



Workshop on SMT Stencils

Sakthivel Padmanapan

What is STENCIL?

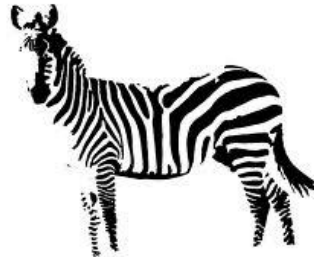
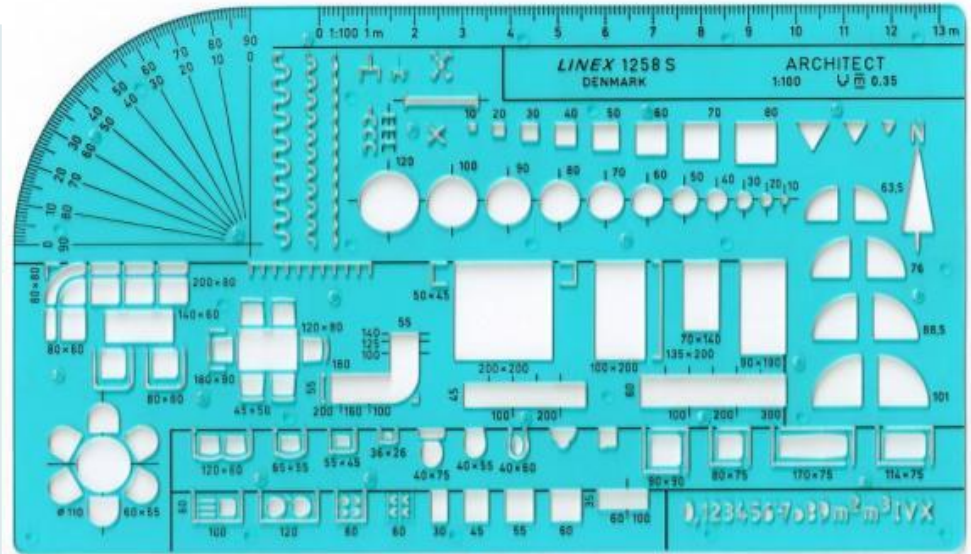
**In general,
the stencil is a simple tool to
make repetitive impression.**

**Is being commonly used by
every one at least once in life
time.**

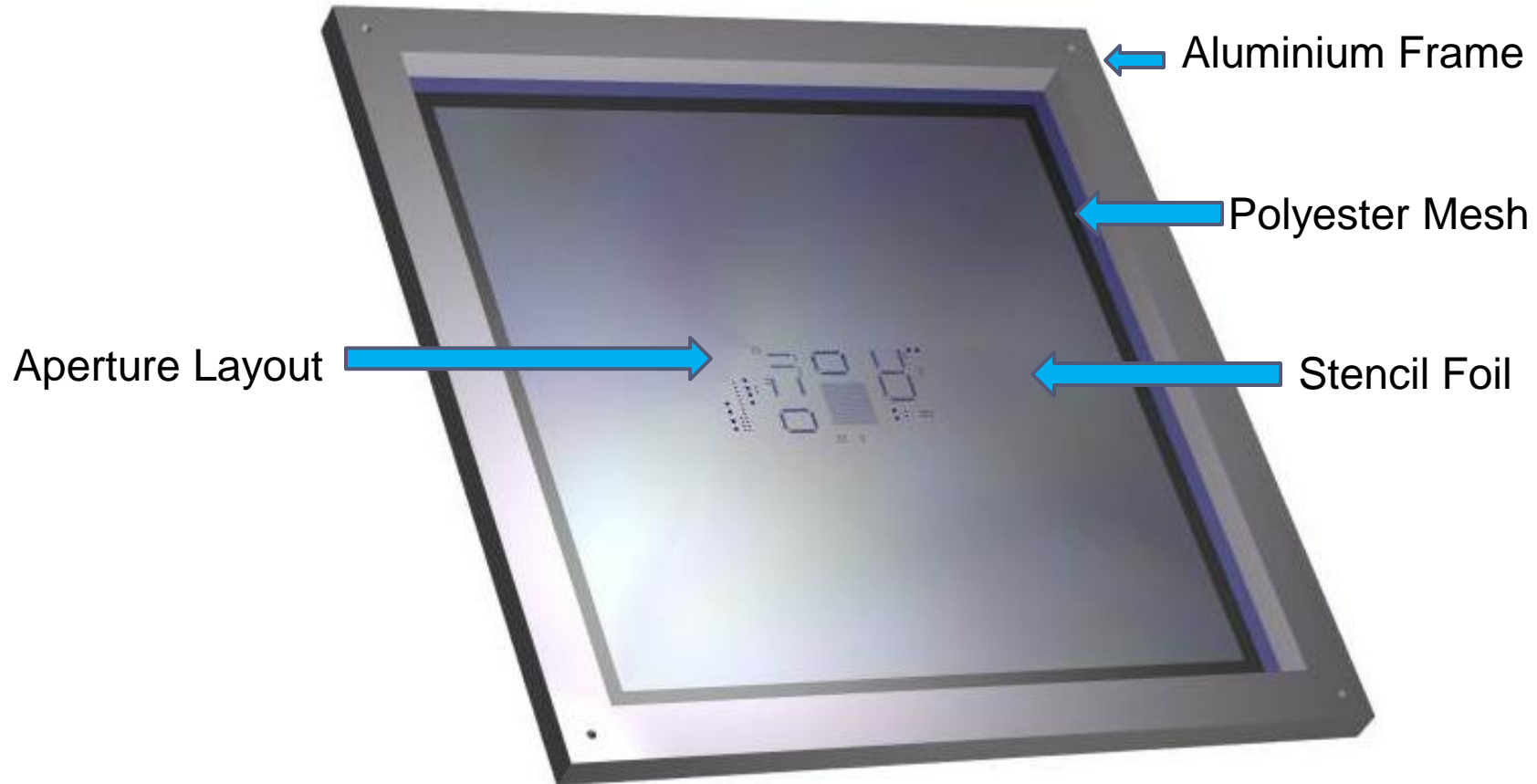
Varieties of STENCILS



Varieties of STENCILS

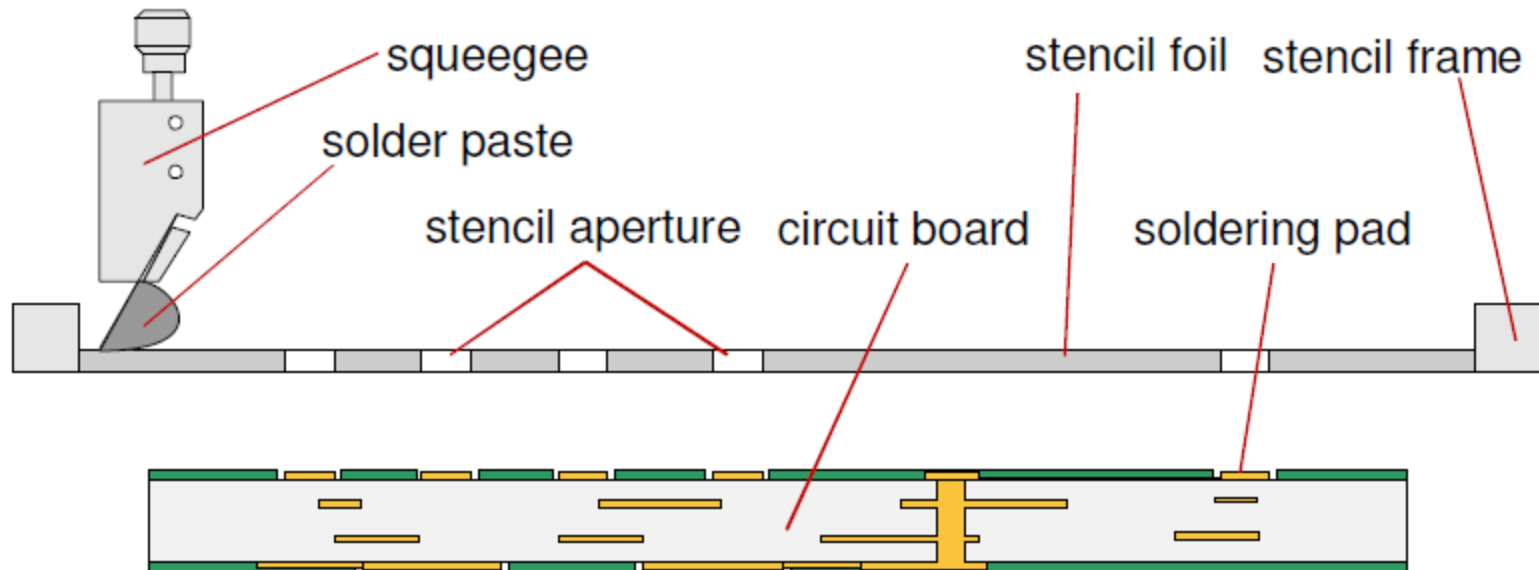


What is SMT Stencil?



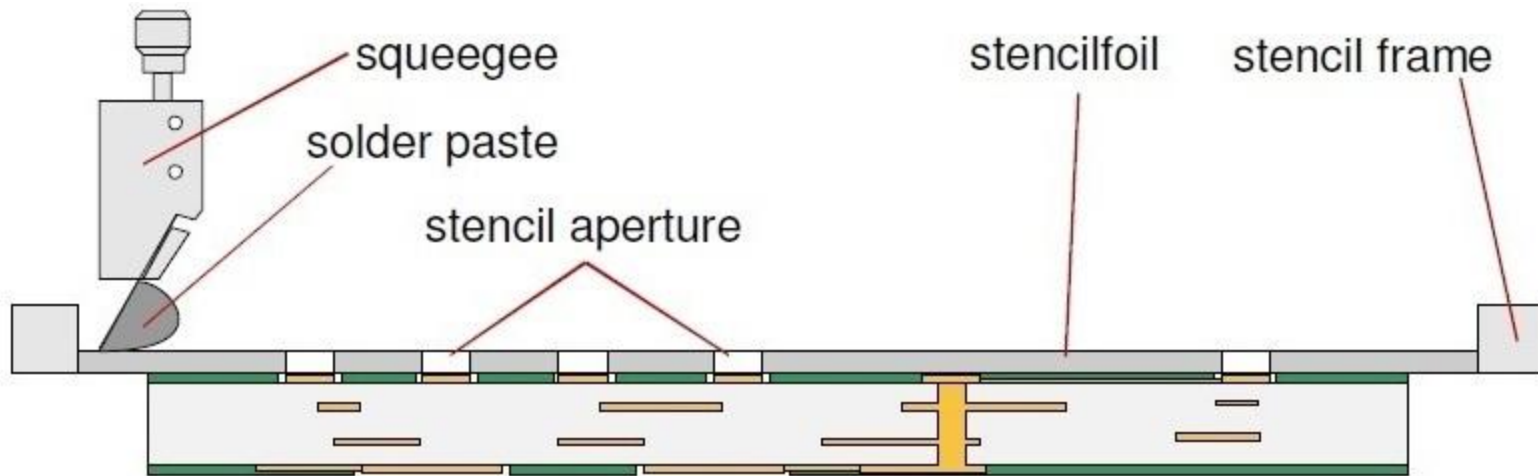
The Stencil foil is tensioned and fixed to the frame by polyester mesh. The Tension of the Stencil Foil is around 40N/cm (± 5 N/cm)

