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FACTORS AFFECTING STENCIL APERTURE DESIGN FOR NEXT GENERATION ULTRA FINE PITCH PRINTING

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ABSTRACT:

Miniaturisation is pushing the stencil printing process. As features become smaller, solder paste transfer efficiency is becoming more critical.

In latest research work, actual paste deposit volumes and transfer efficiency have been monitored and compared for both square and round apertures with area ratio's ranging from 0.20 thru to 1.35. This covers apertures sizes of between 100 and 550 microns in a nominal 100 micron thick stencil foil. In addition, the effect of ultrasonically activated squeegees (ProActiv) has been assessed as part of the same experiment. A further comparison has also been made between type 4 and type 4.5 solder paste aswell.

The data presented here will help provide guidelines for stencil aperture designs and strategies for ultra-fine pitch components such as 0.3CSP's.

Key words: Paste transfer efficiency, paste volume, area ratio, aperture design, stencil printing, 0.3mm pitch CSP's, ultra fine pitch components.

INTRODUCTION:

The SMT print process is now very mature and well understood. However, as consumers continually push for new electronic products, with increased functionality and smaller form factor, the boundaries of the whole assembly process are continually being challenged.

Miniaturisation raises a number of issues for the stencil printing process. How small can we print? What are the tightest pitches? Can we print small deposits next to large for high mix technology assemblies? How closely can we place components for high density products? …and then on top of this, how can we satisfy some of the cost pressures through the whole supply chain and improve yield in the production process!

Today we are operating close to the limits of the stencil printing process. The area ratio rule (the relationship between stencil aperture opening and aperture surface area) fundamentally dictates what can and cannot be achieved in a print process. For next generation components and assembly processes these established rules need to be broken!

New stencil printing techniques are becoming available which address some of these challenges. Active squeegees have been shown to push area ratio limits to new boundaries, permitting printing for next generation 0.3CSP technology. Results also indicate there are potential yield benefits for today's leading edge components aswell.

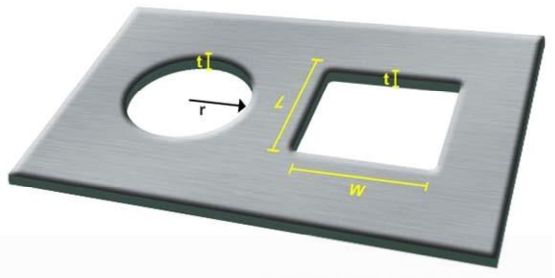
An increasingly important part of the overall equation that is often overlooked is stencil aperture shape/design. With shrinking area ratio's, every cubic micron of solder paste that can be printed is becoming critical. For a given aperture area ratio a square aperture design provides the opportunity to deposit 21.5% more than its circular counterpart. When working with sub 0.5 area ratio apertures then this becomes very significant.

The work reported here represents the start of a series of experiments to help further understand the significance of square vs circular aperture formats, together with the impact of other material factors, and to ultimately provide design guidelines for ultra-fine pitch printing.

STENCIL PRINTING RULES:

Area Ratio

Whilst there are many facets to the stencil printing process it is the stencil aperture area ratio that governs what can and cannot be printed. This is a simple ratio rule (figure 1) between the surface area of an aperture wall and the surface area of the aperture opening (which effectively is the landing area of the pad onto which the solder paste is to be printed).



$$\text{Area Ratio (Rect)} = \frac{\text{Aperture Open Area } (L \times W)}{\text{Aperture Wall Surface Area } 2(L+W)}$$

$$\text{Area Ratio (Circle)} = \frac{\text{Aperture Open Area } (\pi r^2)}{\text{Aperture Wall Surface Area } (2\pi r)t}$$

Figure 1. Stencil Aperture Area Ratio

If the surface area of the aperture wall exceeds that of the aperture opening then the solder paste will want to 'stick' to the aperture wall more than the pad, resulting in a contaminated aperture and an incomplete solder paste deposit. Conversely, if the aperture opening area is greater, then the solder paste will favor ‘sticking’ to the pad rather than the aperture wall leading to a more complete printed deposit. From this, it can be appreciated that as the stencil aperture area ratio decreases then the chances of successful printing with full deposits become slimmer. A typical paste transfer efficiency curve is shown in figure 2.

SOLDER PASTE TRANSFER EFFICIENCY:

Where we are today

For many years the design of stencil apertures has been based around the original IPC7525 specification[1] which recommended that aperture area ratios should be greater than 0.66 for acceptable stencil printing (to achieve in excess of 70-75% transfer efficiency).

