Nanocoatings Webinar
&
NanoClear® Stencil Treatment

WINNER
2014 Circuits Assembly
New Product Introduction Award

Agenda

- Overview
- Independent Testing & Studies
  - Print studies
  - Understencil Wipe studies
  - Durability Testing
  - Ongoing Studies
- NanoClear Product Information
- Nanocoatings Comparison
- Summary
- Questions

Presenters

Edward Hughes

- CEO of Aculon, producers of NanoClear® stencil nanocoating

Chrys Shea

- President of Shea Engineering Services, an independent consulting firm

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Overview

NanoClear wipes:

- Modify stencil contact surfaces with a **flux-repellent** nanocoating in minutes
  - Increase yields and output on SMT assembly lines
  - Improve print quality and reduce variation
  - Decrease understencil wipe frequency
- Utilize proprietary SAMP technology
- Surpass competitive coatings in cost, performance and ease of use
- Are gaining industry recognition as the defacto standard for stencil nanocoatings

Proven technology in PCB assembly for over 3 years

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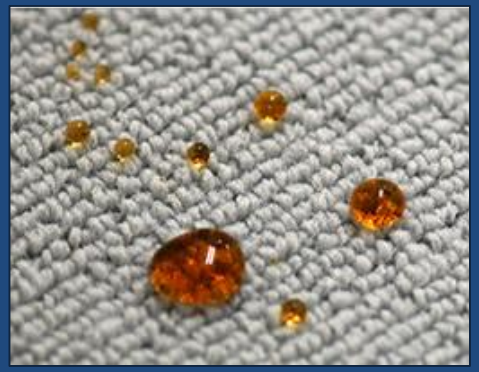
NanoClear is a Repellency Treatment

- Water repellent: ***hydrophobic***
- Oil repellent: ***oleophobic***

Examples of Common Water and Oil Repellency Treatments

On fabric



On carpet

On paper food containers

Image source: Daikin Industries (UNIDYNE web page)

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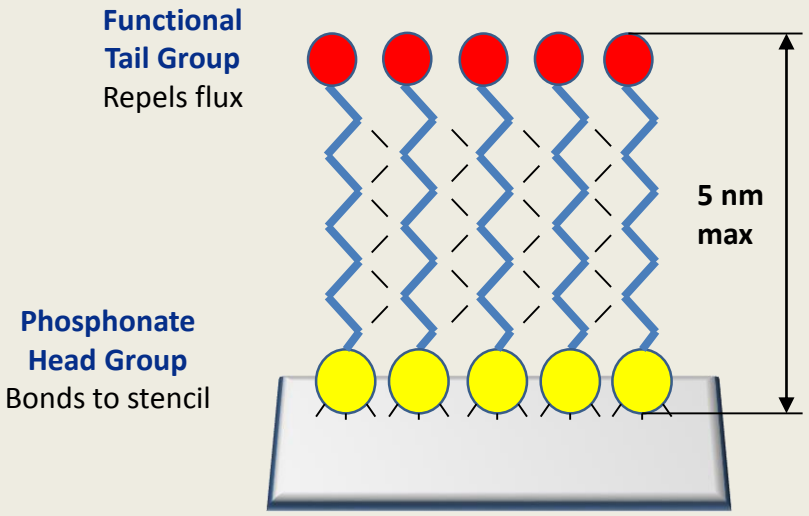
NanoClear Technology

Aculon's proprietary **Self Assembled Monolayer of Phosphonates (SAMP)** can treat surfaces to impart fluxophobicity. The SAMP monoloayer is comprised of a phosphonic acid and a repellent, carbon-based molecule:

- Phosphonic acid reacts with the stencil surface and aperture walls and creates a covalent bond at the substrate: phosphonic acid interface
- The carbon group connected to the phosphonic acid is the functional mono layer
- The monolayer is less than 5 nanometers thick



Chrys Shea
President , Shea Engineering Services

Applications Research Overview

- **Testing of original SAMP coatings began in 2011**
  - Dramatic improvement to print process
  - Made every stencil perform better, regardless of metal or manufacturing process
- **Comparison of new SAMP coatings with original in 2013**
  - New outperformed original
  - Extending wipe intervals *improved* print performance
  - Drove UV study to see what was happening on contact surface
- **UV Tests, 2013-2014**
  - Showed flux spread on stencil contact surface with and without NanoClear

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Applications Research Overview (2)

- **Durability testing, 2012-2013**
  - Kyzen tested with multiple solvents used in PCB assembly
  - Zestron tested with typical stencil cleaning solvent and 160 wash cycles
  - In-house tests with abrader in excess of 100K cycles
- **Combined effects of nanocoating and solvent underwiping together, 2014**
  - May be key to next level of process capability
- **Nanocoating's Effects on Print Definition, 2014**
  - Ongoing

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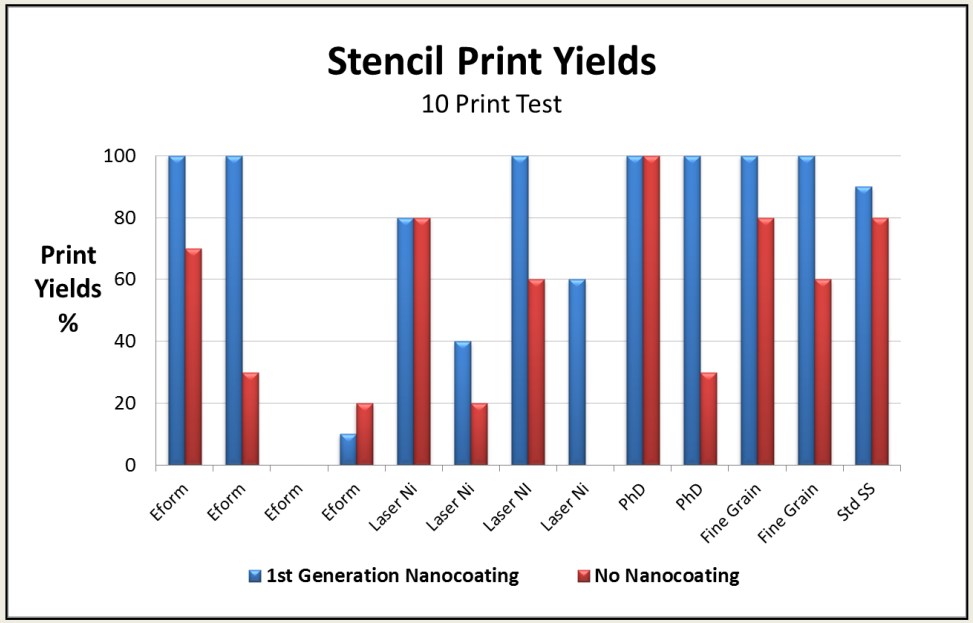
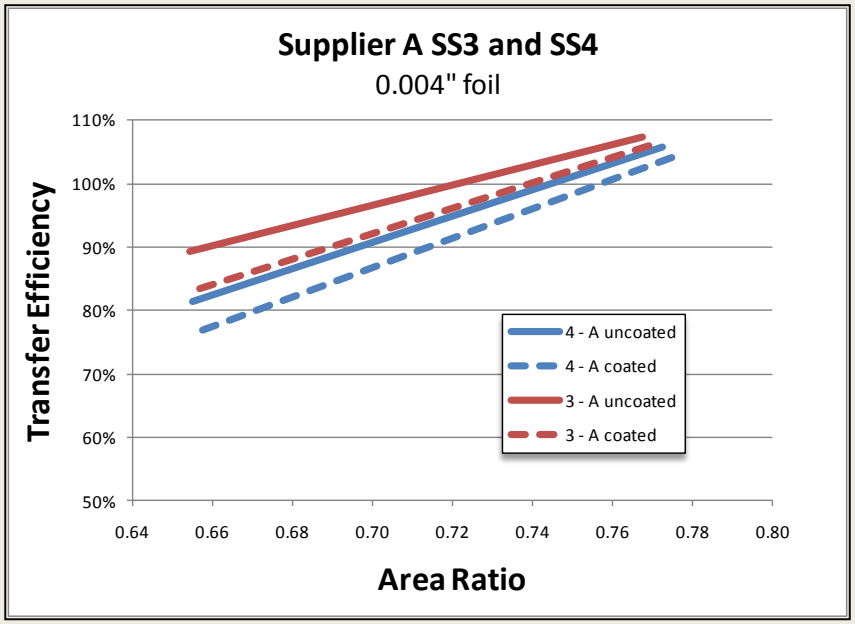
Print Studies

Initial Tests, 2011[2]





Nanocoating dramatically improved print yields

Nanocoating slightly decreased TE

Trends were consistent among all experimental results

- *** Tests used original formulation of nanocoating; a new formulation has since been introduced**
- **** Nanocoating then applied to production stencils and raised print yields by ~5% across the assembly operation**

2"Evaluation of Stencil Materials, Suppliers and Coatings," C. Shea and R. Whittier, Proceedings of SMTA International, October, 2011

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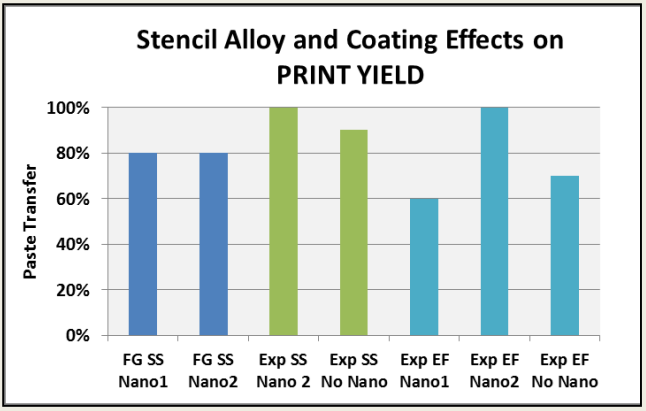
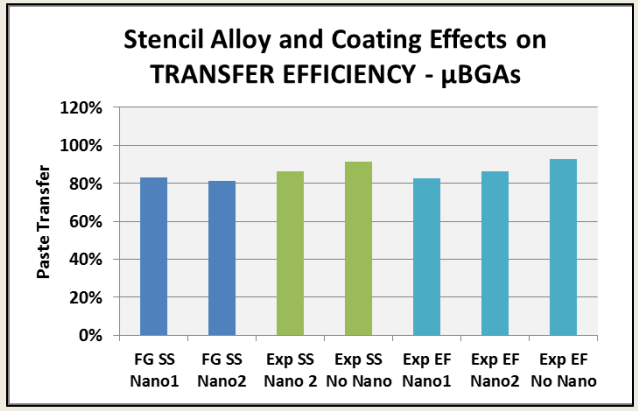
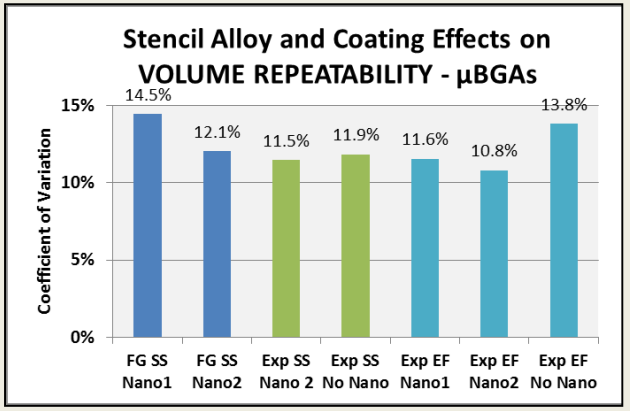
Subsequent Tests, 2013 [1]







YIELD

Stencils treated with Nano2 equaled or outperformed Nano1 or No Nano.

TRANSFER EFFICIENCY

Nano shows slightly lower TEs than No Nano.

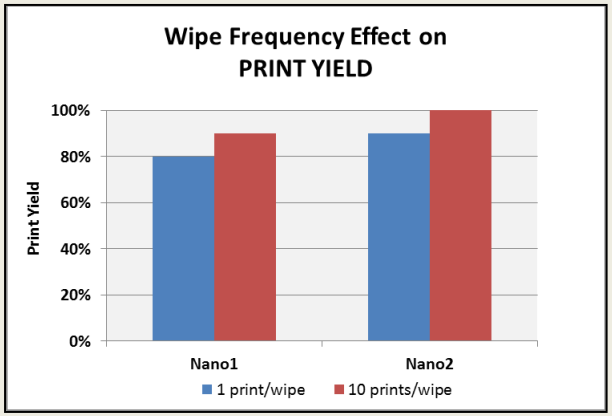
Nano2 shows slightly lower TE than Nano1.