Stencil Printing

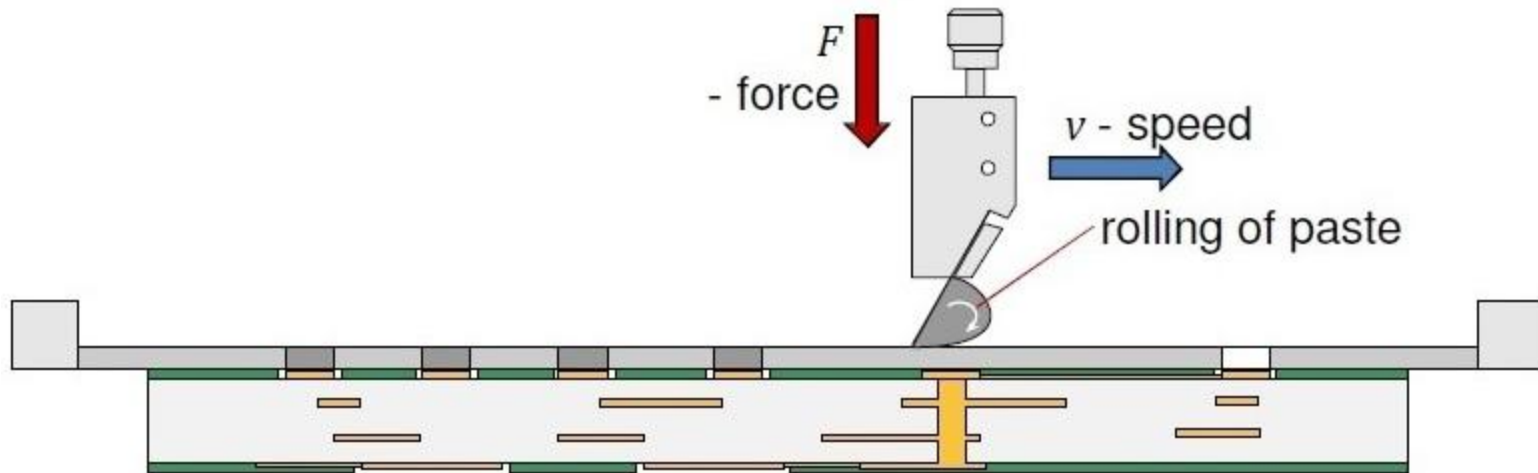


Stencil Printing Process

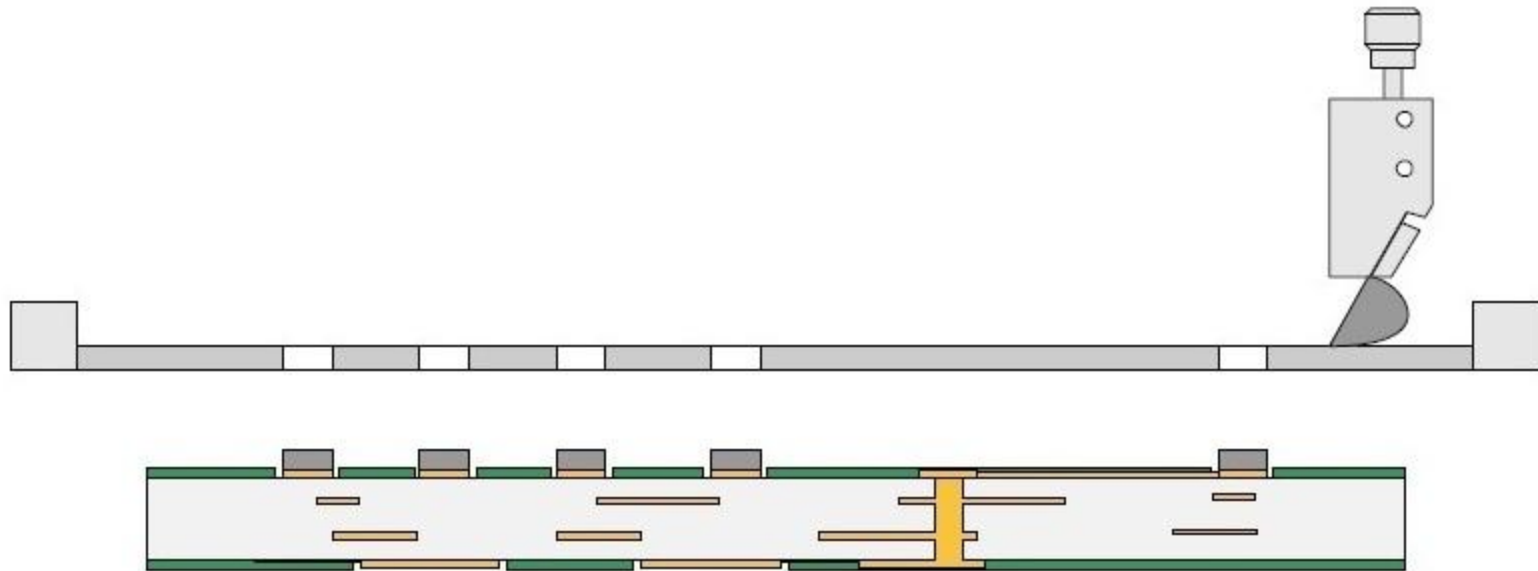
1. Aligning Board to Stencil



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

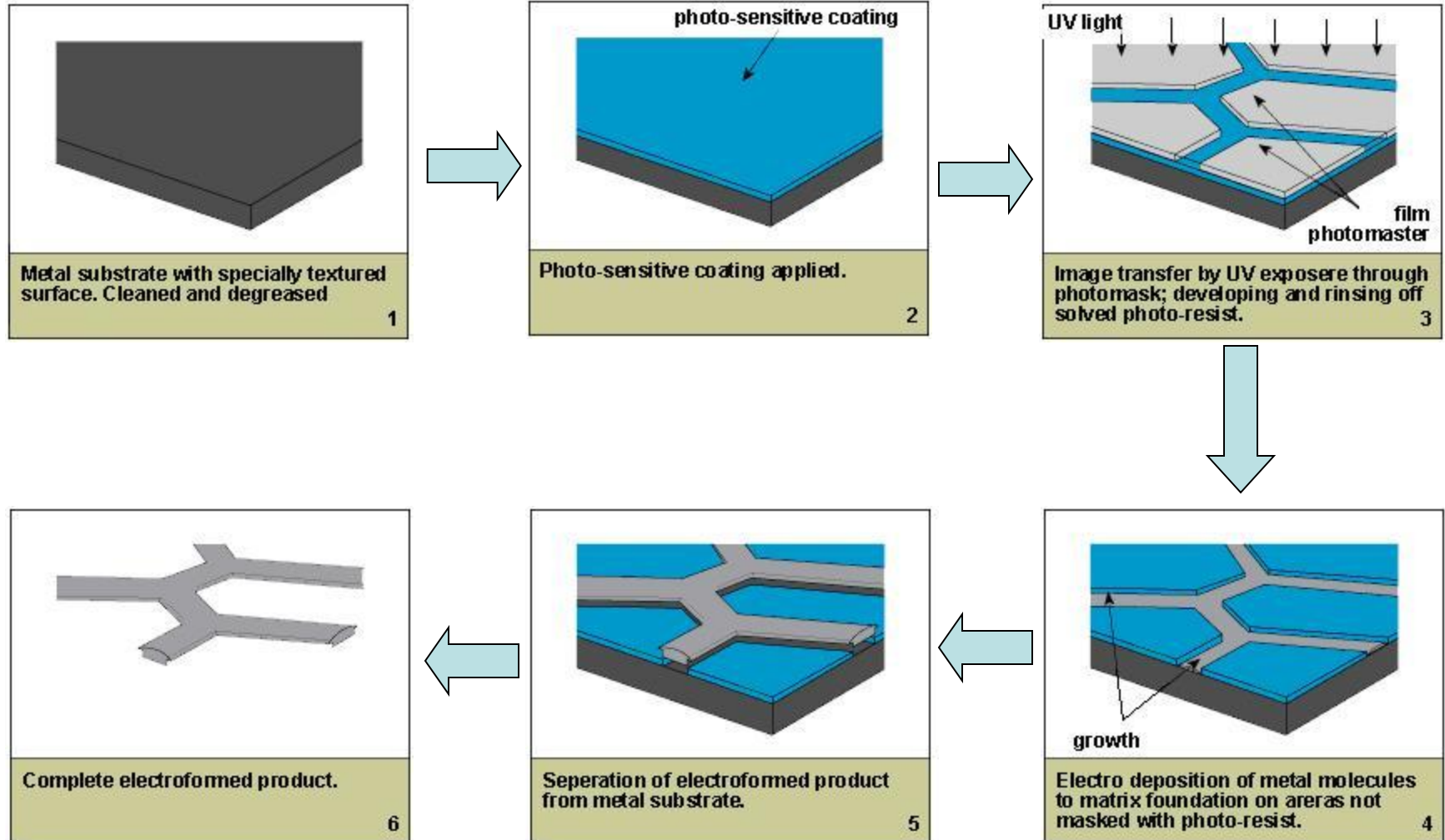
Electroforming, is an additive process whereby the stencil foil is created by electroforming nickel.

Chemical Etching Laser Cutting

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.

Electroformed Stencil

Manufacturing Process



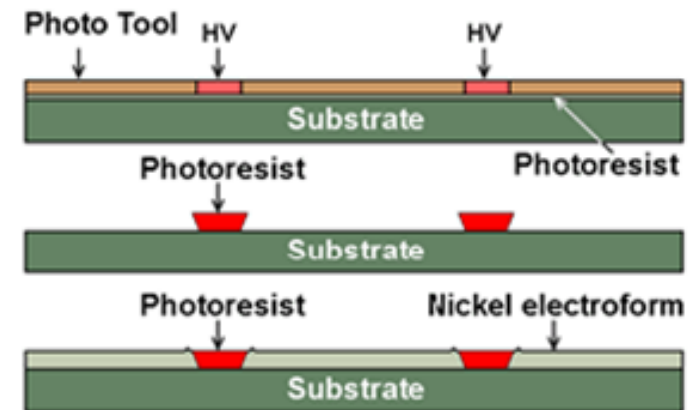
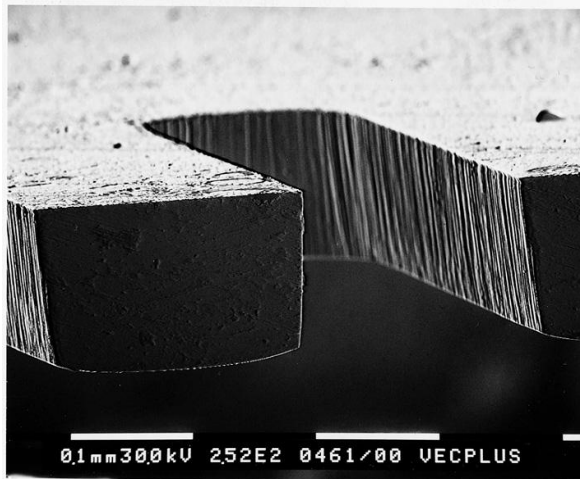
Electroformed Stencil...

Advantages

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

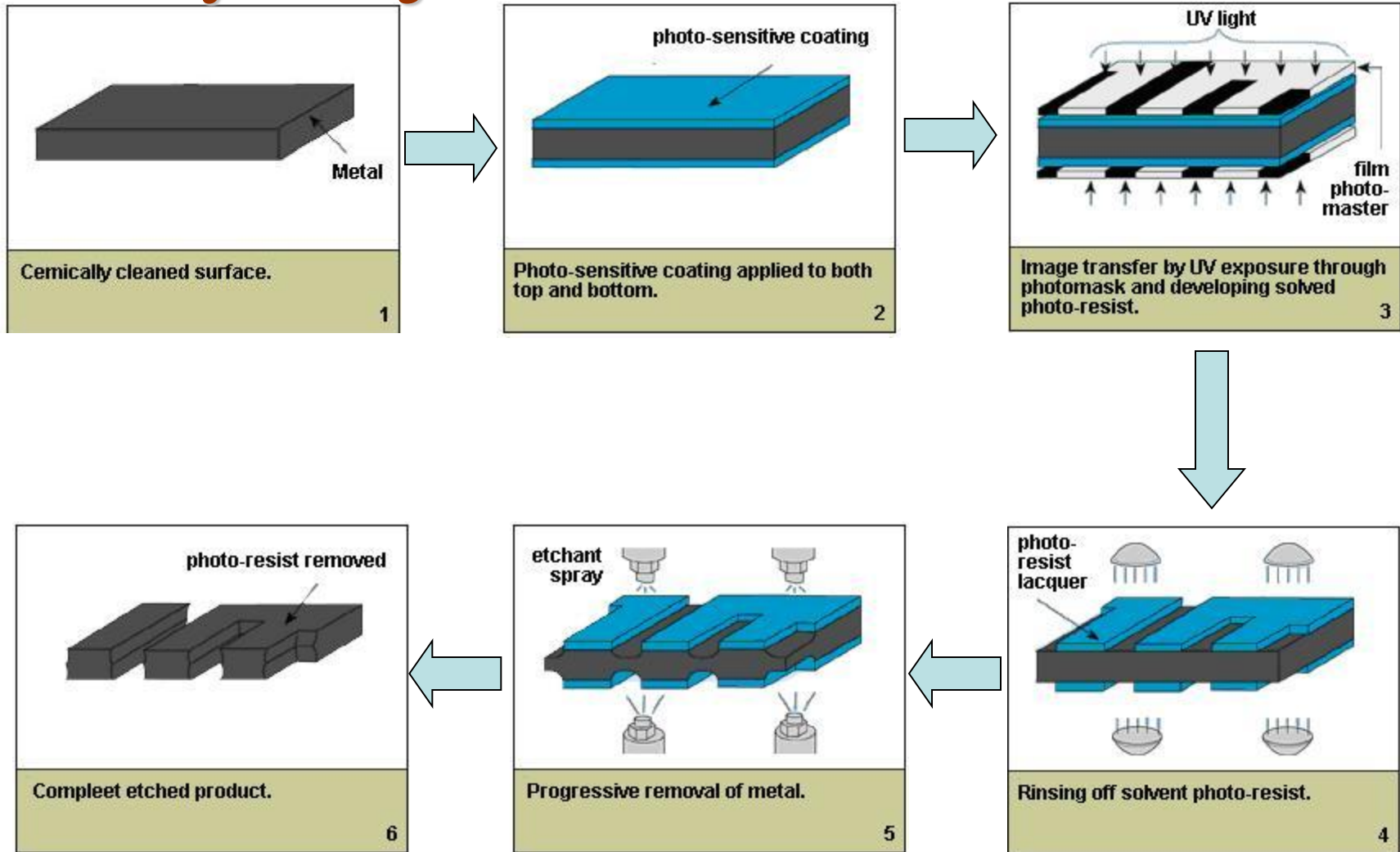
Disadvantages

- Higher initial cost
- Higher processing time
- Film tooling required



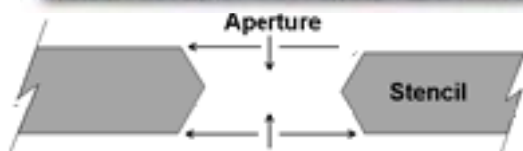
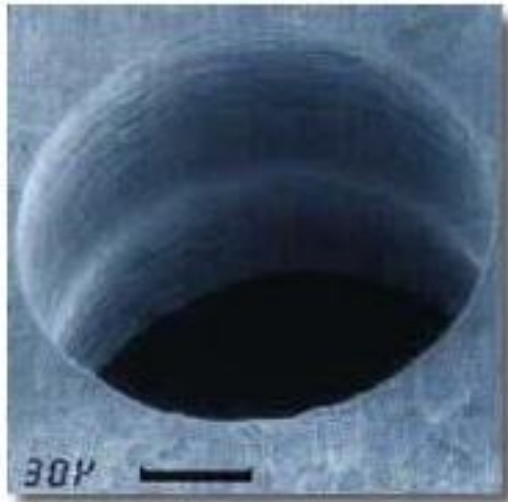
Chemical Etching Stencil

