

SPEED PRINTING OF SMT ADHESIVES

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Abstract

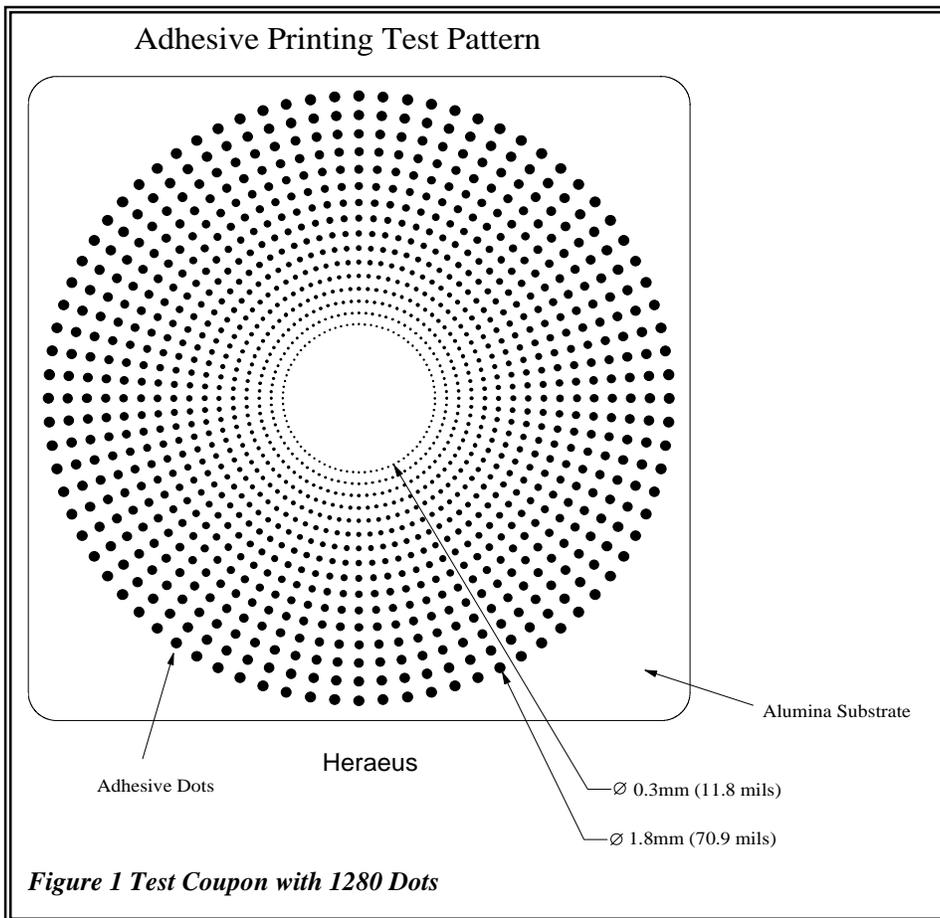
High-speed printing techniques are revealed that break the speed barrier resulting from air entrapment in large apertures at fast squeegee speeds. Adhesive printability test results using conventional thickness stencils to achieve a significant range of deposit heights and diameters are presented. Quantitative adhesive deposit height and diameter data are obtained from a novel application of laser triangulation. The effects on the deposit height range for a spectrum of aperture diameters is quantified with stencil and process guidelines proposed. A high volume speed printing method is further verified on an automotive application involving passive chips only.

Introduction

Adhesive is applied for holding SMT components to the bottom side of mixed technology boards during the wave solder operation. Although adhesive printing has been utilized in lieu of high speed dispensing for years, renewed interest due to higher speed chip shooters has driven material manufacturers towards developing adhesives with custom tailored rheologies for printing. Printable adhesives have been developed to yield a wide range of deposit heights from a single stencil thickness. Many aperture shape options are available with printing adhesives but the most prevalent shape today is the round aperture. Laser triangulation measurement methods have been used to quantify the printability of these new adhesives. The printability results discussed in this paper compare two high-speed printing methods. The first speed printing method exceeds 400,000 dots per hour [1]. Developed for automotive electronic manufacturing this process is capable of replacing pin transfer methods for chips only designs. The second method, although somewhat slower, is capable of a very wide dot height range necessary for high standoff components such as QFP's.