The ‘historical’ transfer efficiency curve in Figure 2 is generally accepted as a point of reference for where the industry was back in the late nineties and is still used widely today as a baseline for setting up a process.

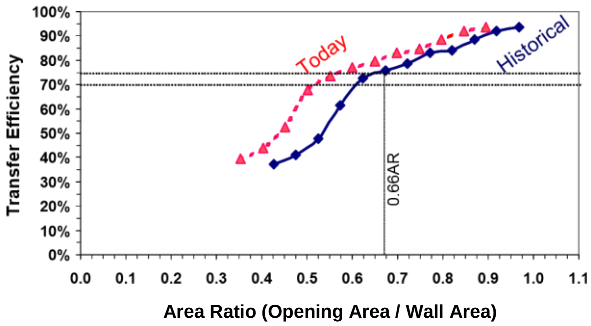


Figure 2. Typical solder paste transfer efficiency – comparison between historical and “today’s” capabilities.

In recent years though, a tremendous amount of research and development has taken place with solder paste materials, stencil technologies and process enhancements to improve paste transfer efficiency. Much work has been done by Ashmore et al[2], Mohanty et al[3] and Babka[4] to name but a few on the importance of squeegee angle to paste transfer efficiency. Many research dollars have been spent on looking at stencil manufacturing techniques, stencil materials and stencil finish[5,6,7,8,9]. Recently nano-coated stencils have been in vogue[10,11], and much work has been conducted by the current authors with ultrasonic squeegees[12,13,14].

Taking all these changes and improvements into account, then with a fully optimised process the ‘today’ paste transfer efficiency curve (figure 2) is a truer reflection of where the smt printing industry is today.

Whilst some of these technology advancements are recognised in latest IPC 7525B[15] specifications, it is clear that we are operating on the boundaries of existing area ratio rules for today’s leading edge components (figure 3). Although many individual operators are able to achieve a stable, capable process with these fine pitch components, extreme care and control over materials is required. In the future, if trying to incorporate 0.3mm pitch CSP’s into existing processes, then stencil apertures with area ratios of approximately 0.4 will be required which are challenging and beyond today’s printing rules (figure 3). Anything which can been done to assist/optimise the printing process for sub 0.5 area ratio processes will therefore greatly benefit the electronic assembly process.

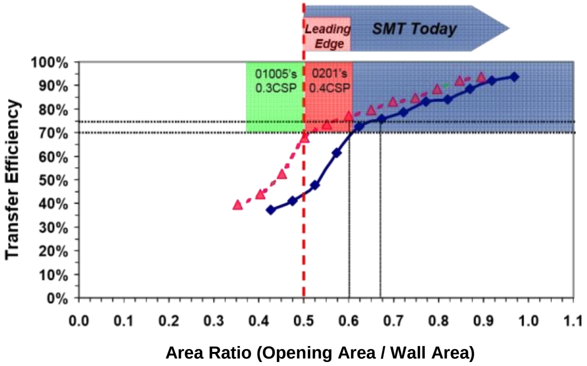


Figure 3. Area Ratio requirements for current and future component technologies

EXPERIMENTAL:

Outline

30 board print runs were conducted using a test pattern consisting of both circular and square apertures. Individual experiments were ran with and without activated squeegees and with both type 4 and type 4.5 solder paste.

Equipment & Materials

A DEK Horizon automatic stencil printer fitted with a “ProActiv” squeegee assembly (ultrasonic squeegee system) was used to print a test pattern through an industry standard 100 micron thick laser cut stainless steel stencil. Printed deposits were measured for volume using a CyberOptics SE500 fitted with a micropad sensor. The test substrates used throughout the investigation were a set of numbered 1.6mm thick, FR4 boards. During the print cycle the test substrates were secured in place with a dedicated vacuum tooling plate.

The same squeegee assembly together with 170mm long metal blades (with 15mm overhang) were used for all testing in both the standard and activated print mode. For a standard print process the ultrasonic capability was simply disabled. Prior to each test run the squeegees were automatically calibrated.

Industry standard lead-free type 4 and type 4.5 solder pastes from a single solder paste vendor were used for printing.

Test Substrate & Stencil Design

An example of the test substrate used is shown in Figure 4. The simple design contains a range of industry standard components. However, for the purpose of this experiment, focus was placed on the four area arrays highlighted in figure 4. These arrays consist of 0.5mm diameter pads on a 1mm pitch. With the corresponding stencil design, a combination of square and circular apertures were incorporated with reducing aperture sizes, ranging between 100 microns and 550 microns (relating to area ratios of between 0.25 and 1.375). The outline of one of these arrays is shown in Figure 5. Each stencil aperture was measured using a semi automatic co-ordinate measuring machine (CMM) to enable "true" transfer efficiency curves to be generated (as opposed to using stencil gerber dimensions).

