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FINE TUNING THE STENCIL MANUFACTURING PROCESS AND OTHER STENCIL PRINTING EXPERIMENTS

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ABSTRACT

Previous experimentation on a highly miniaturized and densely populated SMT assembly revealed the optimum stencil alloy and flux-repellent coating for its stencil printing process. Production implementation of the materials that were identified in the study resulted in approximately 5% print yield improvement across all assemblies throughout the operation, validating the results of the initial tests.

A new set of studies was launched to focus on the materials themselves, with the purpose of optimizing their performance on the assembly line. Using a similar test vehicle as the prior experiments, DOEs characterized key aspects of the stencil manufacturing process by varying the laser cutting parameters and coating materials. As the scope of the DOE grew, it also included evaluation of new materials and a comparison of microBGA aperture designs. Eventually, additional runs were added to investigate the effects of nanocoating on wipe frequency and compare two different stencil cutting processes.

Results of the prior tests are reviewed, and the new test vehicle, experimental setup and results are presented and discussed.

BACKROUND AND INTRODUCTION

This study builds upon the results of a previous investigation that identified the best stencil technology for the production of a high density, highly miniaturized PCB assembly.[1] The test vehicle used in that study is shown in figure 1.

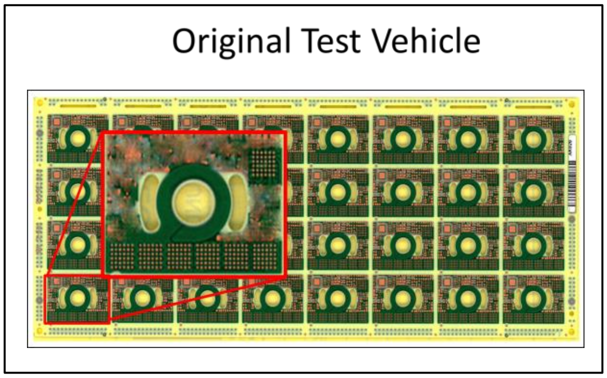

Figure 1. Test Vehicle used in previous tests (non-BGA circuitry on closeup is intentionally blurred)

The PCB design packed nearly 15,000 paste deposits in a 3x7 area; 8500 of those were 0.5mm microBGAs. The study used print yields, transfer efficiencies, and print volume consistency as metrics to evaluate a number of stencil technologies, including electroformed nickel stencils, electroformed nickel that had been laser cut, and two different types of laser-cut stress relieved stainless steel (SS). The study concluded that the best print quality was produced with laser-cut fine grain (FG) SS foils with two-part Self Assembling Monolayer Phosphonate (SAMP) nanocoating applied.

With the key materials identified, a new study was launched to optimize the laser cutting parameters on the FG SS. It tested three experimental parameter sets against the process of record (POR). Prior to the outset of the tests, a new two-part SAMP nanocoating was introduced to the market, so additional tests were planned to benchmark the new generation of nanocoating against the original one.

In response to recent reports that cite square apertures as superior to circular ones on fine features[2], a leg was added to the DOE that directly compared the two.

As the time to execute the experiments approached, a new, experimental SS foil materials were introduced, as was a new electroforming process, so another leg was added to analyze their performance. During the execution of the tests, two additional runs were added to begin understanding the relationship between nanocoating and stencil under wipe frequency.

Upon review of the results, a final run was added to benchmark the performance of a different laser stencil cutting process.

All the tests were executed in a similar fashion, using the same ten-print test and the same metrics for analysis. Detailed information on the derivation of the Area Ratio, Transfer Efficiency and Coefficient of Variation metrics used in this study is provided in the original report, cites as reference #1.

EXPERIMENTAL SETUP

Test Vehicle

The original test vehicle shown in figure 1 was used for a multitude of comparative tests over a two-year span. It is a production PCB that offers vast amounts of comparative data. The design was recently revised; the new test vehicle used in this evaluation is shown in Figure 2.

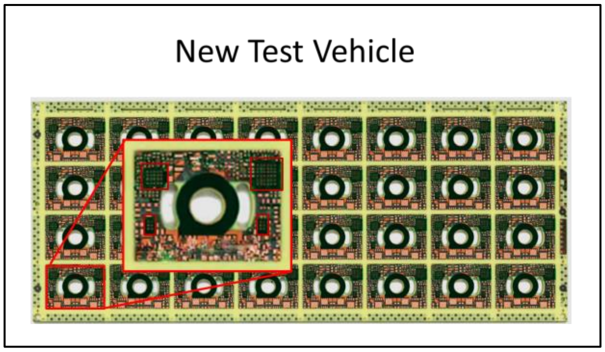

Figure 2. New Test Vehicle.

This new design replaced some of the microBGAs with FETs, reducing the number of BGA I/Os from 8500 to 2176 per board. The number of 0201s increased on this design, from 1900 deposits per print to 3712. A ten-print test using the new TV now produces 21,760 BGA data points and 37,120 0201 data points.

Test Methods

For each stencil, 10 prints were produced sequentially on a well maintained and calibrated 2009 DEK horizon stencil printer using, both front-to-back and back-to-front squeegee strokes, with an automatic dry wipe after each print. Print parameters were:

- Print speed: 7 mm/sec
- Print pressure: 8 kg (250mm blades)
- Separation speed: 20mm/sec
- Wipe sequence vacuum/dry/vacuum

The solder paste used in all tests was Indium 3.2 HF Type 3, water soluble, lead-free, halogen-free, lot numbers PS52867 and PS54561. Fresh paste was used on each stencil. The paste was not kneaded; 2 dummy prints were produced before measurements were taken. The 17 stencils were print tested in a climate controlled NPI manufacturing area over 9 different runs. During the tests the room temperature ranged from 22.0 to 25.3°C, and relative humidity ranged from 36.3 to 42.9%.

The PCB was supported with a flat, non-vacuum tooling plate and edge clamps. Deposit volume measurements were taken with a Koh Young 3020VAL using a Bare Board Teach to set the reference plane.

Test Matrices

All the experimental stencils were produced by the same supplier. Their thickness was specified at 4mil. The laser cut stencils were all produced on the same cutter within a two-week period. The first-generation nanocoating, Nano1, (DEK NanoProTek) was applied to the specified stencils at the supplier's site; second-generation coating, Nano2, (Aculon NanoClear) was applied at the test site. The designs of the individual experiments are listed in tables 1-4.

