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Stencil Printing Process Tools for Miniaturisation and High Yield Processing

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Abstract

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 too 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 as well.

Stencil coatings are also showing promise. In tests performed to date it is becoming apparent that certain coatings can provide higher yield processing by extending the number of prints that can be performed in-between stencil cleans during a print process.

Preliminary test results relating to the stencil coating technology and how they impact miniaturisation and high yield processing will be presented.

Introduction

The SMT printing process can be broken down into two parts, filling and release. The hydrodynamic pressure (filling pressure) created by the squeegee system is a key element to successful aperture fill. To ensure the aperture is correctly filled there are many trade-offs that the engineer has to make. The most simplistic approach is to increase all parameters that produce the highest filling pressure. Such a process could take the approach of squeegee angles of 45deg and less, a high print pressure and low print speeds. This approach would indeed give high filling pressure but the externalities of this process set-up would be detrimental to the overall process. The high filling pressure would cause print medium to breach the gasket between stencil and PCB land thus creating a "wet bridge" between neighbouring apertures. The issue of wet bridging becomes more critical as the distance between apertures reduces. Unfortunately for the process engineer, the introduction of fine webbed 01005 and 0.3mm CSP technologies will produce further wet bridge opportunities.

The presence of wet bridging within an SMT print process is a catastrophic failure mode and therefore must be remedied. If a high pressure produces detrimental externalities then the process engineer could set the print process to produce a low filling pressure, increased squeegee angle, lower print pressure and higher speeds. This approach would reduce the filling pressure but now the outcome would be one of incomplete aperture fill and deficient interconnect integrity.

From the above we can see the filling process is a balance that has to be fully understood by the process engineer. In the real-world a perfect balance can never be achieved due to throughput requirements and exogenous factors, therefore the process engineer tends to take a cautious approach and choose a higher filling pressure set-up. By choosing the higher pressure set-up the tendency to wet bridge increases. However modern fully automatic printing machines are equipped with under stencil cleaners that have the capability to remove small amounts of wet bridged material from around the stencil apertures. Therefore by choosing the high pressure filling process the process engineer now has a process in which the occurrence of insufficient are minimised and wet bridging occurrences are managed by a under stencil cleaning strategy.

The compromise described above seems acceptable - but the action of cleaning is one that reduces throughput and increases costs. The time penalty associated with a most basic under stencil clean operation is approximately 20 seconds, if this cleaning action is instigated every 5 boards then the cycle time overhead becomes significant. Also the under stencil cleaner requires consumable materials, solvents and paper, these materials increase the overhead cost of the printing process. Therefore running a print process which uses the under stencil cleaner to "compensate" a process has both time and cost penalties associated.

This paper will discuss a novel technology that allows process engineers to challenge the relationship between high filling pressures and associated wet bridging thereby gaining productivity benefits without incurring additional overheads.

An explanation of the technology

The phenomenon of wet bridging occurs when a print material breaks the gasket between stencil aperture and the printed circuit board land. The breach between this gasket usually occurs over time but once the underside of the stencil becomes contaminated it acts as a "tipping point" and thus the wet bridge quickly cascades. Diagram 1 graphically illustrates the concept.