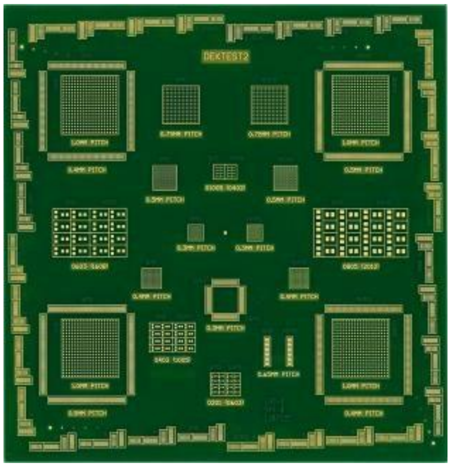


Figure 4. Test substrate with the four arrays used for the reducing array apertures highlighted.

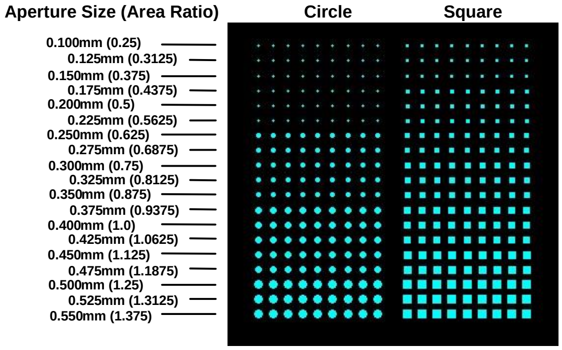


Figure 5. Reducing area array pattern used for generating solder paste transfer efficiency curves. *Note: figures based on a stencil thickness of 100 microns.*

EXPERIMENTAL RUN PROCEDURE:

For each experimental condition, 30 consecutive prints were made. After the 10th and 20th print, the stencil was manually cleaned. Print runs were conducted with and without the ultrasonic squeegee system activated and with both type 4 and type 4.5 solder pastes.

The main process parameters are listed in Table 1. Immediately following each print run the individual boards were measured using a CyberOptics SE 500 inspection tool. The 30 board print runs provided 1080 replicates for each individual aperture shape and design.

Table 1. Print Parameter Summary.

Print Speed	50mm/sec
Print Pressure	4kg
Separation Speed	3mm/sec
Separation Distance	3mm
Temperature	21-22^{o}C
Relative Humidity	50-55%

RESULTS & DISCUSSION:

The first important observation to consider arose from measuring the stencil apertures. The data in table 2 details the actual measurements made for both the circular and square apertures and compares the actual aperture volume to that of the theoretical volume from the gerber dimensions used to manufacture the stencil. Both the top and bottom side of stencil apertures were measured (to take into account any taper), and the average of the two measurements were taken for volumetric calculations.

Table 2. Stencil aperture measurements and volume calculations for circular and square apertures compared to gerber theoretical values.

Circular Aperture Data

Gerber			Measured		
Size(um)	Area Ratio	Vol(nl)	Size(um)	Area Ratio	Vol(nl)
100	0.25	0.79	85.5	0.21	0.57
125	0.31	1.23	111.5	0.27	0.98
150	0.38	1.77	137.0	0.34	1.47
175	0.44	2.41	162.5	0.40	2.07
200	0.50	3.14	185.5	0.46	2.70
225	0.56	3.98	215.0	0.53	3.63
250	0.63	4.91	237.0	0.58	4.41
275	0.69	5.94	261.0	0.64	5.35
300	0.75	7.07	289.0	0.71	6.56
325	0.81	8.30	314.0	0.77	7.74
350	0.88	9.62	337.5	0.83	8.95
375	0.94	11.04	361.5	0.89	10.26
400	1.00	12.57	386.5	0.95	11.73
425	1.06	14.19	415.0	1.02	13.53
450	1.13	15.90	440.0	1.08	15.21
475	1.19	17.72	463.0	1.14	16.84
500	1.25	19.63	489.0	1.20	18.78
525	1.31	21.65	516.0	1.27	20.91
550	1.38	23.76	540.5	1.33	22.94