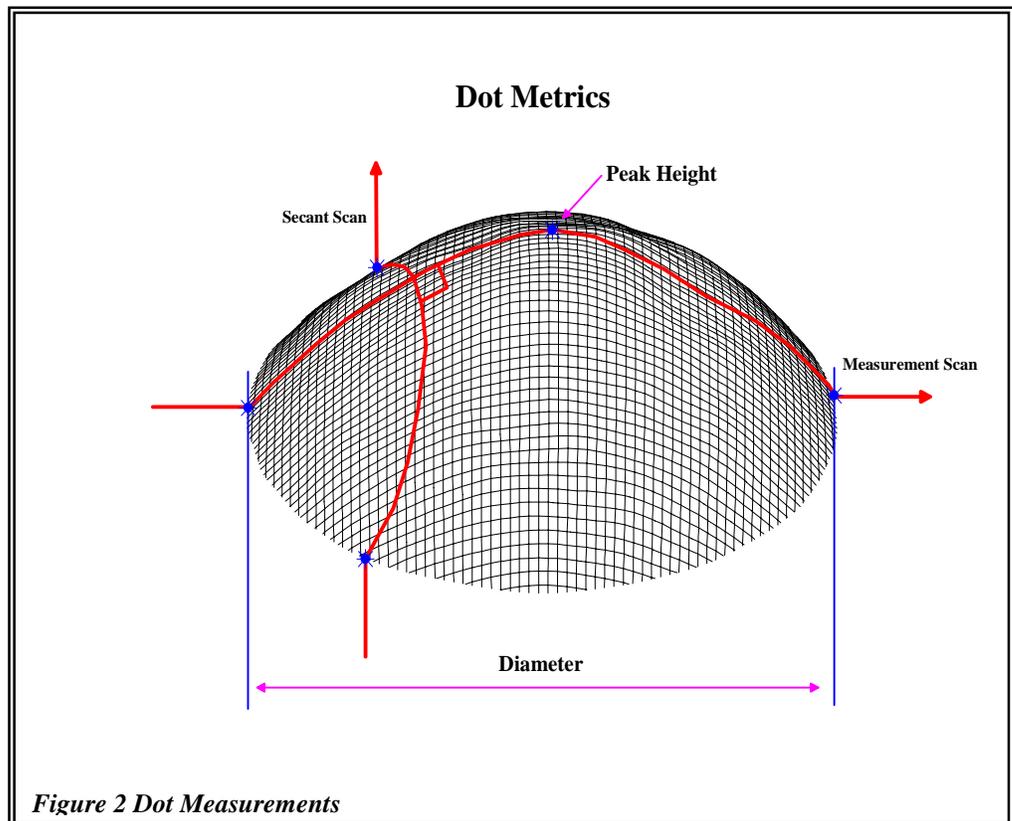
Quantifying Adhesive Printability

In order to quantify the ability of a given adhesive to produce high dot profile deposits, as well as measure the output consistency of a printing process, an automated and objective measurement method had to be developed. Laser triangulation was chosen because of its proven ability to quantify solder paste fine pitch printability and its correlation to Haake rheology [2]. As can be seen in Figure 2, a printability test pattern was designed with a spectrum of stencil aperture diameters from 0.3mm (0.0118") to 1.8mm (0.0709") in 0.1mm (0.0039") increments. This radial array of apertures contains 16 bands, with each band containing 80 apertures of a given diameter for a total of 1,280 apertures. A total of 4 test patterns are printed and measured for a grand total of 5,120 dots per test. The test patterns were printed through stainless steel stencils of various thicknesses onto 4.5" square alumina (Al_2O_3) substrates using a semi-automatic screen printer with a programmable squeegee head. An alumina substrate was chosen for its flatness and reflective properties. Since there is no shrinkage or change to the shape of the dots of adhesive from curing, the test patterns were cured for ten minutes @ 110°C to facilitate handling and storage.



In order to obtain the width of the dot at its base diameter and the peak height along its diameter (as illustrated in Figure 3), an automatic inspection program was created. The system utilizes a fixed laser triangulation sensor that measures the height (Z) at each stage location (X & Y). The sensor used for this study has a working range of 160 mils, a beam diameter of 1.0 mil and a resolution of 0.4 mils (0.0004”). Height measurements are taken every 0.5 mils in a linear scan or slice through a secant of the circular dot. Once the intersections of this secant and the dot perimeter were established,

the center of the secant is calculated and a second measurement scan is taken at 90° to the secant scan. The intersections of this second scan and the dot perimeter is the diameter of the dot (± 0.5 mil). This information is reported to a data file, along with the peak height (± 0.4 mil) that was measured along the diameter. Since this was a radial array, a simple algorithm preceded the measurement portion of the program to measure and compensate for any



rotation of the pattern with respect to the X-Y stages of the measurement system. Data from the 4 test coupons is imported into a spreadsheet where the standard deviation, average, range and Coefficient of Variance (CV) are calculated for both the peak height and diameter.

Although there are numerous variations of printing adhesives through conventional stencil thicknesses (6-12 mils thick) they can be grouped into two categories. The selection of the print process should be based on the component types that need to be glued.

The most common method uses a single-stroke print cycle. This method is ideal for chips only (passives) applications. Before printable rheology adhesives were available to the market this was the only viable method. Dot heights from 1/2 to 1 1/2 times the stencil thickness can be achieved depending on the aperture diameter selection.

