The Evolution of Stencil Technology

Over the past 20 years, the size of electronic packages has continued to shrink as the density of I/O leads has increased. Requirements for printing solder paste have also changed dramatically over this period. In the mid-’80s, thick-film screens provided acceptable performance in printing solder paste for SMT devices. Stencil technology evolved to chem-etch, laser-cut, and electroformed foils as printing requirements dictated performance enhancements. Multi-level steps for all stencil technologies were also desirable.

In the beginning, there were thick-film screens; however, the wire mesh weaving across the aperture openings impeded paste transfer. Chem-etch stencils provided better open areas and worked well for SMT devices with lead pitches down to 0.8 mm. The chem-etch trapezoidal aperture, along with enabling post processes of electropolish and nickel plating, helped smooth aperture sidewalls, improving paste transfer. One process problem for chem-etch apertures was different etch rates for small apertures compared to large ones. Band etching helped resolve this problem, but had limitations for small apertures. Laser-cut stencils were introduced in the early ’90s - just in time to meet the print requirements of 0.65-mm-pitch SMT devices. The small laser beam spot size cut small and large apertures with equal accuracy. Enabling post processes of electropolish and nickel plating again helped smooth aperture sidewalls. Early laser-cut speeds were slow, so hybrid stencils were popular where large apertures were chem-etched and small apertures were laser-cut. Rubber squeegee blades worked well with screens, but scooped paste from larger apertures, reducing paste volume transferred. The introduction of metal squeegee blades resolved this problem, and quickly became popular. Contained paste-head delivery systems were also introduced. These systems used pressure to push paste into the apertures, while wiper blades helped contain the paste in the head and wipe clean after traversing the aperture.

Electroformed stencils were introduced in the mid-’90s. Whereas chem-etch and laser-cut stencils are subtractive processes - apertures are formed by etching or cutting material from a solid metal foil - electroformed stencils use an additive process. In this process, the aperture is formed by electroplating nickel on a temporary forming mandrel, which has photoresist pillars imaged on the surface, each pillar forming an aperture when the nickel is plated up around it to the desired stencil thickness. The photoresist is dissolved and the stencil is pealed away from the mandrel. Aperture walls are extremely smooth because they are formed one molecule at a time in a non-destructive mode. Post-processing, such as electropolish and nickel plating, which can change aperture sizing, is not necessary due to smooth aperture walls. Electroformed stencils are effective for some small electronic packages like 0.5- and 0.4-mm-pitch microBGAs, 0.4-mm-pitch QFPs, 0.5- and 0.4-mm QFNs, as well as 0201 and 01005 components.

Step or multi-thickness stencils are useful for some applications. CBGAs have solder balls that don’t melt during normal reflow temperatures. Thus, slight non-coplanarity issues can be a problem. To solve this issue, the stencil is stepped-up to 0.2-mm thick for the CBGAs and left at 0.125 mm for remaining SMT apertures. The foil is chem-etched to form the multi-thickness, and laser-cut to form apertures in both levels. Multi-thickness electroformed stencils are made by electroforming (plating) thicker in the step areas.

Intrusive reflow is a process where solder paste is printed for both SMT and thru-hole devices. Both devices are placed and reflowed at the same time, eliminating wave soldering. Thru-holes require more solder volume than normal SMT devices, so step stencils are used. When the thru-hole volume requires a stencil more than 0.300-mm thick, a two-print stencil is a good solution. A normal 0.125-mm-thick stencil is used to print all SMT apertures. A thick stencil (typically 0.4 mm) is used to print thru-hole apertures. This stencil has relief pockets etched on its contact (board side) to provide clearance to the SMT paste previously printed by the SMT stencil. The relief pocket typically is 0.1 mm thicker than the SMT stencil.

Conclusion

In the early SMT era, aspect ratio was the generally accepted design guide to determine if aperture design and stencil thickness would provide acceptable paste transfer. When aspect ratio, defined as aperture width (W) divided by stencil thickness (T) is greater than 1.5, good paste transfer could be anticipated. Aspect ratio is a good guide if the length of the aperture is greater (at least 5×) than the width. With the introduction of BGAs and QFNs, this is not the case. A new guideline was introduced in which area ratio is defined as the area of the aperture opening divided by the area of aperture walls. The walls of the aperture are trying to hold the paste in the aperture, while the pad under the aperture opening tries to pull the paste away. Initially, the accepted area-ratio guideline for good print performance was 0.66; however, test results show that 0.5 is acceptable for electroformed stencils. An area ratio calculator tool can help predict marginal paste transfer performance, and correct it before committing to a stencil design.