Square rture Data

Ape Gerber			Measured		
Size(um)	Area Ratio	Vol(nl)	Size(um)	Area Ratio	Vol(nl)
100	0.25	1.00	84.5	0.21	0.73
125	0.31	1.56	112.5	0.28	1.29
150	0.38	2.25	137.0	0.34	1.91
175	0.44	3.06	162.0	0.40	2.67
200	0.50	4.00	186.5	0.46	3.53
225	0.56	5.06	212.5	0.52	4.59
250	0.63	6.25	236.5	0.58	5.68
275	0.69	7.56	261.0	0.64	6.92
300	0.75	9.00	286.5	0.70	8.34
325	0.81	10.56	311.5	0.77	9.86
350	0.88	12.25	337.0	0.83	11.54
375	0.94	14.06	361.0	0.89	13.24

400	1.00	16.00	384.0	0.94	14.98
425	1.06	18.06	413.5	1.02	17.37
450	1.13	20.25	436.0	1.07	19.31
475	1.19	22.56	464.5	1.14	21.92
500	1.25	25.00	487.5	1.20	24.15
525	1.31	27.56	512.5	1.26	26.69
550	1.38	30.25	536.5	1.32	29.24

Notes:
Gerber stencil thickness used in calculations = 100um
Measured stencil thickness used in calculations = 101.6um.
1 nanoliter = 1,000,000 cubic microns.

Typically all apertures were undercut by 10-15 microns. For larger aperture dimensions this is not necessarily a major issue. For example, a 550 circular aperture has a volume of 23.76 nanoliters. The corresponding cut aperture was measured at 540 microns (diameter) with a volume of 22.94 nanoliters; 3.42% less than with its intended gerber dimensions.

For smaller aperture sizes though, such a differential can have a significant impact on the volume of the aperture and its area ratio. This in turn can affect transfer efficiency and the final volume of paste deposited. With the nominal 250 micron apertures, the % difference in measured volume compared to gerber dimensions was approximately 10%. The differential increased to 17% with apertures based on a target size of 150 microns.

This highlights the increased importance of stencil design and stencil manufacturing accuracy when considering ultra fine pitch stencils (with aperture area ratio's below 0.5). It can be the difference between a successful process and a failure!

The benefits of using ProActiv ultrasonic squeegees have been reported by these authors before[13,14,15]. In this study similar trends were observed. Table 3 provides the average paste transfer efficiency for both circular and square apertures for each of the conditions tested – with/without ProActiv, and with type 4 and type 4.5 solder paste. Each data point represents the average of 1080 measurements made over the 30 board print run. The data is shown graphically in figure 6.

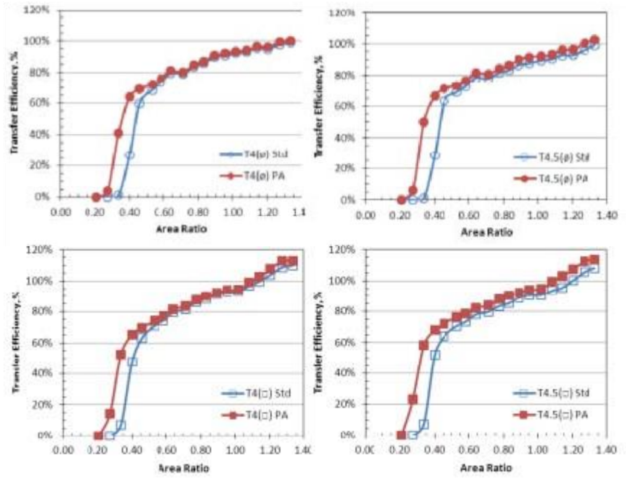


Figure 6. Paste transfer efficiency for various circular (ø) and square (□) aperture area ratios; with/without ProActiv (PA) and with type 4 (T4) and type 4.5 (T4.5) solder paste.

Table 3. Average paste transfer efficiency for various circular and square aperture area ratios; with/without ProActiv (PA) and with type 4 (T4) and type 4.5 (T4.5) solder paste.