Table 1. Laser cutting parameter experiment

Experiment #1	
Compare Cutting Parameters on FG SS	
Stencil #	Description
1	POR with Nano1
1a	POR w/o Nano
2	Param Set 1 with Nano1
2a	Param Set 1 w/o Nano
3	Param Set 2 with Nano1
3a	Param Set 2 w/o Nano
4	Param Set 3 with Nano1
4a	Param Set 3 w/o Nano

Table 2. New stencil materials experiment

Experiment #2 Compare Materials	
Stencil #	**Description**
5	POR FG with Nano1
5a	POR FG with Nano2
6	Exp Eform with Nano1
6a	Exp Eform with Nano2
6b	Exp Eform w/o Nano
8	Exp SS with Nano2
8a	Exp SS w/o Nano

Table 3. MicroBGA aperture shape experiment

Experiment #3 0.5mm BGA Aperture Geometry	
Stencil #	**Description**
7	Round - POR FG with Nano1
7b	Square -POR FG with Nano1

Table 4. Under wipe experiment

Additional Runs 10 Prints with No Under Wipe	
Stencil #	**Description**
5a	POR FG with Nano2
7	POR FG with Nano1

RESULTS

Aperture Measurements

To calculate actual transfer efficiencies and area ratios, the stencils' apertures and thicknesses were measured. Their specifications are as follows:

- Circular microBGA apertures: 10.8mil
- Square microBGA apertures: 10.8mil
- Rectangular 0201 apertures: 11.8x13.8mil
- Foil thickness: 4mil

The apertures were measured on the PCB side with a Microvue automated vision system; 32 of each aperture size were measured per stencil. Round apertures all measured to within 0.5mil of their specification; square or rectangular ones measured within 0.7mil of their specification. Foil thickness were consistent at 4.0mil on the SS due to its precision manufacturing process and averaged 3.9-4.0mil on the electroformed stencils.

The average measurements are reported in table 5.

Table 5. Average Aperture measurements

Stencil #	Device	Dia. or X (mils)	Y (mils)
1	BGA	10.4	
	0201	13.1	11.3
2	BGA	10.8	
	0201	13.5	11.6
3	BGA	10.4	
	0201	13.1	11.2
4	BGA	10.5	
	0201	13.2	11.2
5	BGA	10.5	
	0201	13.2	11.2
6	BGA	10.5	
	0201	13.2	11.3
7	BGA	10.4	
	0201	13.1	11.2
8	BGA	10.5	
	0201	13.2	11.3
1A	BGA	10.4	
	0201	13.1	11.2
2A	BGA	10.8	
	0201	13.5	11.6
3A	BGA	10.4	
	0201	13.1	11.2
4A	BGA	10.4	
	0201	13.1	11.2
5A	BGA	10.5	
	0201	13.2	11.2
6A	BGA	10.4	
	0201	13.1	11.3
6B	BGA	10.4	
	0201	13.2	11.3
7A	SQ BGA	10.2	10.1
	0201	13.1	11.2
8A	BGA	10.4	
	0201	13.2	11.3

The measurements were used to calculate the actual aperture volumes and area ratios shown in table 6.

Table 6. Aperture volumes and area ratios for test stencils

Stencil #	Device Type	Volume (cu mil)	Area Ratio
1	BGA	337	0.65
	0201	592	0.76
2	BGA	366	0.67
	0201	627	0.78
3	BGA	342	0.65
	0201	590	0.76
4	BGA	344	0.65
	0201	593	0.76
5	BGA	344	0.65
	0201	593	0.76
6	BGA	343	0.65
	0201	595	0.76
7	BGA	337	0.65
	0201	587	0.75
8	BGA	346	0.66
	0201	599	0.76
1A	BGA	342	0.65
	0201	589	0.76
2A	BGA	365	0.67
	0201	627	0.78
3A	BGA	341	0.65
	0201	589	0.76
4A	BGA	341	0.65
	0201	586	0.75
5A	BGA	343	0.65
	0201	593	0.76
6A	BGA	341	0.65
	0201	592	0.76
6B	BGA	340	0.65
	0201	594	0.76
7A	SQ BGA	410	0.63
	0201	589	0.76
8A	BGA	340	0.65
	0201	595	0.76

Paste Volume Measurements & Print Yields

The paste volume information and print yields resulting from the 10-print tests are shown in tables 7-9.

Table 7. Measured Print Volume Results for microBGAs and Print Yields

Aperture	Stencil	Mean	Std dev	CV	YIELD
BGAs	1	344	31	9%	80%
	1A	273	31	11%	60%
	2	306	30	10%	80%
	2A	306	34	11%	70%
	3	273	35	13%	90%
	3A	302	43	14%	70%
	4	313	50	16%	0%
	4A	289	42	15%	60%
	5	285	41	14%	80%
	5A	278	34	12%	80%
	5A-No Wipe	288	31	11%	90%
	6	282	33	12%	60%
	6A	295	32	11%	100%
	6B	307	42	14%	70%
	7	279	44	16%	70%
	S7-No Wipe	297	35	12%	100%
	7A	358	41	11%	70%
	8	298	34	11%	100%
	8A	311	37	12%	90%

Table 8. Measured Print Volume Results for 0201s at 0 degree orientation and Print Yields

Aperture	Stencil	Mean	Std dev	CV	YIELD
0201s at 0 degrees	1	717	67	9%	80%
	1A	632	71	11%	60%
	2	618	65	11%	80%
	2A	635	77	12%	70%
	3	582	69	12%	90%
	3A	611	82	14%	70%
	4	631	93	15%	0%
	4A	597	88	15%	60%
	5	589	84	14%	80%
	5A	584	67	11%	80%
	5A-No Wipe	593	61	10%	90%
	6	579	77	13%	60%
	6A	606	68	11%	100%
	6B	604	77	13%	70%
	7	586	90	15%	70%
	S7-No Wipe	600	66	11%	100%
	7A	603	72	12%	70%
	8	609	66	11%	100%
	8A	631	72	11%	90%

Table 9. Measured Print Volume Results for 0201s at 00 degree orientation and Print Yields

Aperture	Stencil	Mean	Std dev	CV	YIELD
0201s at 90 degrees	1	694	63	9%	80%
	1A	608	67	11%	60%
	2	595	64	11%	80%
	2A	611	75	12%	70%
	3	564	66	12%	90%
	3A	591	81	14%	70%
	4	608	95	16%	0%
	4A	579	86	15%	60%
	5	567	80	14%	80%
	5A	562	63	11%	80%
	5A-No Wipe	571	59	10%	90%
	6	551	79	14%	60%
	6A	583	70	12%	100%
	6B	591	79	13%	70%
	7	569	86	15%	70%
	S7-No Wipe	582	64	11%	100%
	7A	580	70	12%	70%
	8	590	64	11%	100%
	8A	612	72	12%	90%

SPI databases were also queried for the microBGAs average positional offset in X and Y. The results are shown in Table 10.

