How Stencil Manufacturing Methods Impact Precision and Accuracy

A presentation of the white paper written by: Ahne Oosterhof, Oosterhof Consulting, & Stephan Schmidt, LPKF Laser & Electronics North America
Live!

Laser & Electronics Studios
Our presenters


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Questions

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As the old saying goes...

“I can make a bad stencil on any laser and a good stencil only on some lasers.”

You’re telling me!
Q: Which of these do you think is the most important factor in manufacturing a “good” stencil?

a) Consistent thickness of the stencil foil
b) Consistent aperture dimensions
c) Correct aperture location
d) Straight and accurate aperture sidewalls
e) Smooth sidewalls for good paste release
Introduction

Stencil positional accuracy is a function of the manufacturing process.

The 4M’s: Machines, Methods, Manpower, and Materials

- The quality of the equipment being used (Machines)
- The degree of control over the fabrication process (Methods)
- How well the processes are executed (Manpower)
- The quality and behavior of the metal during fabrication (Materials)

Additionally

- The temperature differences during the process
- Change in tension on the materials
Topics

• A brief history of stencil manufacturing technologies

• Process breakdown of the two most prevalent stencil manufacturing technologies of today

• The effects of tension and temperature differences on the stencil manufacturing process

• Analysis of 13 different laser-cut stencils and 1 electroformed stencil
History of Stencil Manufacturing Methods
**Timeline**

- **Silk screening**: individual threads get in the way of paste transfer
- **Chemical etching**: single sided results in cup shape; double sided etching leaves ridge in aperture
- **Electroforming**: Great sidewalls, but many production steps open door for inaccuracies
- **Laser cutting**: getting better and better
**Timeline**

Silk screening: individual threads get in the way of paste transfer

Chemical etching: single sided results in cup shape; double sided etching leaves ridge in aperture

Electroforming: Great sidewalls, but many production steps open door for inaccuracies

Laser cutting: getting better and better
Chemical etching

Note the ridge (perpendicular to paste release direction) that results from etching from both sides.
Silk screening: individual threads get in the way of paste transfer

Chemical etching: single sided results in cup shape; double sided etching leaves ridge in aperture

Electroforming: Great sidewalls, but many production steps open door for inaccuracies

Laser cutting: getting better and better
Electroforming

Electro-formed stencil. Striations in line with paste-release direction.
Timeline

Silk screening: individual threads get in the way of paste transfer

Chemical etching: single sided results in cup shape; double sided etching leaves ridge in aperture

Electroforming: Great sidewalls, but many production steps open door for inaccuracies

Laser cutting: getting better and better
Laser cutting, lamp pumped
Laser system development

Then: Low frequency led to a postage stamp-like scalloped cut

- Now: Newest lasers are diode pumped, fiber lasers with higher frequencies and smaller beam that produce a knife-like cut…
Laser cutting, diode pumped, fiber laser
Prevalent Processes of Today
Electroforming process

- Process data
- Transfer image to mandrel
- Remove from mandrel
- Produce film
- Grow nickel
- Mount in frame

Electroforming

- Nickel Metal
- Electrolytic Solution
- Mandrel
- Electrodeposition Process
- Electroform
Laser cutting process

Process data → Mount in frame*

Cut on laser system

*Can be cut in frame, saving time and reducing location inaccuracies due to tension changes.
Laser cutting
Moving mechanism evolution

Stationary laser, table moves on X & Y axes
Old laser system: Stationary laser, moving XY table
Moving mechanism evolution

Stationary laser, table moves on X & Y axes

Laser moves on X axis, table on Y

Table stationary, laser does all movement
Modern laser system: stationary material, low mass laser head

Due to the reduction in mass being moved, the best modern laser systems have

- Faster cutting speeds
- Accuracy within ±4 µm
- Low vibration
- Excellent control
Video: modern laser system
Laser cutting variables

Two main factors determine how effective a laser will be when it comes to producing precise, accurate stencils

- The size and stability of the beam
- The moving mechanism of the machine
Machine stability

Unstable beam and/or movement

Stable beam and movement
Topic #3

Tension and Temperature
Material tension

Cut in sheet

- In the machine: Tension in one direction, about 18 N/cm (typically no tension in one axis of image)

- Mounting in frame:
  - Mesh tension of 35 N/cm in X and Y direction
  - For 125 µm steel stencil strain: 0.0131%
  - Elongation over 50 cm (20”): up to 65 µm (2.5 mil)

Cut in frame

- No change in tension
- No elongation!
Loose leaf vs. cut in frame

Loose leaf

In frame
Temperature

Stencil cut at 25° C/used at 20° C

• Coefficient of thermal expansion
  • Steel: 17 ppm/°C
  • Nickel: 13 ppm/°C

• Over 50 cm (20”): 0.50 * 5 * 17 µm (13 µm nickel)
  • Steel: \textbf{42 µm} (1.7 mil)
  • Nickel: \textbf{32 µm} (1.3 mil)
To recap...

Possible sources of inaccuracies:

- Modern laser system positional accuracy \((\pm 4 \ \mu\text{m})\)
- Tension variations \((\text{up to } 65 \ \mu\text{m})\)
- Temperature variations \((\text{up to } 42 \ \mu\text{m})\)

Result of the inaccuracies:

- Printing solder bricks in the incorrect location

Q: How do we know if stencil is manufactured correctly before using it?
AOI Technology
Verify (scan the stencil)

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<th>No</th>
<th>Aperture Type</th>
<th>CAD Position</th>
<th>CAD Size</th>
<th>Status</th>
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<th>Pos. Error Y</th>
<th>Size Error</th>
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</tbody>
</table>

20594 selected apertures verified. Position tol.: 2.062.0 mil

Selected: 20594 apertures
A quick note on debris…
Cp Analysis
$C_p$ Analysis
Good/bad choices

Same laser: cut as loose sheet vs. cut in frame

Different lasers: both stencils cut in frame.
Results
Paste release

Remember: Paste release characteristics are only meaningful if the paste is deposited in the right place!
Back to our hypothesis…

Stencil positional accuracy is a function of the manufacturing process

• The quality of the equipment being used
  ✓ $C_p$ analysis: Having the right and well maintained laser machine matters

• Varying tension on the materials and temperatures throughout the process
  ✓ $C_p$ analysis: Cutting loose leaf v. cutting in frame

Conclusion 1: Using the best laser while cutting in the frame limits distortion and yields best positional accuracy.

Conclusion 2: Know your vendor and know how and what he is doing!
Thank you for your attention!

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Questions

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