Manufacturing Process



Advantages

- Other materials possible
- Low Cost

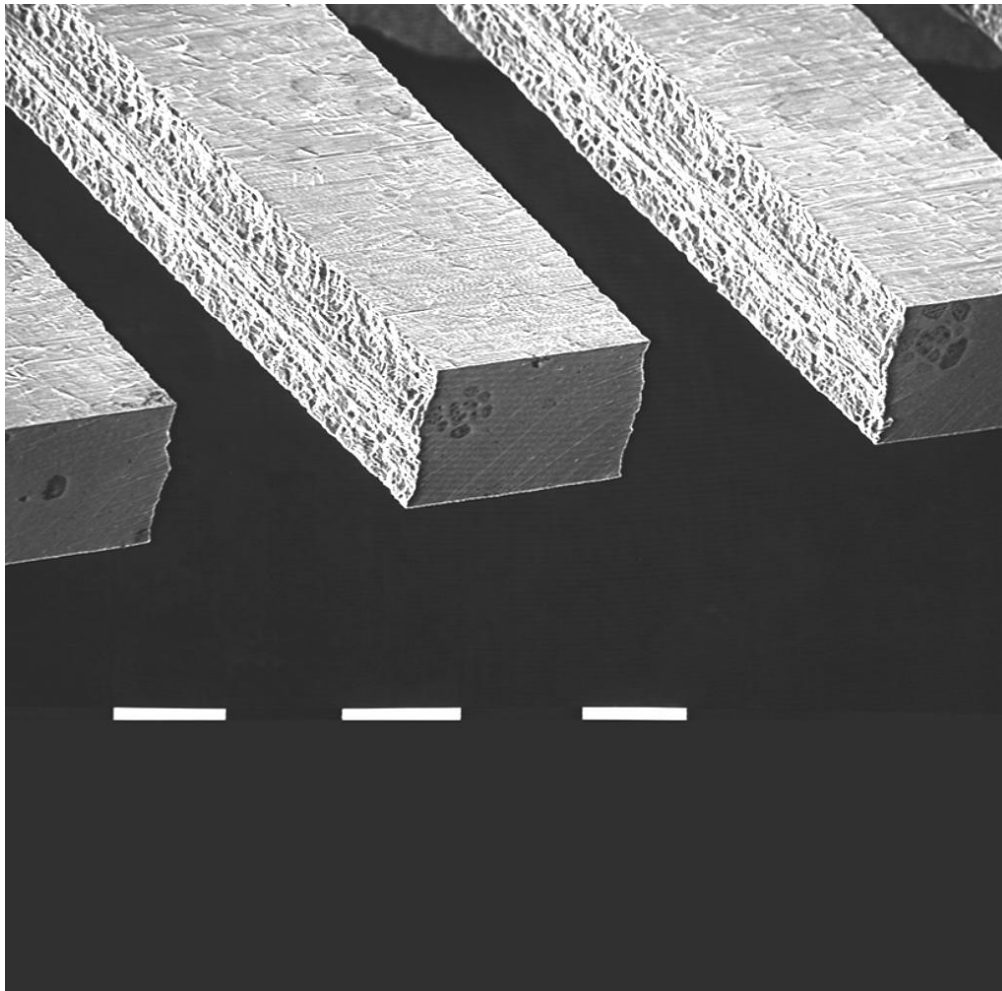


Disadvantages

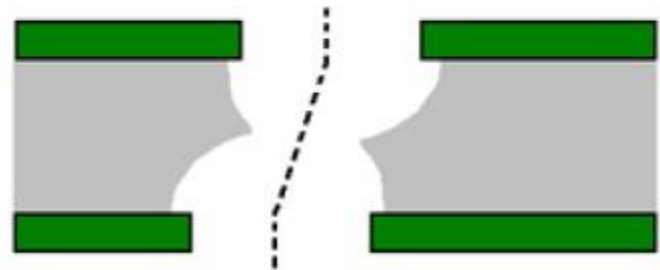
- Rough aperture sidewalls
- Hour Glass Shape of sidewalls
- Process releases tension in stainless steel
- Restricted to Minimum pitch size is 0.63mm



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

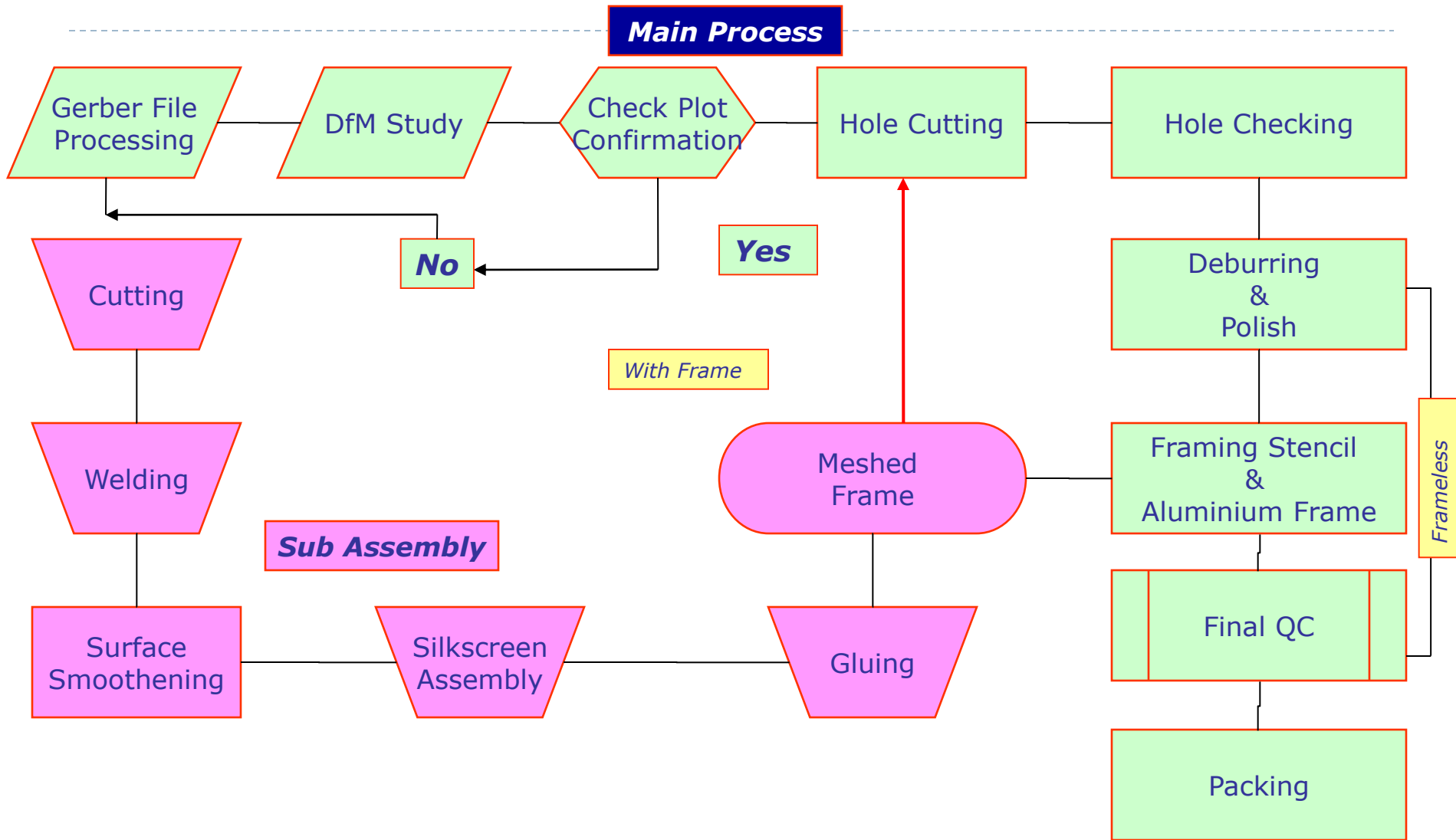


Why Laser Cut STENCILS?

- 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

Laser Cut Stencil Manufacturing

Main Process



Works Direct from
CAD/CAM Data

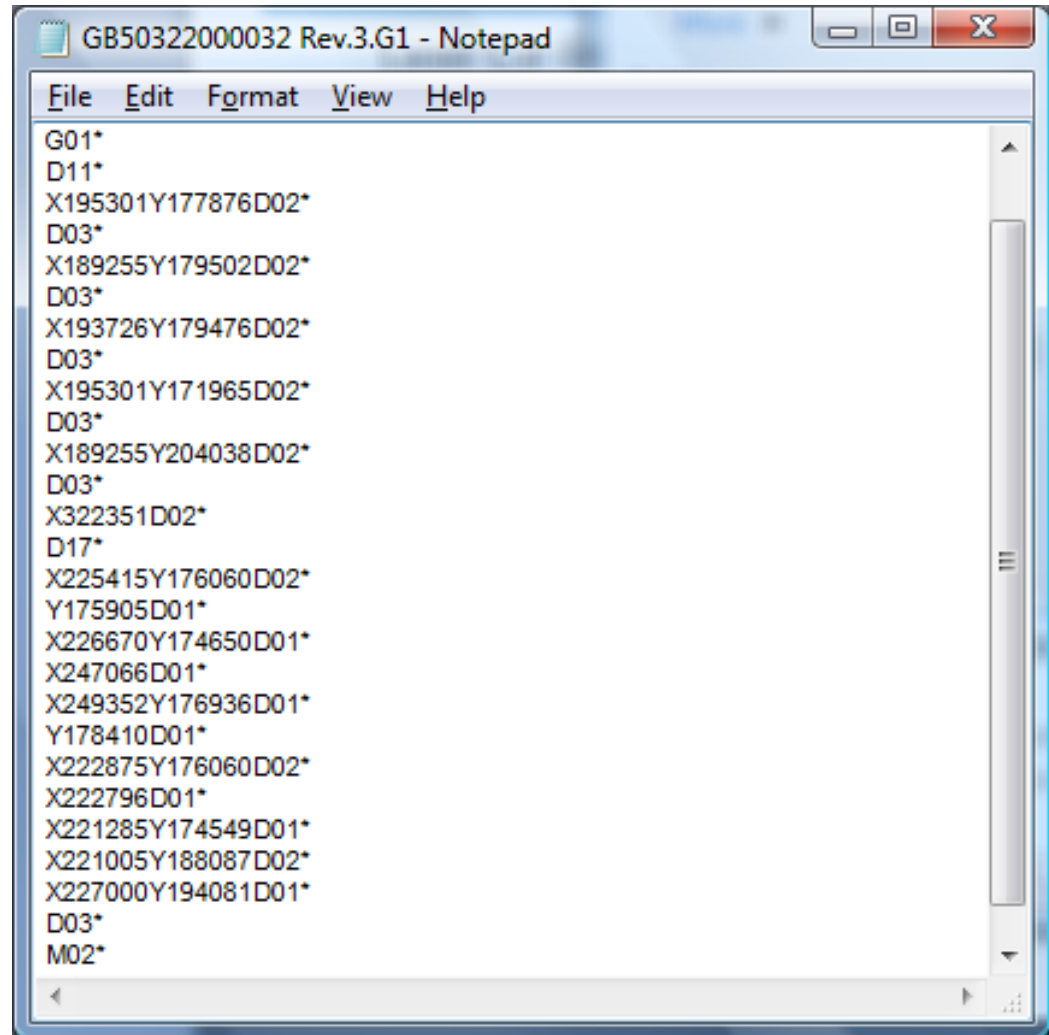
Preferably in
GERBER-X format

Other CAD outputs
also can be taken

a) AutoCAD DXF/DWG

b) HPGL format

c) CNC data

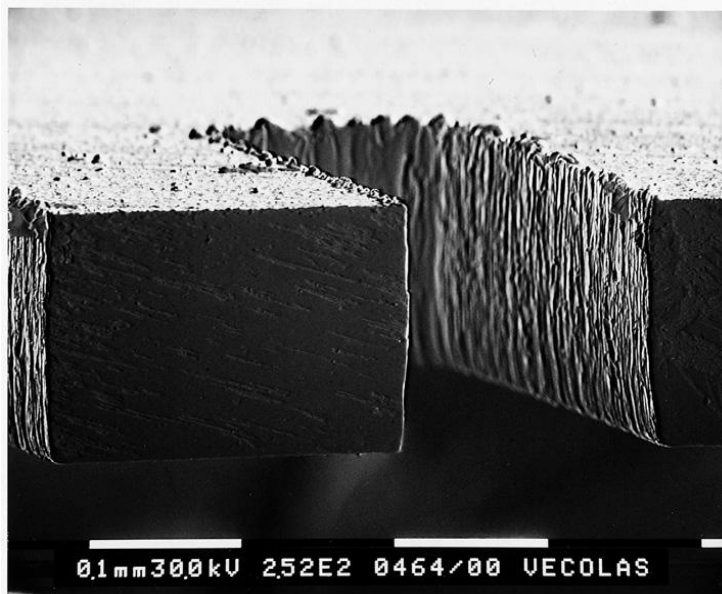


GB50322000032 Rev.3.G1 - Notepad

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File Edit Format View Help
G01*
D11*
X195301Y177876D02*
D03*
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D03*
X193726Y179476D02*
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X222875Y176060D02*
X222796D01*
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X227000Y194081D01*
D03*
M02*
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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

Technology	Accurate apertures	High number of holes	Long production runs	Fast delivery	Paste yield	Price/performance
Etched	-	+++	+	++	+	+
Laser*	+++	+++	+++	+++	+++	+++
Electroformed	+++	+++	+++	+	+++	+++

* Laser Cut Stencils with Hole Wall & Surface Polish

On Design:

- Aperture Design
- Aperture Reduction
- Component PAD Geometric

On the Stencil

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

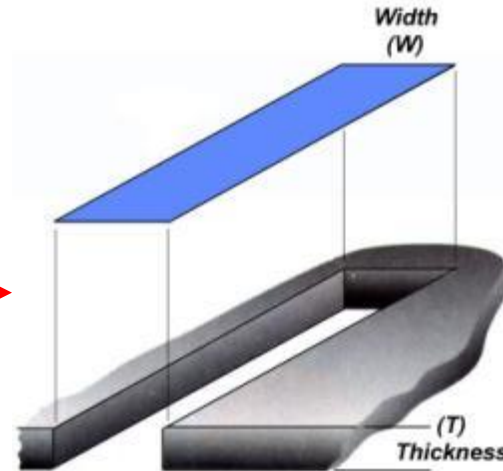
On the Performance of the Stencil

- DfM Analysis Skill
- Manufacturing Experience
- Effect of Squeegee Blades

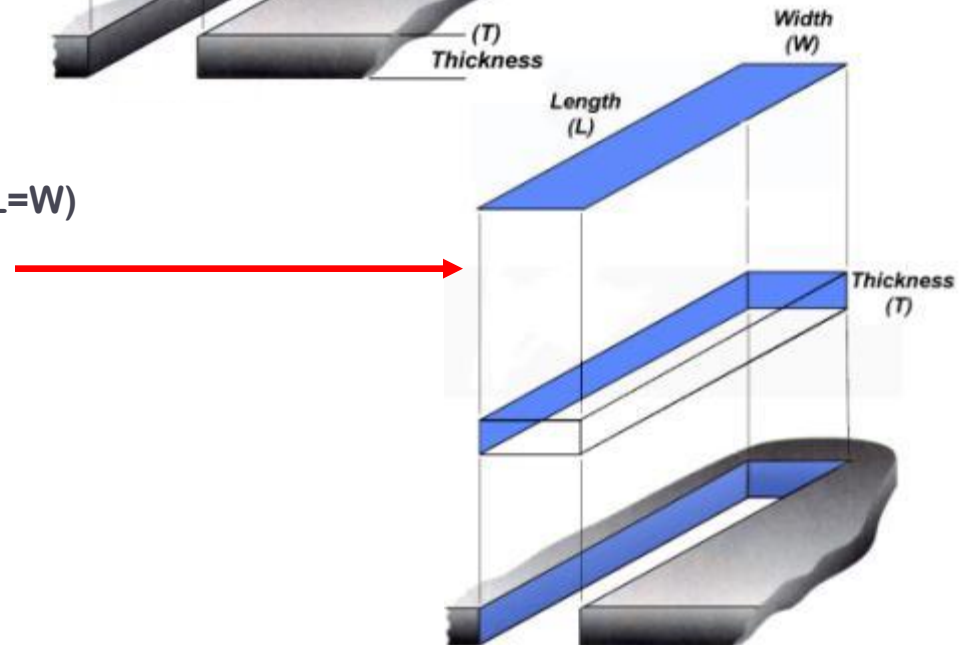
Aperture Dimensional Parameters

Empirical relationships between aperture size and thickness

- ▶ Aspect Ratio (for components with $L > 5W$)
 $Width / Thickness (W/T)$
 should be > 1.5