Table 10. Average positional offset of microBGA prints

Postional Offsets		
Stencil	X(mils)	Y(mils)
1	0.44	-0.41
1a	0.46	0.39
2	0.09	0.67
2a	0.52	0.14
3	0.44	0.35
3a	0.52	0.60
4	0.60	0.66
4a	0.53	0.69
5	0.48	0.71
5a	0.57	0.37
6	0.69	0.95
6a	0.37	0.88
6b	0.58	0.86
7	0.40	0.63
7a	0.47	0.41
8	0.48	0.53
8a	0.55	0.40
PRODUCTION	0.41	0.00

ANALYSIS

Experiment #1 - Effect of Cutting Parameters and Nanocoating

1) Print Yields

Print yields are determined by the automatic solder paste inspection system. All 9472 deposits must fall within their specified ranges for the print to be considered a pass. As little as one deposit out-of-spec will cause the print to be a fail.

The print yields are show in figure 3. With the exception of parameter set 3, the treated stencils yielded 10-20% better than the untreated ones. Additionally, parameter set 2 produced the highest yields. The treated stencil in Parameter set 3 yielded 0% due to a miscut aperture (figure 4).

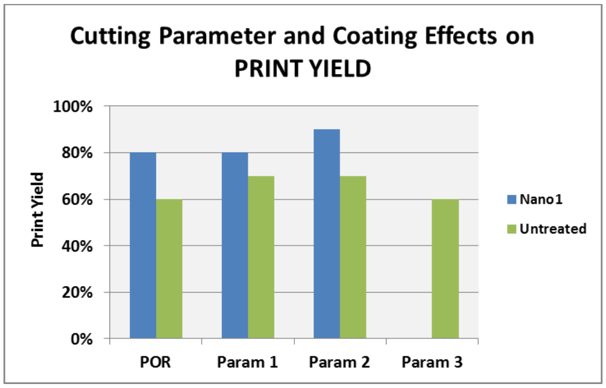

Figure 3. Effect of cutting parameters and nanocoating treatment on print yields.

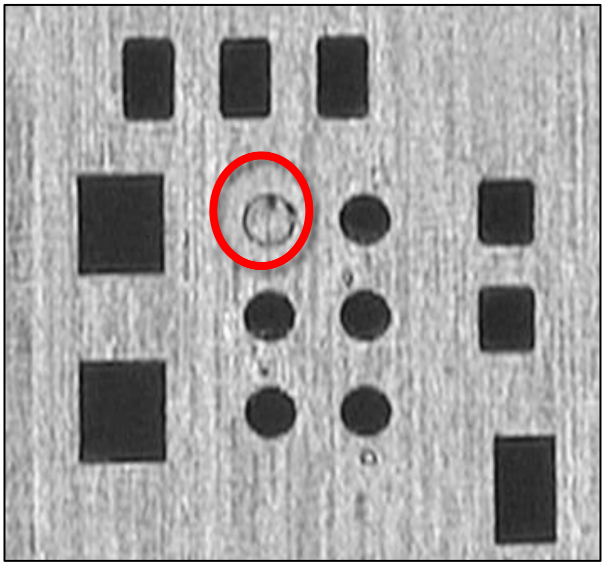

Figure 4. Miscut stencil aperture on stencil 4.

2) Transfer Efficiency

Transfer efficiencies (TE) are the ratio of the volume of the measured deposit to the volume of the stencil aperture and are expressed as a percent, or, more simply put, the percentage of solder paste that releases from the aperture. The aperture volumes used in the calculations are computed based on the average measured aperture dimension and stencil thickness, not on their specifications.

The data from parameter set 3 were not included in transfer efficiency or repeatability comparisons due to the miscut aperture.

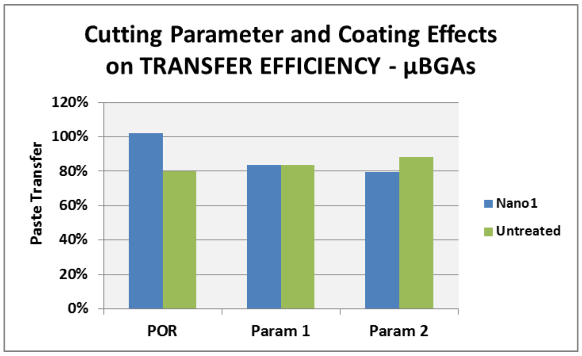

Figure 5. Effect of cutting parameters and coating on transfer efficiency. The higher the TE, the better.

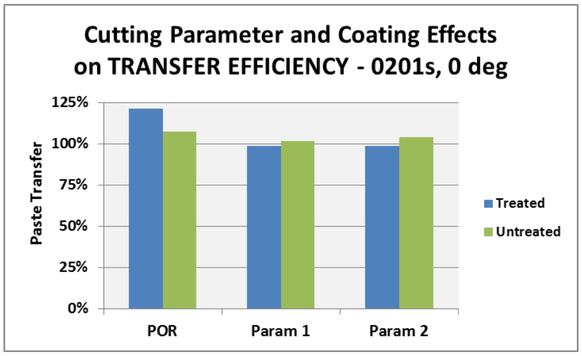

Figure 6. Effect of cutting parameters and coating on transfer efficiency of 0201s oriented at 0 degrees.

Most of the stencils transferred about 80% for BGAs (figure 5) and 100% for 0201's. Figure 6 shows the TE results for 0201s oriented at 0 degrees; similar results were found at 90 degree orientation (not shown). No significant difference in transfer efficiency was noted with the different cutting parameters, with the exception of the POR sample. The treated stencil that was cut at the POR parameters appears to have 100% TE for the BGAs and 120% for the 0201s. Years of baseline data indicate mean TEs of approximately 80% and 100% for the two device types, respectively. At the BGA's 0.65 area ratio, 100% TE is not realistic; neither is 120% for the 0201s. Therefore, special causes of the anomalous data were investigated.

Positional inaccuracy, the most likely possible cause of excess solder volumes, was investigated first. The positional accuracy was found to be within 0.5mil in both X and Y directions, so it was ruled out as a root cause. The investigation then turned to the bottom of the stencil, where numerous topographical features were observed (figure 7). Small bits of metal fused to the bottom of the stencil appear to have separated the stencil from the PCB, preventing good gasketing. The origin of these features is unknown. Closer inspection of stencil 4 indicates that similar features may be a contributor to the miscut aperture (fig 4).

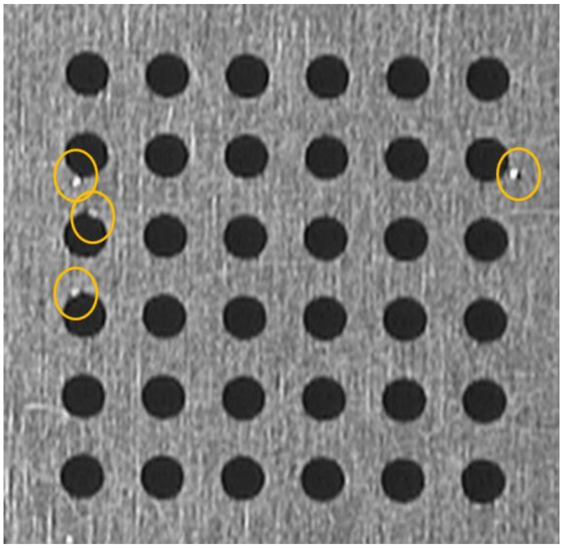

Figure 7. Topographical features found on the PCB side of stencil 1.

