Workshop on SMT Stencils

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What is STENCIL?
In general, the stencil is a simple tool to make repetitive impression. Is being commonly used by every one at least once in life time.
Varieties of STENCILS
Varieties of STENCILS

SMTA Chennai     30th May 2014
What is SMT Stencil?

The Stencil foil is tensioned and fixed to the frame by polyester mesh. The Tension of the Stencil Foil is around 40N/cm (± 5N/cm)
Stencil Printing

- squeegee
- solder paste
- stencil aperture
- circuit board
- stencil foil
- stencil frame
- soldering pad
1. Aligning Board to Stencil
2. Moving Squeegee on the Stencil
Filling Apertures
3. Separating Stencil from the Board
The holes, or apertures, are formed by one of these three methods:

**Electroforming**

Electroforming, is an additive process whereby the stencil foil is created by electroforming nickel.

**Chemical Etching**

These TWO processes are subtractive in that the removal of material from the stencil foil, either by chemical etching or laser cutting, creates the aperture.

**Laser Cutting**
Electroformed Stencil

Manufacturing Process

1. Metal substrate with specially textured surface. Cleaned and degreased.
2. Photo-sensitive coating applied.
3. Image transfer by UV exposure through photomask; developing and rinsing off solved photo-resist.
4. Electro deposition of metal molecules to matrix foundation on areas not masked with photo-resist.
5. Separation of electroformed product from metal substrate.
6. Complete electroformed product.
**Advantages**

- No stress in the material
- Any thickness
- Cost price independent from number of apertures
- Tapered slots
- High precision

**Disadvantages**

- Higher initial cost
- Higher processing time
- Film tooling required
Chemical Etching Stencil

Manufacturing Process

1. Cemically cleaned surface.
2. Photo-sensitive coating applied to both top and bottom.
3. Image transfer by UV exposure through photomask and developing solved photo-resist.
6. Complete etched product.
Chemical Etching Stencil...

Advantages

- Other materials possible
- Low Cost

Disadvantages

- Rough aperture sidewalls
- Hour Glass Shape of sidewalls
- Process releases tension in stainless steel
- Restricted to Minimum pitch size is 0.63mm
Chemical Etching Stencil...

Double-side etching – "hour glass" cross-section

Misalignment of phototools between the two sides
Laser Cut Stencil

Stencil Manufacturing by Laser Cutting
Why Laser Cut STENCILS?

- The repeatability of dimensions in laser-cut stencils is generally better than that of chemical etching.

- With laser cutting, there are no photo films requiring precise alignment or protection from moisture.
Works Direct from CAD/CAM Data

Preferably in GERBER-X format

Other CAD outputs also can be taken

a) AutoCAD DXF/DWG
b) HPGL format
c) CNC data
Advantages

- Faster Production Turn around.
- Tapered slots
- No film tooling

Disadvantages

- Rough aperture sidewalls
- Additional Deburring process to smoothen the hole wall.
# Comparison of Technologies

<table>
<thead>
<tr>
<th>Technology</th>
<th>Accurate apertures</th>
<th>High number of holes</th>
<th>Long production runs</th>
<th>Fast delivery</th>
<th>Paste yield</th>
<th>Price/performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Etched</td>
<td>-</td>
<td>+++</td>
<td>+</td>
<td>++</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Laser*</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
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<tr>
<td>Electroformed</td>
<td>+++</td>
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<td>+++</td>
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* Laser Cut Stencils with Hole Wall & Surface Polish
Controllable Elements

On Design:

- Aperture Design
- Aperture Reduction
- Component PAD Geometric

On the Stencil

- De-Burring Process
- Stencil Material
- Laser Cutting Parameters

On the Performance of the Stencil

- DfM Analysis Skill
- Manufacturing Experience
- Effect of Squeegee Blades
**Aperture Dimensional Parameters**

**Empirical relationships between aperture size and thickness**

- **Aspect Ratio (for components with L>5W)**
  \[
  \frac{\text{Width}}{\text{Thickness}} (W/T)
  \]
  should be > 1.5

- **Area Aspect Ratio (for components with L=W)**
  \[
  \frac{(\text{LW})}{(2T(\text{L+W}))}
  \]
  should be ≥ 0.66
Aspect Ratio and Area Ratio Rules

- Aspect ratio ensures that the aperture will allow the printed material to release onto the substrate

- Area ratio ensures that the forces pulling a material onto the pad are greater than the forces holding it in the aperture

\[
\frac{\text{Pad Pulling Tension (P)}}{\text{Retaining Wall Tension (R)}} = \frac{\text{Aperture (Length (L) x Width (W))}}{\text{Stencil Thickness (T) x Aperture Perimeter (2 x (L+W))}} \geq 0.66
\]
Trapezoidal Shaped Apertures

- Aperture openings which are 0.010 to 0.030 mm larger on the contact side (PCB side) than on the squeegee side based on foil thickness.