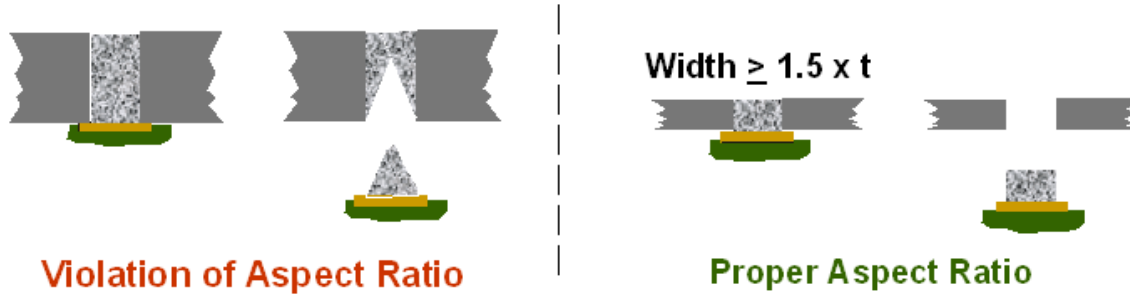


- ▶ Area Aspect Ratio (for components with $L=W$)
 $(LW) / (2T(L+W))$
 should be ≥ 0.66



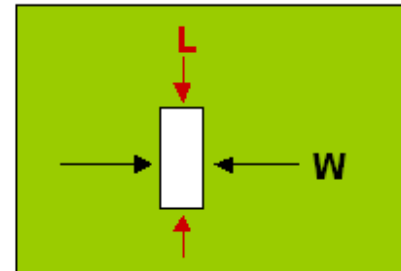
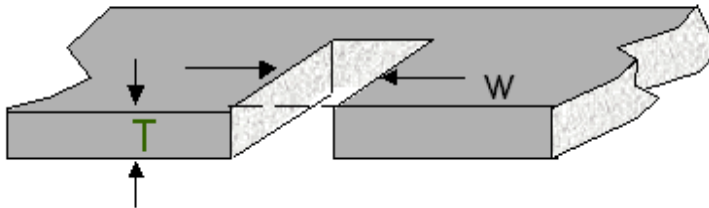
Aspect Ratio and Area Ratio Rules

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



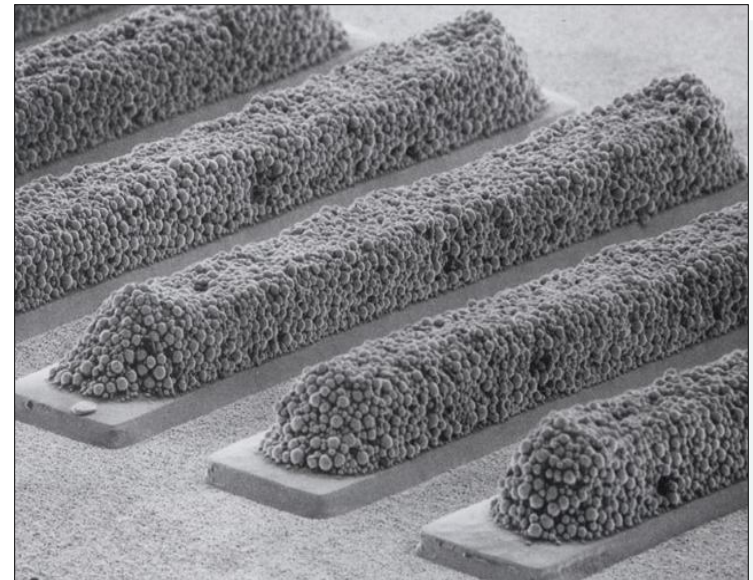
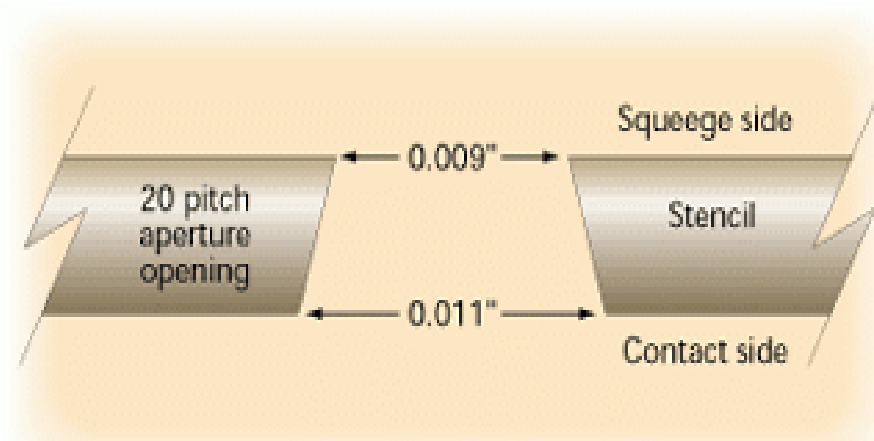
- ▶ Area ratio ensures that the forces pulling a material onto the pad are greater than the forces holding it in the aperture

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



Trapezoidal Shaped Apertures

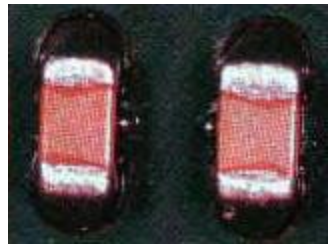
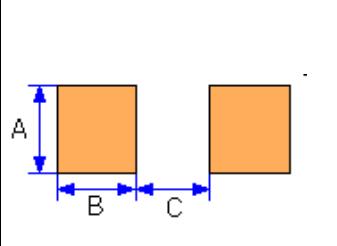
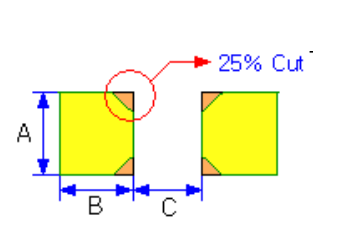

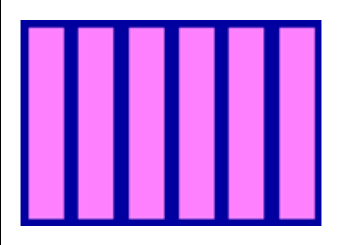
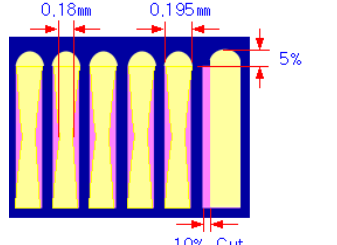

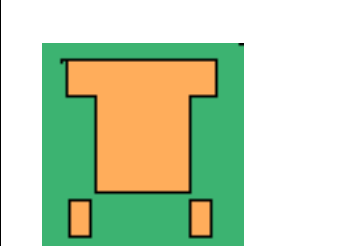
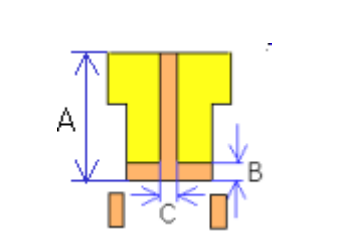
- ❖ Aperture openings which are 0.010 to 0.030 mm larger on the contact side (PCB side) than on the squeegee side based on foil thickness.
- ❖ Trapezoidal apertures, which enhances effective solder paste release, also form a “brick-like” deposit that assists firm component placement



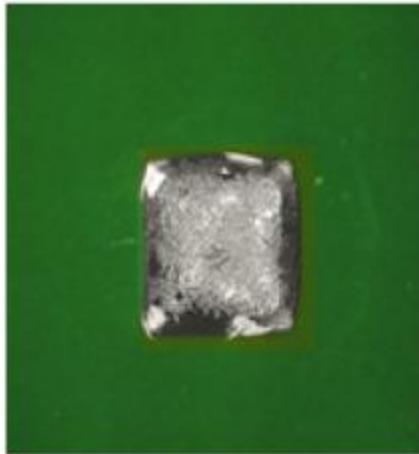
DfM Analysis on Aperture Design



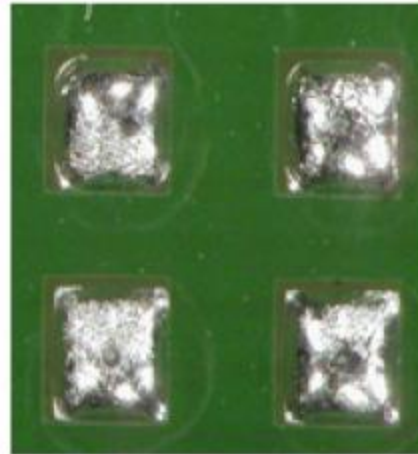
Microsoft Excel
Worksheet

Defect	Photo	Stencil Design	After DfM Design	Result
Mid Chip Solder Balling				<ul style="list-style-type: none"> -R/C Chip -Medial 25% Cut -Solder Ball prevention
Solder Bridging at QFN Pads				<ul style="list-style-type: none"> --Centre PAD Cut : Hourglass shape application - → Inside 0.18mm, outside 0.195mm -Dummy PAD : Medial 10% Cut Hourglass shape DNA -Reverence (the way) 5% extension -A Round (Oblong) outside application
Slitting of Heat Sink area				<ul style="list-style-type: none"> A : CAD PAD width B : 1/4 Cutting work C : Mask reinforcing band width (1.0 mm) D:Outside : 0.3mm extension

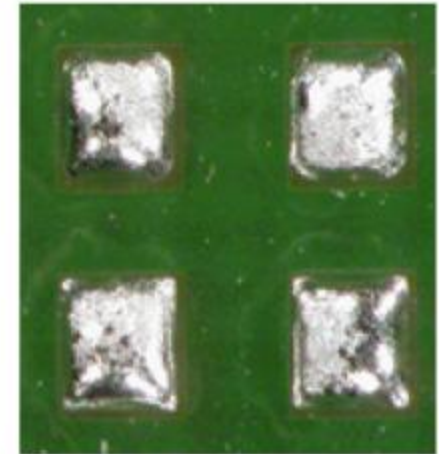
Stencil Design Guide



Ni/Au – 10% reduction



ImAg – 10% reduction

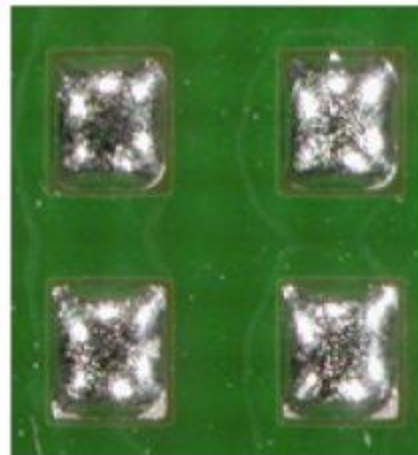


LF HASL – 10% reduction

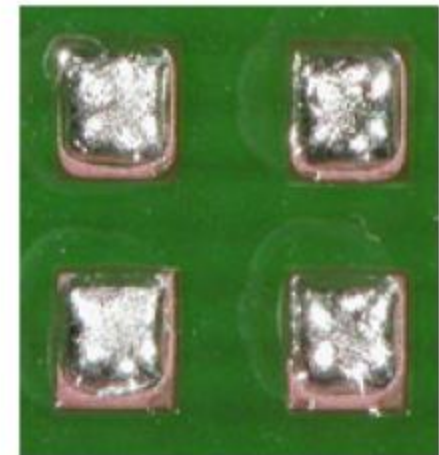
The possibility of aperture reduction depends on the solder alloy

Leaded alloy: reduction is always possible

Lead-free alloy: reduction is possible only in case of PCB finishes with good wettability

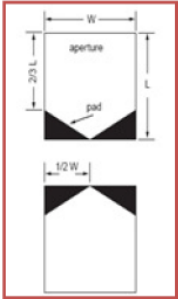
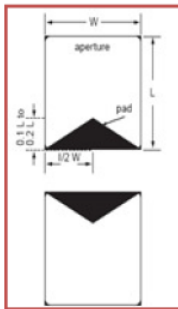
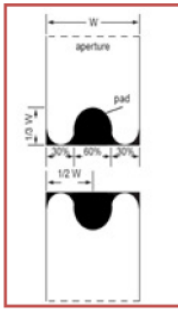
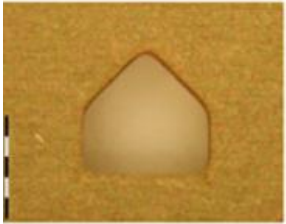
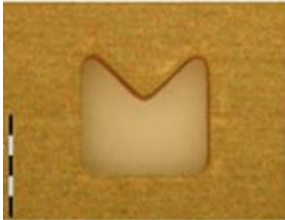

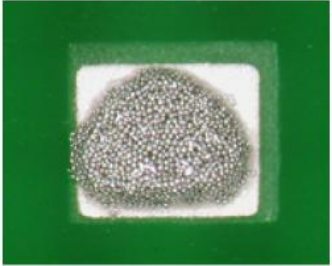
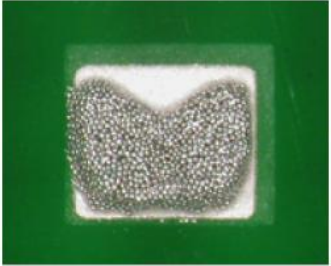
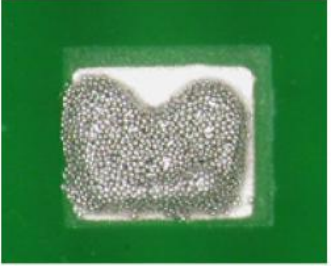