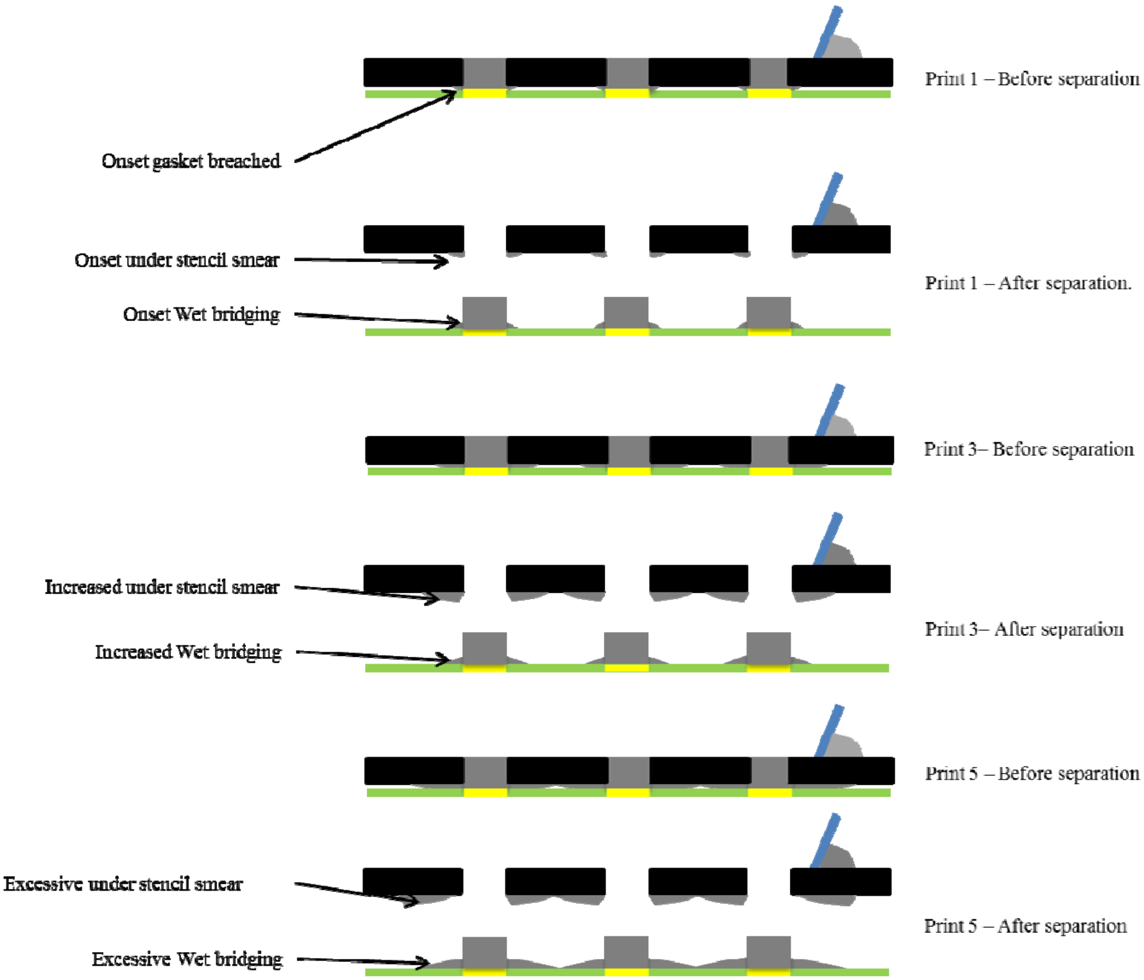


Diagram 1 - Cascade effect of wet bridge

As seen from Diagram 1 the cause of wet bridging is derived from the onset of under stencil smear (this is derived from the break down in gasket between stencil and PCB). Therefore to reduce wet bridging we either reduce the occurrence of violations between stencil and PCB or contain the print material that creates the under stencil smear. The first argument is of course the correct approach but due to the exogenous factors within the print process this approach can rarely be achieved. This leaves the latter line of reasoning; one such mechanism which generates a containment effect is Nano coating (Nano-ProTek®). This material is applied to the underside of the stencil where it chemically bonds itself to the stencil foil. The Nano coating modifies the surface tension of the stencil material such that a "barrier" around the aperture is created. This barrier prevents print medium migrating across aperture interspaces and thus creating a wet bridge, Diagram 2 graphically illustrates the effect of Nano coating.

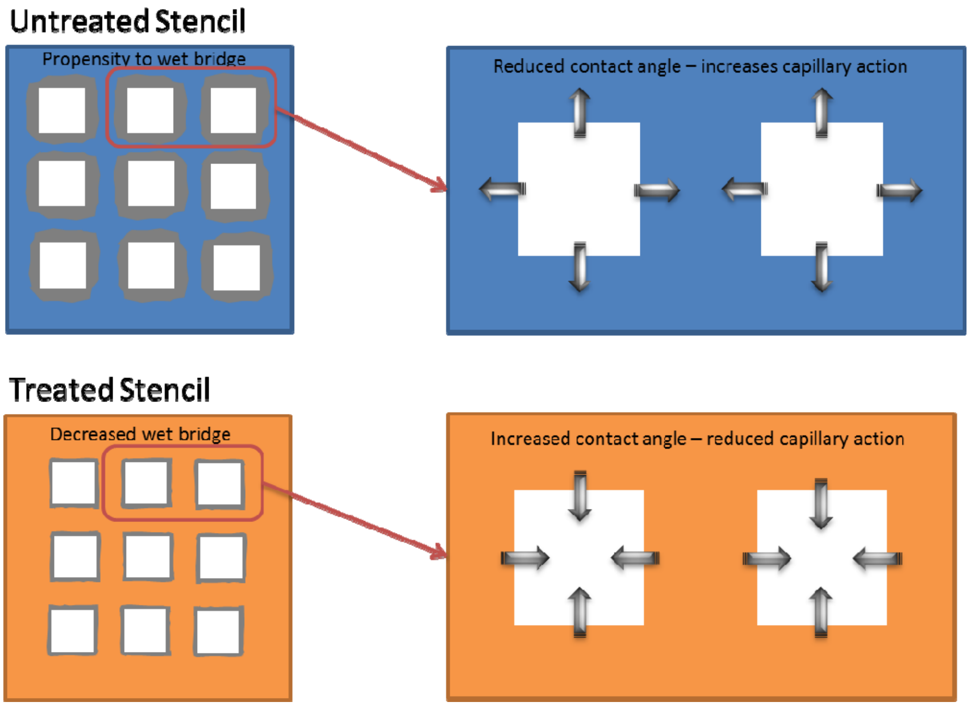


Diagram 2 – Hypothesis of contact angle influencing wet bridge occurrence

Figure 1a and b further explain the effect of changing a stencils surface tension and how this has a positive externality to the print process. The photographs show a test in which a controlled quantity of rework flux was deposited onto a stencil. Figure 1a shows the untreated stencil, the reduced contact angle allowed the flux to spread, this can be observed in the overall dimensions of the flux deposit. Figure 1b illustrates the treated stencil, the flux deposit exhibits a more amalgamated characteristic, indicating that the Nano coating has reduced the spread and therefore reduced the capillary action of the flux. This simple test has shown that a Nano technology has the ability to react and alter the flow characteristics of thixotropic materials, such as flux.

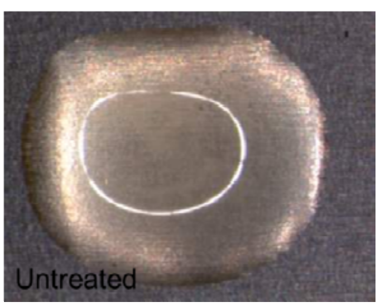


Figure 1a: Untreated stencil with flux deposit

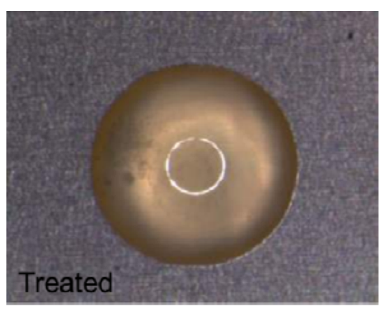


Figure 1b: Treated stencil with flux deposit

To conclude this section the application of Nano technologies within the printing process for surface mount technologies will be discussed. As illustrated in Diagram 1, wet bridging is an externality of a breakdown in print gasket, the effect also cascades in severity. Diagram 3 illustrates the influence of a Nano technology applied to the underside of the stencil. The barrier effect of a Nano technology does not stop the gasket breach but it produces a barrier which maintains the paste deposit integrity. This barrier effect can be simply thought of as an area of higher "resistance" to print material thus print material will not migrate across the aperture webs.

