“Stencil Design, Materials & Processes for Today’s Miniaturized Electronics Assembly”

Bruce Barton, Alent
Jim Price, ASM/DEK
Ben Scott, Datum Alloys
Sue Holmes, Photo Stencil
Tony Lentz, FCT Assembly
Ahne Oosterhof, Eastwood Consulting

Miniaturization of all electronics from tablets & smart phones to implantable medical devices continues to drive assembly complexity & creates major challenges in yield & reliability. Stencils play a key role in these assemblies as we approach several physical limitations in the printing processes, particularly those for applying solder paste. This panel explores the options currently in use as well as future directions for ensuring high yield, high quality & reliable electronics assemblies of all types. Topics of discussion include stencil materials, processes, coatings & design; solder & flux formulations; as well as interactions between components, boards & reflow processes.
Stencil Design, Materials & Processes for Today’s Miniaturized Electronics Assembly

Rheology & Thixotropy – Bruce Barton, Alent
Specialized Printing Tools – Jim Price, ASM DEK
Stencil Metallurgy – Ben Scott, Datum Alloys
Specialty Stencils (3D) – Sue Holmes, Photo Stencil
Stencil Coatings – Tony Lentz, FCT Assembly
User Perspective – Ahne Oosterhof, Eastwood Consulting
Measuring Rheology

Because solder paste is subjected to a range of shear forces, and the viscosity is different at each force, rheology of solder paste is key. There are three very common ways to measure solder paste viscosity. Brookfield viscometry, Malcolm Viscometry and Bohlin Rheology. Brookfield viscometry is not commonly used because it is not easy to vary the shear rate applied to the paste and make multiple measurements. The viscosity shear curve is very steep at low viscosity. Very small changes in shear have very large changes in viscosity.
Thixotropic nature of solder paste

Thixotropic - ADJECTIVE

Becoming more fluid when shaken or stirred and returning to a gel state when allowed to stand.

Forces on Solder Paste:
1. Printing – forces applied during squeegee motion across the stencil.
2. Squeegee Lift – adhesive forces between paste & squeegee.
Thixotropic - ADJECTIVE
Becoming more fluid when shaken or stirred and returning to a gel state when
allowed to stand.

The first type of shear force applied to the solder paste is the printing of the
board. A critical success factor is that the paste's viscosity, or resistance to
movement, be minimized when the paste is being forced into the stencil
aperture. If a squeegee is moving at 100mm/second, and an aperture is
0.25 mm wide (typical for a 0.4mm pitch BGA), the solder paste has only
0.0025 seconds to flow into its designated aperture, usually .1mm deep.

The second type of shear force applied to solder paste is the lifting of the
squeegee off of the stencil after each print stroke. The bead of solder must
not stick to the squeegee, and remain on the stencil. Paste that has lost too
much solvent due to excess duration on the stencil and/or exposure to
elevated temperatures is prone to this failure mode. Improperly formulated
water soluble paste may suffer this consequence under very low humidity
conditions.

The third type of shear force applied to solder paste is the separation of
the stencil from the freshly printed PCB. The stencil must be
separated cleanly, leaving as much as the paste on the board as
possible. It is well known that if the area of the aperture walls is too
high relative to the area of the PWB pad that the paste was printed
on, some or all of the solder paste will remain in the aperture. This
results in too little solder paste to form the desired component to
board solder joint.

The fourth shear force seen by solder paste is the force of gravity after
the stencil has been removed. It is common to have .100mm high
deposits of solder paste printed in 0.400mm intervals. This requires
high viscosity when paste is subjected to the relatively low shear
force of gravity (and motion of the board). Without high viscosity at
low shear, the paste deposits would run together, causing bridging
and electrical failures.
**What do You Need to Do?**

The following things must happen when printing those world class applications:

- Make certain the bottom of the stencil is as clean as is practically possible in a production setting.
- The board to the rail to the stencil must be as flat as is physically possible.
- The board is flat to the table and supremely supported by the tooling.
- Make sure the apertures are as fully loaded with solder paste as possible.
- Make certain the PCB and the stencil separate at the same time over the entire printed surface.
- Confirm the squeegee pressure and support tooling are stable.
What Features are Needed?