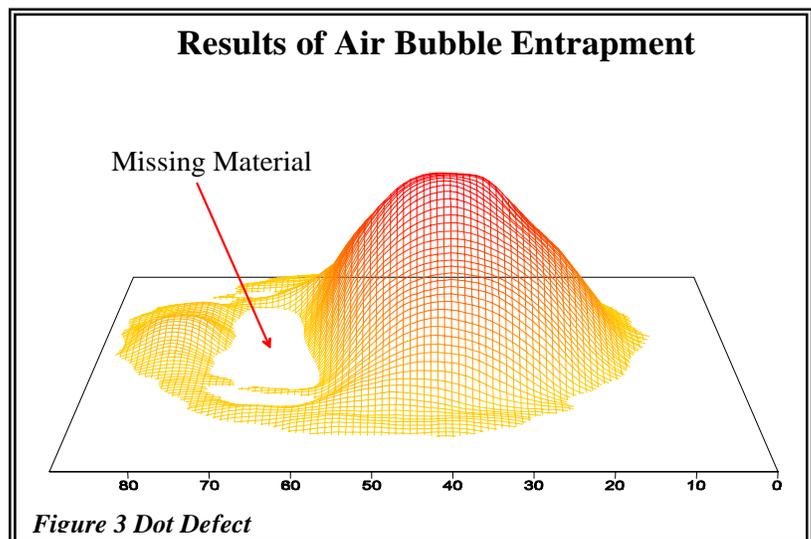
Another method uses a print-flood print cycle. This method is extremely valuable in producing a large range of deposit heights. This method should be used when both leaded (active) and chips are to be glued. Dot heights from 1/3 to 3 times the stencil thickness can be achieved depending on the aperture diameter selection.

Speed Printing

Single-Stroke Method

This method offers the fastest cycle time due to the single squeegee stroke action at very high squeegee speeds. The most common problem encountered with this method are large aperture (> 30 mil) filling problems with thick stencils (≥ 10 mils). The portion of the dot that is facing the squeegee direction tends to have a void or missing material as in Figure 3. This may contain a thin ring of adhesive that outlines the stencil aperture. Printing with 2 deposits (print-print) can alleviate this but causes bleed-out of material on the board-side of the stencil demanding frequent stencil wiping. With printable rheology adhesives and 6 mil thick stencils this defect did not appear on any size aperture (≤ 70 mils) with squeegee speeds in excess of 7 ips (inches per second). This problem is believed to be caused by the entrapment of air in the aperture near the leading edge of the squeegee and can be eliminated by using a combination of printable rheology adhesives and some snap-off. The off-contact printing allows the aperture to degas during printing. The concern over off-contact printing was that this process would require the operator to wipe the stencil more frequently. Using the measurement method described, a run of 50 test coupons was done without wiping using a conventional chemical etch 6 mil thick stainless steel stencil. The setup was as follows:

Printer:	DEK 265 GSX
Squeegee:	6" DEK metal blade @ 45°
Squeegee Speed:	6 inch/sec (150mm/sec)
Squeegee Pressure:	8.4 kg
Print Gap:	31 mils (0.8mm)
Separation Speed:	10mm/sec (fast) for 1.4mm



Total Cycle Time: 9.7 seconds (1280 dot round test pattern)
 Wipe Frequency: None

Every dot on every 5th coupon was measured for diameter and peak height after visual inspection for air bubble defects. There were no visual defects and the dot diameters remained consistent throughout the run (Figures 4 and 5) indicating that more than 50 coupons could be made without wiping.