Circular Apertures: Average Transfer Efficiency					
Measured		T4	T4	T4.5	T4.5
Size(um)	Area Ratio	Std	PA	Std	PA
85.5	0.21	0.0%	0.0%	0.0%	0.0%
111.5	0.27	0.0%	3.7%	0.0%	6.2%
137.0	0.34	1.2%	41.0%	1.3%	49.9%
162.5	0.40	26.9%	63.8%	28.4%	66.3%
185.5	0.46	59.9%	68.9%	63.3%	71.0%
215.0	0.53	68.4%	72.3%	68.8%	73.4%
237.0	0.58	73.3%	75.7%	72.7%	76.5%
261.0	0.64	79.4%	81.2%	78.3%	81.4%
289.0	0.71	79.2%	80.2%	77.8%	80.6%
314.0	0.77	83.7%	84.7%	81.5%	84.4%
337.5	0.83	86.0%	86.9%	83.3%	86.4%
361.5	0.89	89.6%	90.7%	86.6%	90.2%
386.5	0.95	90.9%	92.3%	87.7%	91.6%
415.0	1.02	92.2%	93.3%	89.5%	92.2%
440.0	1.08	93.2%	94.2%	90.5%	93.3%
463.0	1.14	95.4%	96.4%	92.7%	96.2%
489.0	1.20	94.9%	96.3%	92.8%	96.4%
516.0	1.27	97.5%	99.4%	96.2%	100.6%
540.5	1.33	99.1%	100.3%	99.1%	102.6%
Square Apertures: Average Transfer Efficiency					
Measured		T4	T4	T4.5	T4.5
Size(um)	Area Ratio	Std	PA	Std	PA
84.5	0.21	0.1%	0.0%	0.0%	0.1%
112.5	0.28	0.0%	14.4%	0.1%	23.3%
137.0	0.34	7.3%	52.7%	7.5%	58.3%
162.0	0.40	47.5%	65.2%	52.3%	68.1%
186.5	0.46	63.1%	69.7%	64.1%	72.2%
212.5	0.52	71.0%	74.2%	70.5%	76.3%
236.5	0.58	74.3%	77.3%	73.6%	78.5%
261.0	0.64	79.6%	81.6%	78.2%	82.2%
286.5	0.70	81.6%	83.5%	79.8%	83.9%
311.5	0.77	86.2%	87.7%	83.4%	87.8%

337.0	0.83	88.5%	90.2%	85.4%	90.4%
361.0	0.89	91.1%	92.4%	88.7%	92.3%
384.0	0.94	92.7%	94.1%	90.5%	94.1%
413.5	1.02	93.1%	94.4%	90.6%	94.8%
436.0	1.07	96.9%	99.0%	93.7%	99.5%
464.5	1.14	99.7%	102.6%	95.5%	103.0%
487.5	1.20	104.0%	107.7%	100.4%	107.3%
512.5	1.26	108.8%	112.8%	105.7%	112.6%
536.5	1.32	110.0%	113.0%	108.2%	113.7%

For aperture area ratios below 0.5, the use of ProActiv affords an increase in solder paste transfer efficiency over a standard squeegee process. Effectively, the knee of the transfer efficiency curve is kicked out resulting in the opportunity to work with aperture area ratio's down to 0.4, whilst still maintain paste transfer efficiency above 60%. The charts in figure 7 are scaled to highlight this point.

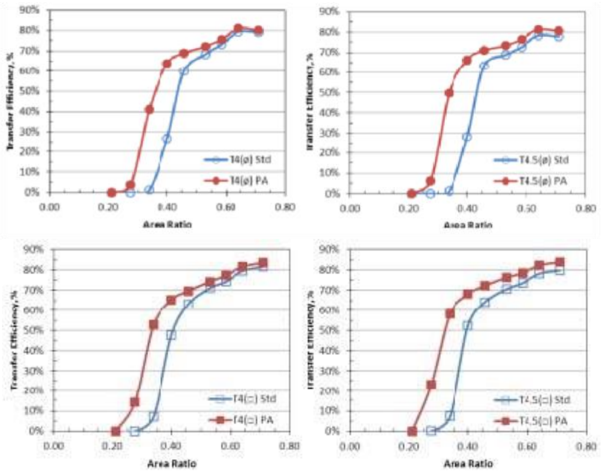


Figure 7. Paste transfer efficiency for circular (ø) and square (□) aperture with area ratios below 0.8; with/without ProActiv (PA) and with type 4 (T4) and type 4.5 (T4.5) solder paste.

With regards to solder paste particle size, the data indicates only small differences (in transfer efficiency) between using type 4 and type 4.5 solder paste. With low area ratios, the net gain of using type 4.5 solder paste was an extra 2-3% in transfer efficiency. Please bear in mind though, that only one solder paste formulation was tested and other type 4/4.5 solder pastes might behave differently.

Whilst transfer efficiency data is a good reference point for the effectivness of a process, a solder joint ultimately requires a "certain" amount of solder for a good connection; therefore actual volume is a more critical and useful measurement.

Table 4 below provides the average volume of solder paste printed for both circular and square apertures for each of the conditions tested – with/without proActiv, and with type 4 and type 4.5 solder paste. Again, each data point represents the average of 1080 measurements made over a 30 board print run.

Table 4. Average volume deposited for various circular and square aperture area ratios; with/without ProActiv (PA) and with type 4 (T4) and type 4.5 (T4.5) solder paste.