Either Edge Clamping Snuggers or Over the Top Snuggers

With standard PCB clamps, up to 50% of stencil release control is lost and purely dependent on stencil rebound speed.

What Features are Needed? Con’t

Closed Loop Squeegee Pressure with Tooling Deviation Monitor

Super co-planed PCB rails to the printing table to the stencil
+/- 10 microns rising table to rails to stencil support flatness

ProActiv squeegees, unique to DEK, patented
Activation of the squeegee blade

- locally modifies the rheology of the solder paste increasing fluidity and...

- increases the downward interaction at the blade tip

This combination improves the packing density of particles into apertures and enhances the cohesive bond between solder paste particles.

What About Other Needed Process Items?

DEK High Tension VectorGuard stainless steel stencil

No mesh mount to distort over time

4 mil thickness is typical for .6 AAR or lower AAR's when 0201 / .4mm CSP's or smaller are being printed

Square apertures will increase the available volume of past by 23%

DEK Nano ProTek stencil treatment

Resists paste leakage when gasketing is compromised

Type 4 solder paste is typically used as type 3 solder particles are too large
Results

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Presented by
Ben Scott, CEO
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Stencils Today
A lack of science

Substrate
• Chosen because of availability and wear resistance

Fabrication
• Laser cut
• Etching
• Additive

Mounting
• Trampoline screens evolved from silk screen printing
• Frameless systems driven by space saving

Supply Chain
• Lack of coordination between stencil houses, paste manufacturers, substrate suppliers and point-of-use

SMT Stencils
Understand the variables at each process event

Substrate
• Squeegee side
• In the apertures (wall topography)
• Board side

Aperture Cutting
• Given we actually understand what we want from the aperture wall, what cutting process would deliver this
• Do we actually need to apply secondary coatings?

Mounting
• Mounting impacts print performance
• Stencil must be held absolutely in X, Y and Z
Problems to Solve
Some observations

Substrate
• Tolerances, CP values
• Delta in service environments
• Creep resistance
• Suitability to paste and flux

Manufacturing
• Precision
• Repeatability
• Multi level/ 3D
• Environment

Mounting
• Stencil moves, vibrates in Z
• X and Y control could be better

The data says yes.

Stencil Check
Summary

Apertures
• Concentricity
• Registration
• Wall topography
• Aspect ratio

Multi level / 3D
• Sharp edges
• Pockets

Stencil surface
• Desired Ra, Rz etc
• Do these differ between sides
• Contact angle

Semicon
• Over lay tolerances
• Stand-offs
• Creep resistance
• Thickness tolerances
• Aperture tolerances
• Clean sharp edges

All tolerances should be within a single micron!
Thank you for your time
If you have any questions, please contact

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Presented by
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Photostencil

3 topics

1- Broadband printing (printing solder paste when both small pitch and normal pitch components are on the same substrate).

2- 3D Electroform Stencils for printing paste or flux when components are already attached to the substrate.

3- Area Ratio Calculator for determining proper aperture size, stencil thickness and stencil type for acceptable paste transfer.
Challenge of Broadband Printing large and small components on same substrate

**Thick Stencil**
- Large Component
- Small Component

**Thin Stencil**
- Large Component
- Small Component

**Area Ratio Matrix**

<table>
<thead>
<tr>
<th>Component and typical Aperture Size</th>
<th>Stencil Thickness</th>
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<tbody>
<tr>
<td></td>
<td>2 mil</td>
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<tr>
<td>01005</td>
<td></td>
</tr>
<tr>
<td>6 mil (150u)</td>
<td>0.75</td>
</tr>
<tr>
<td>7 mil (175u)</td>
<td>0.88</td>
</tr>
<tr>
<td>.3 mm CSP</td>
<td></td>
</tr>
<tr>
<td>6 mil (150u)</td>
<td>0.75</td>
</tr>
<tr>
<td>7 mil (175u)</td>
<td>0.88</td>
</tr>
<tr>
<td>8 mil (200u)</td>
<td>1.00</td>
</tr>
</tbody>
</table>