3) Volume Repeatability

Print volume repeatability is measured by dividing the standard deviation of the print volume readings by the mean of the readings, and is also known as the Coefficient of Variation. It is expressed here as a percentage. The effect of the cutting parameters and coatings on volume repeatability is shown in figure 8.

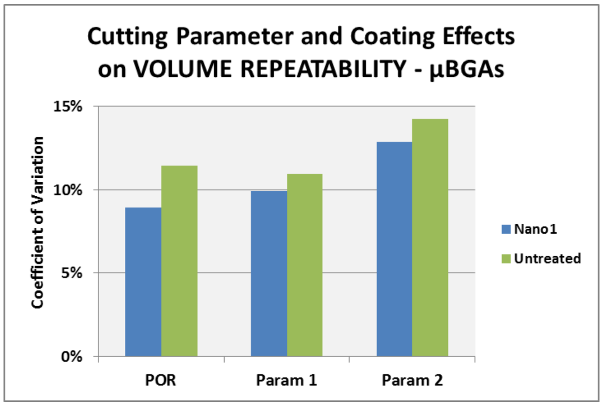

Figure 8. Effect of cutting parameters and coating on print volume variation. The lower the CV, the better.

Parameter set 2, which offered highest yields in this test, also produced the highest variation, which is undesirable. Historical data indicates CVs of approximately 10%, which is the benchmark for the BGA device. Interestingly, the CV for stencil 1, the one with the metal projections on the bottom side, was the lowest of the test and slightly lower than the benchmark. The CVs for the 0201s were nearly identical to those of the BGAs and are not shown. Regardless of cutting parameters, stencils treated with nanocoating consistently provided better print volume repeatability than those without.

Experiment #2 – New Stencil Materials

1) Print Yields

The FG SS with both the first and second-generation nanocoatings produced 80% yield. The experimental SS without nanocoating produced 90% print yield, and with the new generation nanocoating produced a 100% print yield. The experimental electroform (EF) stencil with the new nanocoating also produced 100% print yield, but the experimental EF stencils with first-generation or no nanocoating only produced 60 and 70% yields, respectively. Print yields for the different materials and coating are compared in figure 9.

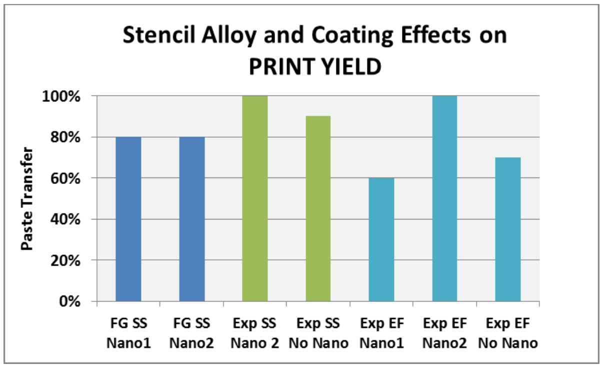

Figure 9. Effects of stencil alloy and coating on print yields.

2) Transfer Efficiency

All stencils tested transferred at least 80% on the microBGAs and close to 100% on the 0201s. Figure 10 shows the microBGA results. The experimental SS and EF stencils without any nanocoating at all transferred 91 and 92% respectively, approximately 10% higher than the production process. The same materials with second-generation nanocoating released more than 86%, a less substantial yet noteworthy 5% increase from the benchmark. The other stencils performed in the expected 81-83% range.

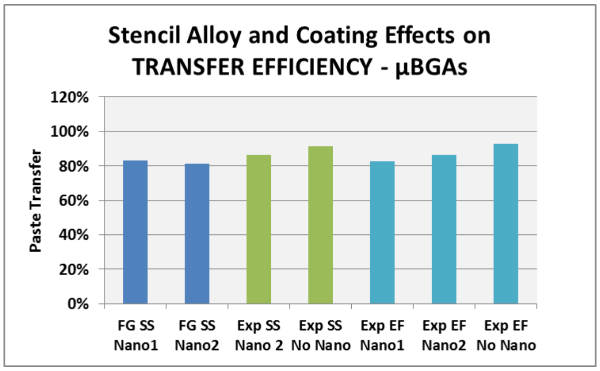

Figure 10. Effects of stencil alloy and coating on BGA transfer efficiency.

The TE of the 0201s hovered around 100%, with the untreated experimental materials showing the highest release, and the treated materials showing the second highest. The trend shown in figure 11 is identical to that of the microBGAs. Another repetitive trend observed in all print tests is the slightly higher TE (3-6%) for components oriented at 0 degrees versus those oriented at 90%.

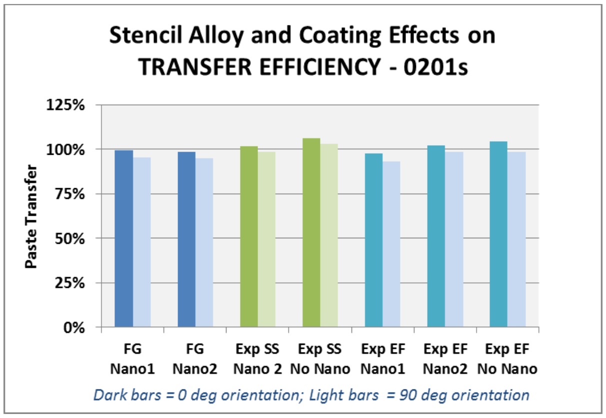

Figure 11. Effects of stencil alloy, coating and component orientation on 0201 transfer efficiency.

3) Variation

The lowest CV for the microBGAs was on the experimental EF stencil coated with second-generation nanocoating, at 10.8%. The next lowest was the experimental SS with the second-generation nanocoating (figure12) at 11.4%. This trend is again observed in the 0201 CV data, but transposed, with the Nano2 experimental SS at 10.9 and the Nano2 experimental EF at 11.3% (figure 13). The remainder of the stencils all produced higher variation.

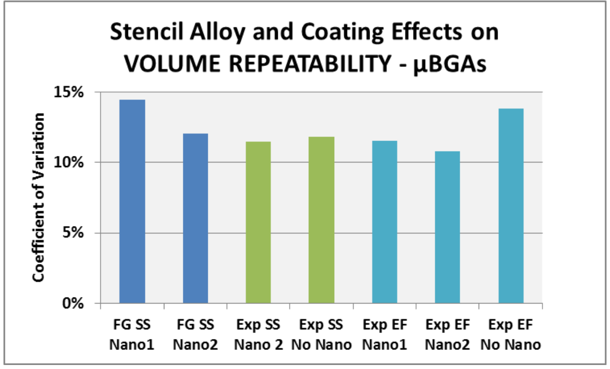

Figure 12. Effects of stencil alloy and coating on BGA volume repeatability.

