Electroformed vs. Laser-cut: A Stencil Performance Study

There have been claims in the industry that laser-cut electroformed nickel foil blanks provide stencil print performance comparable to electroformed stencils. A study was established to measure the quantitative differences in performance between the two during an independent lab study.

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A comparison test was established to measure the quantitative differences in performance between laser-cut electroformed nickel foil blanks and electroformed stencils. This article details the results of the print performance test. A 4-mil-thick electroformed foil blank was grown on a standard mandrel using a manufacturing process identical to the standard electroformed process, except that no apertures were imaged in the electroformed nickel foil.* The blank nickel foil was stretched and the chosen test pattern was laser cut.** Small aperture features from 120- to 300-µm circles and squares, microBGAs with 280-µm apertures, and 0201 apertures were cut at 33% of the normal speed. After cutting, the foil was sanded to remove any residual dross. The stencil foil was placed in an ultrasonic tank for five minutes to remove loose dross.

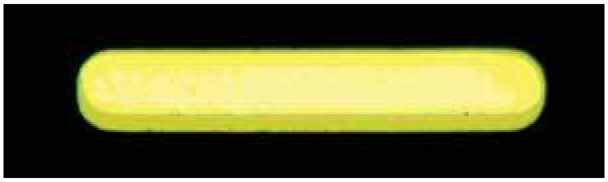


Figure 1a. *Aperture side-wall smoothness of electroformed stencil.*

The electroformed stencil was manufactured with the standard electroformed process. The photoresist was imaged and developed to provide photoresist pillars with smooth sidewalls on the mandrel, which was placed into the electroformeding tank and plated to 4-mils thick. The foil was then separated from the mandrel and mounted in the 29" × 29" frame.

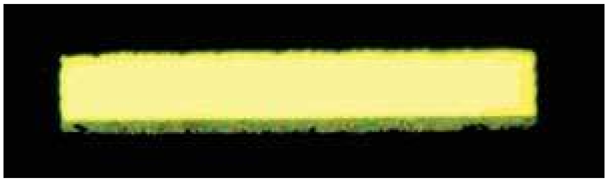


Figure 1b. *Aperture side-wall smoothness of laser-cut electroformed nickel foil.*

The modified test pattern features circle and square apertures ranging from 120 to 300 µm. There also are BGA patterns ranging from 280-µm circles up to 965-µm circles. QFP apertures range in size from 200 × 1220 µm up to 305 × 1778 µm. Chip components range in size from 1206s to 0201s. Circle and square apertures range from 120 to 300 µm, providing a good test of stencil-print performance with an area ratio ranging from 0.30 to 0.74. The 220-µm aperture with a 0.54 area ratio is a useful configuration for direct comparison of the print performance between the two stencil types. The 0201 aperture with a 270-µm circular aperture and a 0.66 area ratio is another useful aperture for measuring direct print-performance comparisons of the two stencils.

Print Test Setup

A screen printer was used to print the PCBs. The squeegee blade was an electroformed blade,*** with a print speed of 500 mm/sec., squeegee pressure of 7 kg for the 250-mm blade, and a separation speed of 10 mm/sec. Two stencils were used with two pastes (63Sn37Pb and SAC 305) for four separate runs, each of which consisted of 15 prints. The printer featured an automatic inspection system to measure a sample of apertures and prints for paste coverage, blockage, and smearing on the bottom side of the stencil for each print. A stencil wipe was performed after the 10th print. Boards for prints 1, 2, 11, and 12 were saved for visual and solder paste volume measurements.

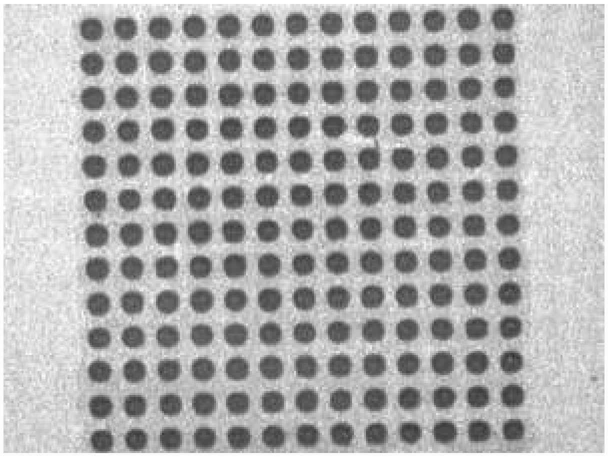
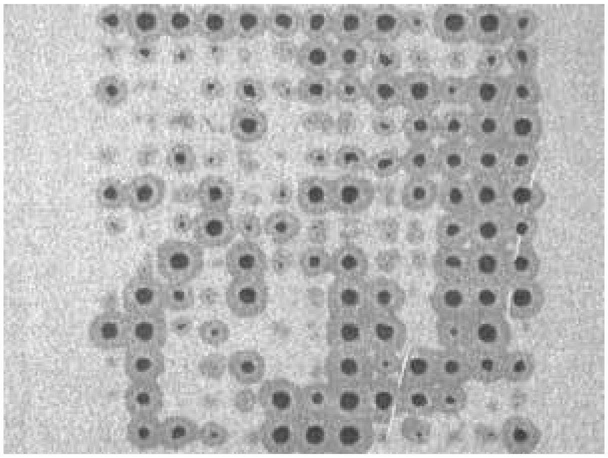