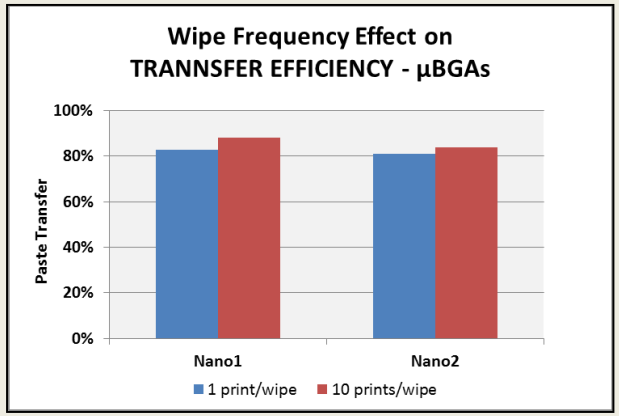
VOLUME REPEATABILITY

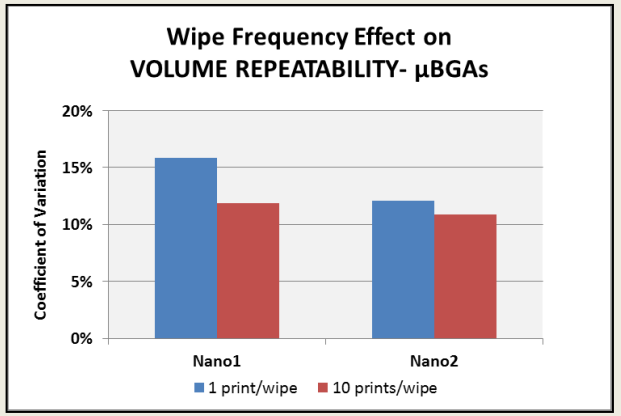
Stencils treated with Nano2 consistently give better repeatability than Nano1 or No Nano.

- **Tests compared original formulation of nanocoating (Nano1) with the new formulation (Nano2)**
- **Both are SAMP-based nanocoatings**
- **Trends of higher yields, lower TEs and better volume repeatabilities with nanocoatings continues**
- **New formulation (Nano2) outperforms original formulation (Nano1)**

Stencil Under Wipe Frequency[1]







PRINT YIELDS

10 prints per wipe better than 1 print per wipe in both tests, with both Nano1 and Nano2

Nano2 gives higher yields than Nano1

TRANSFER EFFICIENCY

10 prints per wipe give slightly higher TE than 1 print per wipe, with both Nano1 and Nano2.

Nano2 slightly lower TE than Nano1 in both cases.

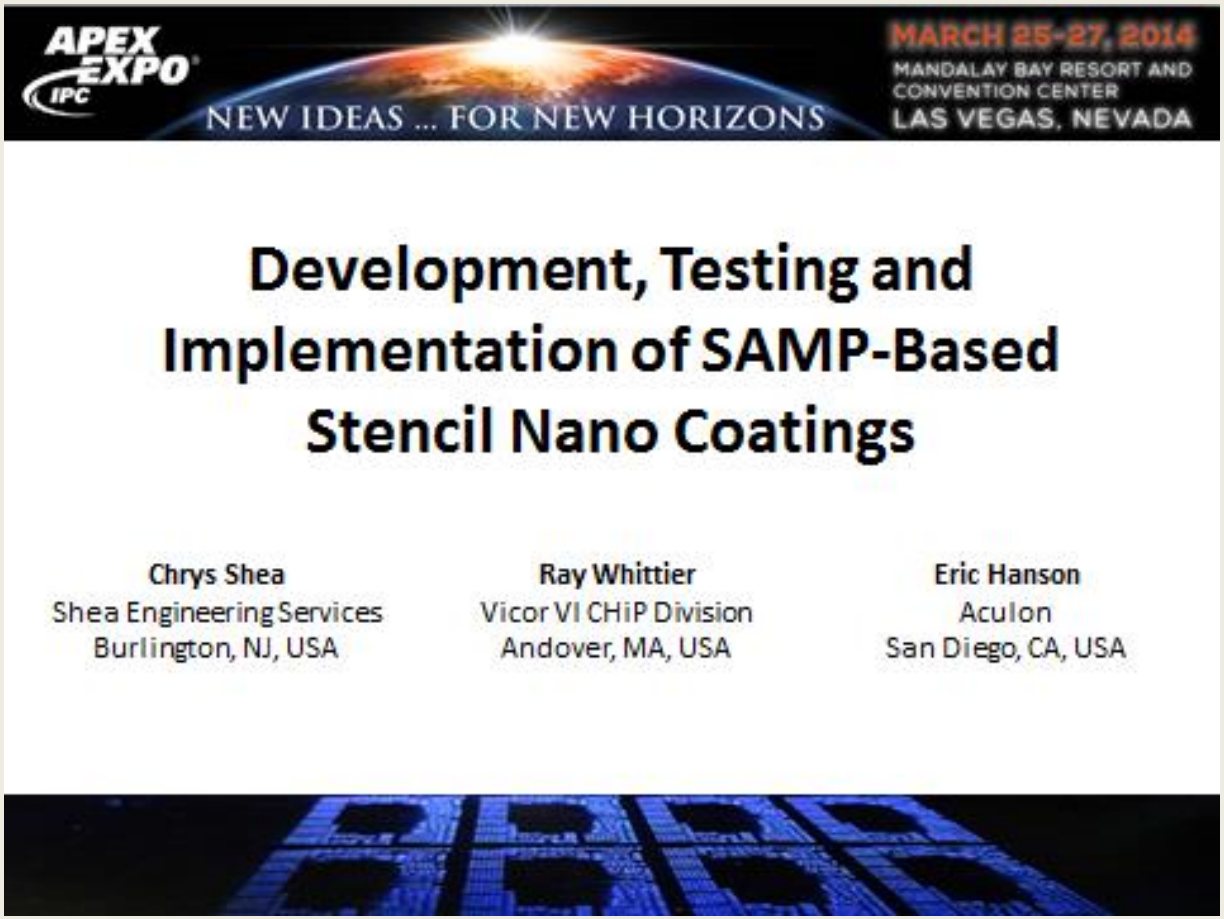
VOLUME REPEATABILITY

10 prints per wipe better than 1 print per wipe in both tests.

Nano2 better than Nano1.

- **With nano coating, 10 prints per wipe outperformed 1 print per wipe, giving better yields and volume repeatability**
- **Theorize that lower TE may be due to crisper print definition**
- **New formulation (Nano2) again outperformed the original formulation (Nano1)**

APEX 2104 Paper



Visualizing the Flux Flow Under the Stencil

- **Objective:**
  - Observe the behavior of the flux on the stencil's PCB side
  - Document differences in behavior caused by coating
- **Experiment:**
  - Coated ½ print area with nano coating (Nano2)
  - Added UV tracer dye to the solder paste
  - Ran print tests at 1 and 10 prints/wipe
  - Photographed results with UV light and video microscope
- **Direct, head-to-head comparison of print performance**
  - Same PCB, stencil, environment, paste, print stroke, support
  - Isolates coating as variable

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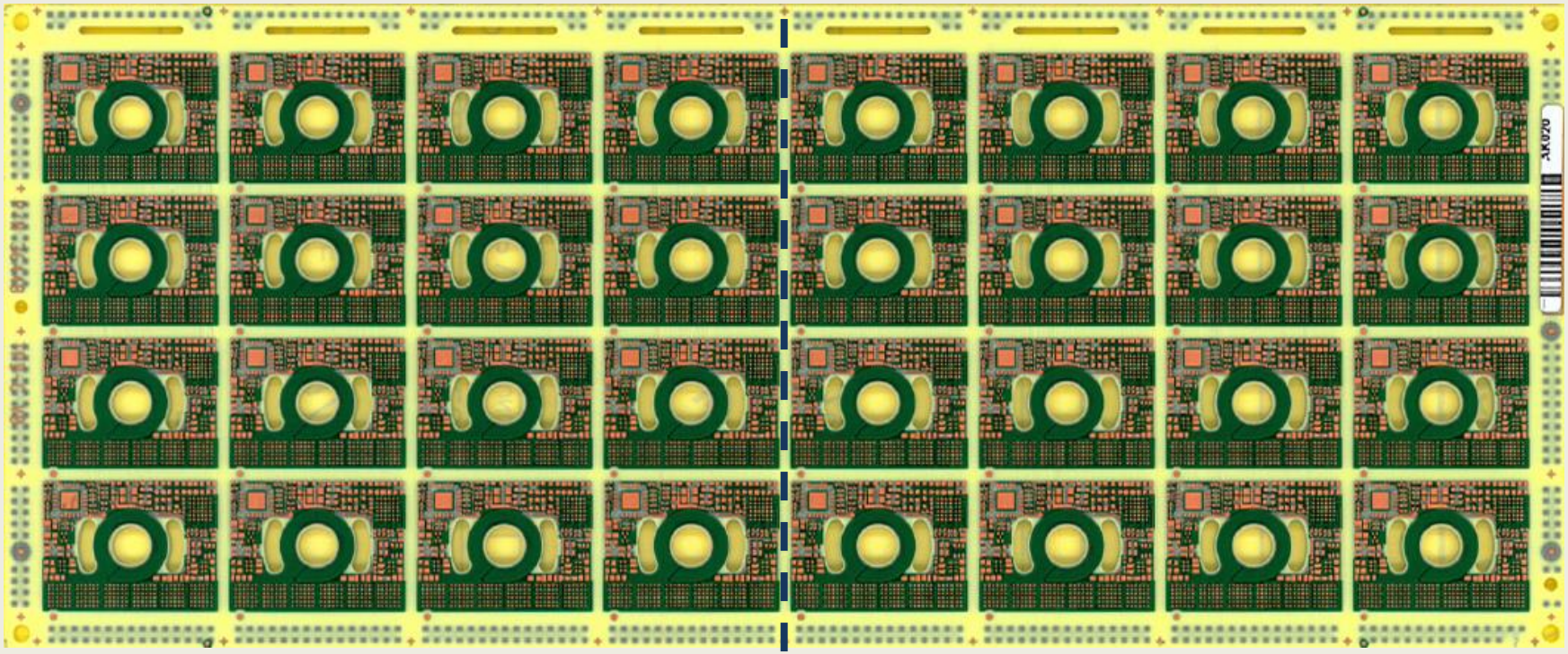
Print Test Vehicle

Stencil was masked along this line and only this half was nanocoated



Untreated side of stencil
Printed without nanocoating

Treated side of stencil
Printed with nanocoating

Test vehicle is 3x7” and has ~8500 BGA pads and ~1900 0201 pads per print

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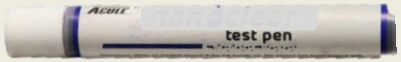
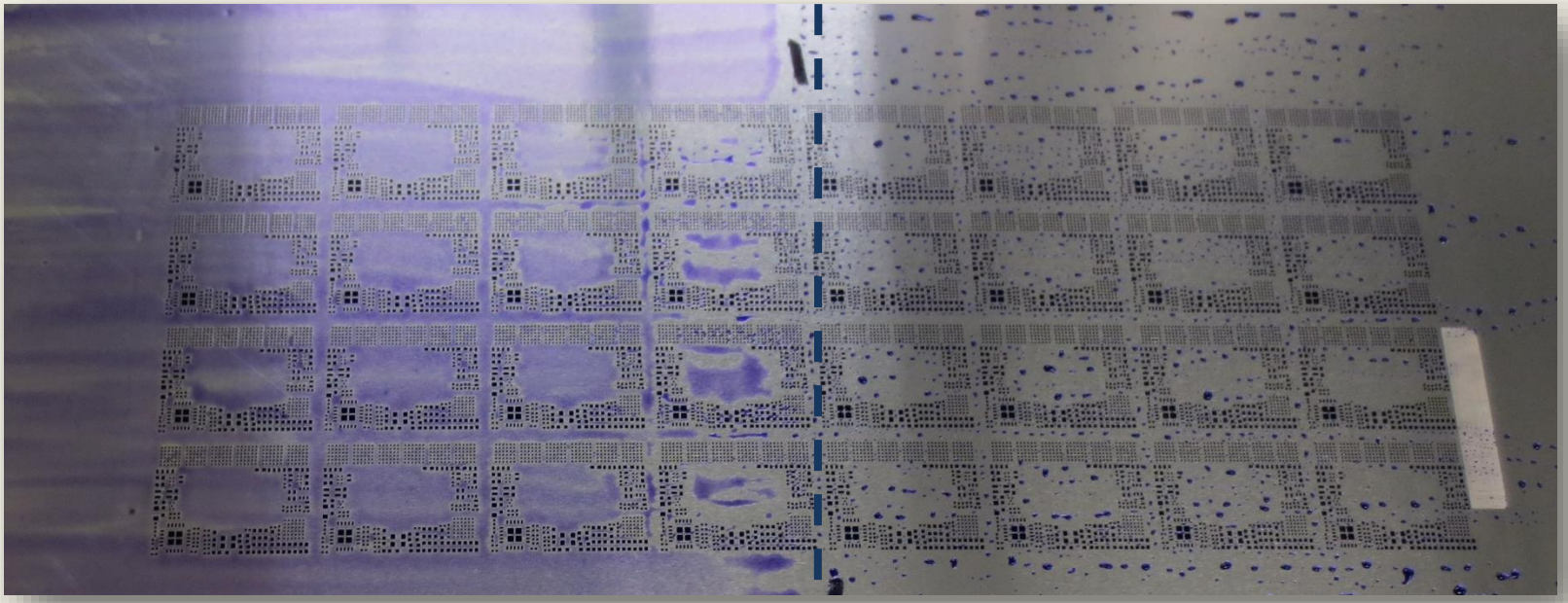
Print Test Stencil