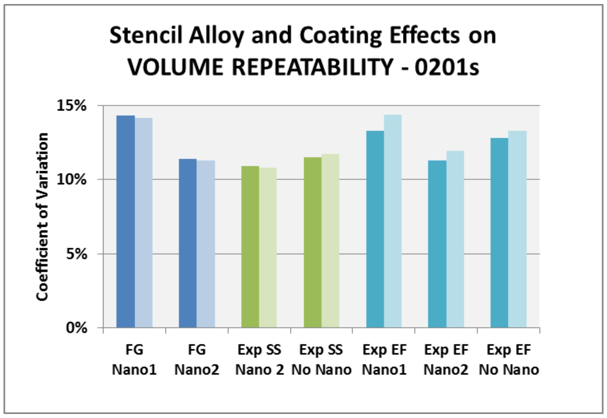

Figure 13. Effects of stencil alloy, coating and component orientation on 0201 volume repeatability.

Experiment #3 – microBGA Aperture Shape

To compare the influence of microBGA aperture shapes on print quality, two stencils were produced with identical aperture geometries for all devices except the BGAs. One stencil had specified 10.8mil circles; the other specified 10.8mil squares with radiused corners.

1) Print Yields

Print yields for both stencils were 70%. They are not depicted graphically.

2) Transfer Efficiency

Figure 14 shows the transfer efficiency for both aperture shapes. The square aperture has a higher percentage of paste transfer; it also has a higher volume of paste due to its geometry. The average paste volume deposited from the square aperture is approximately 358mil^3, whereas the average paste volume deposited by the round apertures was 298mil^3. The square aperture deposits an average of 22% more solder paste than the round one.

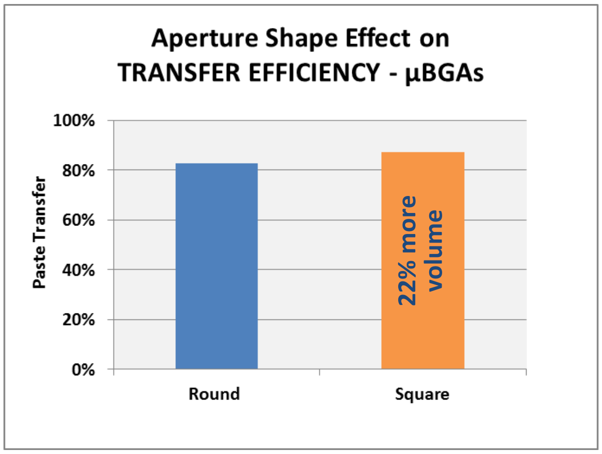

Figure 14. Effect of microBGA aperture shape on transfer efficiency.

3) Variation

The square aperture design also provided better print volume consistency than the round design, as shown in figure 15.

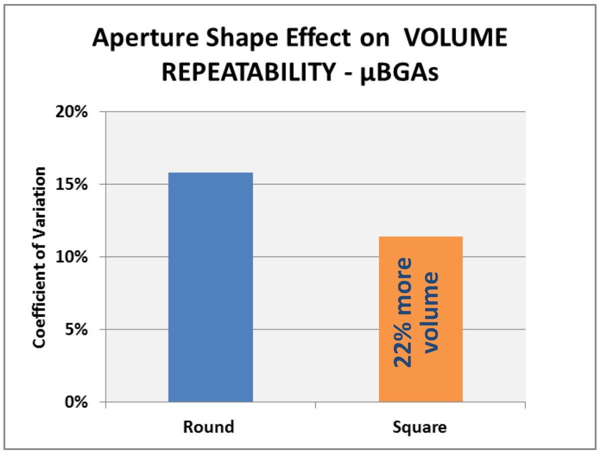

Figure 15. Effect of aperture shape on volume repeatability

Summary of Round vs. Square Aperture Design

Round apertures are the process of record for these 0.5mm microBGA devices. The results of this experiment indicate that the square apertures:

a) provide 20% more solder paste volume
b) increase transfer efficiency from 83% to 87%
c) lower variation from 16% to 11%

The effect of the increased paste volume on reflow yields is unknown at this time. The square aperture design will be implemented on a single product and reflow yields will be closely monitored to quantify the aperture's impact on the overall SMT process.

Experiment #4 – Wipe Frequency

The production print process for this product utilizes a dry/vacuum/dry wipe after every print. The 1 print per wipe interval was set by prior experimentation. To test claims of nanocoating extending wipe frequencies, additional 10-print tests with stencils 5 and 7 were performed without any wipes at all. Both stencils were the FG SS cut with the POR; stencil 5 used first-generation nanocoating; stencil 7 used second-generation nanocoating.

1) Print Yields

Print yields improved when the wiping step was eliminated from each print. Running 10 consecutive prints without wiping increased the print yields from 80 to 90% on stencil 5 and from 90 to 100% on stencil 7, as shown in figure 16.

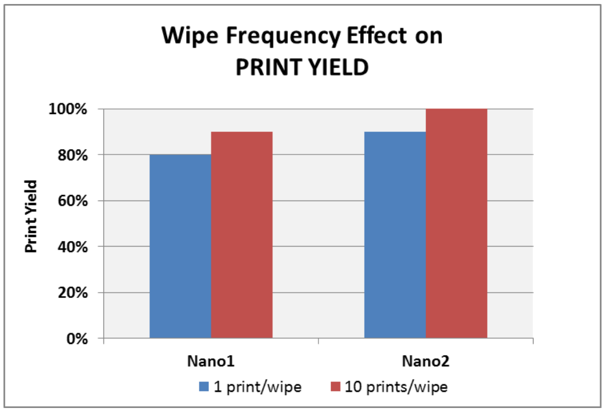

Figure 16. Effect of extending wipe frequency on print yields

2) Transfer Efficiency

Stencil prints at the extended wipe interval showed slightly higher transfer efficiency, as shown in figure 17.