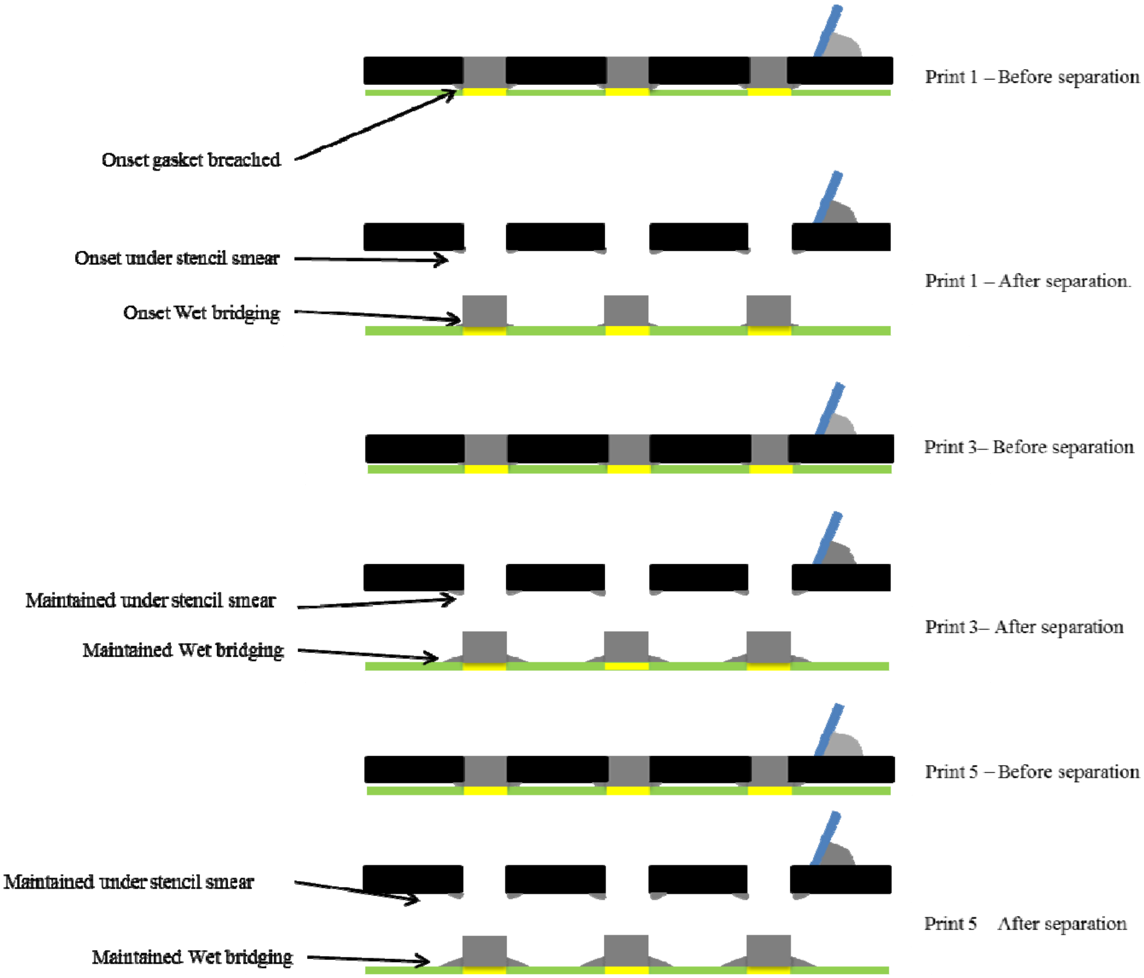


Diagram 3 - Nano coating maintaining wet bridge occurrence

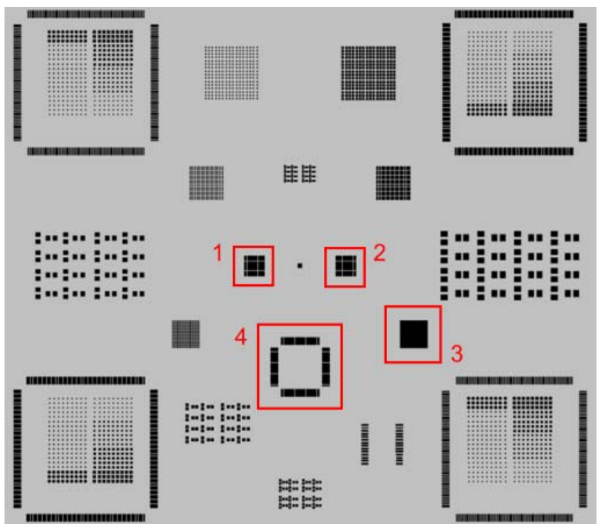
Initial Tests

The following work describes the initial testing carried out on the Nano ProTek material. The purpose of this test was to establish the validity of the Nano coating. The main focus of the initial test is to scrutinise the hypothesis cited in the previous section.

To aid in quickly understanding if a Nano technology has a beneficial effect the results produced from this test will be analysed qualitatively, which allows "real life" comparisons to be made.

Test board

The work was carried out using a qualification test board, the board art work and associated dimensions are shown in Diagram 4.



			Aperture Details	
ID	Type	Pitch	Shape	Size
1	CSP	0.3mm	Circle	0.2mm
2	CSP	0.3mm	Square	0.2mm
3	CSP	0.4mm	Square	0.285mm
4	QFP	0.3mm	Rectangle	1.55 x 0.145mm

Note: ID 2-4 will be analysed

Diagram 4 – Test Board

The process parameters were chosen to reflect a standard set-up, one in which aperture fill pressure would be medium to high. The under stencil cleaner was set-up with standard materials and activated after the 14th print. Table 1 illustrates the test parameters.

Table 1 – Test parameters

Factor	Response
Machine	DEK Europa
Print Speed	50mm/s
Print Pressure	4.4Kg
Separation speed	3mm/s
Squeegee Angle	60deg
Squeegee Length	170mm
Tooling	Block
Under Stencil Cleaner	Vac + Dry (Manually activated)

Test Stencils and Print Medium

To contrast and compare the effect of the Nano coating solution two stencils were employed, one with the coating applied and one untreated, the attributes of the stencil sets are shown in table 2. The solder paste used throughout the test was a SAC305, Type 4 commercially available material.