Figure 2a. *Solder bricks on 2nd print for 220-µm aperture for electroformed stencil using lead-free paste.*

Test Results

Aperture wall smoothness - Figures 1a/b show the electroformed stencil aperture compared to the laser-cut electroformed nickel foil at 100× magnification. The smooth sidewalls of the electroformed stencil are pronounced compared to the rough walls of the laser-cut aperture. The aperture shown is 250-µm wide by 1775-µm long.



Paste transfer from small apertures for tin/lead and lead-free - Figures 2a/b show solder bricks printed on the second print cycle for both stencils using tin/lead and lead-free solder pastes for two different aperture sizes: 120-µm square and 220-µm square (shown). Several observations were made:

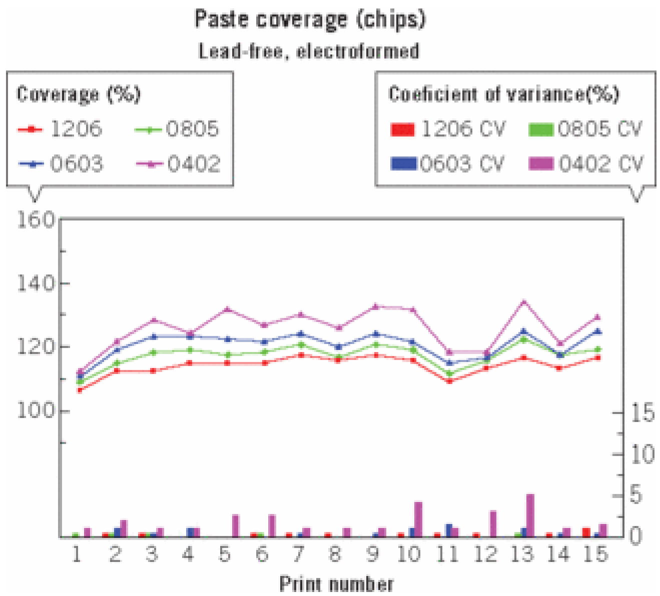


Figure 3a. *Paste coverage for chip component using lead-free solder paste - electroformed stencil.*

• The electroformed stencil transferred paste through a 120-µm square aperture in a 4-mil-thick stencil with an area ratio of 0.30. However, the laser-cut electroformed foil stencil transferred no sign of solder paste for the same aperture using lead-free solder.

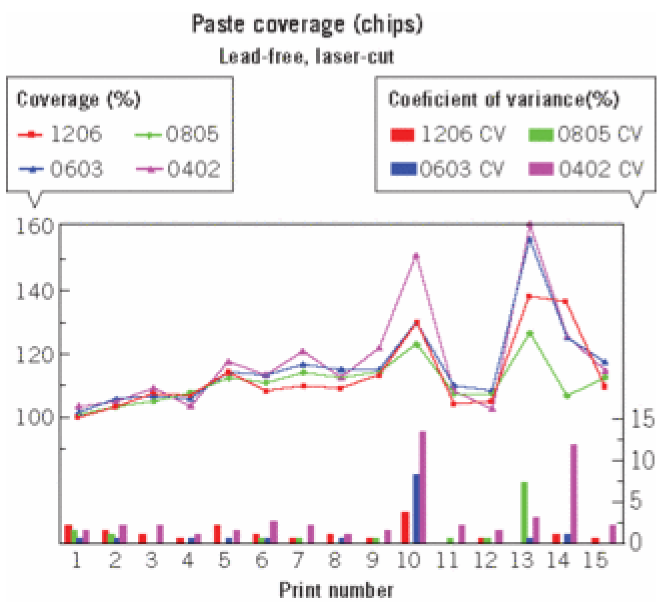


Figure 3b. *Paste coverage for chip component using lead-free paste - laser-cut electroformed stencil.*

• The electroformed stencil transferred suitable solder paste bricks through a 220-µm-square aperture in a 4-mil-thick stencil with an area ratio of 0.54. While the laser-cut electroformed foil stencil did transfer paste for the same aperture size, there were several opens and insufficient paste bricks, rendering it unacceptable.