Stencil was masked along this line and only this half was nanocoated



Test pen was used to confirm coating



Untreated side of stencil
Dyne fluid from test pen wets and spreads

Treated side of stencil
Dyne fluid from test pen beads up

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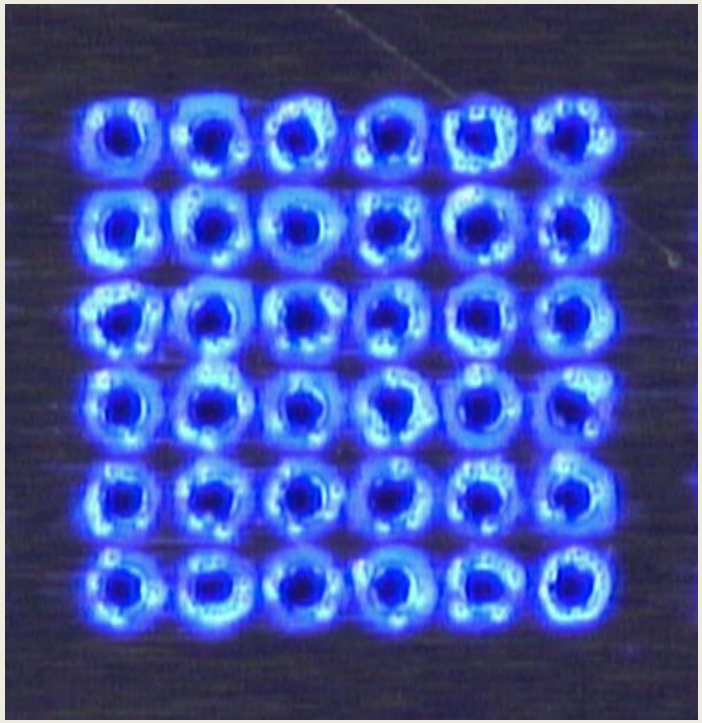
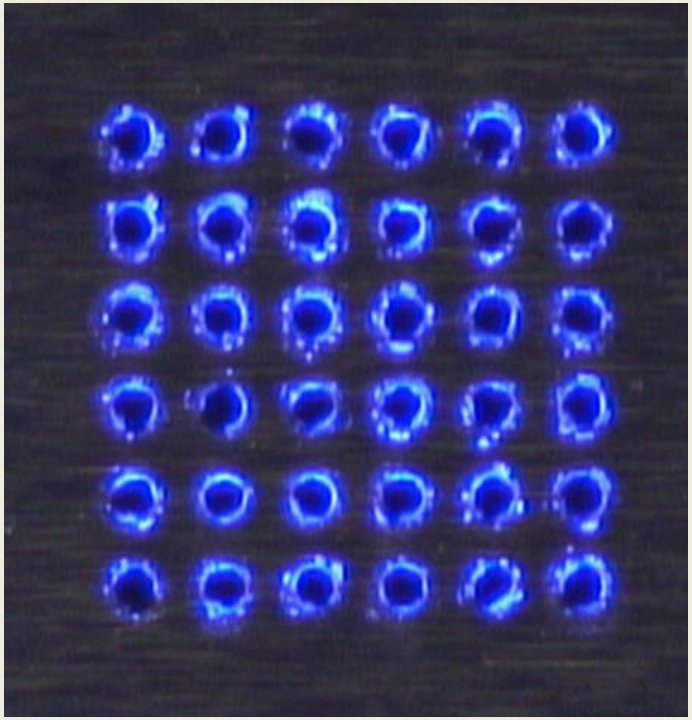
0.5mm BGA

10 prints with no wipe



Untreated



Nanocoated

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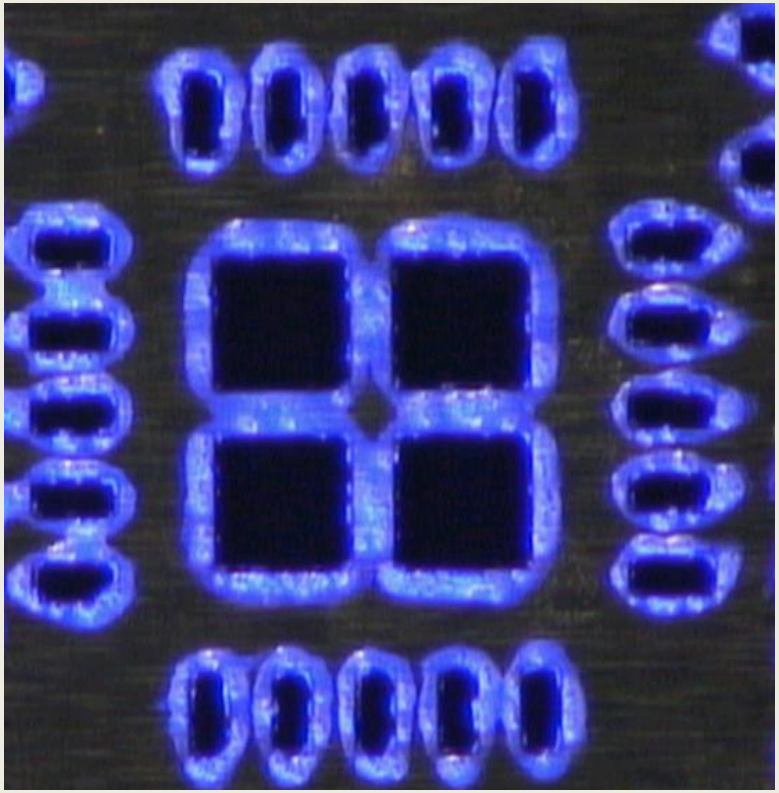
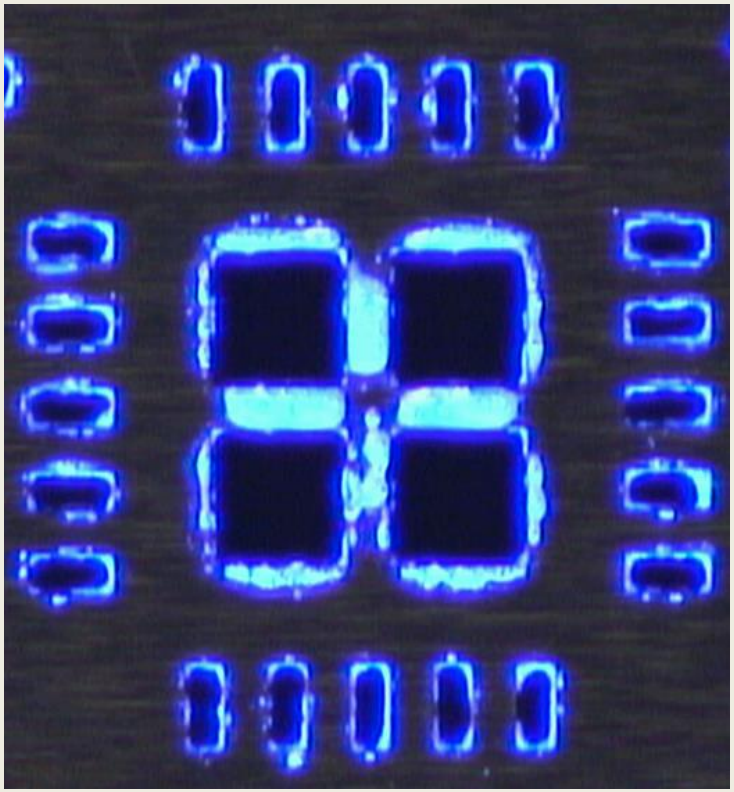
QFN

10 prints with no wipe



Untreated



Nanocoated

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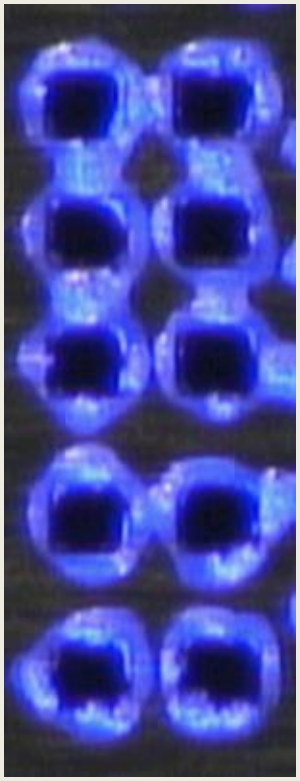
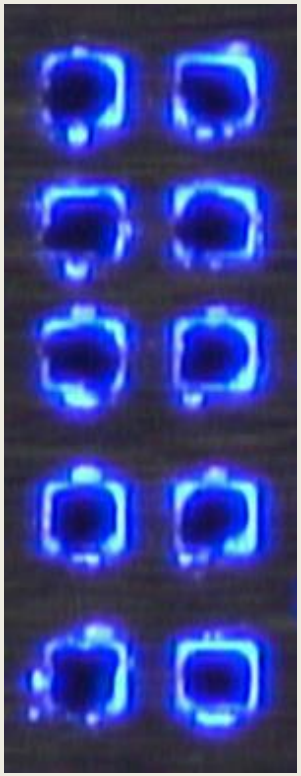
0201s

10 prints with no wipe



Untreated



Nanocoated

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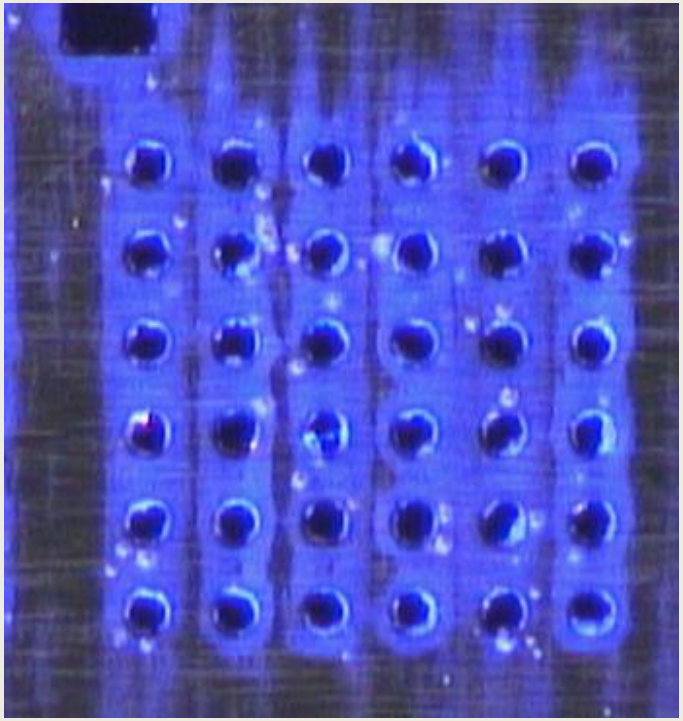
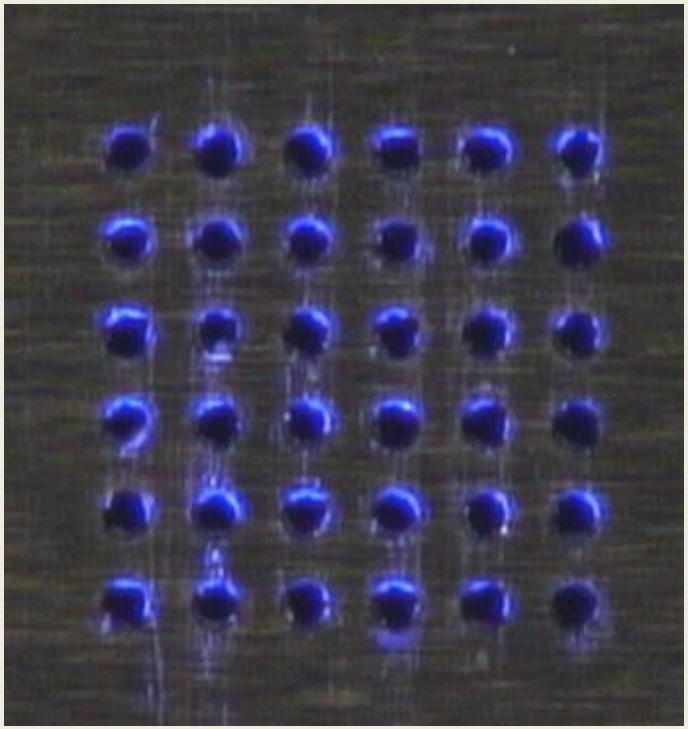
0.5mm BGA

10 prints with1 wipe (vac-dry-vac)