ImSn – no reduction



OSP – no reduction

PAD Design for PASSIVE SMD Components

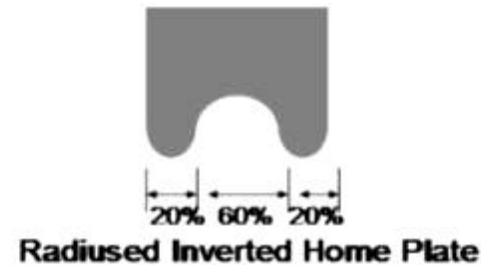
<i>Design</i>	<i>Home Plate</i>	<i>Inverse Home Plate</i>	<i>Rounded Inverse Home Plate</i>
CAD Data			
Stencil Output			
After Print			

PAD Design for PASSIVE SMD Components

“Worst Case”
For MCSB
6 mil foil



“Best Case”
For MCSB
5 mil foil



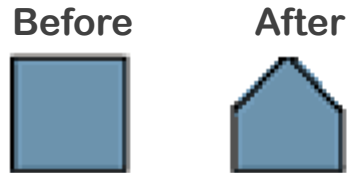
Experimental
Apertures
5 & 6 mil foils

Not
recommended
Potential
squeegee &
stencil damage

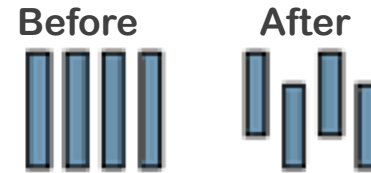


PAD Design for SMD Components

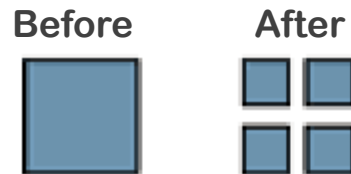
Home Plate



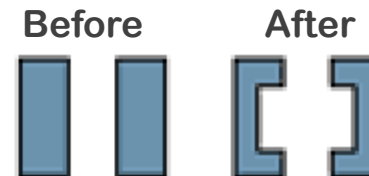
Zipper Pads



Cross Pattern



MELF Pads



Deburring Process (POLISHING)

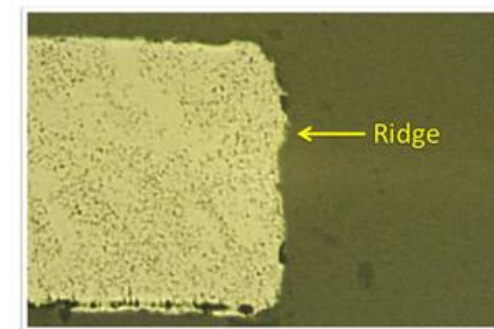
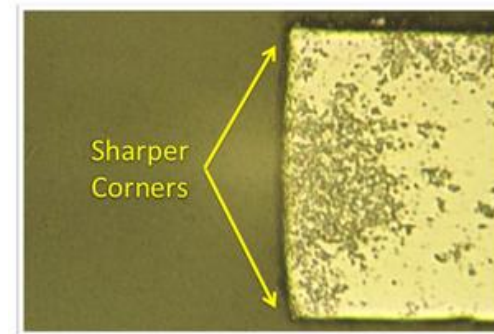
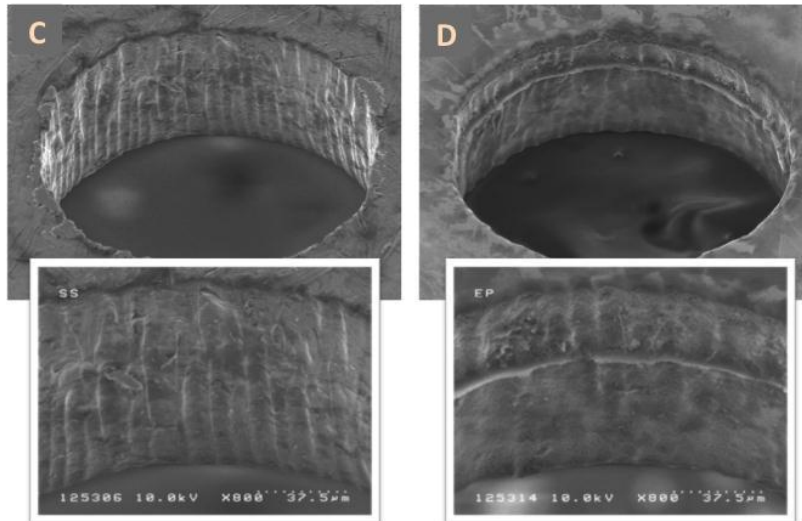
- Electro Polishing
- F2 Polishing
- Pumice Polishing

ELECTRO POLISHING



Effect of Electropolishing on SS

10 mil Circular Apertures at 400 & 800X



F2 Polishing (Deburring Process)

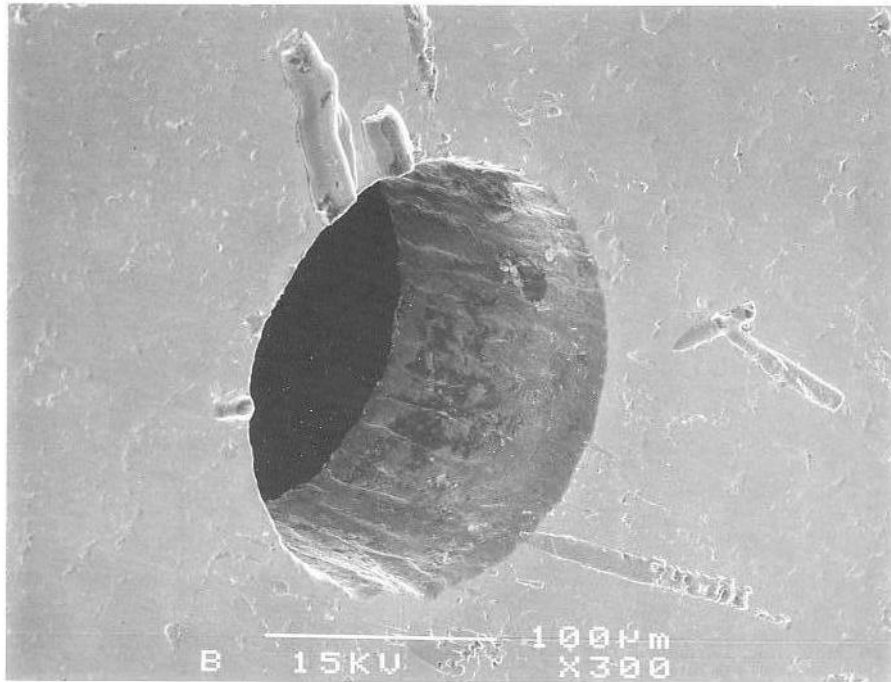
Why is F2 Polish:

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

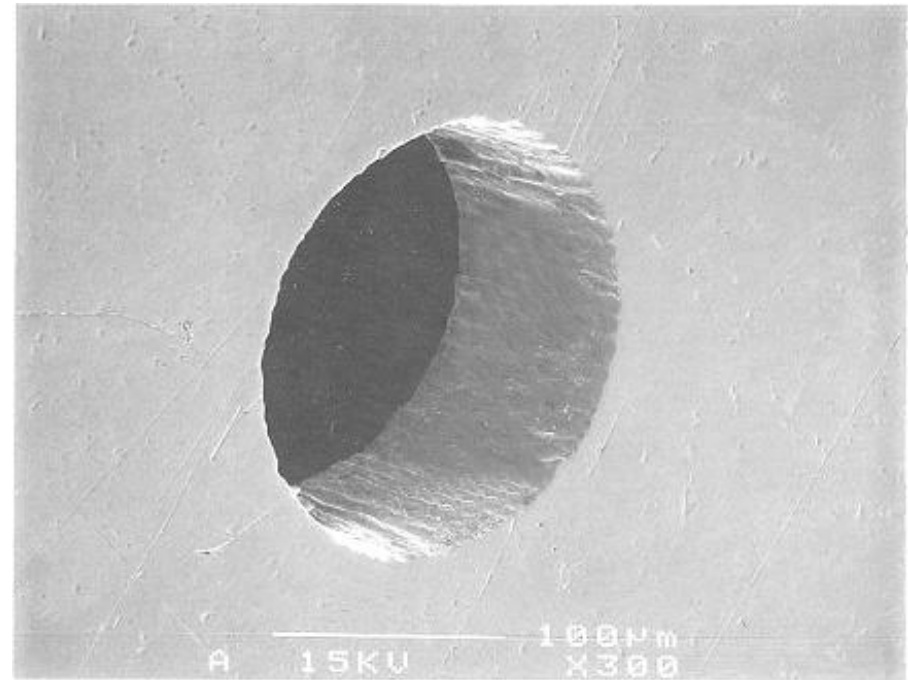
The F2 Polishing was developed for the next generation Laser Cut Stencils. This polishing technology is UNIQUE compared to “Chemical Polishing” and “Electro Polishing”.

F2 Polishing – Aperture Hole Wall Deburring

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



Before F2 processing

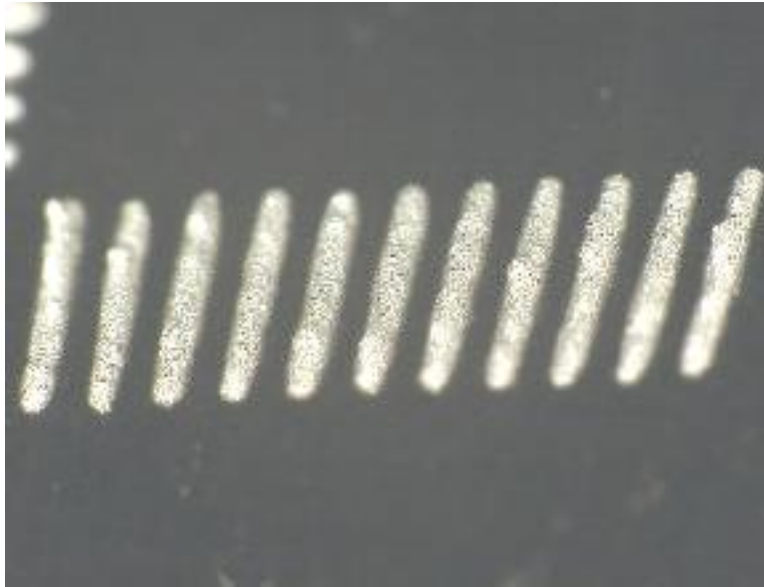


After F2 processing

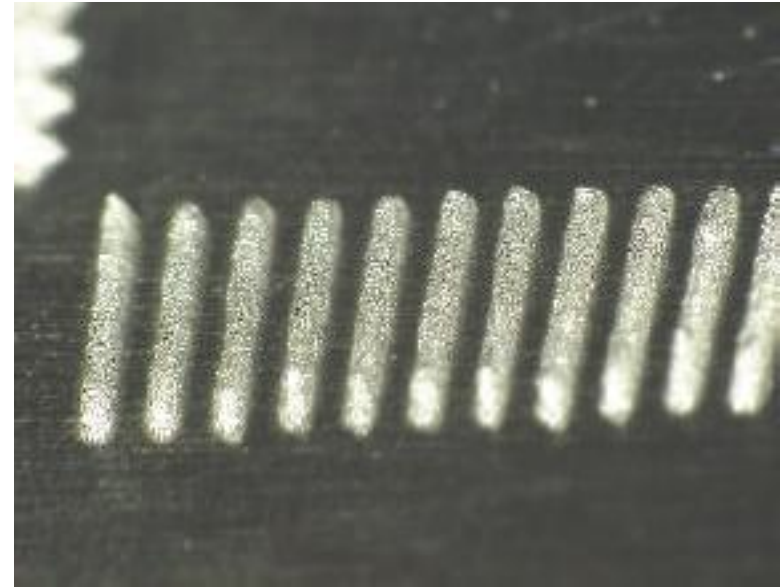
Opening diameter :
0.200mm

Stencil thickness : **0.150mm**

Effect of F2 Polishing after QFP Printing



**Before
Polish**



**After
Polish**

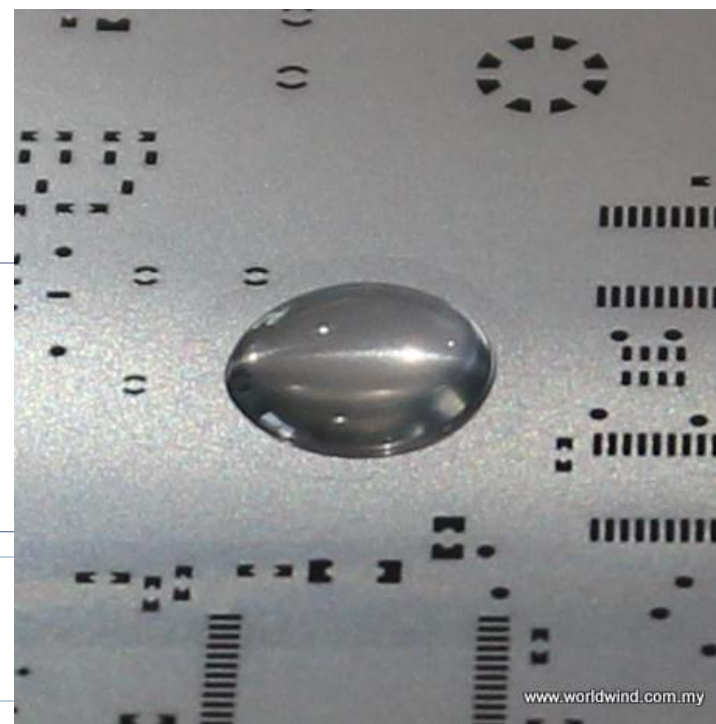
[Pitch 0.400mm, Aperture width 0.210mm on 0.150mm thickness]

