Stencil Print solutions for Advance Packaging Applications

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Abstract

This paper address two significant applications of stencils in advance packaging field: 1. Ultra-Thin stencils for miniature component (0201m) assembly; 2. Deep Cavity stencils for embedded (open cavity) packaging.

As the world of electronics continues to evolve with focus on smaller, lighter, faster, and feature-enhanced high- performing electronic products, so are the requirement for complex stencils to assemble such components. These stencil thicknesses start from less than 25um with apertures as small as 60um (or less). Step stencils are used when varying stencil thicknesses are required to print into cavities or on elevated surfaces or to provide relief for certain features on a board. In the early days of SMT assembly, step stencils were used to reduce the stencil thickness for 25 mil pitch leaded device apertures. Thick metal stencils that have both relief-etch pockets and reservoir step pockets are very useful for paste reservoir printing. Electroform Step-Up Stencils for ceramic BGA's and RF Shields are a good solution to achieve additional solder paste height on the pads of these components as well as providing exceptional paste transfer for smaller components like uBGAs and 0201s. As the components are getting smaller, for example 0201m, or as the available real estate for component placement on a board is getting smaller – finer is the aperture size and the pitch on the stencils. Aggressive distances from step wall to aperture are also required. Ultra-thin stencils with thicknesses in the order of 15um-40um with steps of 15um are used to obtain desired print volumes. Stencils with thickness to this order can be potential tools even to print for RDLs in the package.

Cavity technology can be an effective solution in reducing the total assembled PCB thickness (Z-height), most importantly, on designs utilizing taller - stacked devices. Traditionally, dipping process or dispensing process was used to deposit solder paste, flux, or glue on uneven surfaces. However, this takes a longer time when compared to printing using a stencil printer. Reservoir printing using a stencil printer has greater potential in such application. Extensive work has been done in the past to print glue, solder paste and/or flux into cavities using reservoir printing. This paper focuses on printing solder paste into multiple cavities (stencil pockets) with depths ranging from 355 microns to 450 microns, and with varying cavity size, wall angles and various stencil thicknesses ranging from 100 microns to 150 microns. Apertures varying in area ratio were placed in these cavities and experiments were conducted to analyze the print performance of the stencils. As the size of the components and boards/substrates gets smaller - closer placement of components to the cavity (stencil pocket) walls needed to be assessed as well.

These applications, the associated stencil design and print results were discussed in detail in this paper.

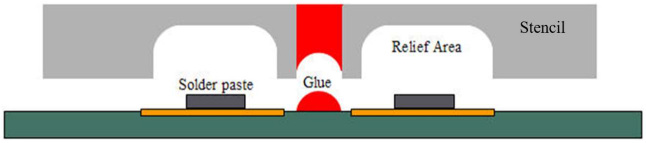
Key words
Cavity stencils, miniature component assembly, reservoir printing, step stencils.

I. Introduction

Earlier stencils were used for SMT applications to print paste, glue, flux and inks on flat surfaces. With latest advancements in stencil manufacturing technology - the applications are widespread and can be used for advance printing applications, such as for multi-level printing, printing in cavities, for miniature components and providing relief for pre-assembled components on the board.

A. Step Stencils

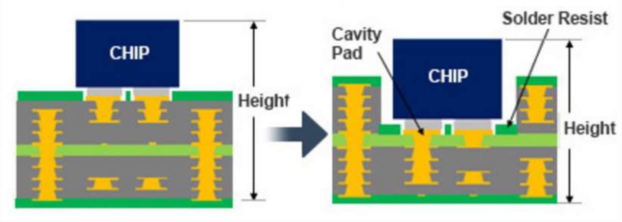
Step stencils have been in use for many years to print on uneven surfaces and to achieve good paste transfer for the distribution of pad size on the board. Step stencils enabled printing for smaller components such as uBGAs and 01005 passives along with more conventional SMT devices like 0.5mm QFPs, 0603 and 0805 passive components at the same time [1], [2]. Examples of step stencils are: Step-Up stencils for Ceramic BGA's and SMT connectors, Step-Down stencils for .5 and .4 mm pitch QFP's, and relief pocket step stencils for raised test Vias or other raised areas on the PCB. Mixed technology applications for Flip-Chip (FC) / SMT required special step stencil designs where flux is printed first for the FC and SMD paste printed next with a second stencil that has a relief pocket etched or formed in the FC area.



Fig# 1: Cross section of Step stencil to print glue, and indicating relief pocket for solderpaste

B. Cavity Printing Technology

Cavity technology can be an effective solution in reducing the total assembled PCB thickness (Z-height), most importantly, on designs utilizing taller - stacked devices. As the size of the components and boards/substrates get smaller and smaller – closer placement of components to the cavity walls needed to be assessed as well.