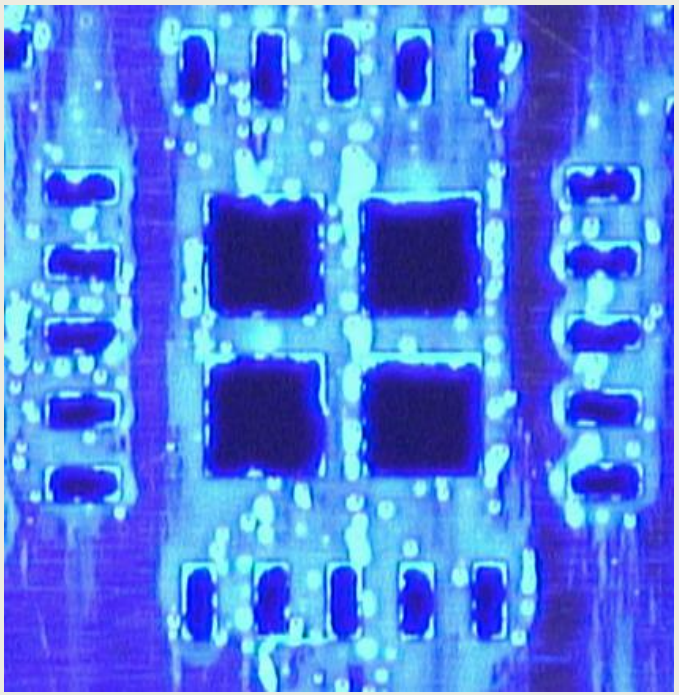
Untreated



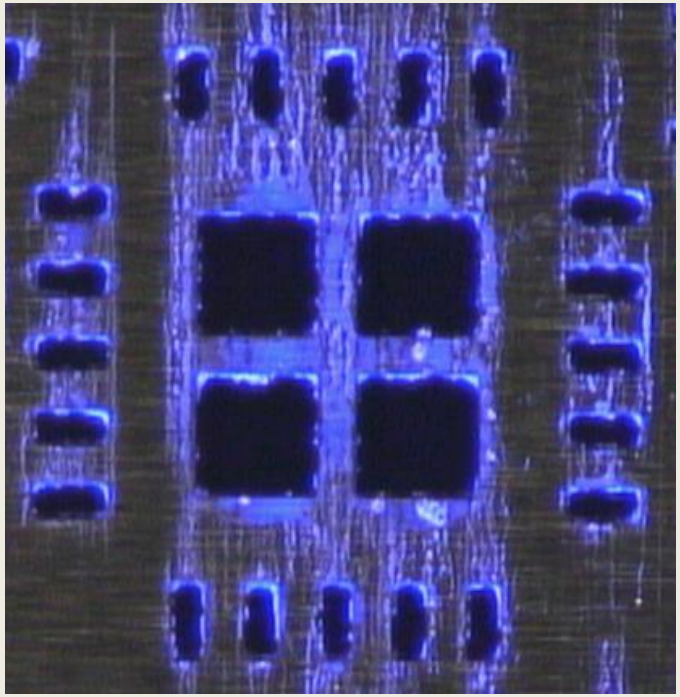
Nanocoated

0.5mm QFN

10 prints with 1 wipe (vac-dry-vac)



Untreated



Nanocoated

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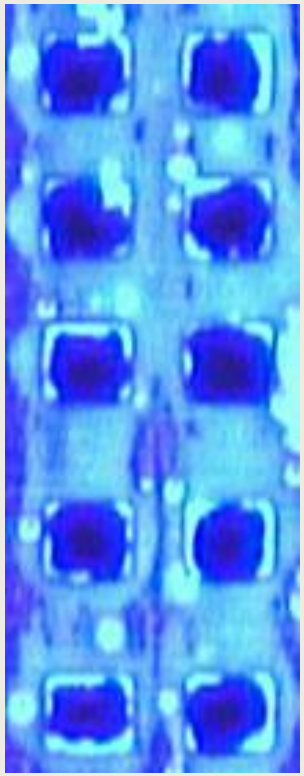
10 prints with 1 wipe (vac-dry-vac)



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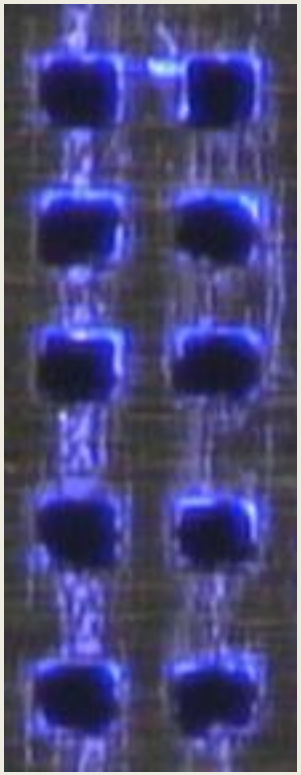

Nanocoated

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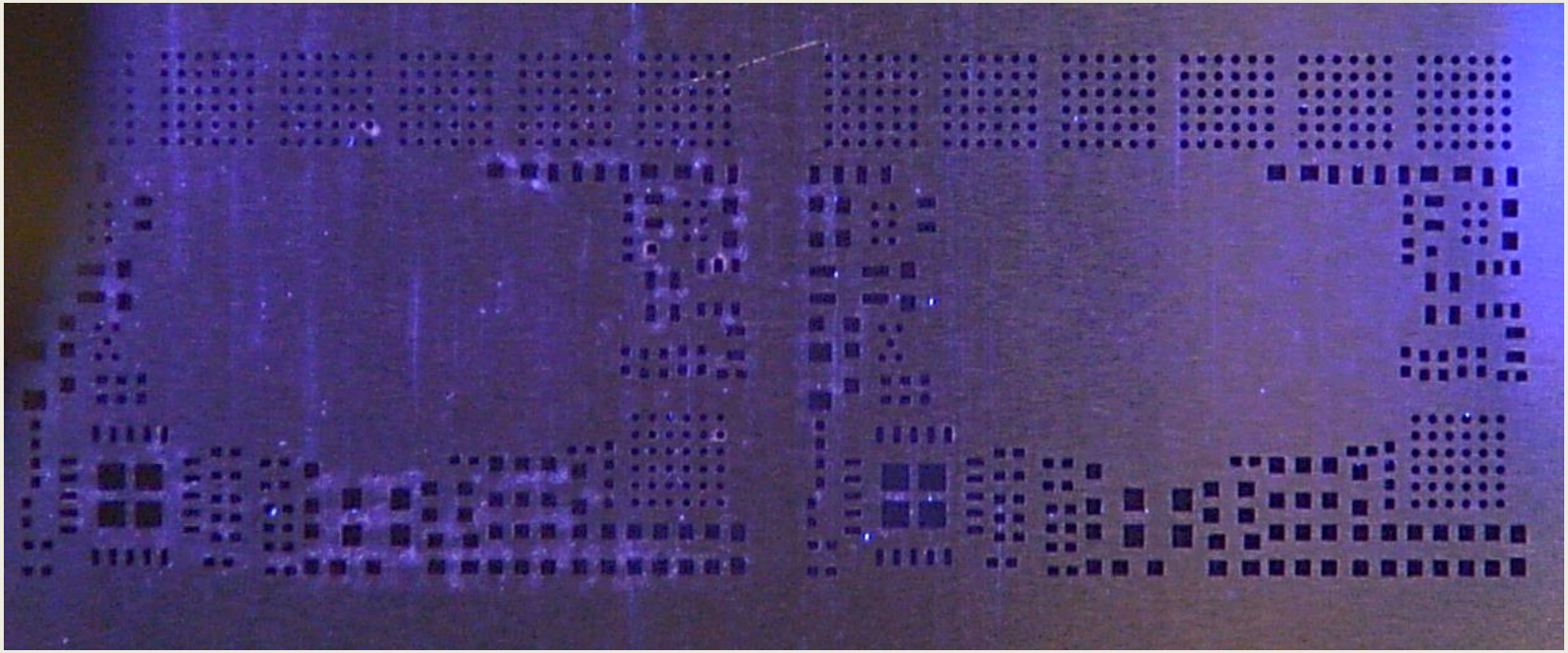
After Solvent Under Wipe

10 print/dry wipe cycles (previous photo)
Followed by solvent underwipe



Untreated

Nanocoated

Solvent wipe removes flux residue and appears more effective on nanocoated area

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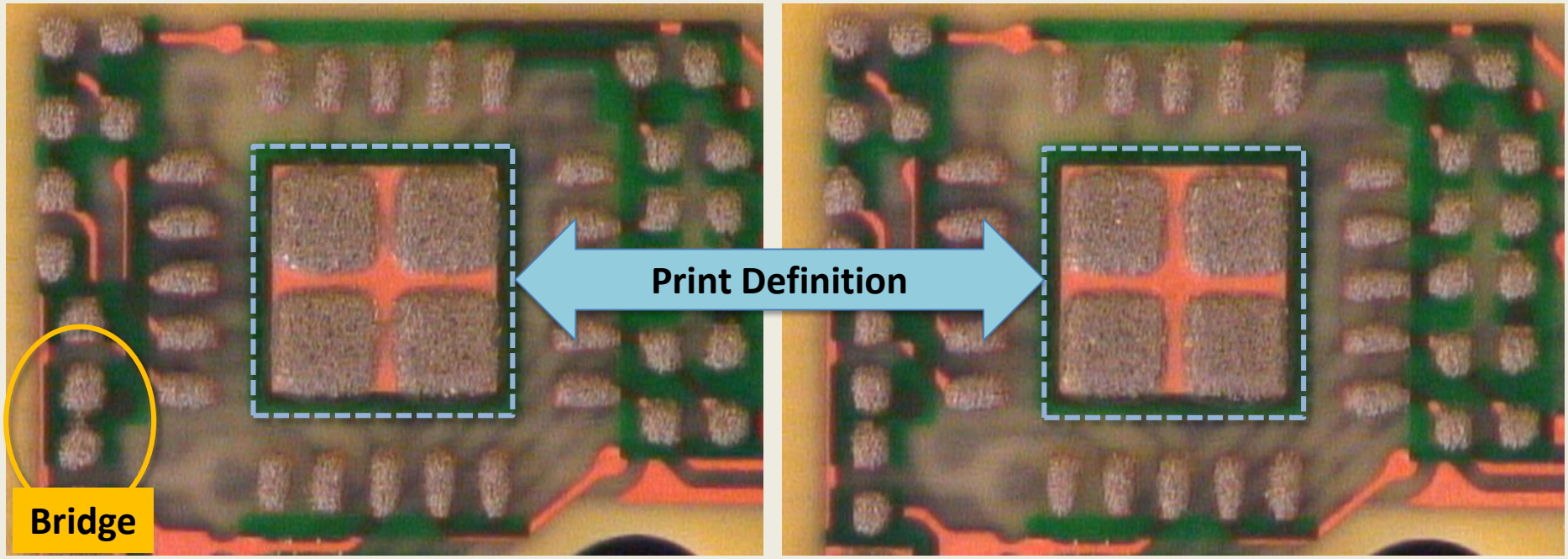
Print Definition Improvements

QFN and 0201s after 10 prints with no wipe

Same board, same stencil, same print stroke



No Nano **Nano**

Is slightly lower TE due to better print definition?