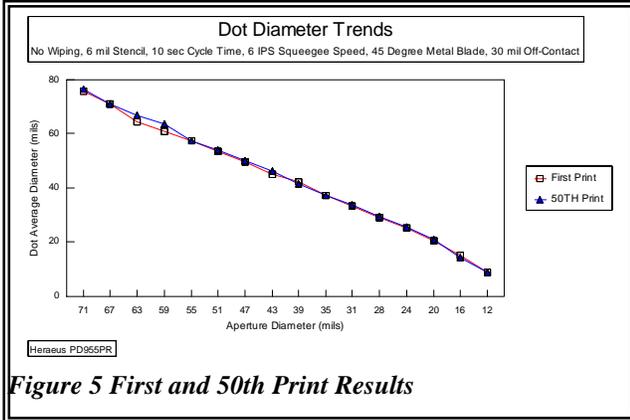


Figure 5 First and 50th Print Results

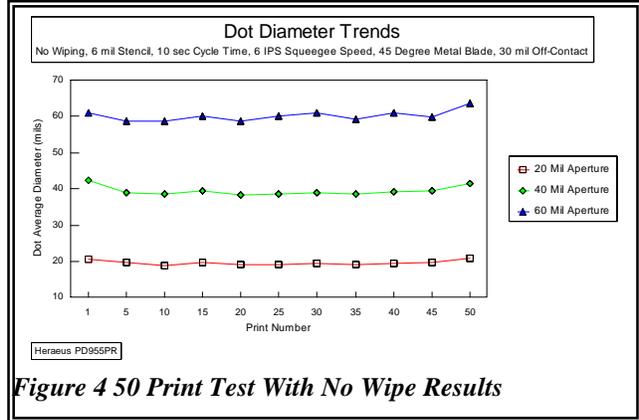


Figure 4 50 Print Test With No Wipe Results

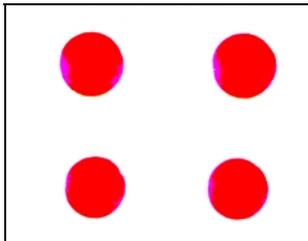


Figure 6 First Print

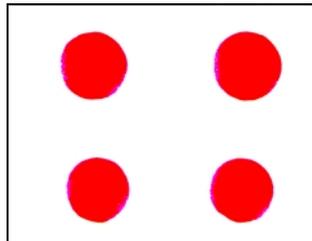
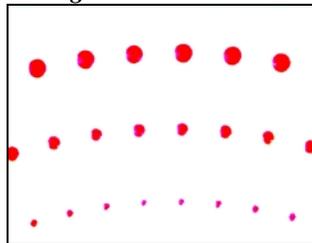
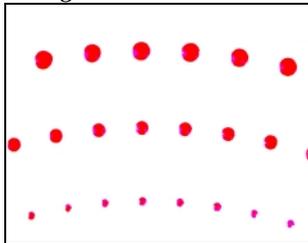


Figure 7 50th Print



Photographs of the 1st and 50th prints in Figures 6 and 7 back up the laser data and indicate no clogging of the small apertures (below) nor evidence of bleed-out or smearing on the large apertures (above). This process yielded a consistent trend of dot peak height with respect to aperture diameter as can be seen in Figure 9 throughout the 50 coupon run. This trend of dot height to aperture diameter is a result of how completely the glue releases from the aperture and is the result of surface tension effects between the glue and the stencil aperture walls. Work done with very thick stencils ($\geq 1\text{mm}$) [3] indicates that all of the apertures remain closed.