Table 2 – Stencil sets

Stencil No	Nano Coating	Stencil Material
Stencil 1	Untreated	Stainless Steel
Stencil 2	Treated	Stainless Steel

Test Strategy

Diagram 4 illustrates the test strategy, a total of 20 boards were run for each stencil. The testing strategy was selected to ensure that wet bridging would be prevalent within the testing, thus guaranteeing the possibility to test the effects of a Nano coating technology. The strategy encompassed four warm up print to ensure the process was stabilised, ten prints were processed with the fourteenth print retained for visual inspection. An automatic under stencil cleaning cycle was activated before the fifteenth print; the fifteenth print was also retained for visual inspection.

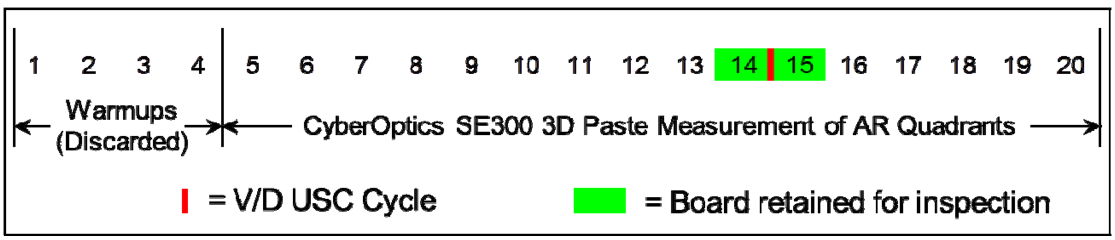


Diagram 4 – Test strategy

Results and observations

0.3mm CSP observation

Figure 2 above shows the results obtained from the 0.3mm CSP. The untreated stencil exhibits significant wet bridging on board 14, indicating that the gasket between stencil and substrate has breached and allowed print medium to traverse across the stencil webs. The results also show the deposit after an automated stencil clean (board 15), remarkably the volume of wet bridging has overwhelmed the cleaning process and left the deposit contaminated.

The print quality from the treated stencil shows the volume of wet bridging produced on board 14 to be minor. The reduction of wet bridge volume allows the automated clean cycle to suitably maintain the integrity of the process.

0.3mm QFP observation

Figure 3 show the results from the 0.3mm QFP device. A QFP device tends to possess additional process issues, namely an imbalance of filling between E-W and N-S apertures but also this imbalance exists regarding the under stencil cleaning process; N-S apertures will tend to have a greater cleaning period than the E-W apertures.

Deposits from print 14 and the untreated stencil show bridging on the N-S apertures; this indicates the extended fill period has forced a wet bridge situation. Interestingly after the clean cycle the defect moves to the E-W apertures indicating that reduced cleaning period has now caused additional process defects. These results illustrate the symbiotic relationship of the printing process.

The result from the treated stencil shows a process that exhibits no wet bridging before or after a clean cycle. This indicates that a significant process shift has taken place.