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Under Stencil Wipe Studies

Nanocoating and Engineered Solvent Wipe Study

- DOE with Kyzen, Indium, Vicor to study effects of solvent under wipe and nanocoating
- Published at International Conference on Soldering and Reliability May 15, 2014
- Used SPI to measure prints and UV tracer in paste for visual assessment of stencil cleanliness
- Attempted to use SPI to study print definition
  - ➢ True impact of nanocoating and underwipe on print definition "flies under the radar"
  - ➢ Requires parameter modifications specific to investigation

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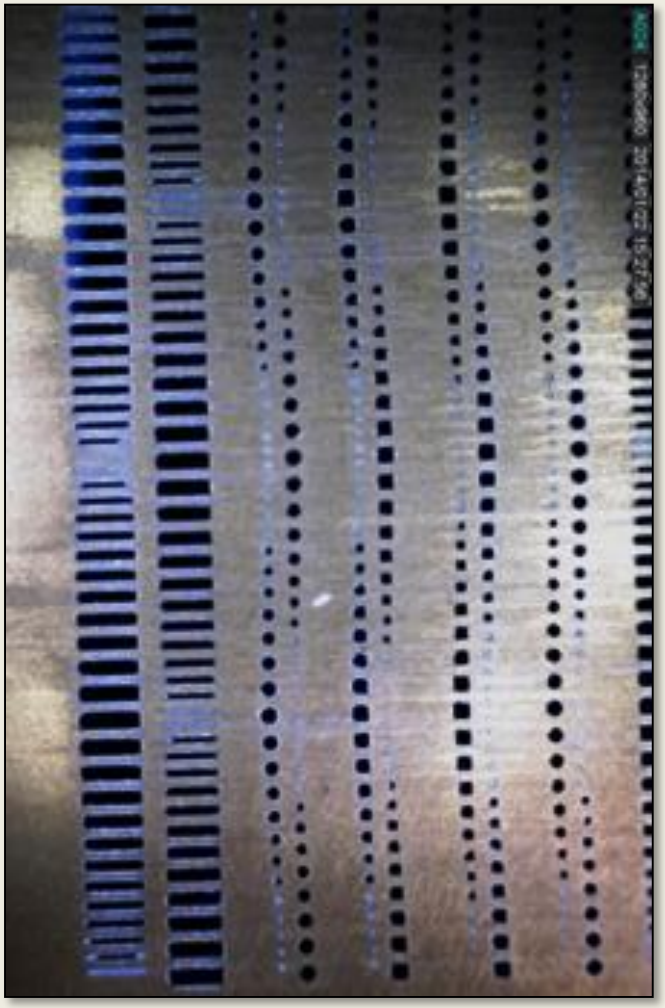
Visual Wipe Assessment

- Ultraviolet tracer added to flux
- Underside of stencils photographed with black light illumination after each print/wipe test
- Readily reveals flux build up and clogged apertures



Enhanced image

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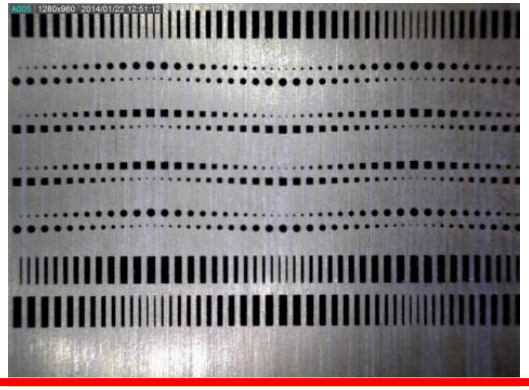
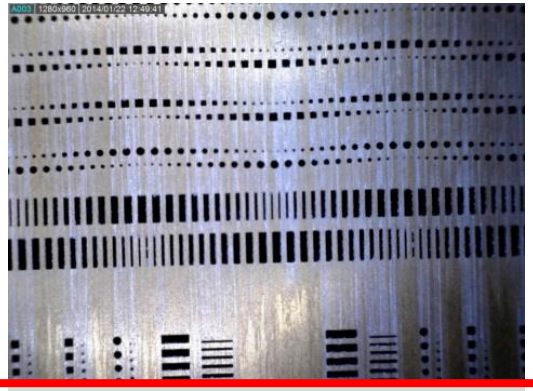
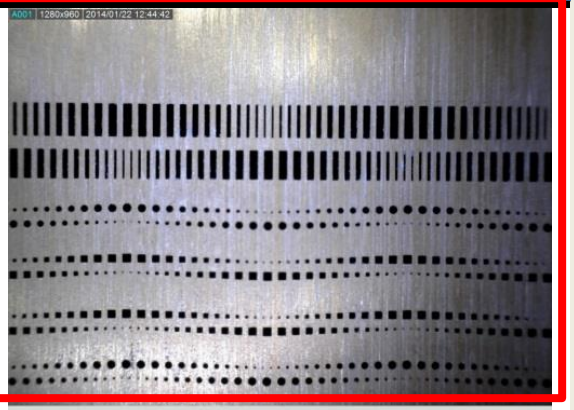
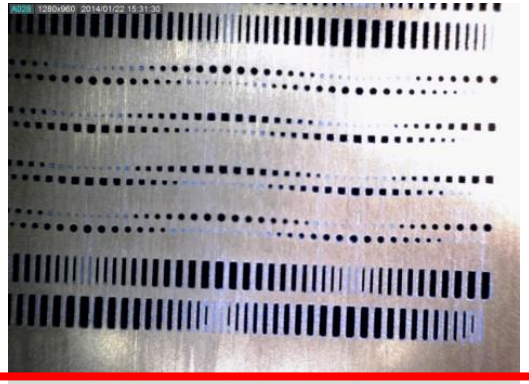
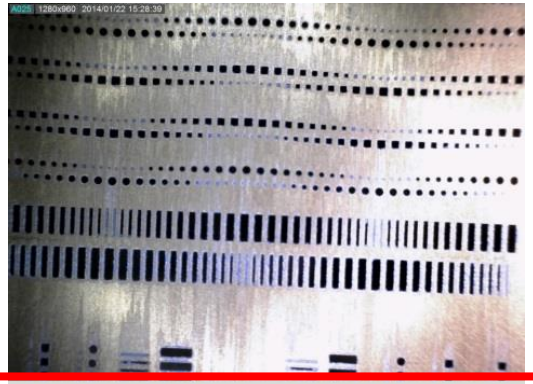
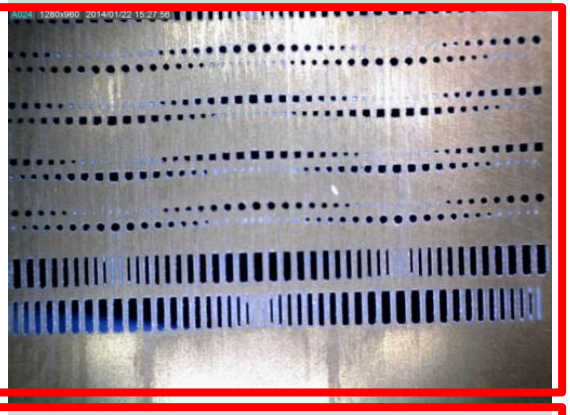
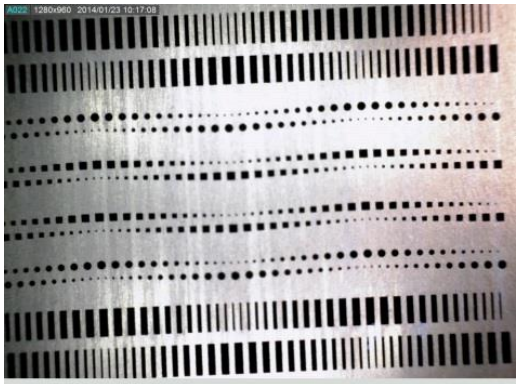
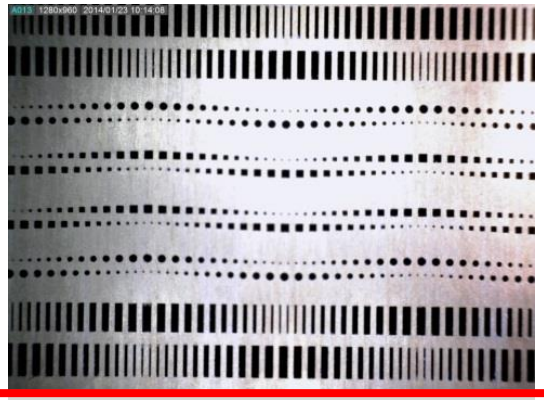
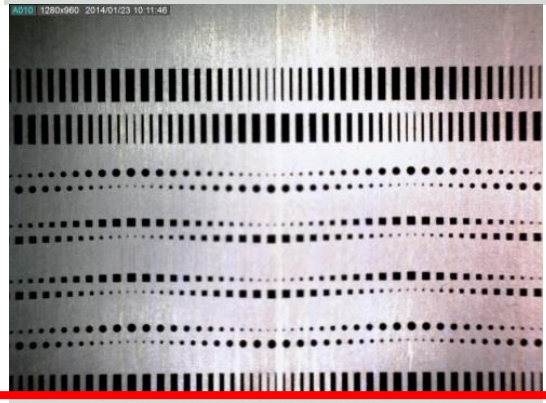
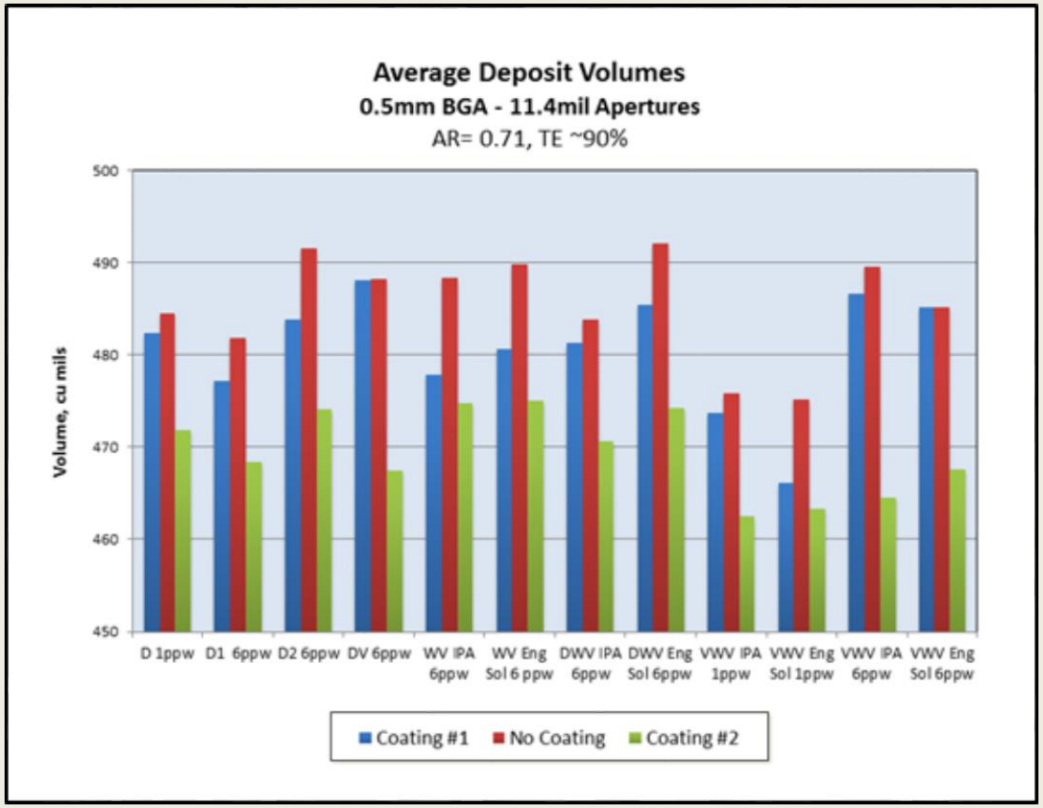
Visual Wipe Results

Wipe Type	Nano-Coating #1	No Coating	Nano-Coating #2
VDV			
VWV IPA			
VWV Eng Solv			

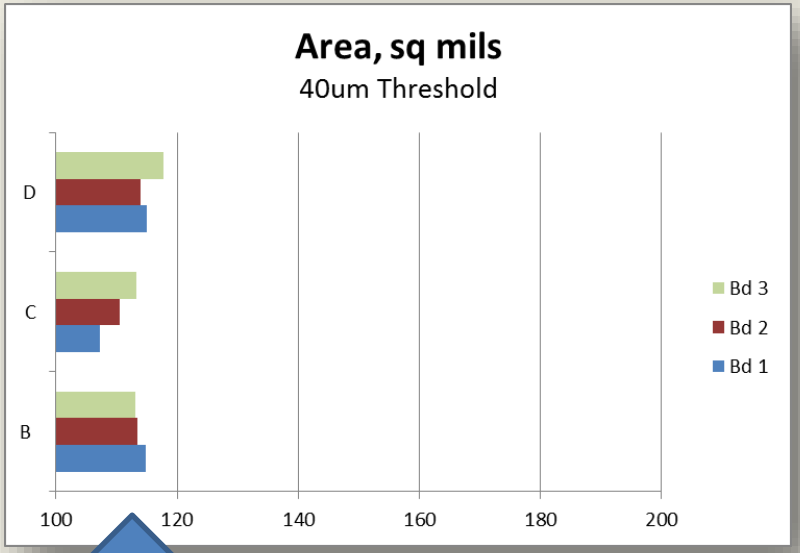
Solder Paste Inspection Results



- Nanocoated stencils again showed slightly lower (2-3%) transfer efficiency
- **This trend has been consistent across all tests over past three years**
- Is it due to crisper print definition?
  - Less smearing, dog ears, peaks, stringing?

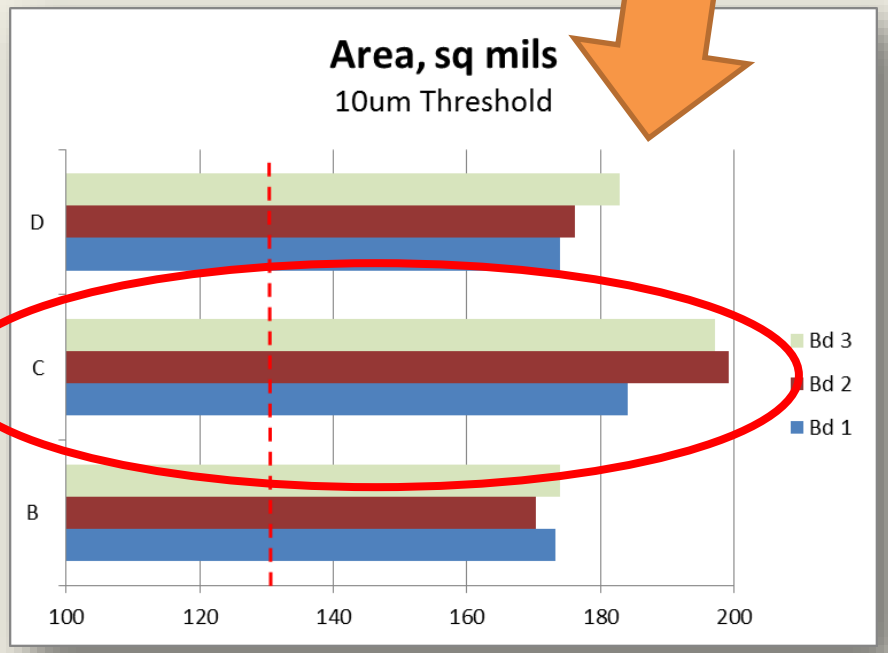
Print Definition Quantification using SPI

Print parameter sets B and C are the same, except C is offset 1.5mils in X and Y to force bad gasketing



At 40µm threshold, all the deposits have basically the same area. To the SPI machine, they all look the same from 40µm down.