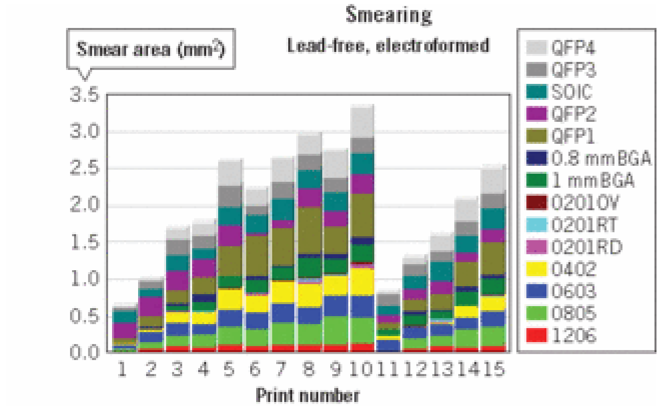


Figure 4a. *Paste smearing for all components using lead-free paste - electroformed stencil.*

• Although paste transfer for tin/lead was better for the 120-µm aperture, the laser-cut electroformed foil stencil provided unacceptable results with opens and insufficient solder bricks. There were no insufficients or opens for the 220-µm laser-cut electroformed foil stencil, but the average solder volume provided by the electroformed stencil was more than that of the laser-cut stencil. The standard deviation was 6.3% for the electroformed stencil vs. 13.5% for the laser-cut electroformed foil stencil.

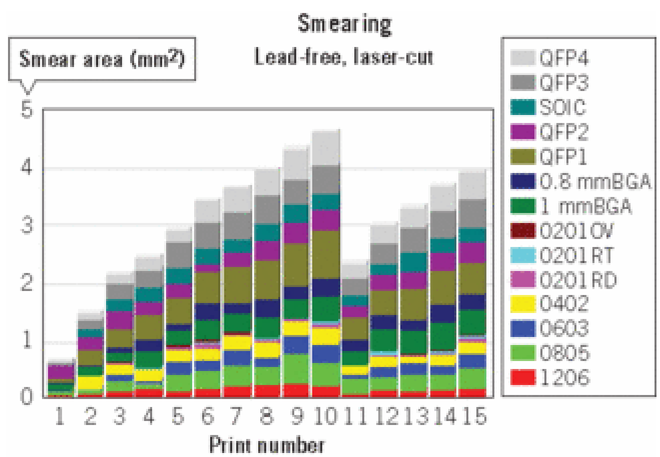


Figure 4b. *Paste smearing for all components using lead-free paste - laser-cut electroformed foil stencil.*

Paste transfer for 0201 devices - A laser scanner measured solder volume of the 0201s when printed through 270-µm circular apertures using lead-free solder paste for both stencils. As a result, solder bricks for the electroformed stencil were observed to be very uniform; the volume is equal for both pad sites of the 0201 device. The laser-cut electroformed foil stencil has little solder paste on one of the 0201 pads, which will result in an open or tombstone.

Automatic Inspection During Printing

The printer's automatic inspection program performs optical inspection of paste coverage on PCB pads, paste blockage in stencil apertures, and paste smearing on the bottom of the stencil for all 15 prints in four specific print runs (two stencils and two pastes). Paste coverage is measured for four types of apertures - chip components, BGAs, 0201s, and leaded devices. Aperture blockage also is measured for the same set of apertures. Finally, paste smearing is measured for all four sets of apertures designs.

For lead-free paste, the electroformed stencil provided better component coverage. The coefficient of variation (CV) is lower for the electroformed stencil compared to the laser-cut electroformed foil (Figures 3a/b). There also is a high variation in paste coverage for the 10^{th}, 13^{th}, and 14^{th} print for the laser-cut electroformed stencil.

There is significantly more aperture blockage of chip component apertures for the laser-cut electroformed foil compared to the electroformed stencil, especially for 0402 apertures. The rough aperture sidewalls of the laser-cut foil causes solder paste to stick in smaller 0402 apertures.

Overall paste smearing on the stencil's bottom side around apertures was less severe for the electroformed stencil (Figures 4a/b), which recovered better after the under-stencil wipe on the 10^{th} print. The electroformed stencil recovered by a factor of 3:1 compared to the laser-cut stencil after the under-stencil wipe on the 10^{th} print.

For tin/lead solder paste, coverage for chip components was better for the electroformed stencil compared to the laser-cut electroformed foil stencil, although this difference was not as dramatic as lead-free. There was little difference in the paste blockage for chip component apertures, and the electroformed stencil provided about 66% less paste smearing compared to the laser-cut electroformed foil stencil.

Conclusion

Prior studies[1] have demonstrated that print performance of electroformed stencils is better than laser-cut without electropolish, laser-cut with electropolish, and laser-cut with electropolish and nickel plate. This study confirms that the electroformed stencil provides better print performance than an electroformed nickel foil stencil with laser-cut apertures. The difference is more pronounced with lead-free than tin/lead solder paste. Mirror aperture walls provided by growing nickel, atom-by-atom, around photoresist pillars in the electroformed stencil process release solder paste better than laser-cut electroformed foil stencil walls.

Acknowledgements

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* AMTX Electroformed Stencil, Photo Stencil, Colorado Springs, Colo.
** Benchmark II boards and files, Heraeus, Conshohocken, Pa.
*** Electroformed E-Blade, Photo Stencil.

REFERENCES

1. Coleman, William E., Ph.D., “Stencil Print Performance,” SMTA International, September 2001.