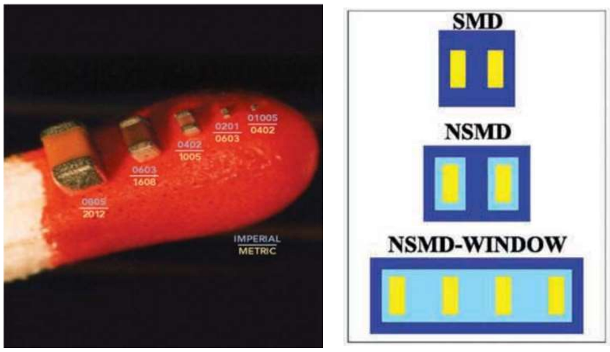


Fig# 2: Flip Chip Assembly [3]

II. Stencil Design

A. Ultra-thin Step Stencil

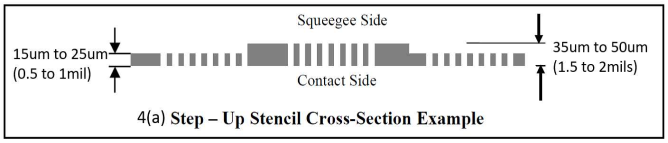
Stencils with thicknesses in the order of 15um or



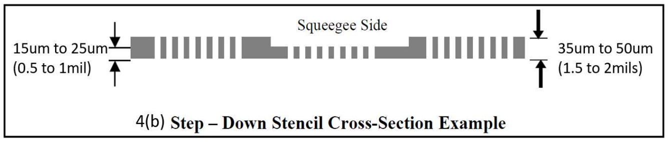
1(a) 1(b)

Fig# 3: (a) Capacitors with decreasing pad size (b) Types of pads on a board Solder Mask Defined (SMD), Non-SMD and NSMD window less are used as shadow masks and those with thicknesses in the order of 25um to 50um are used in semiconductor packaging to print for miniature components ranging from 008005 to 01005 to fine pitch (<200um) flipchip pads..

In some cases a step of 15um to 25um is required on the stencil to print for NSMD pads while printing for SMD pads at the same time. This provides efficient gasketing on the pads in NSMD region. Fine steps in the stencil are also required to print for solder paste on miniature components while providing relief on already printed flux pads during semiconductor packaging.

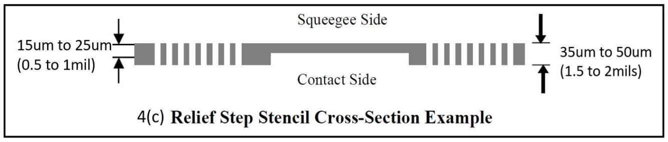


4(a) Step – Up Stencil Cross-Section Example



4(b) Step – Down Stencil Cross-Section Example

Figure 2

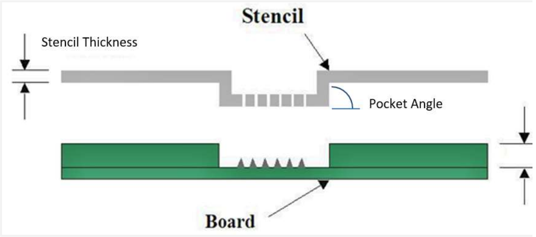


4(c) Relief Step Stencil Cross-Section Example

Fig# 4: Cross-section of various types of ultra-thin step stencils

B. Cavity Printing Technology

In case of printing into cavities in a board, multiple factors come into consideration during the stencil design. These factors include stencil thickness, stencil pocket depth, pocket wall angle, print material (paste or flux), printer used, squeegee blades, etc. Earlier research included printing into cavities as deep as 355um (14mils) [4] – [6]. However, the closest placement of apertures in the cavity as a function of board and stencil design parameters was not assessed. In this paper closest placement of aperture in the stencil pocket as a function of cavity size, wall angle, stencil thickness and print material was analyzed [7].



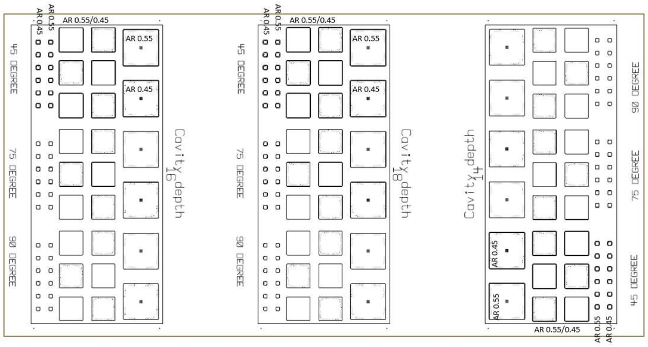
Fig# 5: Stencil geometry details, with apertures placed in the stencil pockets.