Circular Apertures: Average Volume Printed (nl)					
Measured		T4(ø)	T4(ø)	T4.5(ø)	T4.5(ø)
Size(um)	Area Ratio	Std	PA	Std	PA
85.5	0.21	0.00	0.00	0.00	0.00
111.5	0.27	0.00	0.04	0.00	0.06
137.0	0.34	0.02	0.61	0.02	0.75
162.5	0.40	0.57	1.35	0.60	1.40
185.5	0.46	1.64	1.89	1.74	1.95
215.0	0.53	2.52	2.67	2.54	2.71
237.0	0.58	3.29	3.39	3.26	3.43
261.0	0.64	4.32	4.41	4.26	4.42
289.0	0.71	5.28	5.34	5.18	5.37
314.0	0.77	6.58	6.67	6.41	6.64
337.5	0.83	7.81	7.90	7.57	7.85
361.5	0.89	9.35	9.46	9.03	9.40
386.5	0.95	10.83	11.00	10.45	10.92
415.0	1.02	12.67	12.83	12.30	12.67
440.0	1.08	14.39	14.54	13.97	14.41
463.0	1.14	16.32	16.50	15.86	16.45
489.0	1.20	18.12	18.37	17.71	18.39
516.0	1.27	20.73	21.11	20.43	21.37
540.5	1.33	23.09	23.39	23.10	23.92

Square Apertures: Average Volume Printed (nl)					
Measured		T4(□)	T4(□)	T4.5(□)	T4.5(□)
Size(um)	Area Ratio	Std	PA	Std	PA
84.5	0.21	0.00	0.00	0.00	0.00
112.5	0.28	0.00	0.19	0.00	0.30
137.0	0.34	0.14	1.01	0.14	1.11
162.0	0.40	1.27	1.74	1.40	1.81
186.5	0.46	2.23	2.46	2.27	2.55
212.5	0.52	3.26	3.41	3.24	3.50
236.5	0.58	4.22	4.39	4.18	4.46
261.0	0.64	5.51	5.65	5.41	5.69
286.5	0.70	6.80	6.97	6.65	6.99
311.5	0.77	8.50	8.65	8.22	8.66
337.0	0.83	10.21	10.40	9.85	10.43
361.0	0.89	12.07	12.23	11.74	12.22
384.0	0.94	13.89	14.10	13.55	14.09
413.5	1.02	16.18	16.41	15.73	16.47
436.0	1.07	18.71	19.13	18.09	19.22
464.5	1.14	21.85	22.50	20.94	22.59
487.5	1.20	25.10	26.02	24.24	25.92
512.5	1.26	29.02	30.11	28.21	30.06
536.5	1.32	32.18	33.06	31.65	33.24

Notes:
Values have been rounded to 2 decimal places.
1 nanoliter = 1,000,000 cubic microns.

The trends seen in the transfer efficiency analysis (with respect to ProActiv vs standard squeegee printing and type 4 vs type 4.5 solder pastes) are still prevalent in the volume data. However, the volume data serves to highlight the difference in printed volume between circular and square apertures. This can be clearly seen in Figure 8.

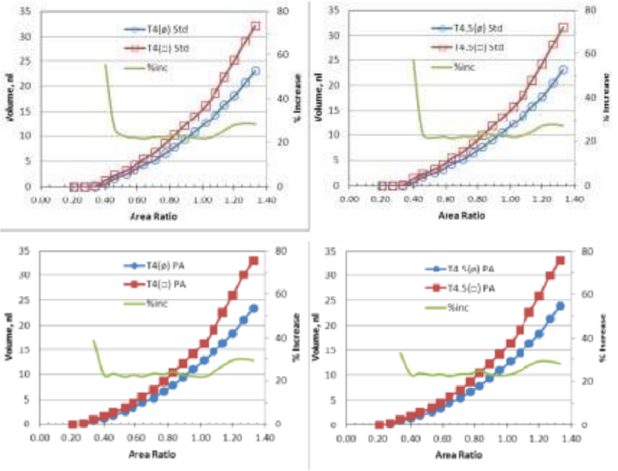


Figure 8. Solder paste volume deposited for various circular (ø) aperture area ratios versus square (□) aperture area ratios; with/without ProActiv (PA) and with type 4 (T4) and type 4.5 (T4.5) solder paste. The % increase in volume deposited with square apertures is also charted.