At 10µm threshold, the SPI machine detects differences in the print.



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Durability Studies

Durability

- Commonly asked question:
  - **How long does it last?**
- Answer:
  - Can be thousands of prints but it depends on your process
  - **Variables:**
    - Solvent or dry wipe
    - Abrasiveness of paper
    - Wipe frequency
    - Stencil cleaning chemistry and process
- Robust against solvents with pH < 9.0
- Tested with many Kyzen and Zestron cleaning chemistries

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Stencil Cleaning Solvents

Testing by both Kyzen and Zestron have determined NanoClear's compatibility and the durability with their respective stencil washes.

A treated stencil was subjected to the following test procedures:

Kyzen	Zestron
Treated samples submerged in Kyzen solutions at room temperature with no agitation	Washed in Vigon SC 210 at 15% concentration
Pieces removed after 15 mins and 1, 4,8,24,48 hours	Washed for a total of 2400 minutes exposure (160 cycles at 15 minutes) each in a Systronic SYS 152/2 system
Rinsed with DI water & Dried	Foil checked for compatibility after each wash cycle
Surface energy measured using dyne pen	Rinsed with DI water
If surface energy < 30 dyne/CM then it was considered a pass	The stencil was inspected and tested every 20-30 cycles for delamination and discoloration and repellency

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Kyzen Results

KYZEN PRODUCT	TIME					
	15 Mins	1 HR	4 HR	8 HR	24 HR	48 HR
Aquanox A8820	PASS	PASS	PASS	PASS	PASS	PASS
Cybersolv C8622	PASS	PASS	PASS	PASS	PASS	PASS
Kyzen E5615	PASS	PASS	PASS	PASS	PASS	PASS
Aquanox A881D	PASS	PASS	PASS	PASS	PASS	PASS
Cybersolv C3400	PASS	PASS	PASS	PASS	PASS	PASS
Water	PASS	PASS	PASS	PASS	PASS	PASS

Conclusion: "All of the Kyzen products tested are safe to use with NanoClear Coating."

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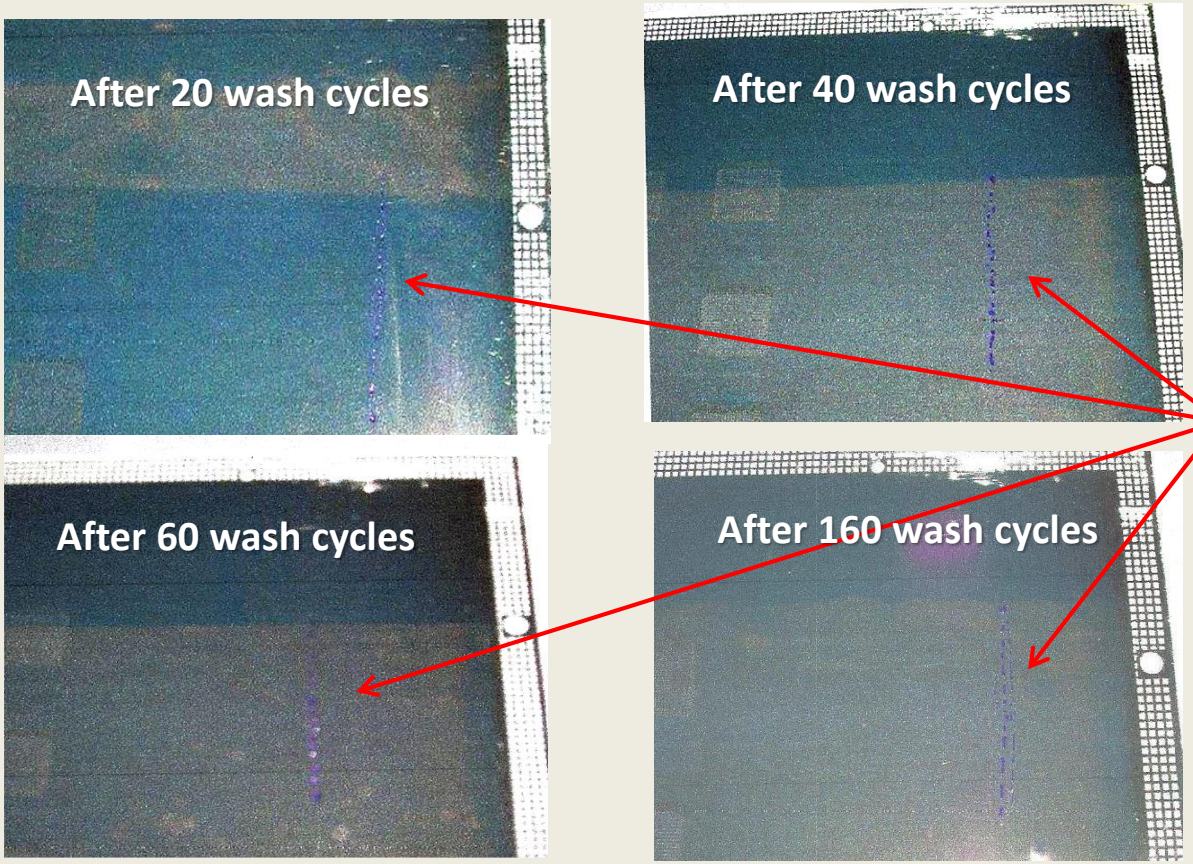
Zestron Results



Dyne fluid beading up, indicating presence of nanocoating

Conclusion: "NanoClear was found to be fully compatible with VIGON SC 210 during the compatibility testing. There was no delamination and/or discoloration to the stencil after exposure to 160 wash cycles"

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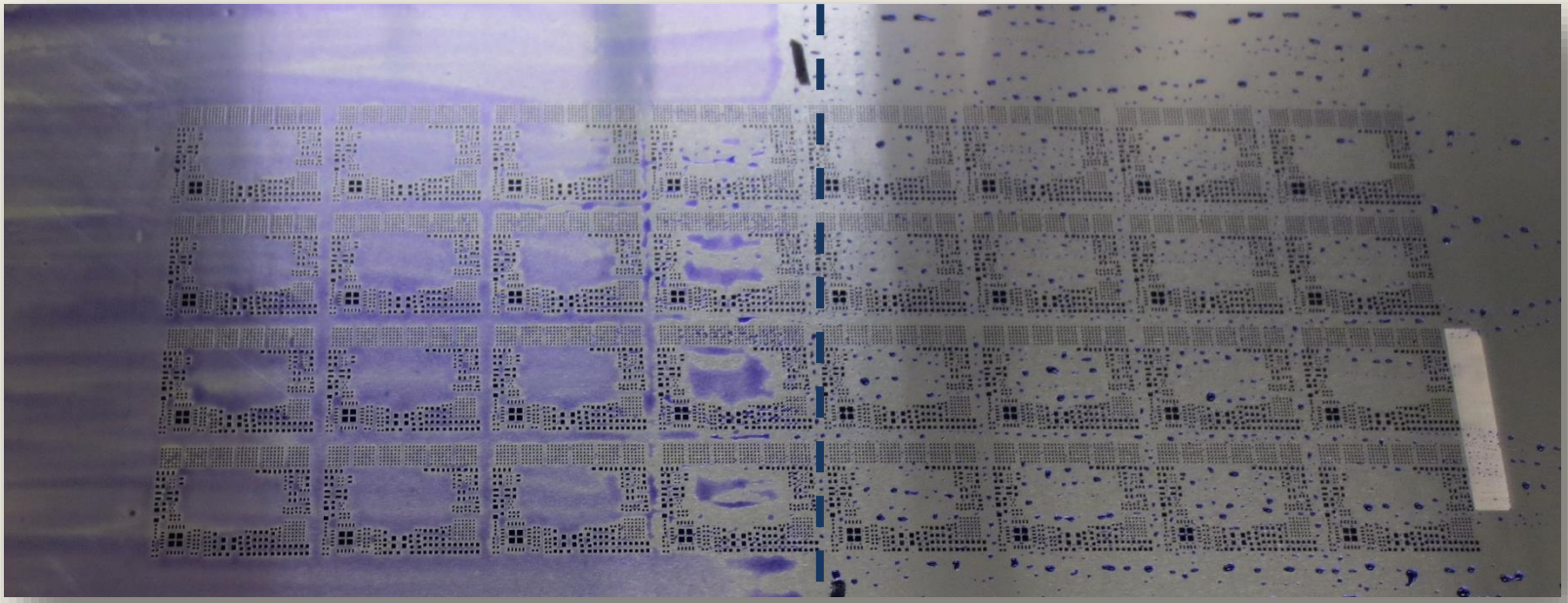
Dyne Fluid Test Pen

Stencil was masked along this line and only this half was nanocoated

Test pen was used to confirm coating



Untreated side of stencil

Dyne fluid from test pen wets and spreads

Treated side of stencil

Dyne fluid from test pen beads up

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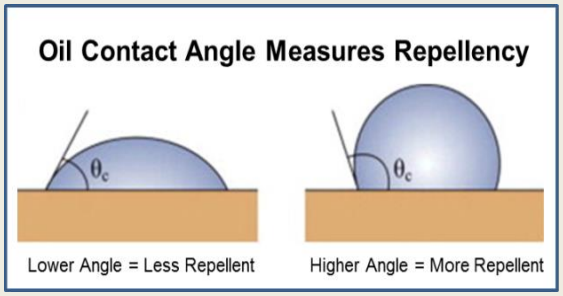
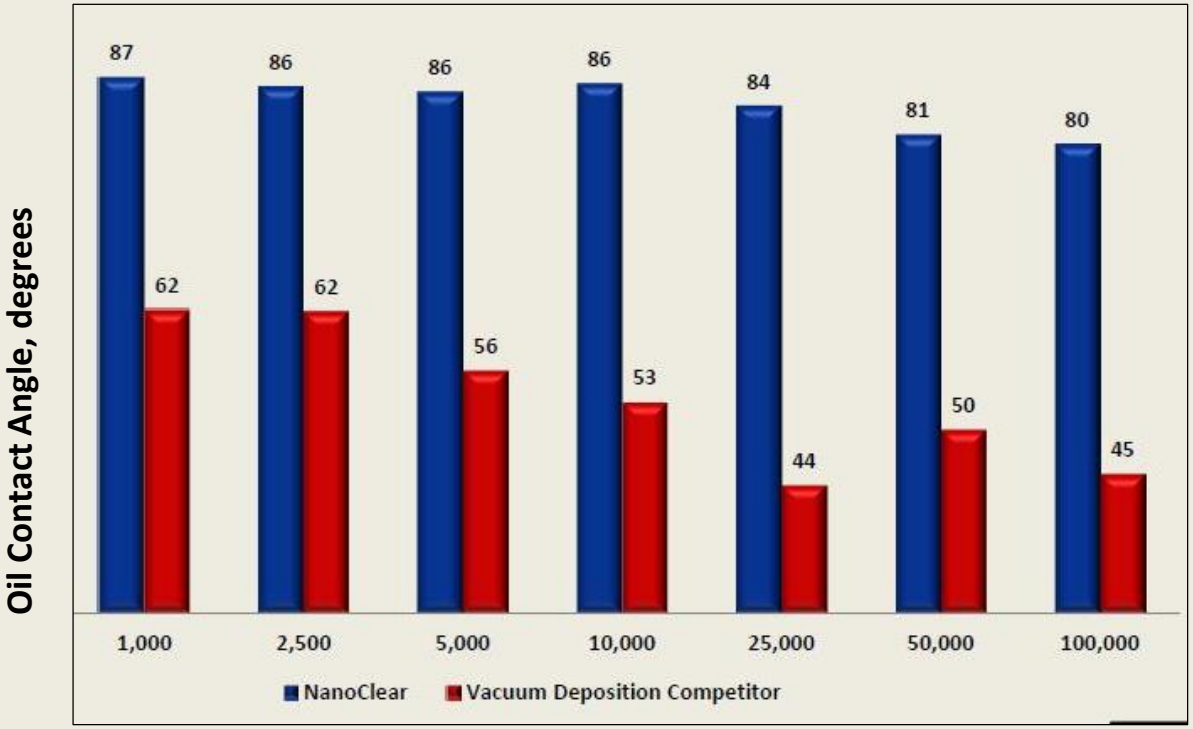
Abrasion Resistance