NANO COATING

Plane Eye View - No Coating

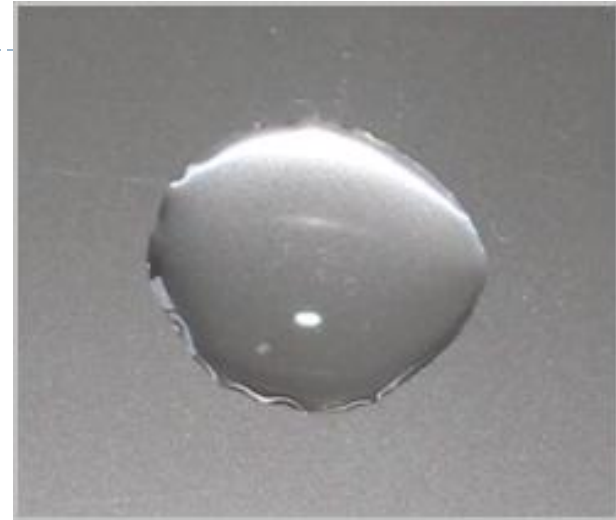


Plane Eye View – After NANO Coating



NANO COATING

Top View No NANO Coating



Top View after NANO Coating

NANO COATING

Side View No NANO Coating

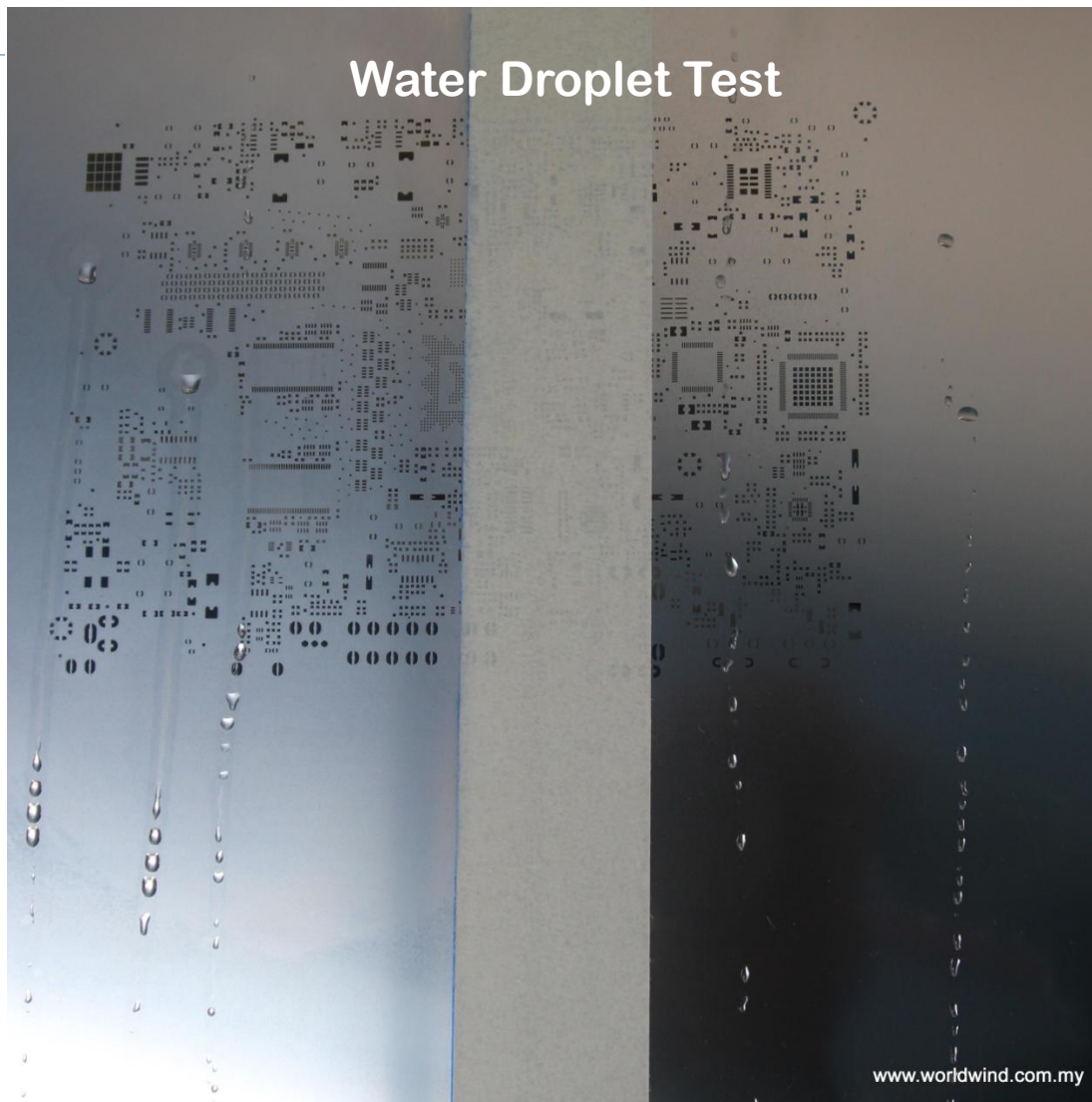


Side View - NANO Coating

NANO COATING

Water Droplet Test

Nano Coated
(L)



No NANO Coat
(R)

- ▶ **Stencil 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

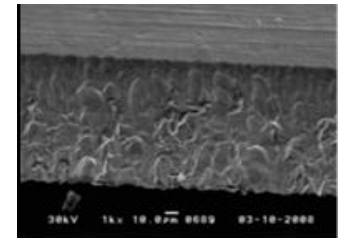
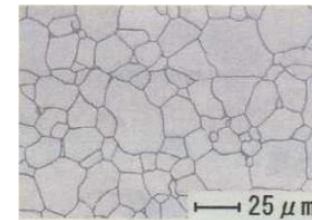
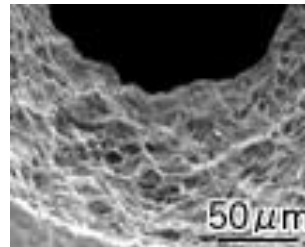
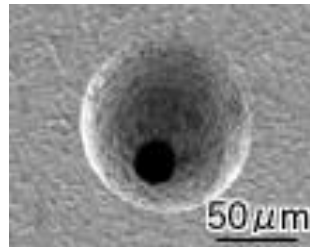
The etching

Magnified View of
Etched Portion

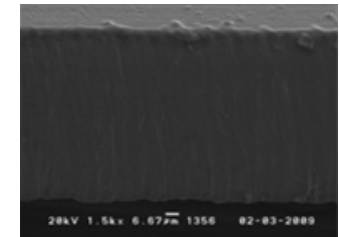
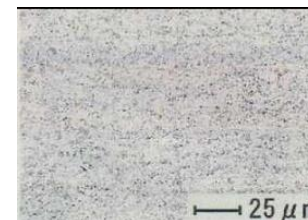
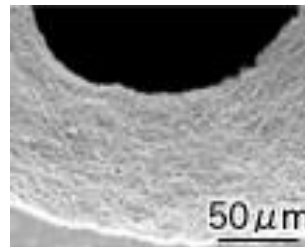
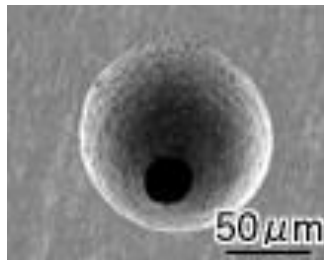
Grain Size

Aperture Wall after
Laser Cut

**Conventional
SUS-304**

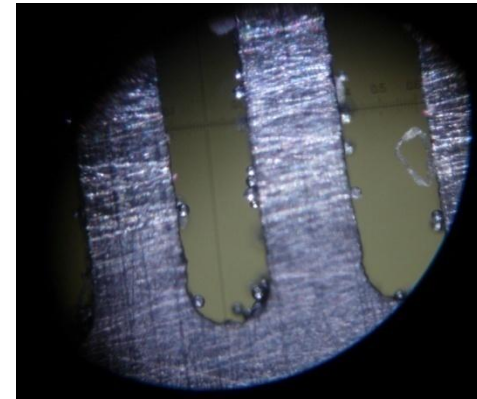
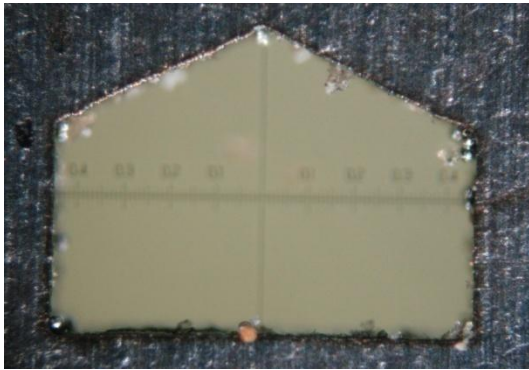


Fine Grain SS

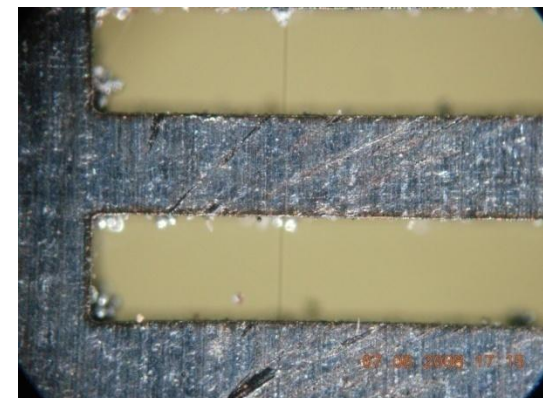
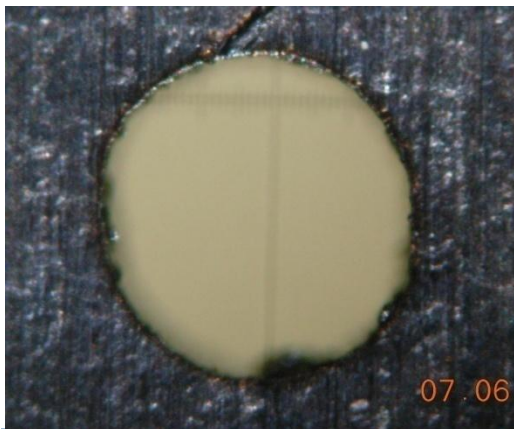


Cutting Parameters

This is what happens when the Laser Cutting parameters are adjusted to increase the stencil *quantity*.

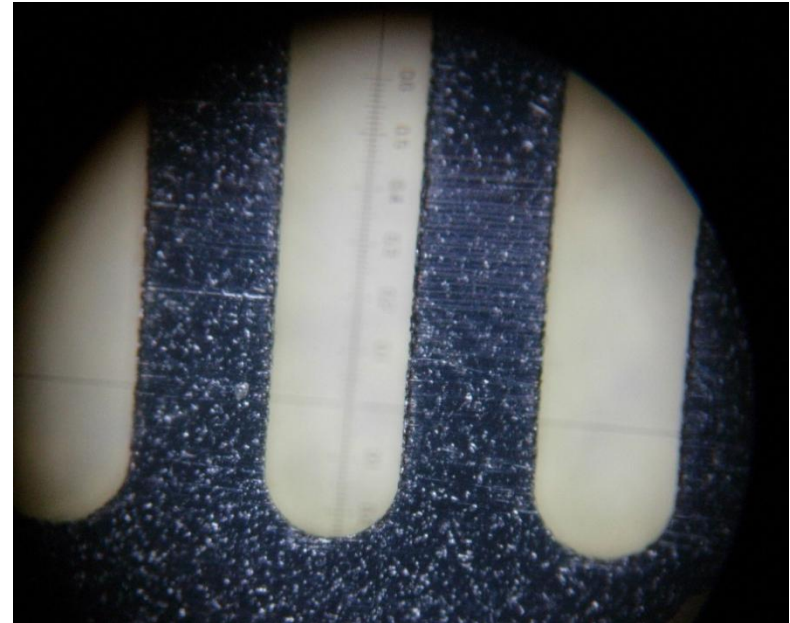


The operators would often run machines faster than the manufacturers recommendations, creating poor hole wall quality. Other problems encountered included warping or oil canning of the stencil material as well as burn marks on or around the apertures.



Cutting Parameters

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

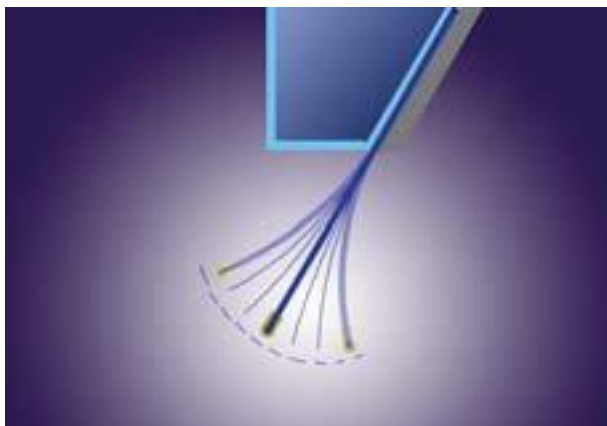
Step stencils for Pin-in-Paste technology:

- ▶ - For squeegee side steps, technological distance to the nearest surface mounted component is $36x \text{ step_thickness}$
- ▶ - For contact side steps, recommended technological distance to the nearest surface mounted component is $1.6x \text{ step_thickness} \cdot \text{foil_thickness}$

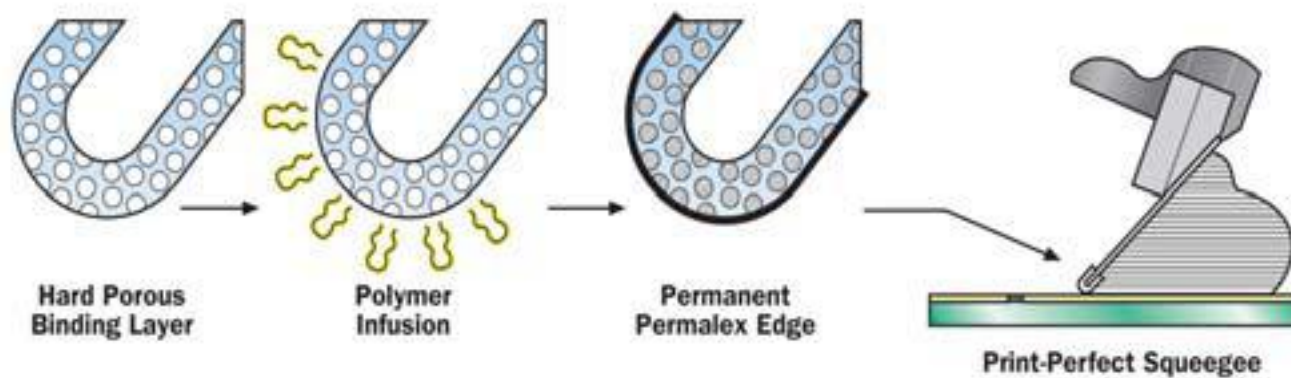
The Effect Of Squeegees



The Effect Of Squeegees

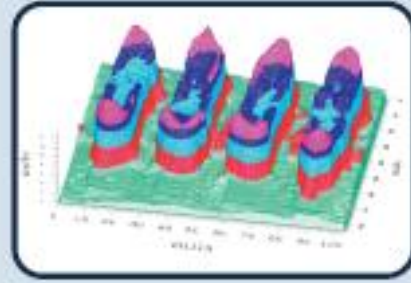
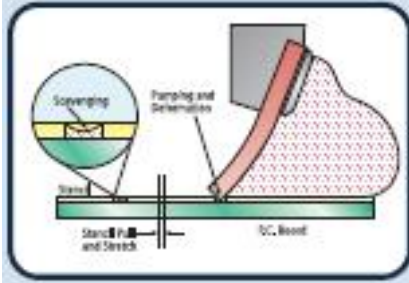


Tempered Spring Steel Alloy assures many thousands of flexures while maintaining original shape, unlike softer etched blades made from stencil material.