A square aperture of a given size has a volume that is 21.5% greater than its circular counterpart. Generally, for apertures with area ratios between 0.44 and 1.00, this trend was observed in all print tests irrespective of ProActiv/squeegee and type 4/type 4.5 comparisons. With apertures having area ratios above ~1.00, then the volume increase in paste deposited with a square rose to 29%. This implies that the filling and release dynamics are different with apertures over a certain area ratio, although the exact mechanism was not investigated further.

With apertures having area ratios below 0.40, the differences in actual volume printed became even more significant. The bar charts in figure 9 detail the paste volume printed (for all experimental conditions) with circular and square apertures having critical area ratios based around the knee of the paste transfer efficiency curve. At the extreme, with aperture area ratios of 0.34, virtually no solder paste was printed with a standard squeegee process, either through a circular or square aperture. By using ProActiv with type 4 solder paste, a printed volume of 0.61 nanoliters was achieved with a circular aperture design and 1.01 nanoliters with a square aperture. By using type 4.5 solder paste the maximum volume printed was increased to 1.11 nanoliters. This data highlights how ProActiv, together with considered choice of square or circular apertures and type 4 / 4.5 solder paste can push the lower limits of the printing process.

Whilst not as extreme, (but nonetheless just as significant), the same trends can be seen in the data with aperture area ratios of 0.40 and 0.46. With an area ratio of 0.40 the volume of paste printed ranged from 0.57 to 1.81 nanoliters, depending on process condition. When working towards a specific volume, for example 1.8 nanoliters (which could become typical for an ultra fine pitch component) then the signifcance of aperture design and process choices becomes apparent. Careful selection will have to be exercised to ensure a process can be delivered.

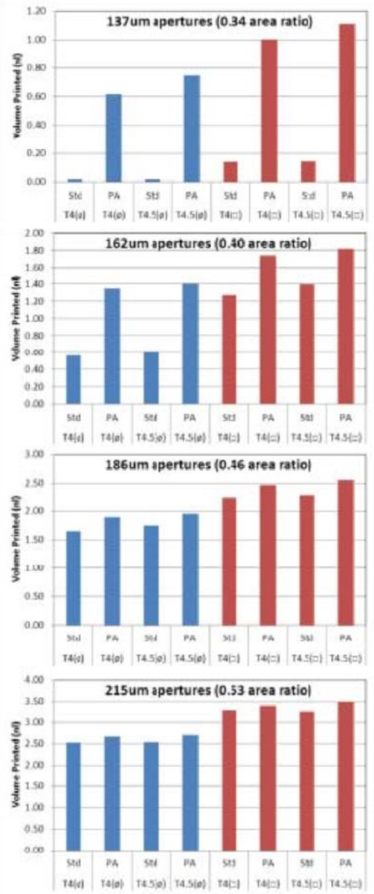


Figure 9. Solder paste volume deposited for specific area ratios. Comparing circular (ø) and square (□) apertures; with/without ProActiv (PA) and with type 4 (T4) and type 4.5 (T4.5) solder paste.

The transfer efficiency and volume data discussed thus far is helpful in understanding the potential scope for future surface mount assembly. For the full picture though, it is also essential to understand the true capabilities and repeatability of a process associated to any material and process choice.

In this respect, the scatter and standard deviation of the experimental data collected was also considered. Focussing in again on aperture area ratios around the knee of the transfer efficiency curve, figure 10 plots every single data point collected for apertures with area ratios of 0.34, 0.40 and 0.46. Simplistically, this gives the engineer a great view of what is happening in a process. The outliers represent potential board level defects and the spread of the data gives an indication of how “in control” the process is. The charts clearly show the benefits of using ProActiv with low, challenging area ratio apertures. This is exemplified by the data for the 162µm (0.40AR) aperture. With a standard squeegee process the scatter of data was large (and low) indicating that the process conditions were not capable. By using ProActiv the data set was significantly tightened up with acceptable volumes being deposited. This phenomena was noted with other low area ratio apertures.