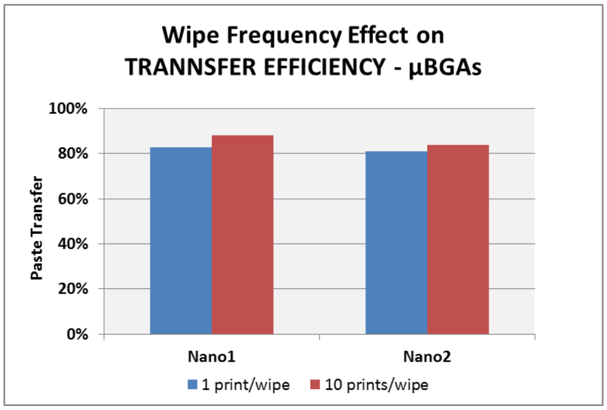

Figure 17. Effect of extending wipe frequency on transfer efficiency

3) Variation

In both cases, the processes that extended the wipe intervals showed the least variation. The trend of the second-generation nanocoating to consistently produce less variation than the first continued, as observed in other comparisons and shown in figure 18.

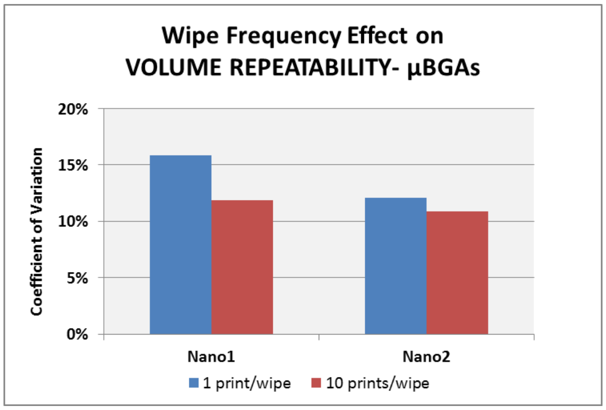

Figure 18. Effect of extending wipe frequency on volume repeatability.

FOLLOW UP TESTS

The results of these tests and comparisons show distinct differentiation between experimental inputs and consistent trends among its outputs. They appear to serve as good relative indicators of performance. However, a considerable difference was observed in comparison to the prior round of tests and typical production results.

The test vehicle is a production product, and historically runs 98.2% print yields. It also consistently produces about 82% TE with less than 10% CV. The relatively low yield numbers, combined with the higher variation produced in this set of tests, indicated a considerable process difference somewhere in the experiment. The sources of variation were explored.

First, the test setup and equipment were investigated via a database search. The test runs always took place on after the first shift finished using the printer, over a course of two weeks. Investigation into the production print yields indicated no out-of-control situations on the assembly line during that time period; print yields for all production prints run on that line were within in their typical 98%+ range. The likelihood of the printer or print test method introducing the variation was unlikely.

Next, the performance of the stencils cut according to the POR – 1,5 and 7 were compared. Issues had already been identified with stencil 1's PCB side topography that produced atypical results, but stencils 5 and 7 did not produce results comparable with each other (stencil 7 had the highest CV of the tests). These stencils were all manufactured using the Process of Record, with one exception: the usual production stencils are manufactured at a local facility, whereas the test stencils were produced at one of the supplier's other sites.

To explore the possibility of differences in the two sites' manufacturing processes, the production stencil for this PCB was print tested using the same 10-print test as the other runs. It yielded 100% (figure 19) and transferred 83% (figure 20) with 9.6% variation (figure 21), correlating with historical data.

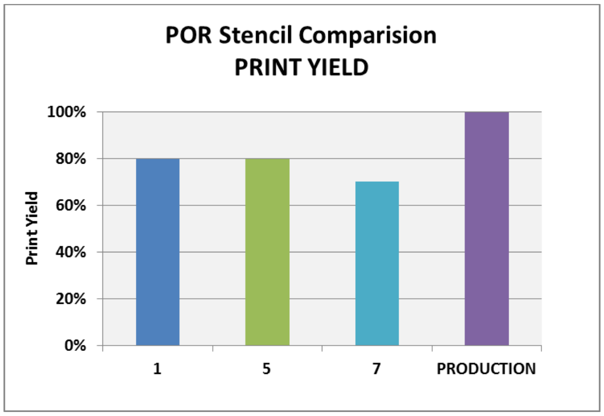

Figure 19. Print yields for theoretically identical stencils

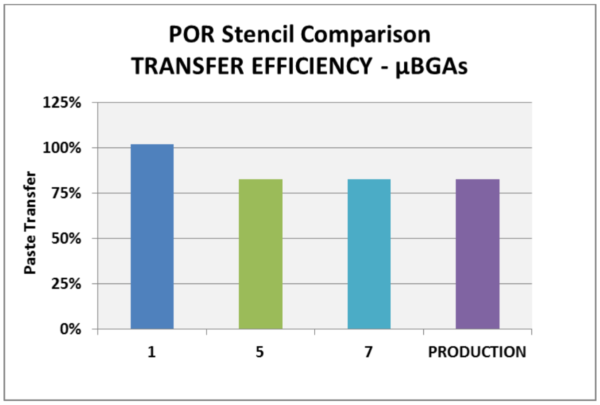

Figure 20. Transfer efficiencies for theoretically identical stencils

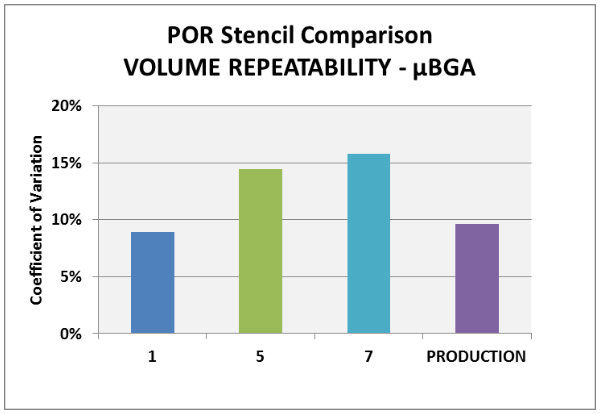

Figure 21. Volume repeatability for theoretically identical stencils.

Investigation into the source of the variation among test stencils and their performance differences indicated considerable dissimilarity between the stencil manufacturing processes at the site making the production stencils and the site making the test stencils. The site providing the test stencils had recently undergone an equipment upgrade, which could be the root cause of the observed performance differences, including the overall lower yields and higher volume variations, and the specific issues noted on stencils 1 and 4. It is under investigation by the supplier at the time of publication.

SEM ANALYSIS

Test coupons were cut into each stencil (except the experimental SS) during their regular manufacturing process for surface roughness analysis. All the laser-cut SS stencil walls demonstrated high levels of striation. Of particular interest was the comparison of wall topography of the POR stencils. The apertures cut using the same parameters at the different facility demonstrate a much smoother wall finish when viewed at 800X magnification, as shown in figure 22. It is likely that the lower yields and higher variation are a direct result of the rougher, more highly striated aperture walls.