The Effect Of Squeegees

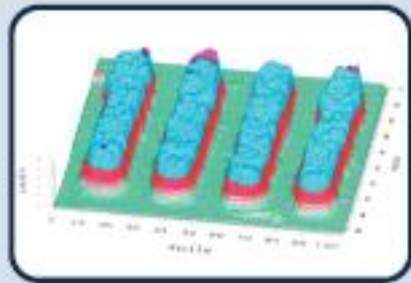
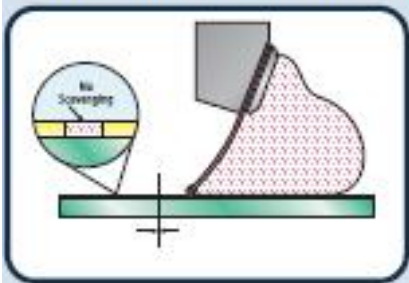
Rubber vs. Metal



Permalex Edge Metal Squeegees eliminate pumping and scavenging

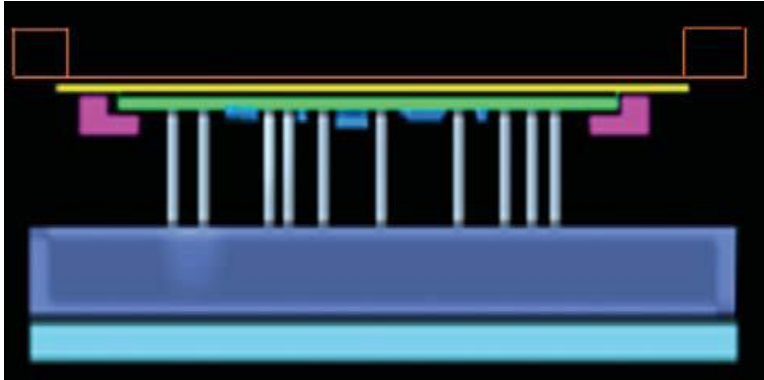
Improving solder paste deposit quality.

Better Results with Permalex

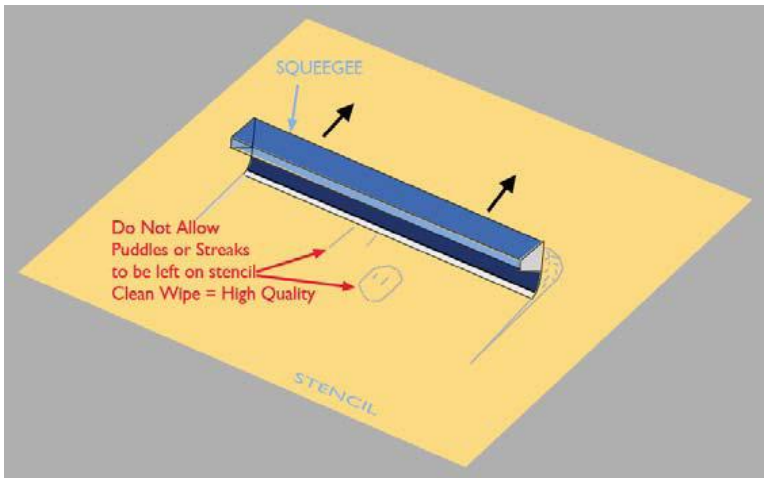


The smooth, lubricated edge reduces stencil pulling and stretching, improving pad registration and stencil life.

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 ?**

▶ **Sakthivel Padmanapan**

- ▶ Email: sakthivel@asahitec.in
- ▶ Mobile: +91 99419 11328

▶ **ASAHITEC STENCILS PRIVATE LIMITED**

Double Dragon Industrial Park

Kannur Village, Kottaiyur,

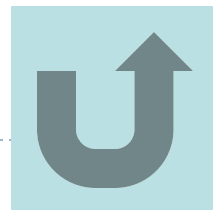
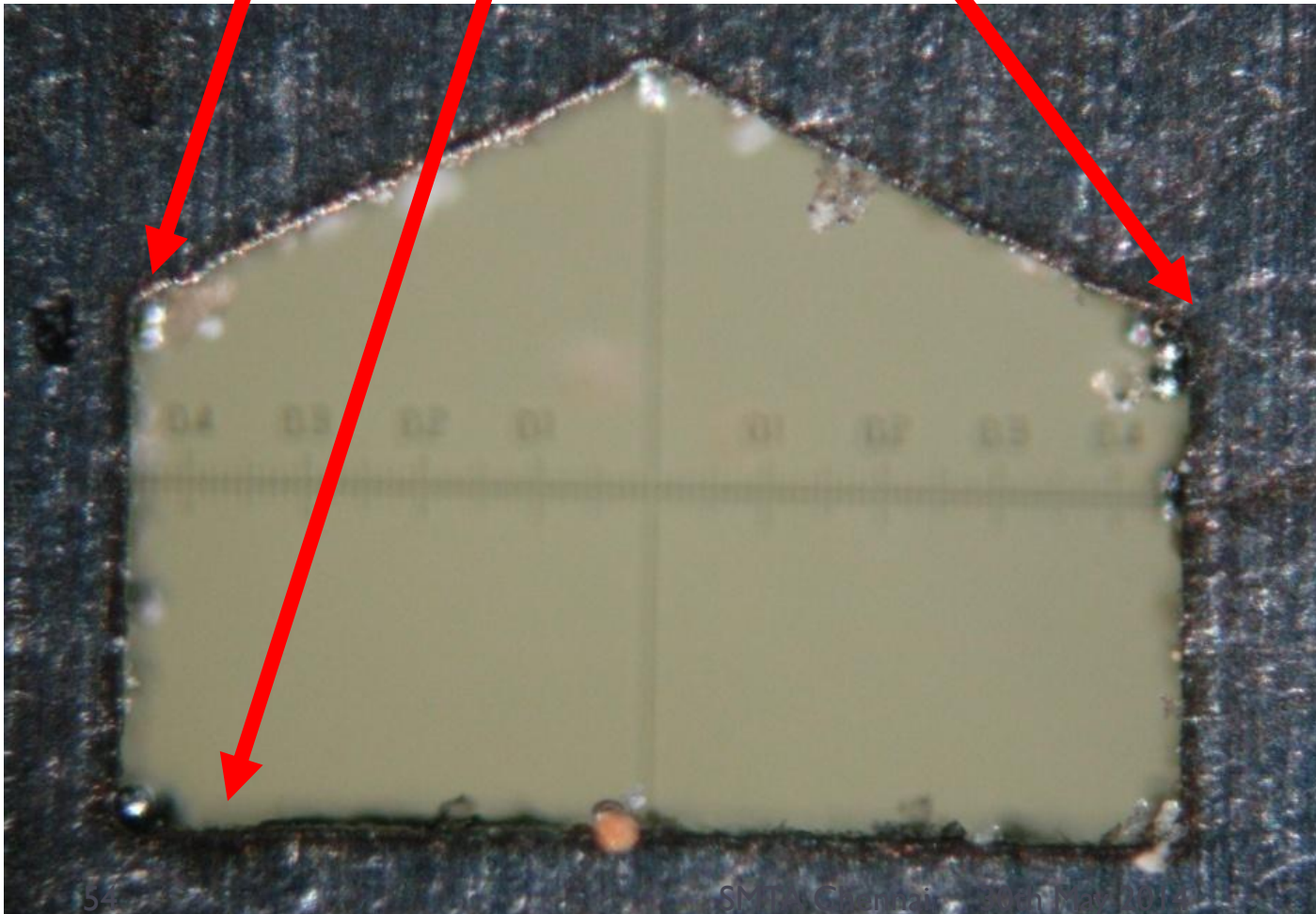
Thiruvallur Dist.

Pincode 602108

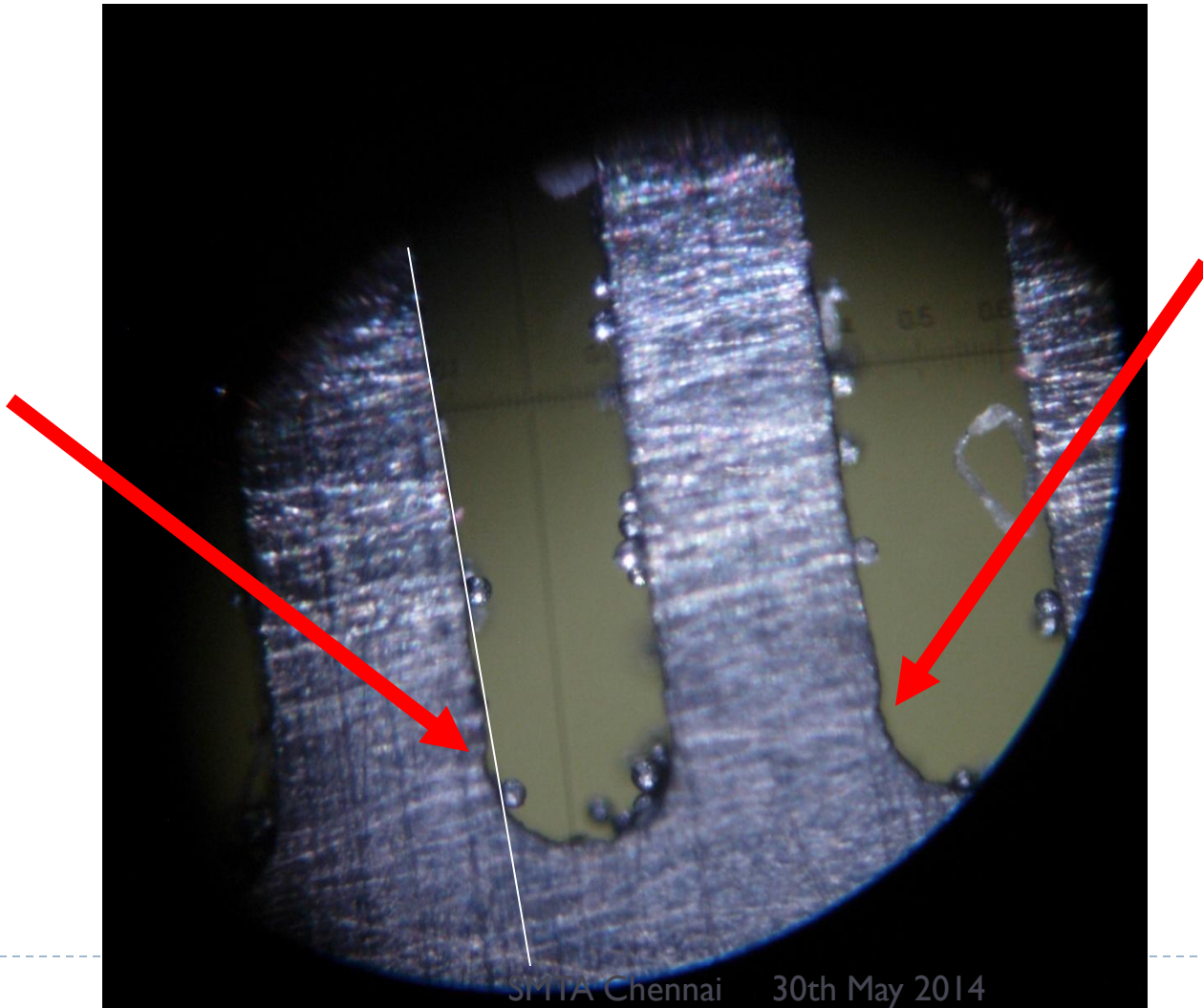
THANK YOU



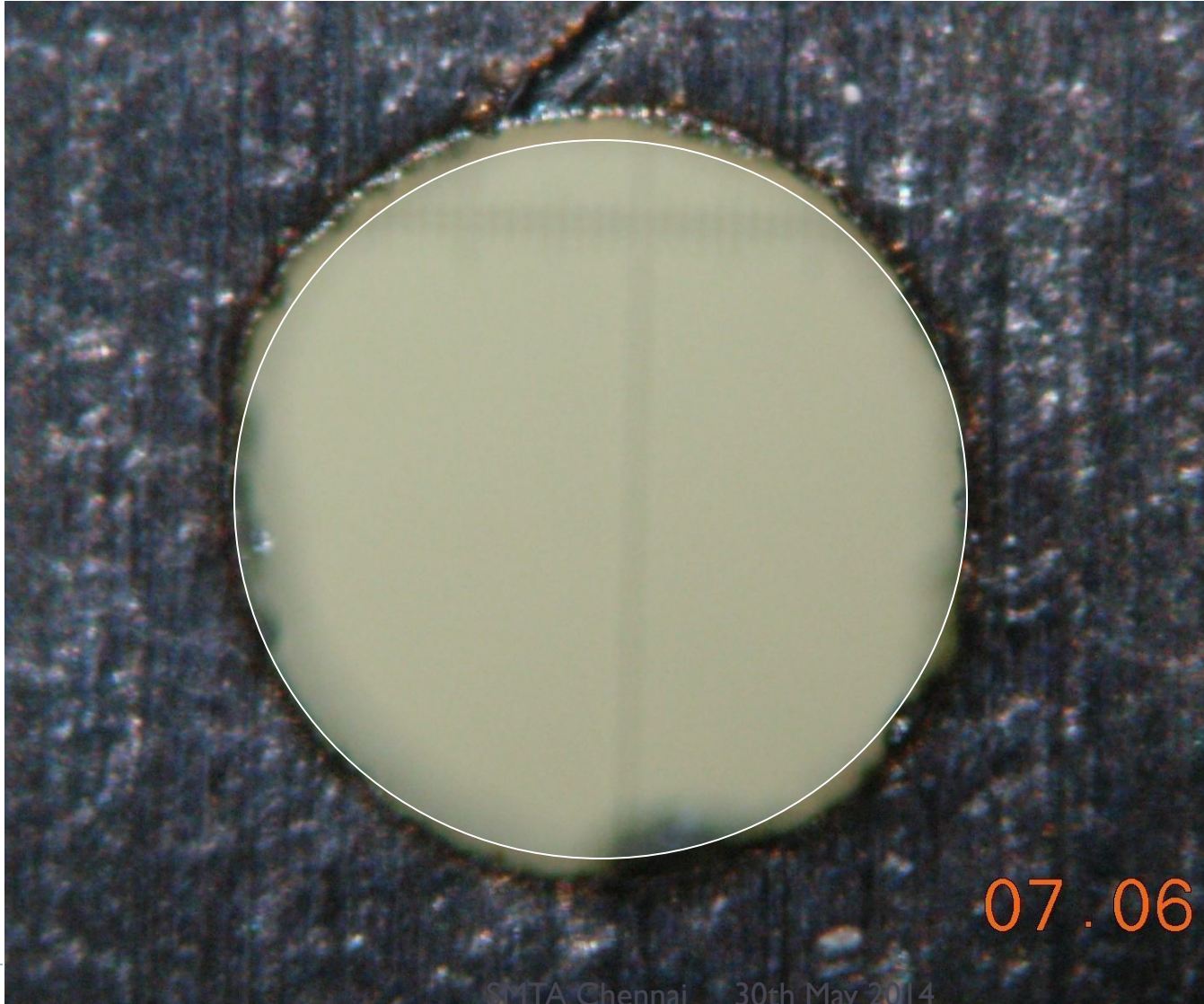
Cutting Overlapping Mismatch due to increase of Cutting Speed