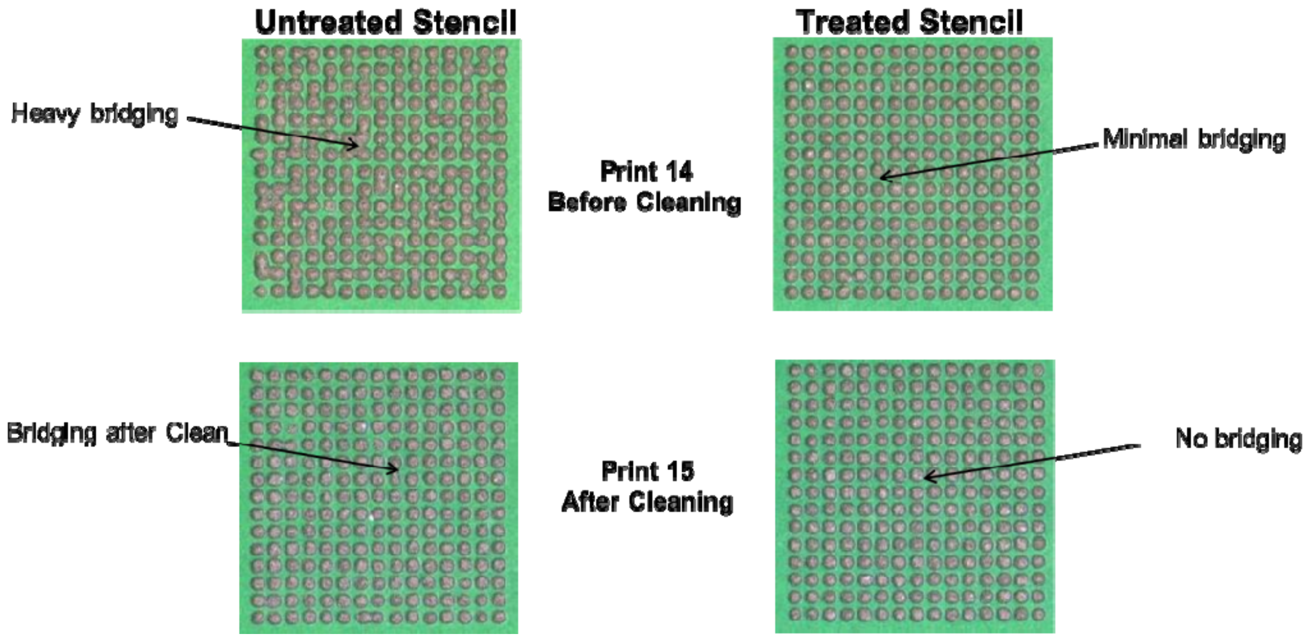


Figure 2 – 0.3mm CSP results

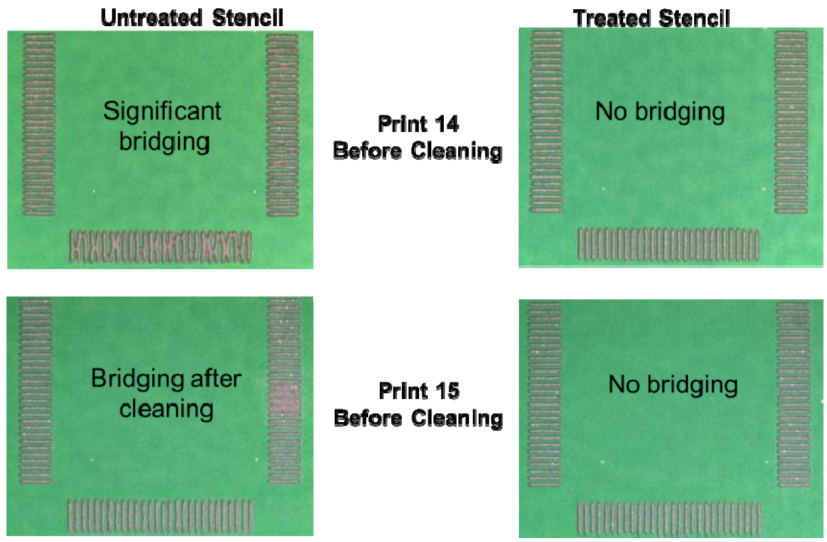


Figure 3 –0.3mm QFP results

Conclusion

This investigation has found that the inclusion of a Nano coating has dramatically reduced the propensity towards wet bridging.

To ensure the Nano coatings efficiency was validated during the test, a test strategy was chosen to yield wet bridging. Therefore the wet bridging results from the untreated stencil were expected, although the untreated stencil did clearly show how one failure mode (wet bridge) can morph into an alternative failure (under stencil contamination).

The results from the treated stencil showed that even under a harsh test strategy a Nano coating inhibited wet bridging on 0.3mm pitch devices. This evidence verifies that the barrier created by the Nano technology has overcome the issues associated with a high squeegee filling pressure and stencil to board gasket violations.

The overall outcome from this test is one in which the process engineer has the ability to extend the number of print between under stencil cleans. This benefit is twofold:

- Increased throughput as a consequence of reduced cleaning.
- Reduced costs through decreased consumable consumption.

Acknowledgement

Jeff Schake for assistance with practical trials

-END-

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Content

- Introduction
- Challenge definition
- Technology explanation
- Test strategy
- Results and Observations
- Conclusions

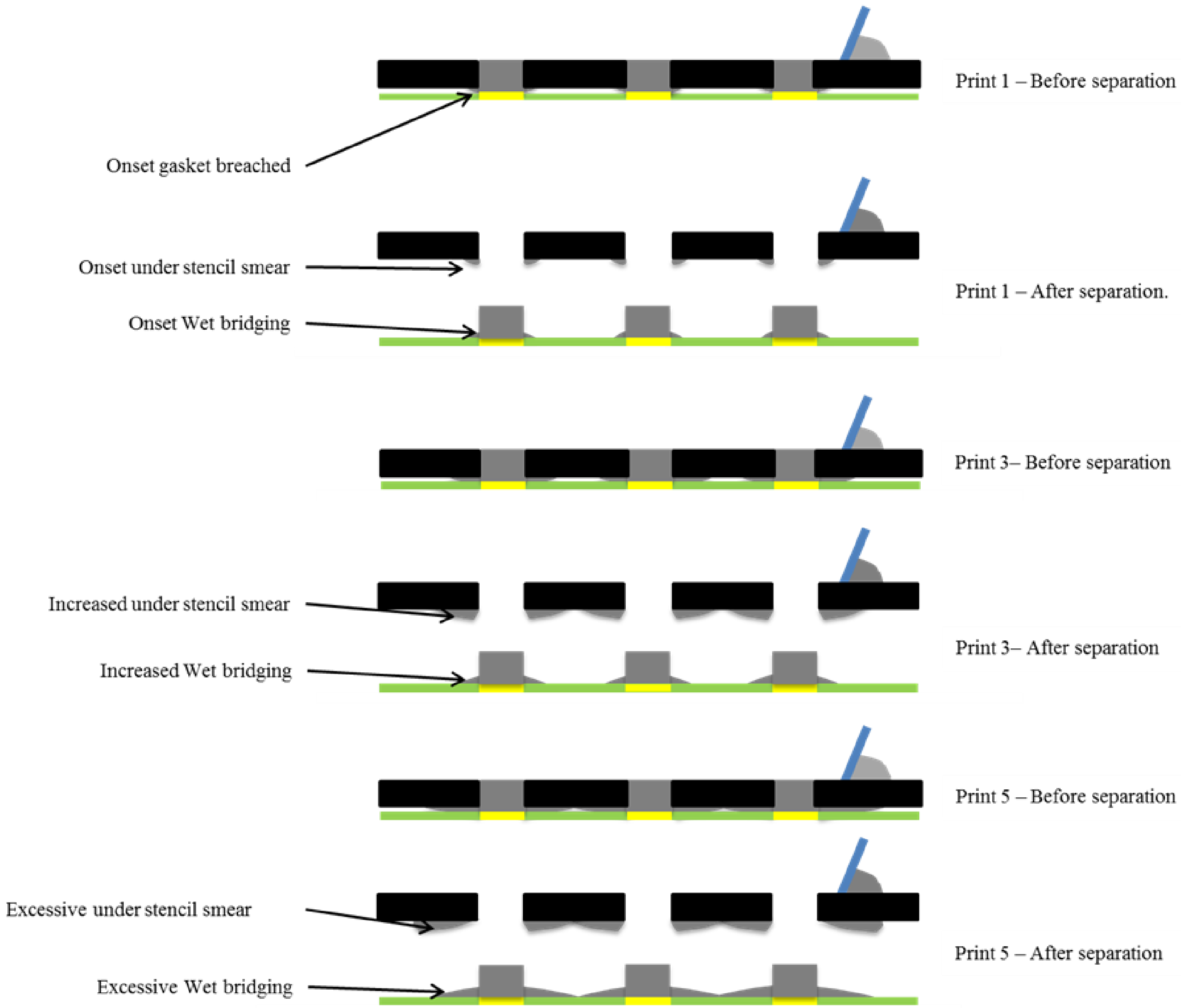
Introduction

- Miniaturisation is not *all* about Area Ratio
- Reduced interspace between apertures introduce additional process issues.
- Novel solution to regain High Yield Processing within an SMT environment.