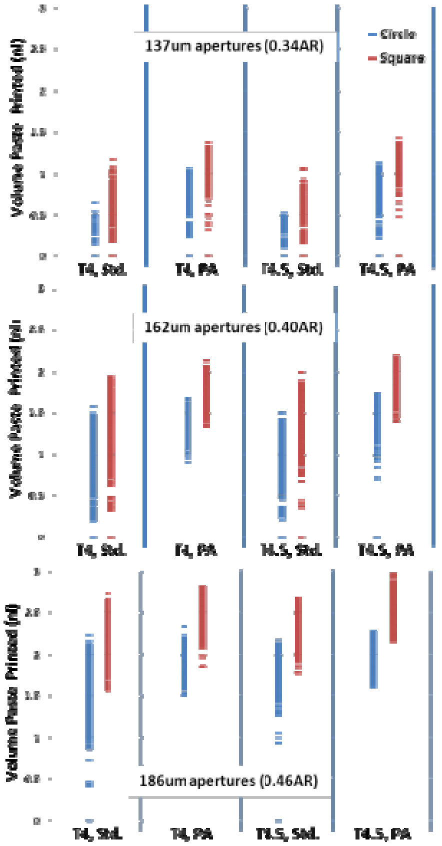


Figure 10. Solder paste volume scatter plots for apertures with area ratios of 0.34, 0.40 and 0.46. Comparing circular (blue) and square (red) apertures; with/without ProActiv (PA) and with type 4 (T4) and type 4.5 (T4.5) solder paste.

The standard deviation charts in Figure 11 help provide a process capability view across all area ratios and process conditions tested. In these charts, standard deviation is quoted as a % of the actual volume printed. It is generally accepted that if the % standard deviation is maintained below 10% then a process is in control. As can be seen from the charts this becomes a more discerning measure with decreasing area ratio.

Generally, each experimental run held a 5% standard deviation with apertures having area ratio's down to 0.53, indicative of a stable process to that point. Below 0.53, then subtle differences were noted. Figure 12 homes in on the % standard deviation data for aperture area ratios below 0.6. Comparing all experimental runs within the same chart, the curves fall into two distinct groups. The curves to the left were the result of using ProActiv. It can be seen that ProActiv enabled process % standard deviation to be kept below 10% with apertures having an area ratio down to 0.4.

Under one specific condition - ProActiv with a square aperture design and type 4.5 solder paste, the process was capable down to an aperture area ratio of 0.34. In contrast the standard squeegee processes bottomed out with area ratios of approximately 0.46.

In comparing aperture shape, the data indicated that lower area ratios designs can be used with square apertures (compared to circular apertures) and still maintain a process with a % standard deviation under 10%.

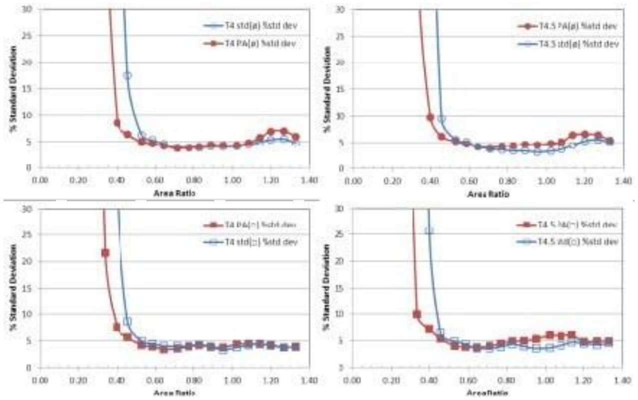


Figure 11. % Standard deviation plots for various circular (ø) aperture area ratios versus square (□) aperture area ratios; with/without ProActiv (PA) and with type 4 (T4) and type 4.5 (T4.5) solder paste.

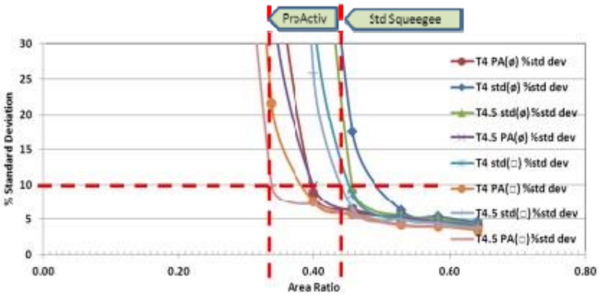


Figure 12. % Standard deviation plots for all experimental runs

From the data presented here it is apparent that there are many interacting circumstances to consider when designing a process; - and these are assuming greater importance as we push into the realms of sub 0.5 area ratios. Ultimately, each component requires a defined amount of solder paste for good joint assembly so this will dictate requirements. However, the mechanism by which this is delivered, as shown from the experimental data here, can vary depending upon aperture design, solder paste material used and printing process utlised.

SUMMARY:

The next generation of ultra fine pitch components will place extreme demands on the stencil printing process. The requirement for printing solder paste through stencil apertures with area ratios below 0.5 will become common place. The data presented here indicates that with judicial choice of stencil design and materials it will be possible for designers to work with aperture area ratios down to 0.4. To optimise a process it is becoming increasingly important that an engineer has a good understanding of stencil aperture design specification, material properties and process options/aids available to him. The interactions between all of these facets is becoming more complex and critical to the successful implementation of a process.

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