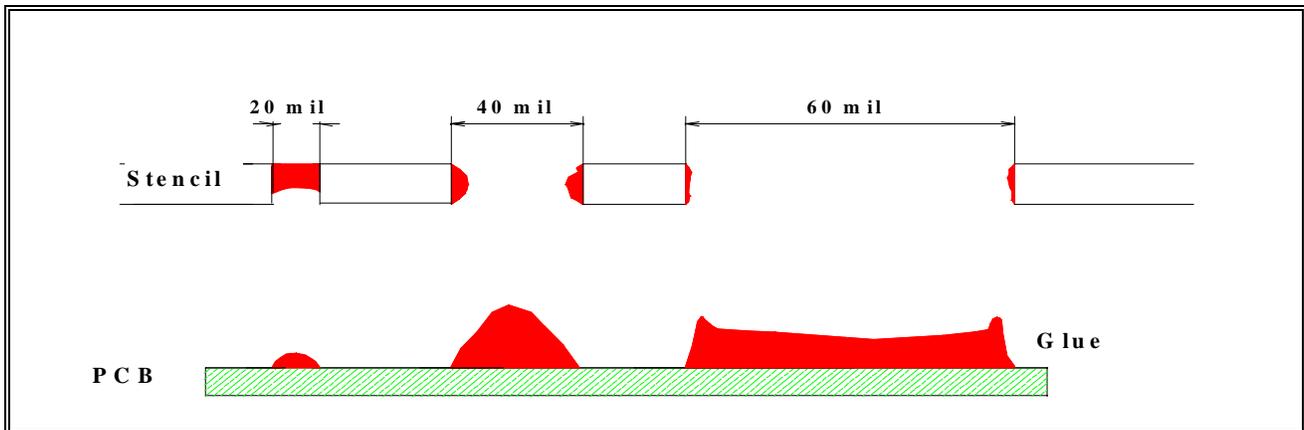


Figure 6 Aperture Surface Tension Effects

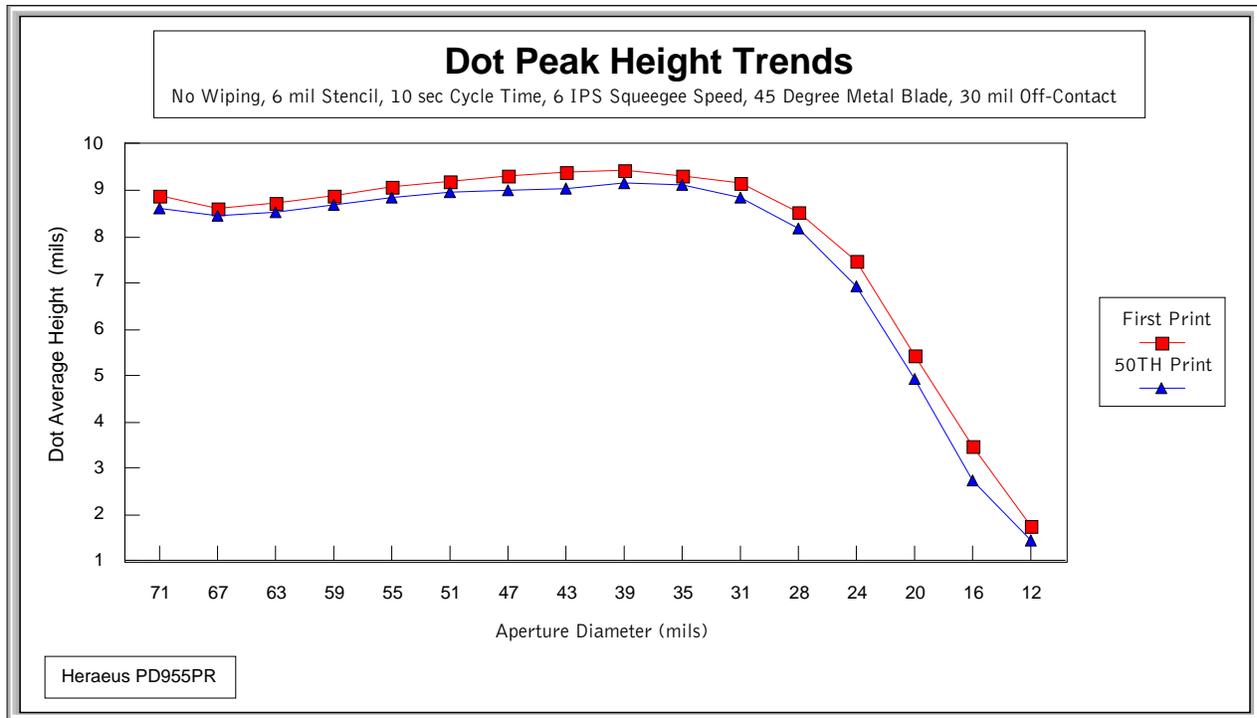


Figure 7 Dot Height Trends

The final step was to verify the performance of this method under similar setup conditions on the automotive customer’s board. The squeegee pressure was increased to get a good wipe with just a slightly visible film of adhesive on the top of the stencil. Slower squeegee speeds would require less pressure. The first board printed and the last (100th) board printed were photographed and several dots scanned for profile. Figures 10 and 11 show the dot placement and shape for the 1206 and 0805 respectively for the first print. Chips were hand placed, then removed to view the “kiss” of the adhesive on the part. Figure 12 shows the largest and smallest dots printed side by side with 3D scans of these two dots in Figures 13 and 14 indicating ample adhesive height for chips. The capability to generate 100 prints without wiping the stencil is further verified in the 100th print photographs in Figures 15, 16 and 17 and the 3D scans in Figures 18 and 19.

Design Guidelines

In the Table below are recommended aperture diameter ranges for different components when printing with a metal, laser-cut stencil of 6-10 mil thickness using the two set-ups described in this paper. When selecting the aperture diameters for small chips (0805 and smaller) it is important to know

Component	Stencil Aperture Range (diameter in mils)
0402	12 - 16
0603	16 - 20
0805	20 - 24
1206	40 - 47
Mini Melf	40
SOT 23	40
1812	50 - 60
SO 8/14	3 dots @ 55 mils spaced equidistant

the spacing between the component pads. Be careful to consider the positioning accuracy of your printer and allow for the printed diameter of the dot to be several mils larger than the aperture.