Green = OK     Orange = Warning    Red = Stop
Stencil Solutions:

• **Step Stencils**
  - Thin area for small devices
  - Thick area for large devices

• **Two Print Stencil**
  - Thin stencil for 1\textsuperscript{st} print (small devices)
  - Thick stencil for 2\textsuperscript{nd} print (large devices)

• **Improve stencil printing process**
  - Improve paste release for Area Ratio’s <.5

View from the squeegee side showing the 3-D raised pocket for relief of the IDC’s or Chip components.
Area Ratio = \( \frac{\text{Aperture Open Area}}{\text{Wall Surface Area}} \)

**Area Ratio Calculator (Rectangles with Radius)**

- **Aperture Width in mils**
- **Aperture Length in mils**
- **Stencil Radius in mils**
- **Stencil Thickness in mils**
- **Area Ratio** (\( \leq 0.66 \) for all stencils)
- **Recommend**
  - E-FAB or NicAlloy-XT or NiCut
  - E-FAB with Nano-Coat or NiCut
  - E-FAB or Nano-Coat
  - #2 Redesign

<table>
<thead>
<tr>
<th>Aperture Width</th>
<th>Aperture Length</th>
<th>Stencil Radius</th>
<th>Stencil Thickness</th>
<th>Area Ratio</th>
<th>Recommend</th>
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<tbody>
<tr>
<td>0</td>
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</tbody>
</table>

- **Area Ratio**: 0.783
- **Recommend**: E-FAB with Nano-Coat or NiCut
- **Calculate**: E-FAB or NicAlloy-XT or NiCut

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**Substrate**

**Stencil**

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**Privileged and Confidential Materials**
Stencil Nano-Coatings

Wipe on
Coating B  
Coating C

Spray coat and cure
Coating A  
Coating D

Self Assembled Monolayer  
Thermally Cured Polymer

Surface Function

Uncoated stencil

Nano-coated stencil
Coatings A, B, C, D

<table>
<thead>
<tr>
<th>Coating</th>
<th>Bridging</th>
<th>Profile Shape</th>
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</thead>
<tbody>
<tr>
<td>Uncoated</td>
<td>174</td>
<td>Deteriorates</td>
</tr>
<tr>
<td>Coating A</td>
<td>0</td>
<td>Consistent</td>
</tr>
<tr>
<td>Coating B</td>
<td>2</td>
<td>Consistent</td>
</tr>
<tr>
<td>Coating C</td>
<td>0</td>
<td>Consistent</td>
</tr>
<tr>
<td>Coating D</td>
<td>0</td>
<td>Consistent</td>
</tr>
</tbody>
</table>

After 20 prints with no underside cleaning
Aperture Function – Transfer Efficiency*

*SMTAI 2013, Can Nano-Coatings Really Improve Stencil Performance. T. Lentz

Aperture Function – Transfer Efficiency*

Benefits & Negative Impacts

<table>
<thead>
<tr>
<th>Benefits</th>
<th>Nano-Coatings Tested</th>
</tr>
</thead>
<tbody>
<tr>
<td>Underside cleaning improved</td>
<td>All coatings – A, B, C, D</td>
</tr>
<tr>
<td>Bridging improved</td>
<td>All coatings – A, B, C, D</td>
</tr>
<tr>
<td>Re-apply by the user</td>
<td>Coatings B and C</td>
</tr>
<tr>
<td>Visible on the stencil</td>
<td>Coatings A and D</td>
</tr>
<tr>
<td>Transfer efficiency increased</td>
<td>Coatings A and D</td>
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</table>

<table>
<thead>
<tr>
<th>Negative Impacts</th>
<th>Nano-Coatings</th>
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<tbody>
<tr>
<td>Coating wears through abrasion</td>
<td>Coatings B and C</td>
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<tr>
<td>Coating wear not visible</td>
<td>Coatings B and C</td>
</tr>
<tr>
<td>Transfer efficiency decreased</td>
<td>Coatings B and C</td>
</tr>
</tbody>
</table>

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Thank You!

Open Discussion

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