CONTACT ANGLE



Durability testing used an abrasion test as a proxy for dry under wiping and contact angle as a measure of repellency

ABRASION RESISTANCE



Conclusion: "The nano coating's oil contact angles were both high and consistent, dropping less than 10% over 100,000 abrasion cycles"

Source: Aculon Internal Testing

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Ongoing Studies

Current Research

Ongoing research projects:

- Continue quantifying print definition with SPI equipment
  - SMTAI 2014 or APEX 2015
- Characterizing durability of coatings against solder paste, solvents and wiper papers
  - APEX 2015
- Videos of stencil-PCB separation
  - SMTAI 2014

- Open to new project opportunities

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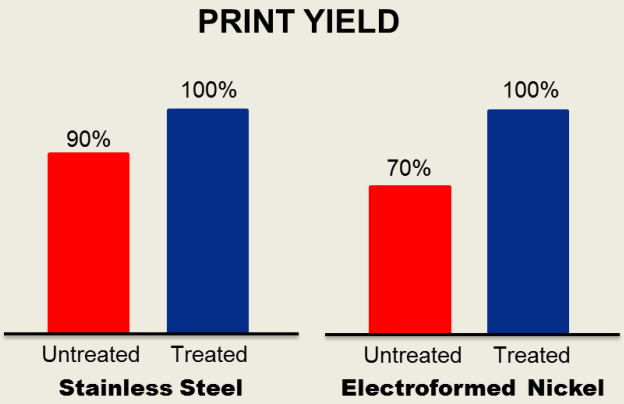
Aculon NanoClear Product Information

Overview of Print Quality Improvements[1]

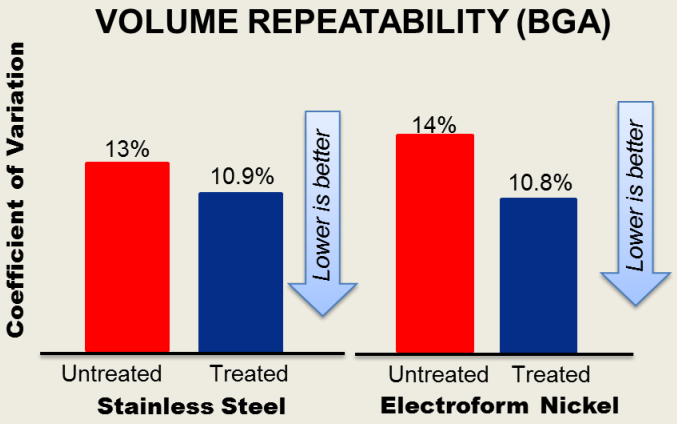
Results of 10-print tests in large DOE

Higher Print Yields

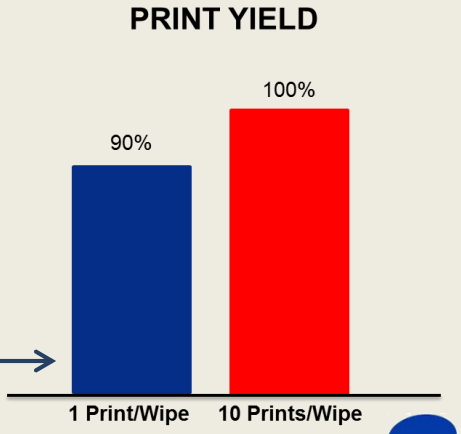


Effective on all stencil materials

Better Volume Repeatability



Reduced Under Wipe Frequency



Improved quality at 10X wipe interval

1: "Fine Tuning The Stencil, Manufacturing Process and Other Stencil Printing Experiments", Shea, C. and Whittier, R., Proceedings of SMTA International, October 2013

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Overview of Customer

- Customers include:
  - Stencil Suppliers
  - CEMs,
  - OEMs & Prototype Centers
- Advocates include:
  - Major Industry suppliers – Indium, Alpha
  - Cleaning Companies – Kyzen, Zestron
- Customers examples
  - Improved Print Yield at high reliability OEMs 5-10%,
  - Improved First Pass ICT Yield at major CEMs by 15-20%
  - Reduced cleaning supplies cost by 50%

Customers save money! NanoClear is the defacto leader

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Costs and Payback

- 2-part treatment per stencil
- Can be applied by PCB assembler or stencil supplier
  - Wipe-on: Prime-Rinse-Apply; takes about 10 minutes total
  - Stencil supplier will charge an application fee
- Cost is $25/treatment
- At paper cost of 10¢ per wipe, payback is in 250 wipes or less
  - Often in 1st production run
- Cost of reworking one BGA is more than the cost of the stencil treatment

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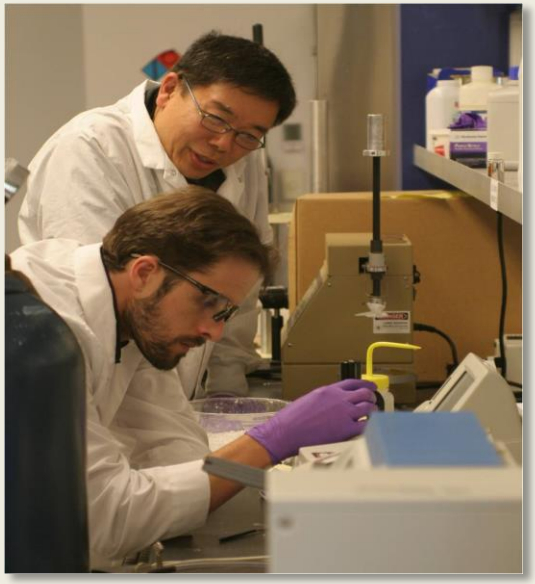
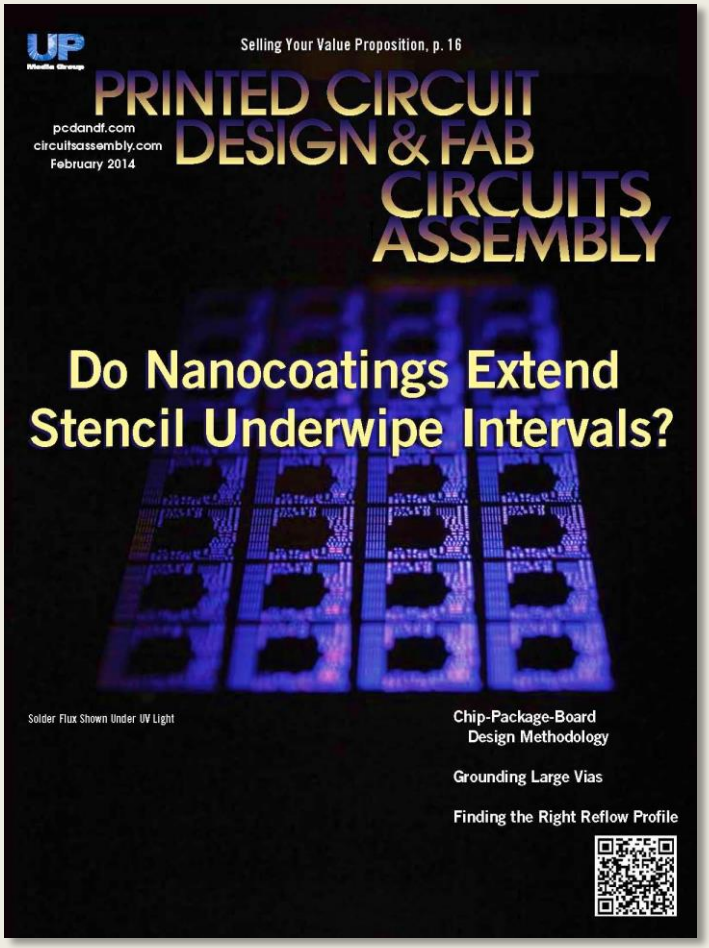
Aculon, NanoClear's Inventors

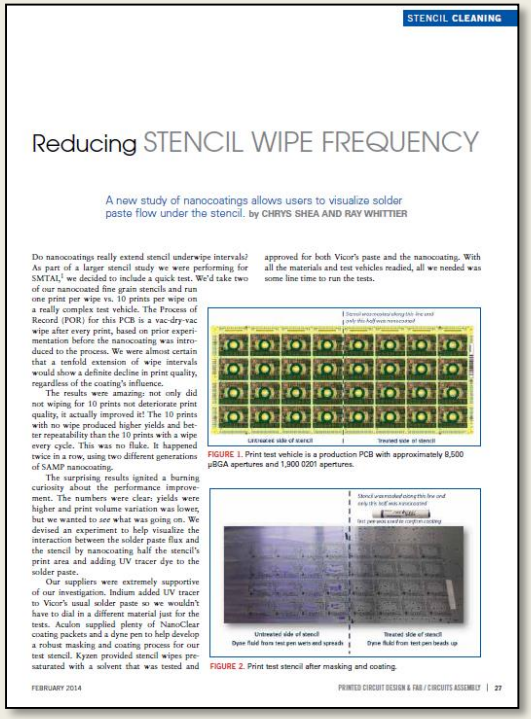
- Specializes in surface modification treatments
- Used in optics, electronics, semiconductor, industrial and consumer goods
- Located in San Diego, CA
- www.aculon.com



NanoClear In the News

February, 2014




STENCIL CLEANING

Reducing STENCIL WIPE FREQUENCY

A new study of nanocoatings allows users to visualize solder paste flow under the stencil. by CHRYS SHEA AND RAY WHITTIER

Do nanocoatings really extend stencil underwipe intervals? As part of a larger stencil study we were performing for SMTAI,[1] we decided to include a quick test. We'd take two of our nanocoated fine grain stencils and run one print per wipe vs. 10 prints per wipe on a really complex test vehicle. The Process of Record (POR) for this PCB is a vac-dry-vac wipe after every print, based on prior experimentation before the nanocoating was introduced to the process. We were almost certain that a tenfold extension of wipe intervals would show a definite decline in print quality, regardless of the coating's influence.

The results were amazing; not only did not wiping for 10 prints not deteriorate print quality, it actually improved it! The 10 prints with no wipe produced higher yields and better repeatability than the 10 prints with a wipe every cycle. This was no fluke. It happened twice in a row, using two different generations of SAMP nanocoating.

The surprising results ignited a burning curiosity about the performance improvement. The numbers were clear; yields were higher and print volume variation was lower, but we wanted to see what was going on. We devised an experiment to help visualize the interaction between the solder paste flux and the stencil by nanocoating half the stencil's print area and adding UV tracer dye to the solder paste.

Our suppliers were extremely supportive of our investigation. Indium added UV tracer to Vicor's usual solder paste so we wouldn't have to dial in a different material just for the tests. Aculon supplied plenty of NanoClear coating packets and a dyne pen to help develop a robust masking and coating process for our test stencil. Kyzen provided stencil wipes pre-saturated with a solvent that was tested and approved for both Vicor's paste and the nanocoating. With all the materials and test vehicles readied, all we needed was some line time to run the tests.

FIGURE 1. Print test vehicle is a production PCB with approximately 8,500 µBGA apertures and 1,900 0201 apertures.

FIGURE 2. Print test stencil after masking and coating.

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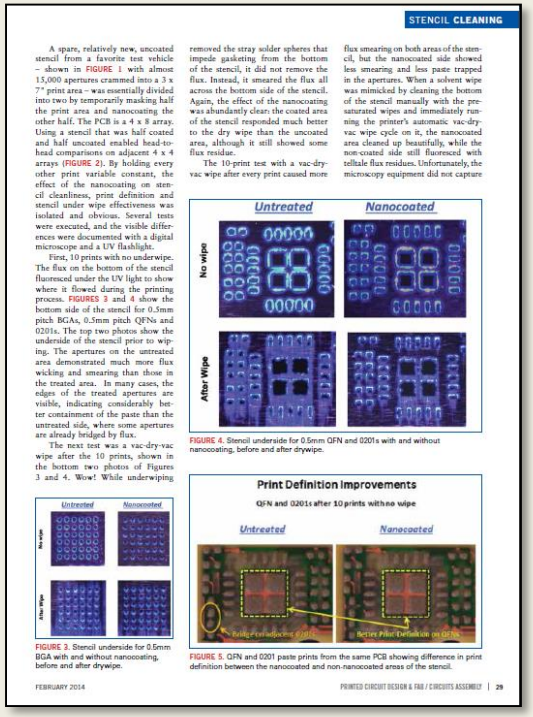
STENCIL CLEANING

A spare, relatively new, uncoated stencil from a favorite test vehicle – shown in FIGURE 1 with almost 15,000 apertures crammed into a 3 x 7" print area – was essentially divided into two by temporarily masking half the print area and nanocoating the other half. The PCB is a 4 x 8 array. Using a stencil that was half coated and half uncoated enabled head-to-head comparisons on adjacent 4 x 4 arrays (FIGURE 2). By holding every other print variable constant, the effect of the nanocoating on stencil cleanliness, print definition and stencil under wipe effectiveness was isolated and obvious. Several tests were executed, and the visible differences were documented with a digital microscope and a UV flashlight.