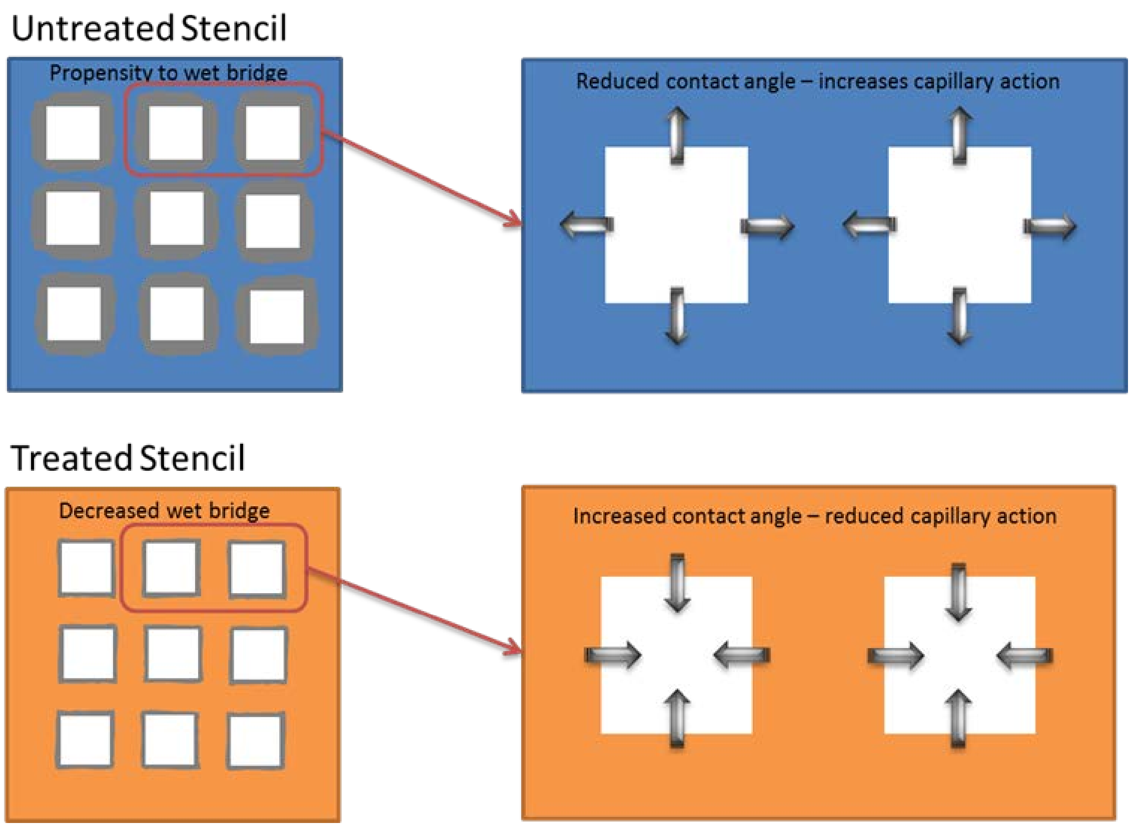
Challenge Definition

- The print process is about filling and releasing
- Filling requires high pressure (trad. methods include reduced squeegee angle, slow speed).
- High pressure gives good fill but has a propensity towards wet bridging.
- Process Engineers traditionally have to trade between filling apertures and cleaning rates