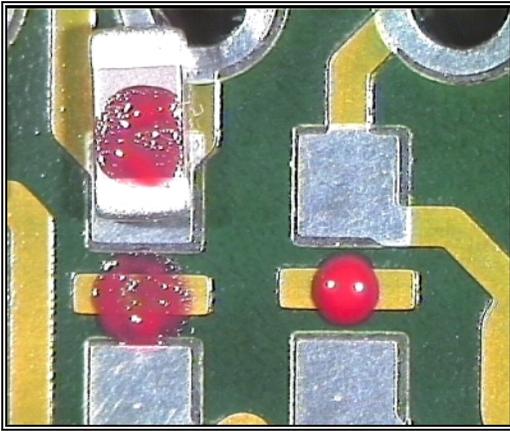


Figure 8 First Print 1206 Deposit

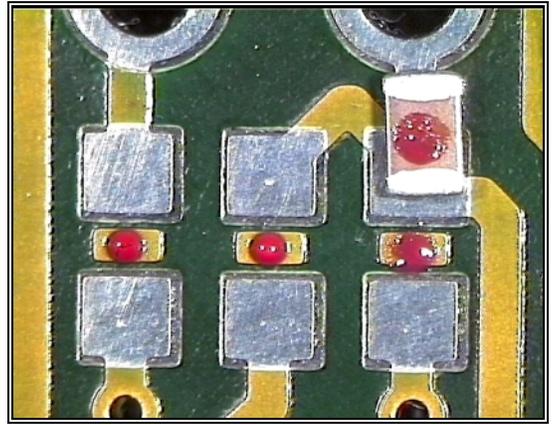


Figure 9 First Print 0805 Deposit

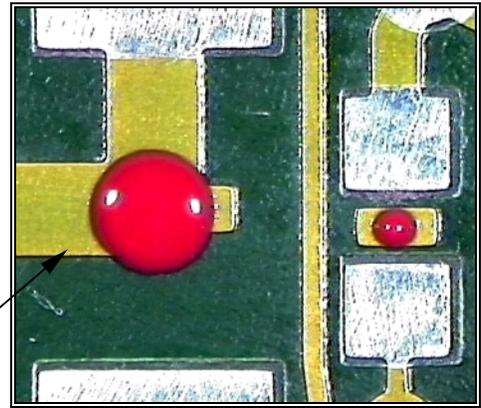


Figure 10 First Print Dots

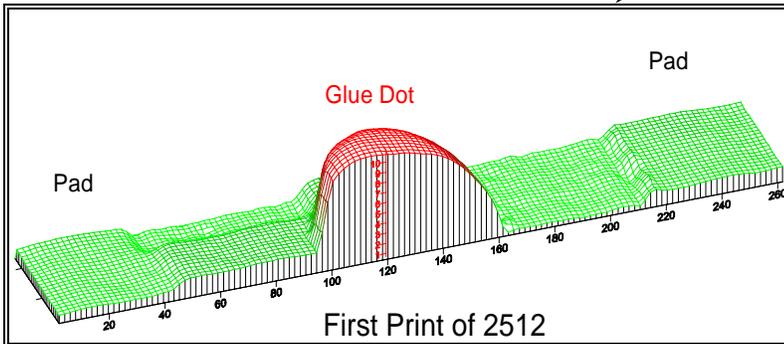


Figure 11 Laser Scan of 2512 Area

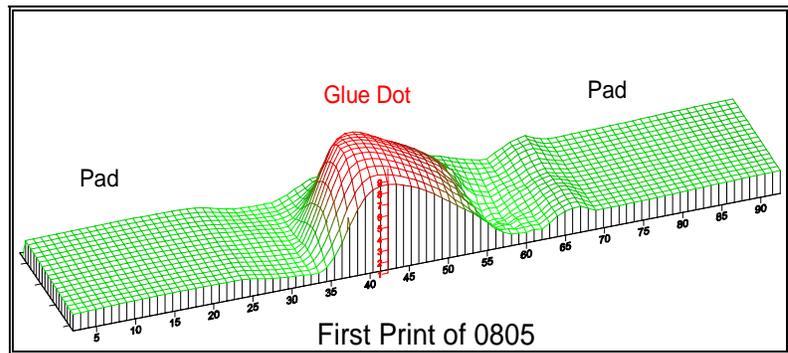


Figure 12 Laser Scan of 0805 Area

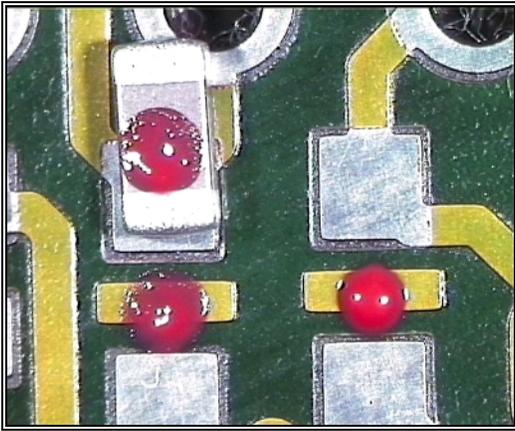


Figure 13 100th Print 1205 Deposit

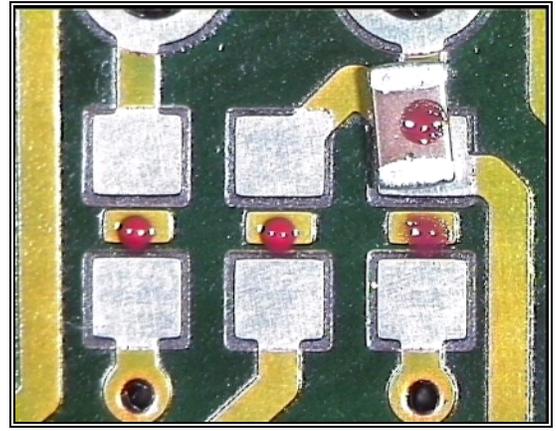


Figure 14 100th Print 0805 Deposit

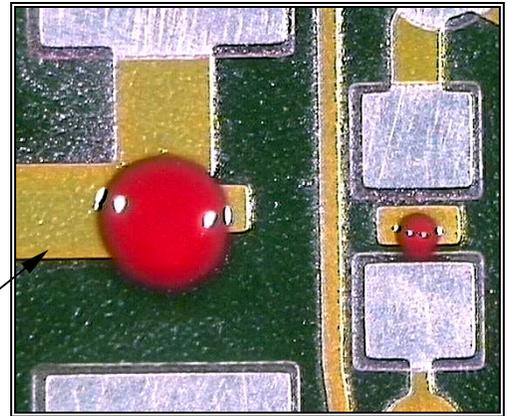


Figure 15 100th Print Dots

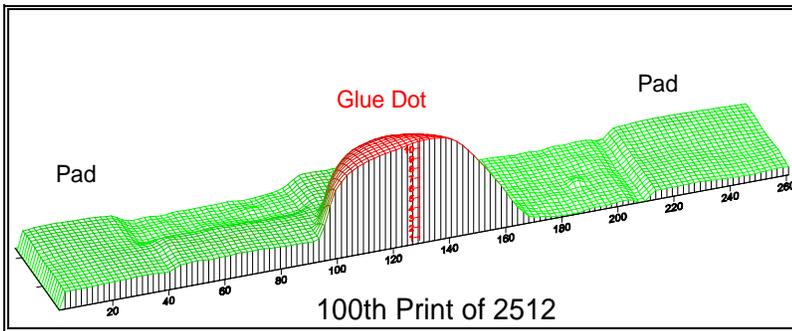


Figure 16 Laser Scan of 2512 Area

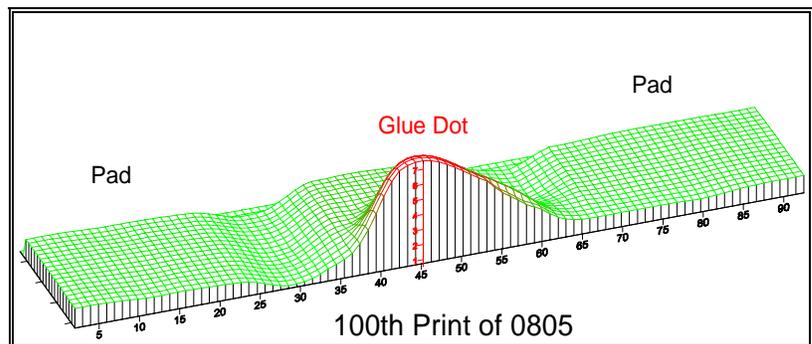


Figure 17 Laser Scan of 0805 Area

Print-Flood Method

This method was developed to fully exploit the rheology of the printable adhesive and use a relatively conventional stencil thickness of 10 mils. To begin the print process cycle a 24 mil (0.6mm) print gap is set for off-contact printing. In this setup the front and rear squeegees were set to different pressures and the second print stroke was set to “Flood” over the stencil top surface at about 1.5mm. The resultant film of adhesive becomes a reservoir for very large dot formation [4] as illustrated in Figure 20. The formation of the dot geometry continues well into the PCB-stencil separation phase of the print-flood cycle. A string is formed between the reservoir of adhesive over the stencil aperture and the printed material on the PCB. This string of material will eventually break and recede back into the stencil aperture and form the final shape of the dot. A very slow separation speed (0.1 to 0.4 mm/sec) assures that this process is complete before the PCB is ejected to the next process. Although slower than the single stroke method, throughput of over 100,000 dots per hour is obtainable with this method. With this print method not even the largest apertures will clear after printing. Wiping the stencil is not effective without first printing an image with the flood stroke removed. This slight drawback is overshadowed by the extremely low CVs and large range of dot heights possible as can be seen in Figure 21 and for dot diameters in Figure 22. The setup was as follows:

Printer: DEK 265 GSX
Squeegee: 6” DEK metal blade @ 45°
Squeegee Speed: 2 inch/sec (50mm/sec) in both print and flood directions
Squeegee Pressure: 6 kg (Print stroke) , 0.6 kg (Flood stroke)
Print Gap: 24 mils (0.6mm)
Separation Speed: 0.1- 0.4mm/sec (slow) for 3mm
Total Cycle Time: 45 seconds (1280 dot round test pattern)
Flood Height: 60 mils (1.5mm)