First, 10 prints with no underwipe. The flux on the bottom of the stencil fluoresced under the UV light to show where it flowed during the printing process. FIGURES 3 and 4 show the bottom side of the stencil for 0.5mm pitch BGAs, 0.5mm pitch QFNs and 0201s. The top two photos show the underside of the stencil prior to wiping. The apertures on the untreated area demonstrated much more flux wicking and smearing than those in the treated area. In many cases, the edges of the treated apertures are visible, indicating considerably better containment of the paste than the untreated side, where some apertures are already bridged by flux.

The next test was a vac-dry-vac wipe after the 10 prints, shown in the bottom two photos of Figures 3 and 4. Wow! While underwiping removed the stray solder spheres that impede gasketing from the bottom of the stencil, it did not remove the flux. Instead, it smeared the flux all across the bottom side of the stencil. Again, the effect of the nanocoating was abundantly clear: the coated area of the stencil responded much better to the dry wipe than the uncoated area, although it still showed some flux residue.

The 10-print test with a vac-dry-vac wipe after every print caused more flux smearing on both areas of the stencil, but the nanocoated side showed less smearing and less paste trapped in the apertures. When a solvent wipe was mimicked by cleaning the bottom of the stencil manually with the pre-saturated wipes and immediately running the printer's automatic vac-dry-vac wipe cycle on it, the nanocoated area cleaned up beautifully, while the non-coated side still fluoresced with telltale flux residues. Unfortunately, the microscopy equipment did not capture

FIGURE 4. Stencil underside for 0.5mm QFN and 0201s with and without nanocoating, before and after drywipe.

FIGURE 3. Stencil underside for 0.5mm BGA with and without nanocoating, before and after drywipe.

FIGURE 5. QFN and 0201 paste prints from the same PCB showing difference in print definition between the nanocoated and non-nanocoated areas of the stencil.

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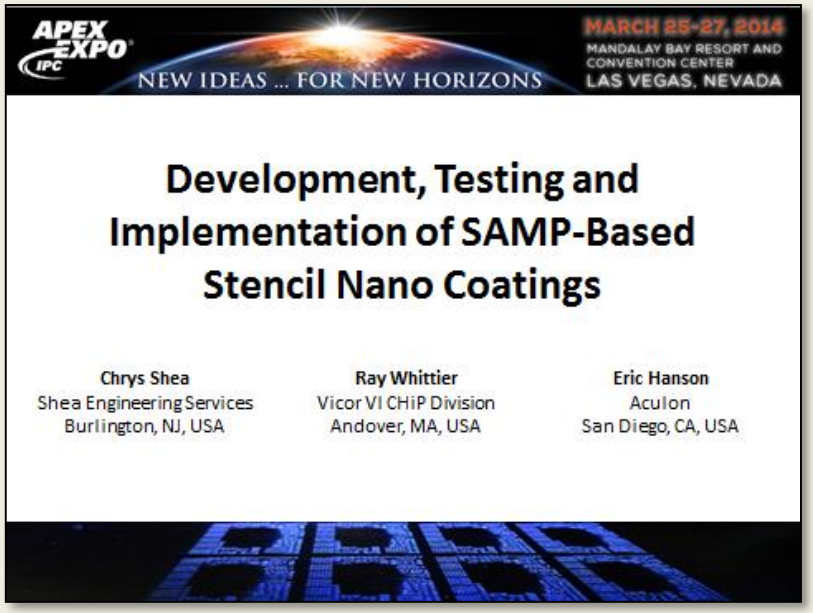
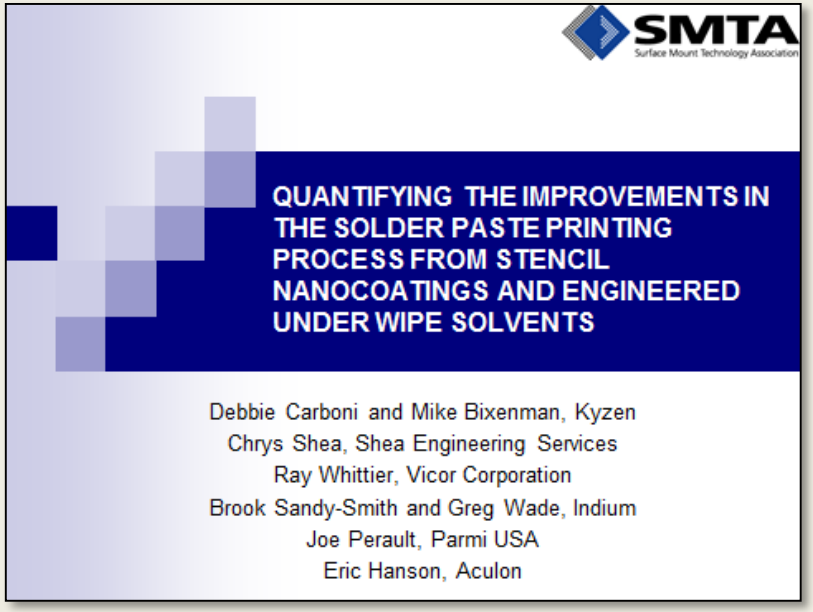
NanoClear At Technical Conferences





IPC APEX, March, 2014

ICSR Toronto, May 2014

More about these later….

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NanoClear In the Industry

Indium Corporation Tech Paper

Nanocoating helped to reduce the flux buildup on the bottom side of a stencil.

For a stencil without nanocoating, the flux spread away from the apertures.

Automatic Wiping

Automatic solvent wiping was not an option during this test, so hand wipes with solvents were followed by a dry/vacuum/dry wipe cycle on the printer. The nanocoating enabled much better cleaning with the mimicked solvent wipe.

For those considering the best approach to an understencil wipe, many factors impact wipe frequency requirements. In general, miniature, high-density designs require more frequent wipes because they present more opportunity for errant paste to remain in the stencil's apertures or to stick to the stencil's bottom surface after separation. Wipe frequencies can range from every print on a highly miniaturized product to every 10 to 20 prints on a low-density design. Wipe frequencies also depend on many wipe process variables: dry, solvent-based, vacuum, wiper-type, paper/fabric-type, and advance rate, wiper speed, and wipe sequence.

Joint Study Performed

Earlier this year, Kyzen and Indium Corporation also performed a study to characterize the relationship between wipe processes and bottom side stencil flux/paste flow. A highly dense PCB and a stencil with nanocoating were used to study the effects of the understencil wiping process. After each print, the stencil was removed from the stencil printer. The apertures were examined to inspect build-up in both the apertures and bottom side of the stencil. Some trace solder balls were found following the first print, with a build-up on the bottom side of the stencil after additional prints. As expected, solder flux combined with solder balls increased with additional prints. A risk is that flux and stray solder balls can be deposited next to the stencil aperture on subsequent prints and get transferred to the PCB. Also, small apertures become clogged at a faster rate.

In the dry wipe studies, there appeared to be streaking on the bottom side of the stencil. On closer examination, the flux vehicle tended to become wiped over the bottom side of the stencil. This effect correlates with what Shea Engineering and Vicor saw from their research. Increasing the numbers of prints increased the level of flux spread on the bottom side of the stencil.

As the board being printed is sandwiched to the stencil, there is a risk that the errant flux can be deposited onto the surface of the board. There may or may not be a reliability risk.

Isopropyl alcohol (IPA) is the common solvent choice when a wet wipe is used. Historically, the choice of IPA made sense as most solder flux formulations were based on IPA. However, solder paste manufacturers are moving away from IPA-based fluxes for several reasons, the most notable of which is higher soldering temperature alloys. IPA is a flammable solvent with a flash point (the minimum temperature required for a substance to produce flammable vapors) of +12°C (54°F), which can be a risk factor.

Flammability Considerations

In addition to the flammability considerations, IPA is also becoming an inefficient solvent for modern solder pastes. When natural rosins were the primary constituents of solder paste flux, IPA was an excellent choice of solvent. Because rosin is highly soluble in IPA, the IPA readily evaporated, and the IPA was extremely affordable. Current fluxes, however, especially no-clean formulations, contain materials not as soluble in IPA as rosin, and require more specialized solvents. The solder paste used for the Kyzen-Indium research was a lead-free, no-clean formulation. Following the IPA/dry wipe action, the bottom side of the stencil was dry and mostly clean. Similar to the dry wipe, there appeared to be flux

From One Engineer To Another®

2

Indium Tech Paper

Best New Product Award

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Nanocoating Comparison

Nanocoating Comparison

Key considerations

1. Is it proven?
2. Who applies the nanocoating?
3. Does it require specialized equipment to apply?
4. Do I need to switch stencil suppliers to have my stencil nanocoated?
5. Do I need to adjust my aperture size?
6. Is it consistent in thickness?
7. Does it flake off?
8. Can it be reapplied?
9. Is it compatible with my cleaning solutions?
10. Is it cost effective?

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Stencil Nanocoatings

TYPE	SOL-GEL POLYMER	SAMP – Gen1	SAMP – Gen2	POLYMER
Year Launched	2009	2011	2013	2014
Application method	Vacuum	Wipe	Wipe	Spray
Cure Required?	Yes	No	No	Yes
Application/cure cycle time	2 hrs	10 min	10 min	45 min
Commercially Available?	Yes	Yes	Yes	No
Thickness	up to 2000 nm	3-5 nm	3-5 nm	2000-4000 nm
Truly a Nanocoating? (<100nm)	No	Yes	Yes	No
Thickness Variation	?	+/- 1 nm	+/- 1 nm	+/- 2000 nm
Aperture redesign required?	Sometimes	No	No	Yes
Stencils treated	One mfr only	Any metal	Any metal	One mfr only
Applied by	One mfr only	Any mfr or user	Any mfr or user	One mfr only
Proven in Production	Yes	Yes	Yes	No
Cost	$800 incl stencil	varies	$25	TBD

Source: www.comparenanocoatings.com

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Nanocoating Information

Key Considerations	NanoClear
Is it proven?	**Yes**
Who applies the nanocoating?	**Stencil supplier or PCB Assembler**
Does it require specialized equipment to apply?	**No**
Do I need to switch stencil suppliers to have my stencil nanocoated?	**No**
Do I need to adjust my aperture size?	**No**
Is it consistent in thickness?	**Yes extremely!**
Does it flake off?	**No**
Can it be reapplied?	**Yes**
Is it compatible with my cleaning solutions?	**Yes probably**
Is it cost effective?	**Yes definitely!**

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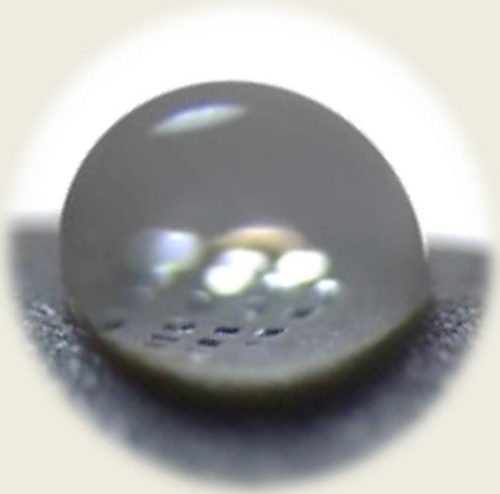
Summary

NanoClear® NanoCoating



- Increases print yields
- Reduces print volume variation
- Improves print definition
- Extends under wipe frequency
- Decreases wipe consumables costs & downtime
- Extensively tested
- Delivers the industry's best cost, performance and ease of use

NanoClear enables a higher quality, more cost-effective stencil print process

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For More Information

Presentation

- Will be emailed to all attendees

Videos

- Introduction & Instruction Videos

For Free samples

- Complete survey

To order NanoClear

- Shopping Cart

For questions and volume quotes for NanoClear

- Contact Mario Gattuso **gattuso@aculon.com**

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For More Information

References

1. “Fine Tuning The Stencil, Manufacturing Process and Other Stencil Printing Experiments”, Shea, C. and Whittier, R., *Proceedings of SMTA International,* October 2013
2. “Evaluation of Stencil Materials, Suppliers and Coatings,” C. Shea and R. Whittier, *Proceedings of SMTA International,* October, 2011
3. “Reducing Stencil Wipe Frequency”, *Circuits Assembly Magazine,* February, 2014
4. “Development, Testing and Implementation of SAMP-based Nanocoatings”, Shea, C., Whittier, R, and Hanson, E., *Proceedings of IPC APEX International,* March, 2014
5. “Quantifying the Improvements in the Solder Paste Printing Process from Stencil Nanocoating and Engineered Under Wipe Solvents”, Carboni, D., and Bixenman, M., et al, *Proceedings of the International Conference on Soldering and Reliability,* May, 2014

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Questions?

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