- Trapezoidal apertures, which enhances effective solder paste release, also form a “brick-like” deposit that assists firm component placement.
## DfM Analysis on Aperture Design

### Mid Chip Solder Balling

<table>
<thead>
<tr>
<th>Defect</th>
<th>Photo</th>
<th>Stencil Design</th>
<th>After DfM Design</th>
<th>Result</th>
</tr>
</thead>
</table>
| Mid Chip Solder Balling | ![Photo](image1) | ![Stencil Design](image2) | ![After DfM Design](image3) | - R/C Chip  
- Medial 25% Cut  
- Solder Ball prevention |

### Solder Bridging at QFN Pads

<table>
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<tr>
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<th>Photo</th>
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<th>After DfM Design</th>
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</tr>
</thead>
</table>
| Solder Bridging at QFN Pads | ![Photo](image4) | ![Stencil Design](image5) | ![After DfM Design](image6) | - Centre PAD Cut : Hourglass shape application  
- → Inside 0.18\(\text{mm}\), outside 0.195\(\text{mm}\)  
- Dummy PAD : Medial 10% Cut Hourglass shape DNA  
- Reverence (the way) 5% extension  
- A Round (Oblong) outside application |

### Slitting of Heat Sink area

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</table>
| Slitting of Heat Sink area | ![Photo](image7) | ![Stencil Design](image8) | ![After DfM Design](image9) | A : CAD PAD width  
B : 1/4 Cutting work  
C : Mask reinforcing band width (1.0 \(\text{mm}\))  
D : Outside : 0.3\(\text{mm}\) extension |
The possibility of aperture reduction depends on the solder alloy:

- Leded alloy: reduction is always possible.
- Lead-free alloy: reduction is possible only in case of PCB finishes with good wettability.
# PAD Design for PASSIVE SMD Components

<table>
<thead>
<tr>
<th>Design</th>
<th>Home Plate</th>
<th>Inverse Home Plate</th>
<th>Rounded Inverse Home Plate</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAD Data</td>
<td><img src="image" alt="CAD Data Home Plate" /></td>
<td><img src="image" alt="CAD Data Inverse Home Plate" /></td>
<td><img src="image" alt="CAD Data Rounded Inverse Home Plate" /></td>
</tr>
<tr>
<td>Stencil Output</td>
<td><img src="image" alt="Stencil Output Home Plate" /></td>
<td><img src="image" alt="Stencil Output Inverse Home Plate" /></td>
<td><img src="image" alt="Stencil Output Rounded Inverse Home Plate" /></td>
</tr>
<tr>
<td>After Print</td>
<td><img src="image" alt="After Print Home Plate" /></td>
<td><img src="image" alt="After Print Inverse Home Plate" /></td>
<td><img src="image" alt="After Print Rounded Inverse Home Plate" /></td>
</tr>
</tbody>
</table>
“Worst Case”
For MCSB
6 mil foil

Square/Rectangular

Radiused Home Plate

“Best Case”
For MCSB
5 mil foil

Home Plate

Radiused Inverted Home Plate

Not recommended
Potential squeegee & stencil damage

Inverted Home Plate

Radiused Inverted Home Plate

Experimental Apertures
5 & 6 mil foils
PAD Design for SMD Components

Home Plate
Before
After

Zipper Pads
Before
After

Cross Pattern
Before
After

MELF Pads
Before
After
Deburring Process (POLISHING)

- Electro Polishing
- F2 Polishing
- Pumice Polishing
ELECTRO POLISHING

Effect of Electropolishing on SS
10 mil Circular Apertures at 400 & 800X

Sharper Corners

Ridge
F2 Polishing (Deburring Process)

Why is F2 Polish:

This F2 Polishing done after Laser Cutting to Deburr the Aperture.

The F2 Polishing was developed for the next generation Laser Cut Stencils. This polishing technology is UNIQUE compared to “Chemical Polishing” and “Electro Polishing”.

Due to extremely smooth processing surface and high dimensional precision, the applied solder paste volume can be uniform and stable.