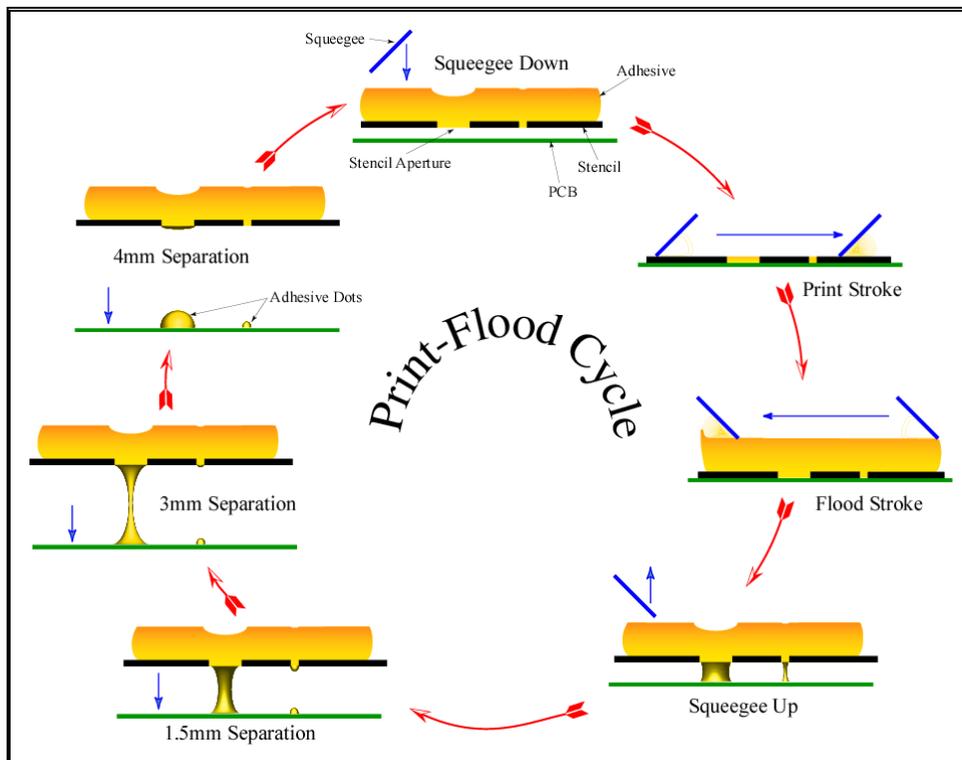


Figure 18 Print Flood Method

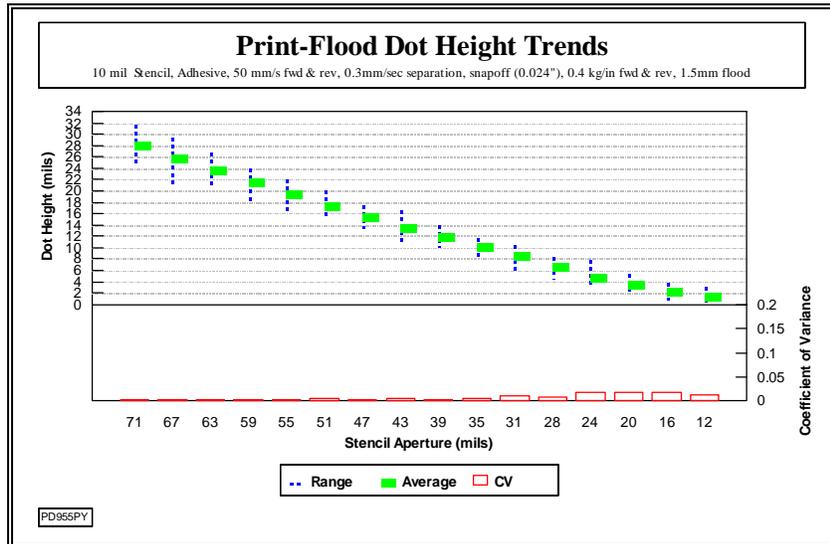


Figure 21 Print -Flood Dot Height Trends

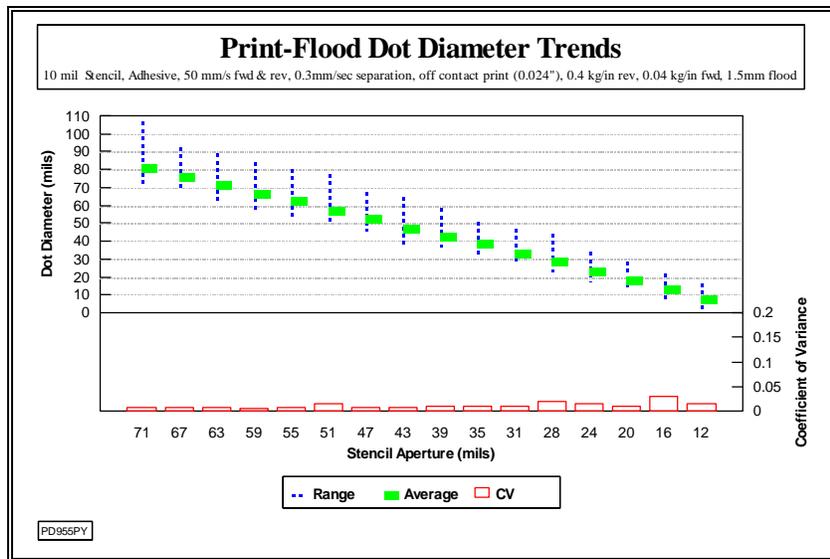


Figure 22 Print-Flood Dot Diameter Trends

Summary

Automated laser inspection of printed adhesive dots continues to reveal the excellent performance of printable adhesives using conventional stencil and printing technology. Minimal need for print process overhead such as stencil wiping has yielded dot deposition rates of over 400K/hour. Using a print-flood cycle where dot heights up to 3 times and as low as 1/3 the stencil thickness are possible can further enhance the performance of the printable adhesive.

References

- [1] Lathrop, Richard R., The Art of Stencil Printing Adhesives, SMT, September 1997, pp. 88-90
- [2] Lathrop, Richard R., Solder Paste Design and Performance Verification for Fine Pitch Printing, SMI97 Proceedings, September 1997, pp. 669-773
- [3] Whitmore, Mark; MacKay, Colin; Hobby, Alan; Plastic Stencils For Bottomside Chip Attach, NEPCON West Proceedings, February 1997, pp. 178-191
- [4] Lathrop, Richard R., The Printing of SMT Adhesives and Evaluation Techniques, NEPCON West proceedings, March 1997, CD