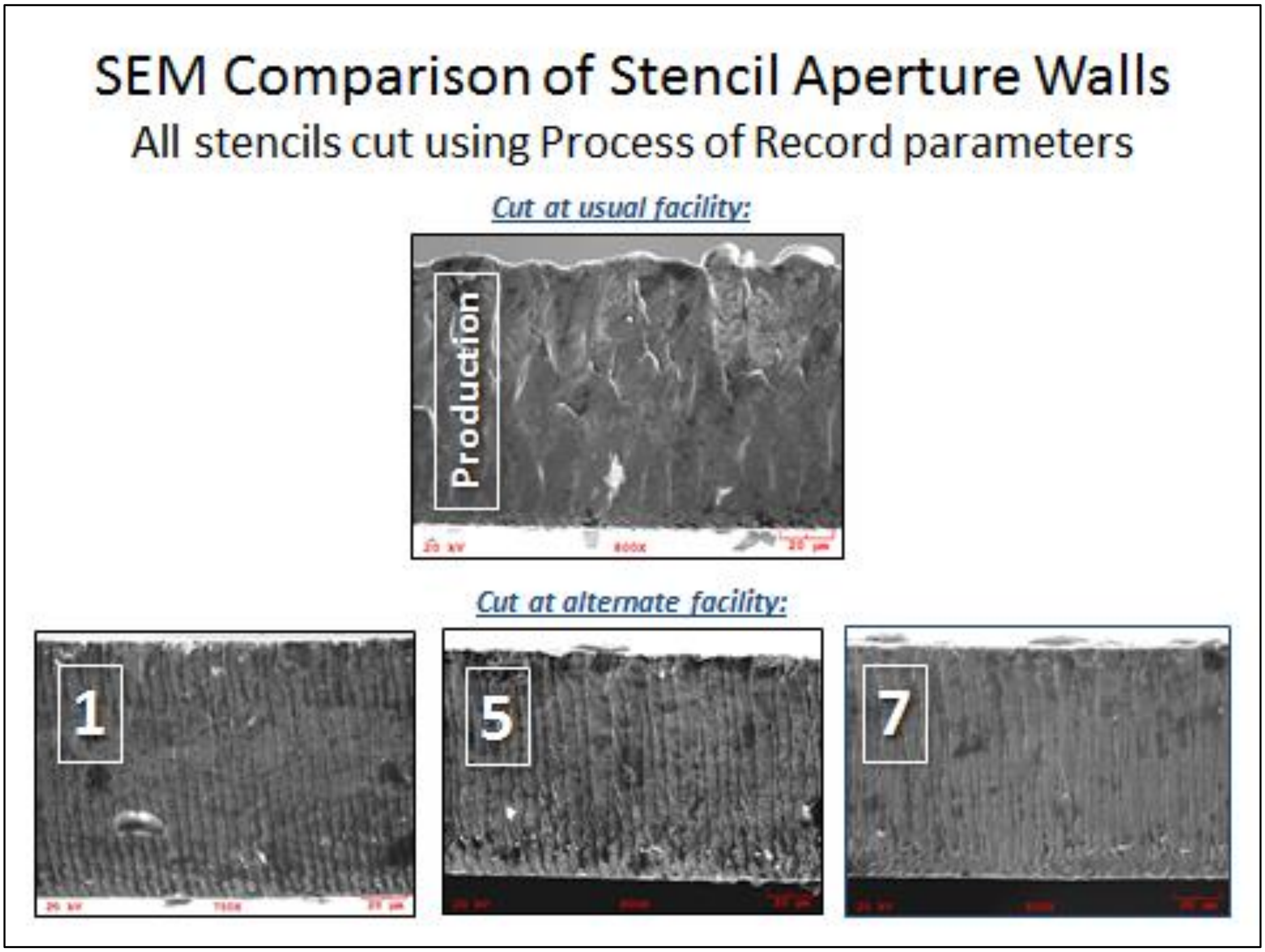

Figure 22. SEM images of aperture walls.

DISCUSSION AND CONCLUSIONS

Despite the experimental noise presumably introduced by the different stencil manufacturing site, the trends in the data are consistent throughout the series of tests.

Experiment #1 - Effect of Cutting Parameters and Nanocoating

Originally, the laser cutters at the two different manufacturing sites were assumed to produce similar results. The considerable differences between their outputs were not known until the print test results were calculated and walls were examined at high magnification. The goal of Experiment #1 – to refine the cutting parameters to optimize stencil print performance on the assembly line – was obviously not reached. Even comparisons within the dataset for this manufacturing facility were hampered by stencil manufacturing issues on two of the four test sets; however, one trend was abundantly clear. The stencils treated with the first-generation nanocoating consistently produced better yields and better print volume variation. The nanocoated stencils demonstrated slightly lower transfer efficiencies than untreated stencils.

Experiment #2 – New Stencil Materials

The experimental materials treated with the second-generation of nanocoating produced the highest yields and best print volume repeatability.

The FG and EF stencil foils were tested with both first- and second-generation nanocoatings, and in both cases, the second-generation product provided better volume repeatability.

Experiment #3 – MicroBGA Aperture Shape

Square apertures provided better release, better repeatability, and higher print volumes than round apertures of the same major dimension (diameter = side of square).

Experiment #4 - Wipe Frequency

Achieving 100% yields at 10 prints per wipe is a considerable achievement. Prior to executing this test, the concept of running this PCB to 10 prints without wiping was completely unrealistic. The production process wipes after every print. Previous tests on the original test vehicle were able to successfully achieve wipe frequencies of 3 prints per wipe using wet wipes with solvents that were chemically matched to the solder paste[3].

Volume repeatability also improved with the extended wipe interval. The influence of under wiping on a stencil treated with the Nano2 is now the subject of a current investigation.

General Comments

The stencil materials test compared current state-of-the art materials with developmental ones, and the results were extremely encouraging. Continued research and development of more sophisticated materials and manufacturing processes will help drive continued advancements in stencil printing technology and enable better economics in the drive for miniaturization.

The results of the nanocoating tests were as anticipated. Lots of data has been generated over the past two years that show the nanocoating improves print yield and repeatability. The new nanocoating formulation's repeated outperformance of the original product demonstrates real improvement in this materials technology and is another example of materials advancements that continue to improve stencil printing technology.

Again in this test, the nanocoated stencils demonstrated slightly lower transfer efficiency than non-treated stencils. This trend was also observed in the original tests in 2011. It is hypothesized that the lower TE of the coated stencils may be due to crisper print definition. This hypothesis may be tested in an upcoming investigation.

The superior print performance of square vs circular apertures on microBGAs was not surprising, based on information in current literature. What was surprising however, was the degree of improvement the square apertures introduced. On a cautionary note, square apertures can present gasketing issues on non-solder mask defined pads, so they should be implemented carefully. The PCB used in this study has solder mask defined pads. The new aperture geometry will still be implemented carefully, and will bear less risk than if the PCBs were designed with non-solder mask defined pads.