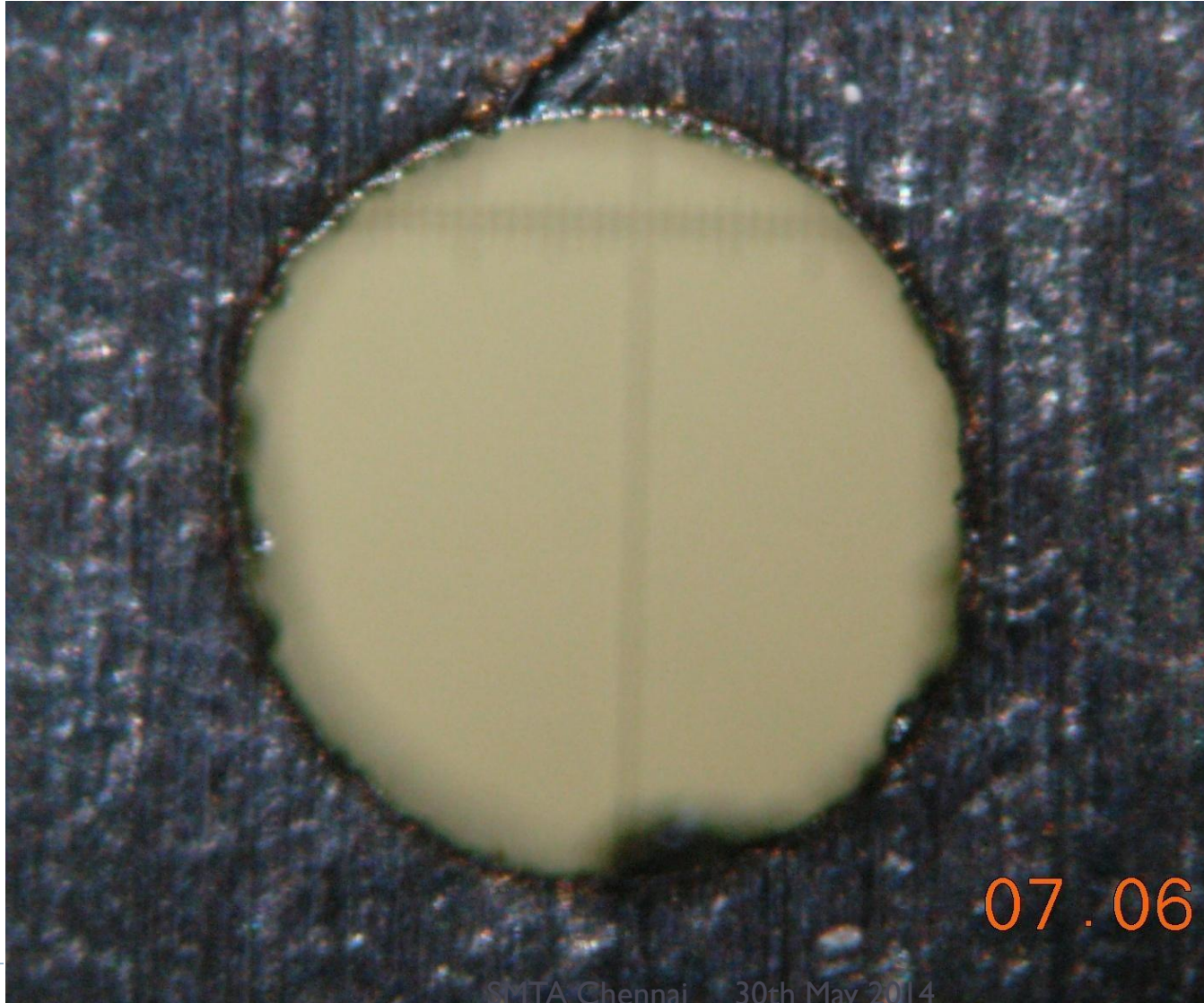
Improper Overlap at Curves - @ QFP Pads due
to increase of Cutting Speed



Oval Shaped BGA Pads



Oval Shaped BGA Pads

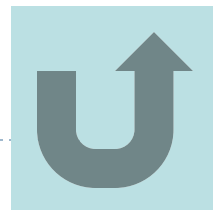


Oval Shaped BGA Pads

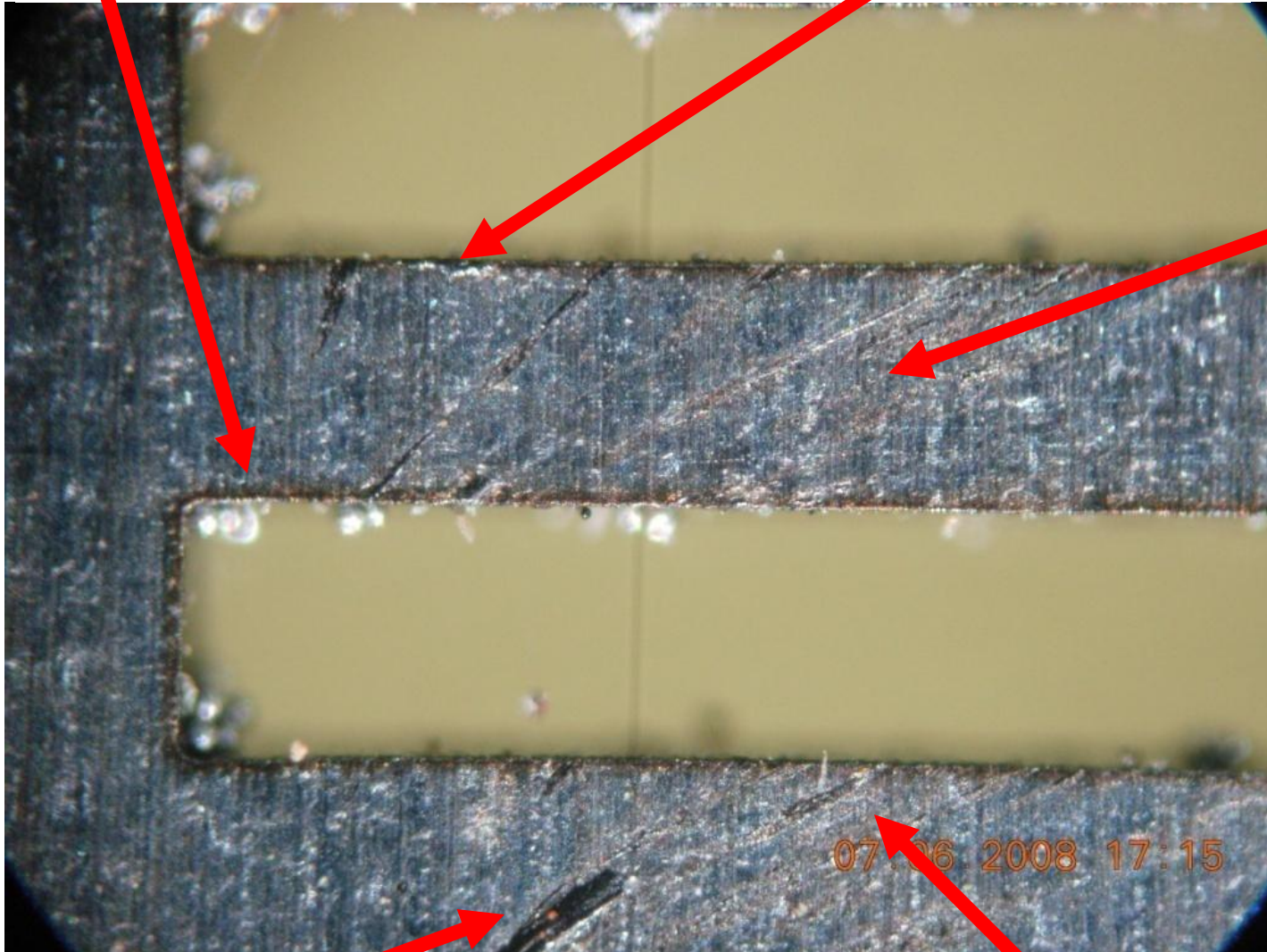


07.06

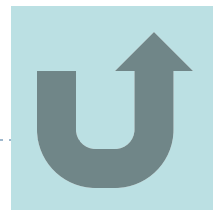
SMTA Chennai 30th May 2014



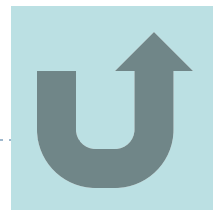
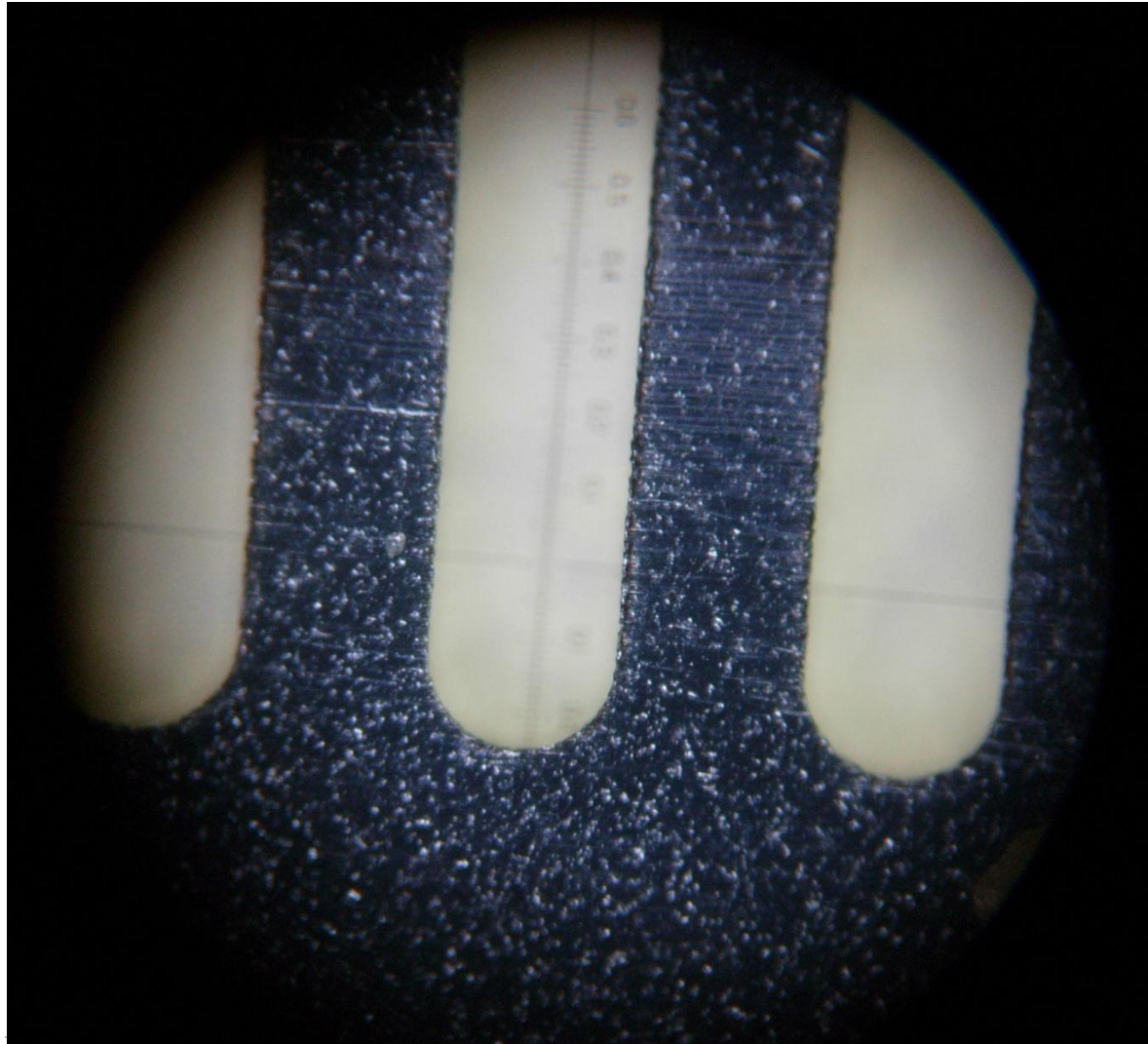
Burrs @ Pad Edge... Oxidation leads to heavy burr...



Good Stencil: Resistor Pad - Just Cut; No Polish.....



Smooth Curves @ QFP Pads....



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.