Challenge Definition

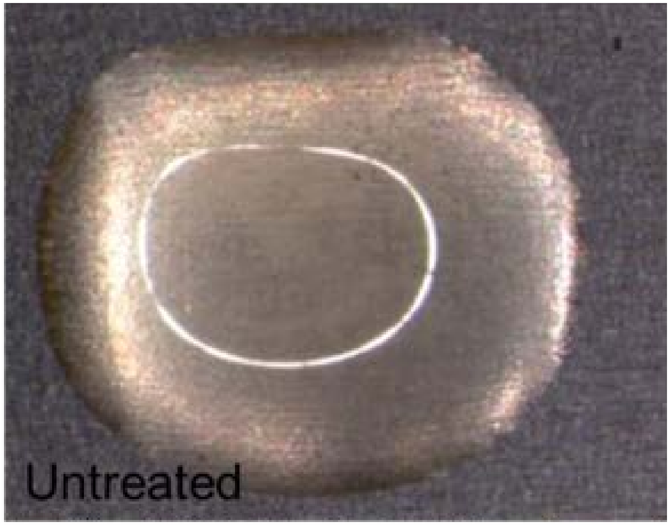


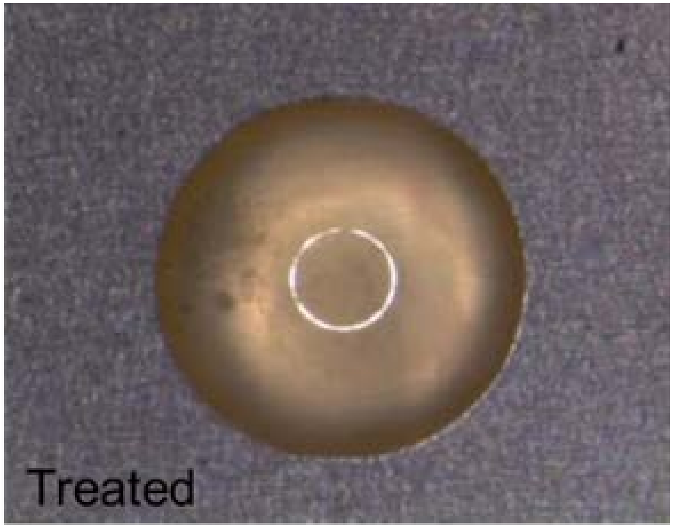
Technology explained



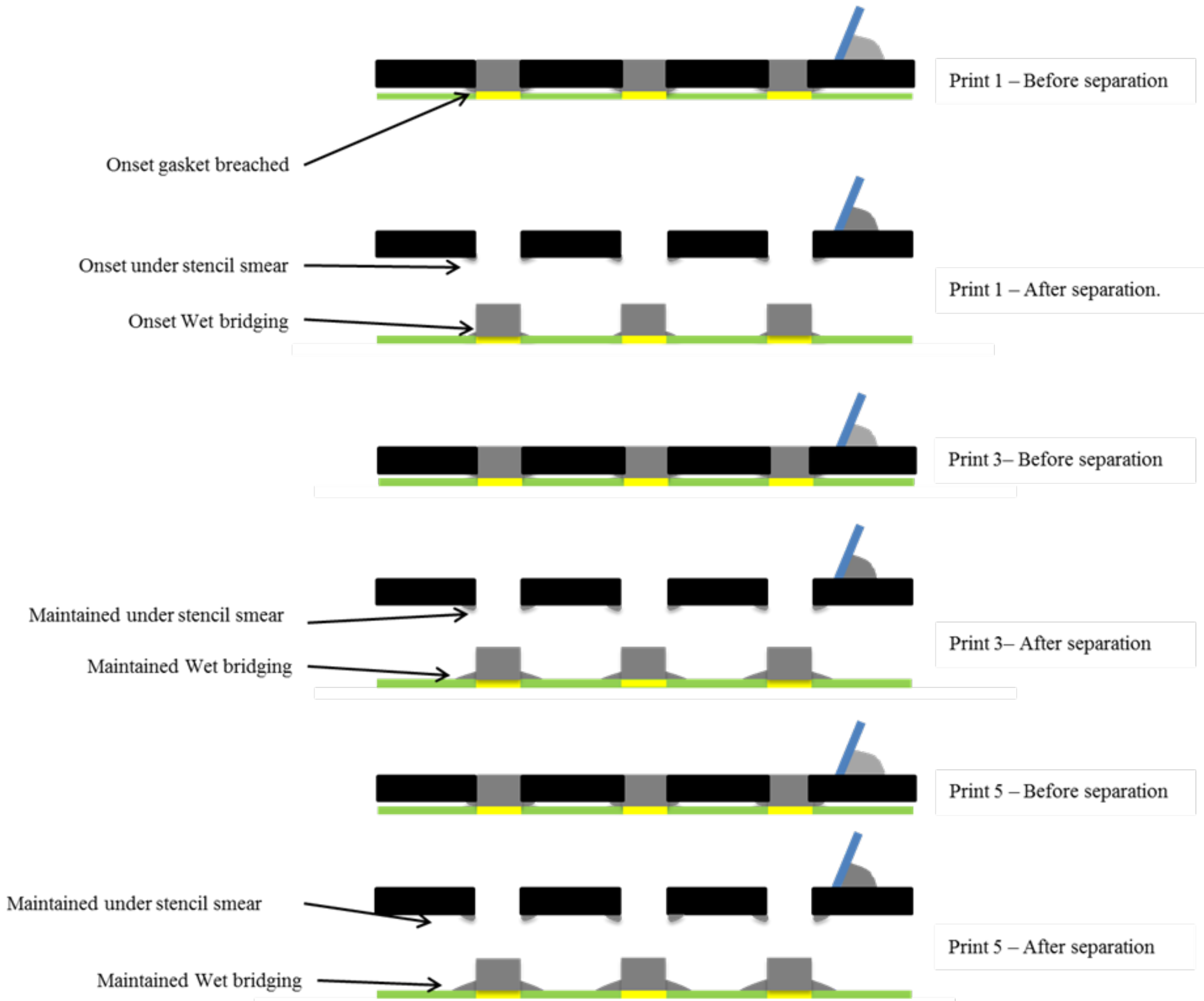
Nano technology modifies the stencil surface

Flux example





Predicted result



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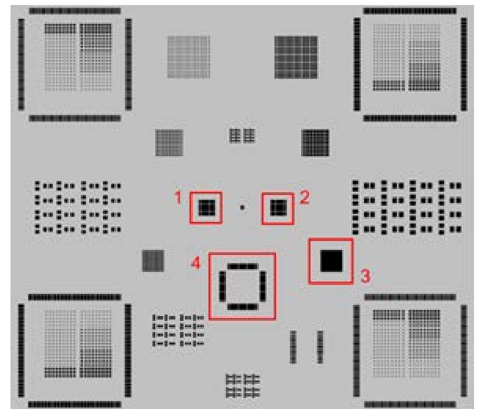