The most surprising – and most remarkable – findings of the entire study were the wipe frequency tests on nanocoated stencils. Not only did print yields go up, so did volume repeatability! These results were completely unexpected, and are currently the subject of continued investigation.

ONGOING AND FUTURE WORK

At the time of publication, a new test had just been executed to attempt to visualize the flux behavior on coated and uncoated stencils with and without under wiping. Using the original test vehicle, an uncoated stencil (from the regular manufacturing site) was masked and treated with Nano2 over one-half of the print area to enable side-by-side comparison and analysis. UV tracer was added to the solder paste, and the PCB side of the stencil was photographed under black light after several different print and wipe scenarios. Photographs of some of the results are shown in figures 23 and 24. The complete results will be published at a future date.

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- Jonathan Dragonas

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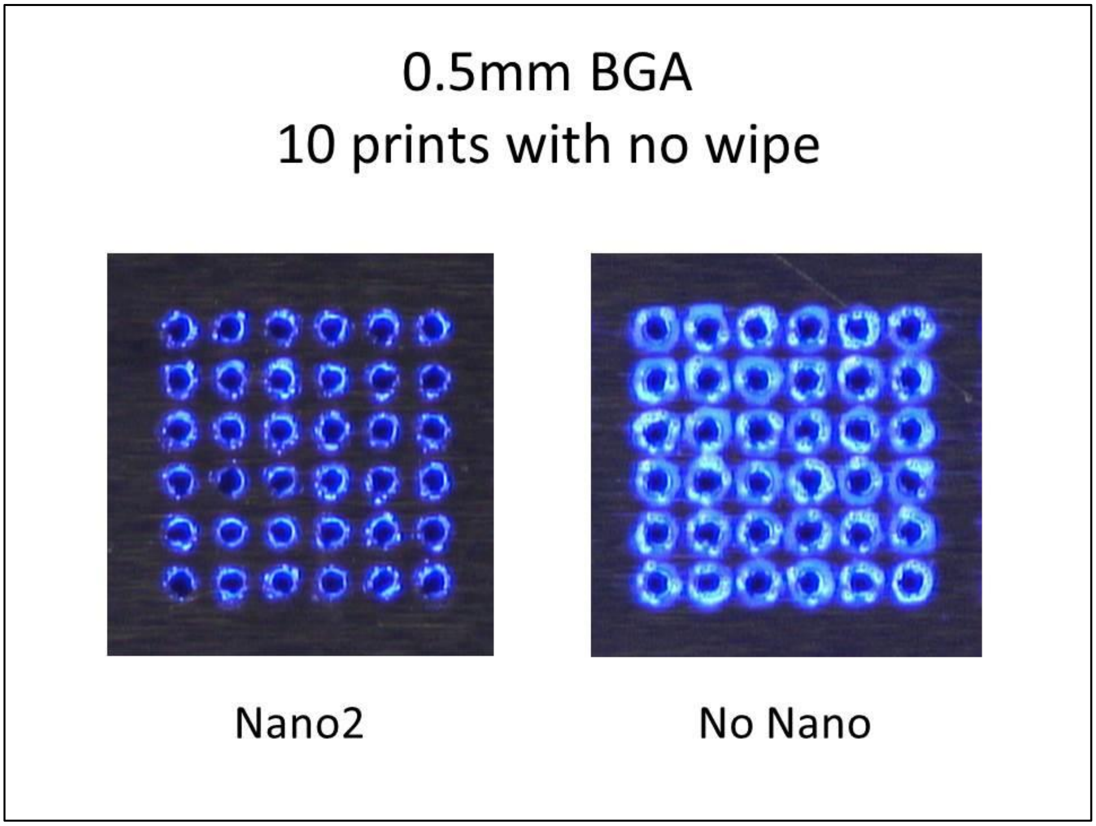

Figure 23. Effect of stencil nanocoating treatment on flux spread on underside of stencil, uBGA

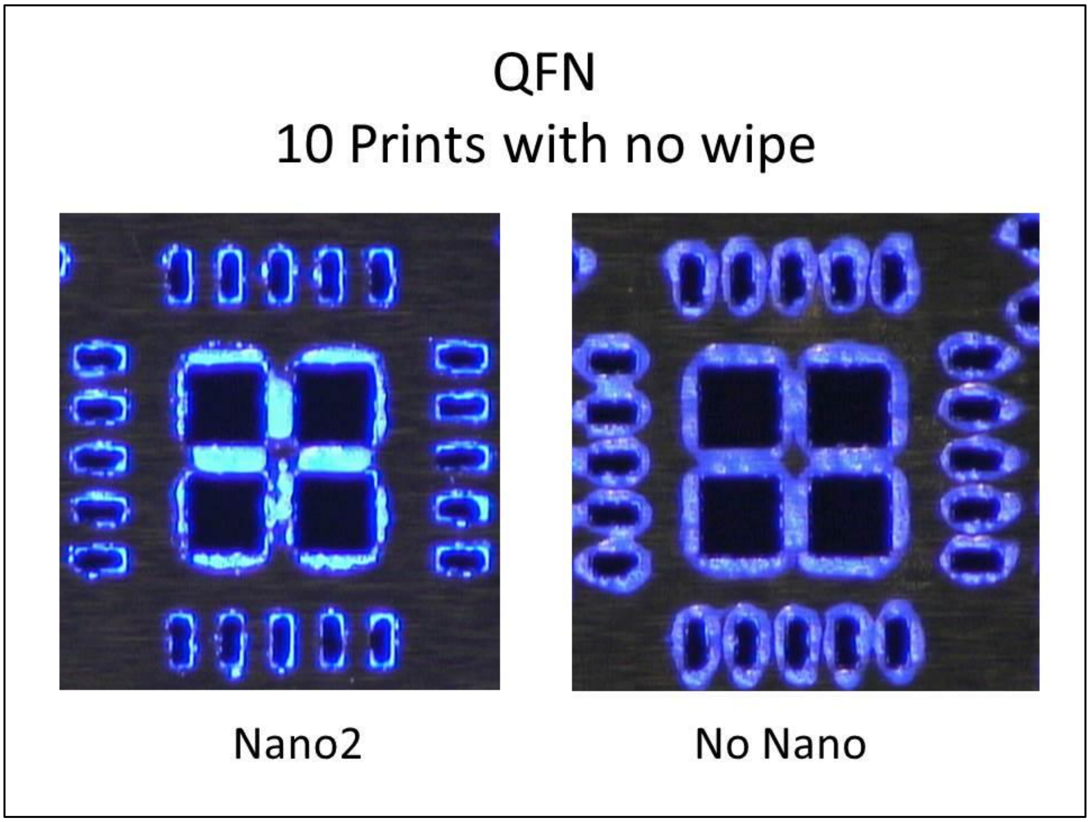

Figure 24. Effect of nanocoating treatment on flux spread on underside of stencil, QFN