Two stencils of 100um (4mil) and 150um (6mil) thicknesses each were used for the print test. Each stencil has three images, and each image corresponds to a given pocket depth. The stencils were grown using the electroforming process, have uniform thickness throughout, and have pockets or cavities of different sizes, depths, and wall angles. Circular apertures with area ratios 0.45 and 0.55 were laser cut into the cavities of each stencil with varying distances from the pocket walls, the closest one being 75um (3mils). Stencil geometry and various stencil design details, for which the conceptual idea was tested, are as shown below.

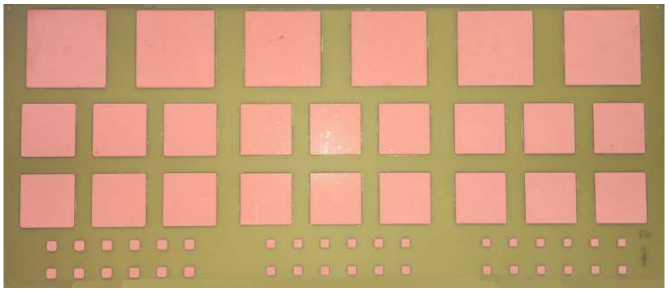
Table I: Various stencil design parameters incorporated into the stencil design.

Cavity Depth (mils)	Stencil Thickness (mils)	Cavity Angle (degrees)	Area Ratio	Apt Shape	Cavity Size
14 (356um) (Image B)	4 (100um)	45	0.45	circle	1.2″
16 (406um) (Image A)	6 (150um)	75	0.55	–	0.8″
18 (457um) (Image C)	–	90	–	–	0.125″

Boards were designed to match the images on stencil. Three different sets of boards, one set per pocket depth, were manufactured by Circuits West Inc., Longmont, Colorado. Large flat copper pads were designed in the pockets for the ease of analysis, instead of designing individual pads to match the corresponding apertures. The printed boards were then visually examined for print quality and missing deposits. The goal was to determine how close to the cavity walls the prints were possible.



Fig# 6: Stencil design with three images incorporating all the design parameters.

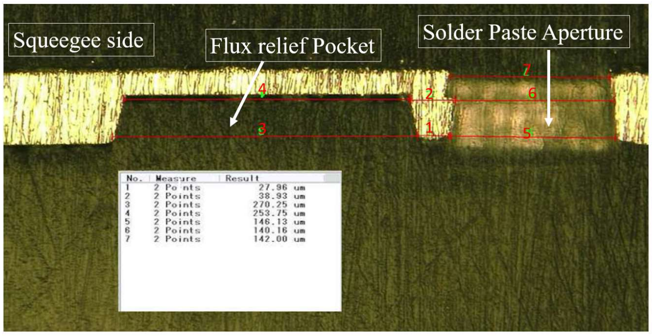


Fig# 7: Board designed to match each image on stencil

III. Results

A. Ultra-thin Step Stencil

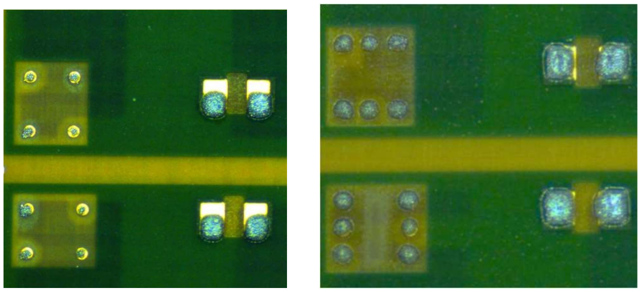
An ultra-thin step stencil was also used to print solder paste aperture while providing relief for already printed flux pads. The cross-section details of the stencil is as shown below, in Figure 8.



No.	Measure	Result
1	2 Points	27.96 um
2	2 Points	38.93 um
3	2 Points	270.25 um
4	2 Points	253.75 um
5	2 Points	146.13 um
6	2 Points	140.16 um
7	2 Points	142.00 um

Fig# 8: Cross section of ultra-thin step stencil showing the closest aperture placement from relief step wall (~40um)

Further, more print results will be presented in the poster presentation during the conference.

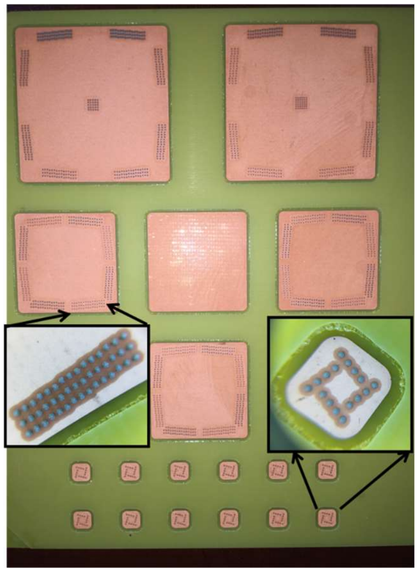


Fig# 9: (a) print with flat electroform stencil
(b) print with electroformed step stencil
(step thickness = 20um)

The difference in print quality with and without using a step stencil was significantly evident from the images shown in figure 9. As the NSMD pads were below the surface of the board there was no gasketing on these pads when using a flat stencil. However, when a step stencil was used, with step thickness as small as the thickness of soldermask (20um), good print was observed in SMD as well as in NSMD region.