Before F2 processing

Opening diameter : 0.200mm
Stencil thickness : 0.150mm

After F2 processing

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Effect of F2 Polishing after QFP Printing

Before Polish

After Polish

[Pitch 0.400mm, Aperture width 0.210mm on 0.150mm thickness]
NANO COATING

Plane Eye View - No Coating

Plane Eye View – After NANO Coating
NANO COATING

Top View No NANO Coating

Top View after NANO Coating
NANO COATING

Side View No NANO Coating

Side View - NANO Coating
NANO COATING

Water Droplet Test

Nano Coated (L)

No NANO Coat (R)
Stencil Physical Parameters for Paste Release

- **Stencil surface finish**
  - Controls proper paste roll over the stencil. Paste should not slip.

- **Stencil wall finish**
  - Controls proper paste flow & release from apertures.
  - Paste should slip on the wall but not stick to it.
  - Dependent on the manufacturing method and secondary operations.

- **Trapezoidal shape for the apertures**
  - Controls stencil release characteristics also dependent on manufacturing method.
Stencil Material:

SUS 304
Fine Grain SUS
Nickel

Stencil Material:

SUS 304: For normal stencil with better paste release option
Fine Grain SUS: Used for Ultra Fine Pitch component pads

Stencil Material Storage:

All Stencil materials like Stainless Steel Foils, Screen Mesh, Adhesive Glue should be stored at controlled environment. The storage room to be maintained the temperature below 22 deg C.
Conventional SUS vs Fine Grain Material

SEM observation of etched surface

The etching

Magnified View of Etched Portion

Grain Size

Aperture Wall after Laser Cut

Conventional SUS-304

Fine Grain SS
The operators would often run machines faster than the manufacturers recommendations, creating poor hole wall quality. Other problems encountered included warping or oil canning of the stencil material as well as burn marks on or around the apertures.

This is what happens when the Laser Cutting parameters are adjusted to increase the stencil quantity.
This is what Happens when the Laser Cutting parameters are Controlled and adjusted to increase the stencil quality.

“A knowledgeable, fully trained staff can run a well-made laser system free of Burr, with smooth walls and a high quality finish”.

“Stencils that have been modified for the component footprint/design and have been properly run on a good laser system, will have maximum paste release and barring outside influences (operator error, poor board quality, non-standard component sizes, etc.), will run defect free.”
**Basic stencil design:**

- For surface mounted passive components aperture reduction rules apply
- For SM perimeter styles components (QFPs, QFNs) aperture reduction rules apply; foil thickness calculation is necessary
- For common plastic BGA packages (pitch>1.27 mm) round aperture is recommended with reduction considerations
- For fine-pitch plastic BGAs (pitch<1.27) square aperture recommended, aperture reduction rules do not apply

**Step stencils for Pin-in-Paste technology:**

- For squeegee side steps, technological distance to the nearest surface mounted component is 36x `step_thickness`
- For contact side steps, recommended technological distance to the nearest surface mounted component is 1.6x `step_thickness·foil_thickness`
The Effect Of Squeegees
Tempered Spring Steel Alloy assures many thousands of flexures while maintaining original shape, unlike softer etched blades made from stencil material.
The Effect Of Squeegees

Permalex Edge Metal Squeegees eliminate pumping and scavenging

Improving solder paste deposit quality.

The smooth, lubricated edge reduces stencil pulling and stretching, improving pad registration and stencil life.
The Effect Of Squeegees

Check that your squeegee, stencil and pcboard “stack” are parallel and rigid as possible.

Set squeegee pressure for a “clean wipe”.

Start at a low squeegee pressure force and adjust UP until a clean wipe is achieved;

Add 10% more for variations.
DISCUSSION...

ANY QUESTIONS?
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THANK YOU
Cutting Overlapping Mismatch due to increase of Cutting Speed
Improper Overlap at Curves - @ QFP Pads due to increase of Cutting Speed
Oval Shaped BGA Pads
Oval Shaped BGA Pads
Oval Shaped BGA Pads
Burrs @ Pad Edge... Oxidation leads to heavy burr...
Good Stencil: Resistor Pad - Just Cut; No Polish.....

Process Friendly... Better Yield....
Smooth Curves @ QFP Pads....

Process Friendly... Better Yield....
What is SMT Stencil?

The SMT stencil is a simple tool — typically a sheet of 75–200 μm thick metal foil, on which apertures are formed according to the solder pads on the printed circuit board for applying either solder paste or flux or glue on to a substrate.

Stencil printing provides a fast, mass solder paste deposition process; relatively inexpensive, appropriate and recommended for mass production.