testing

- **QFN thermal pad dimensions (dims):** 2mm x 2mm
- **Paste:** No-clean solder paste with 89% SAC305, Type 3
- **PWB pad dims:** 2mm x 2mm
- **Stencil dims:** 2mm x 2mm x .004” thick
- **Preform alloy:** SAC305
- **Preform dims:** 1.7mm x 1.7mm x .002” thick
- **Flux coating:** No-clean flux @ 1.5% by weight
- **Profile:** Adjusted soak

*The resulting void average was reduced by over 50%.**
Conclusions

Many approaches to reduce QFN voiding, choose those that fit best with process constraints.

Solutions easily tailored to fit a variety of assemblies.

**Most impactful solution**: Add flux-coated preforms to your QFN assembly to:

- Reduce overall voiding
- Prevent creating large voids
- Fortify your process without increasing line time via tape and reel preforms
- Optimize this strategy to enhance your process
Ongoing Work

• Optimized venting channel size for stencil design and thermal pad design – further room for improvement in voiding
• Additional work optimizing preform process with new flux coating technology
• Final stages of development for new low-voiding paste
• New project: relating voiding performance to thermal performance of components for more application specific optimization
Questions?

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