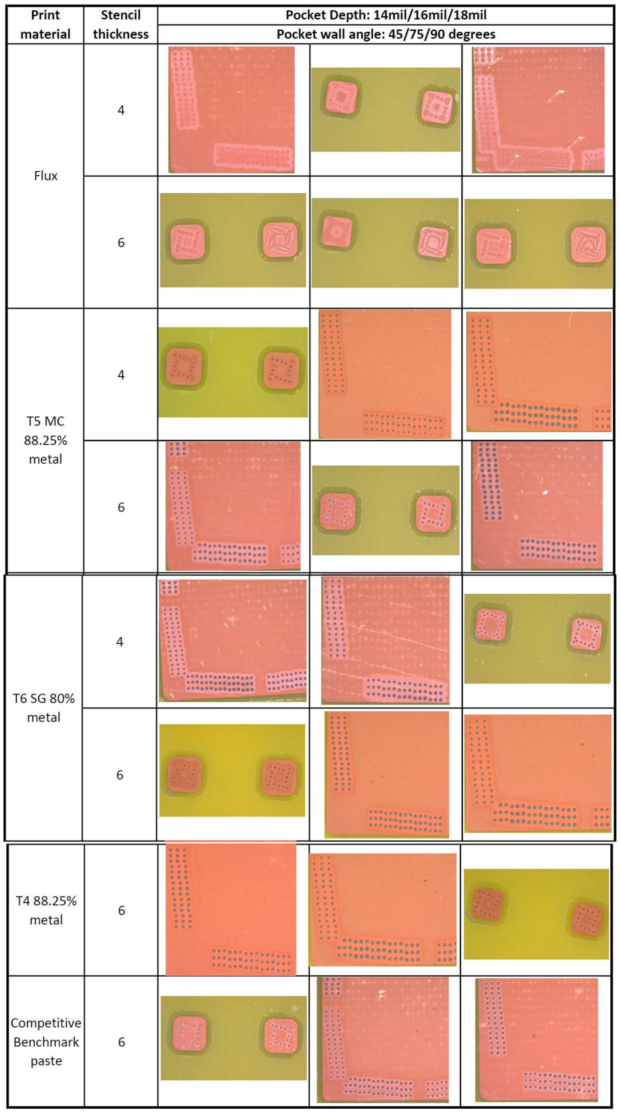
B. Cavity Printing Technology

As mentioned in the previous section, boards with different cavity depths were printed using the stencil image with corresponding pocket depths.



Fig# 10: Single pattern, showing detail of completely printed designs.

Images of each print were taken to compare pockets of different sizes and wall angles to analyze any visible variation in print performance. No significant difference was observed in the print performance with respect to substrate cavity depth and the stencil design variables used such as, stencil pocket angle, pocket size, and print material. Different images of prints per the paste material and stencil used are shown in the Figure 11. As for the optical inspection, apertures with AR of 0.55 resulted in larger print volumes than apertures with AR of 0.45. Similarly, the print volume seemed to increase with stencil thickness.



Fig# 11: Images taken from test board after printing with different flux and paste materials (Thickness in mils).

IV. Conclusion

Step stencils are viable solution to enable printing for large components and small component at the same time by varying the local thickness in the stencil. Photo Stencil produces stencils as thin as 15um and with steps as thin as 15um through electroforming process. Such finer step thicknesses and tighter placement of aperture wall to the step enables closest packing of components on the boards, as well as printing for SMD and NSMD pads at the same time. Further research is underway to decrease the stencil thickness, aperture size and spacing to less than 15um so that the stencils can be used for printing RDLs.

Reservoir printing demonstrated a successful printing process into cavities of the board as deep as 455um (18mils). For the scope of this experiment and the various paste materials and fluxes used, printing was observed as even from the aperture as close as 3mils (75µm) from the pocket wall irrespective of stencil thickness, aperture size, pocket wall angle, and pocket size. This implies that the components can be placed as close as 75µm to the cavity wall of the substrate. However, rubber squeegee blade was using to print using the cavity stencils. Currently Photo stencil is working on printing into cavity as deep as 1.5mm using a slit metal squeegee blade. Further research need to be conducted when printing with (a) metal squeegee blades with slits (b) by placing apertures with different area ratios, smaller than 0.45, to determine the smallest printable aperture; and (c) to perform quantitative analysis (print volume and any variation in the print volume) with respect to the various stencil design factors involved at greater cavity depths.

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