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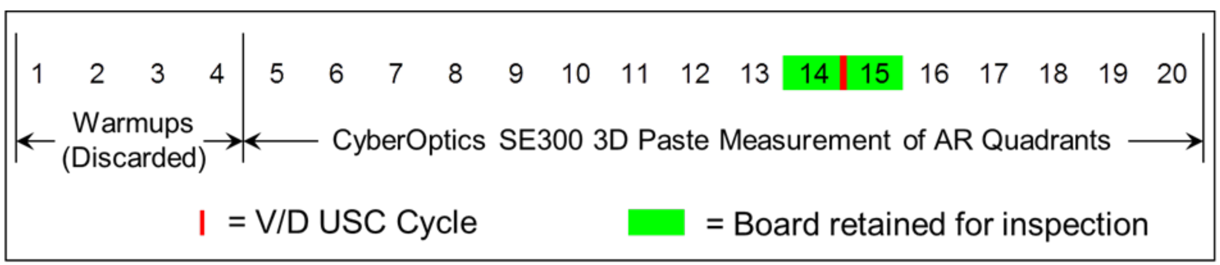
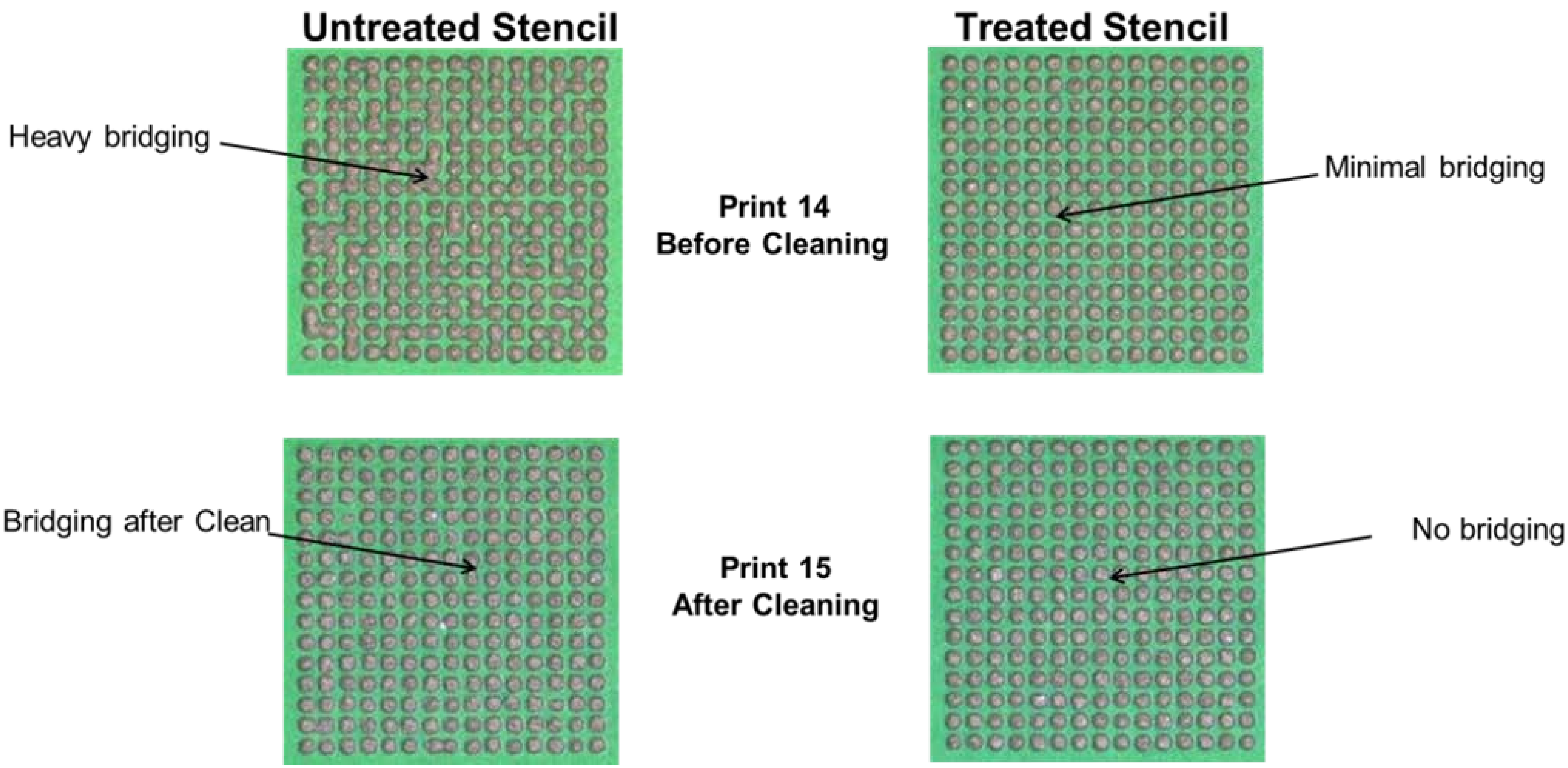
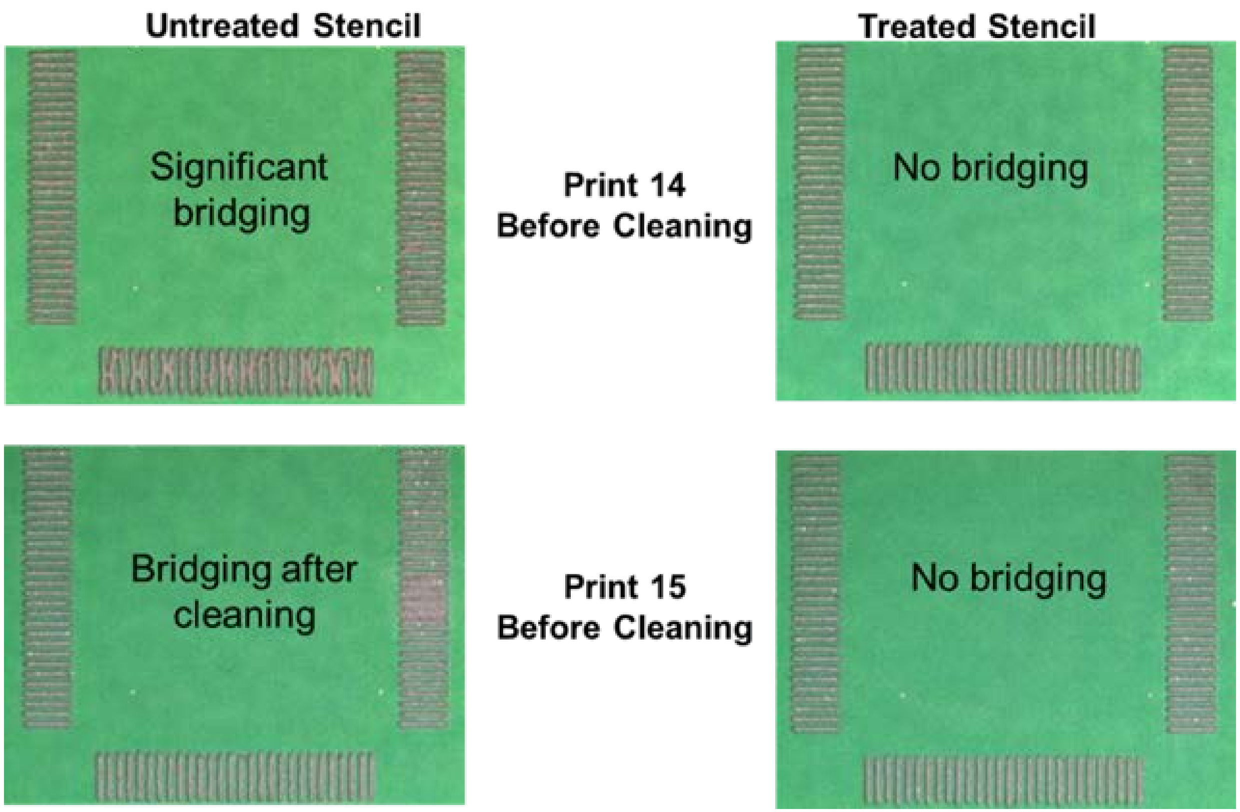


Observations 0.3mm CSP



Observations 0.3mm QFP



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