FINE TUNING THE STENCIL MANUFACTURING PROCESS AND OTHER STENCIL PRINTING EXPERIMENTS

Chrys Shea
Shea Engineering Services
chrys@sheaengineering.com

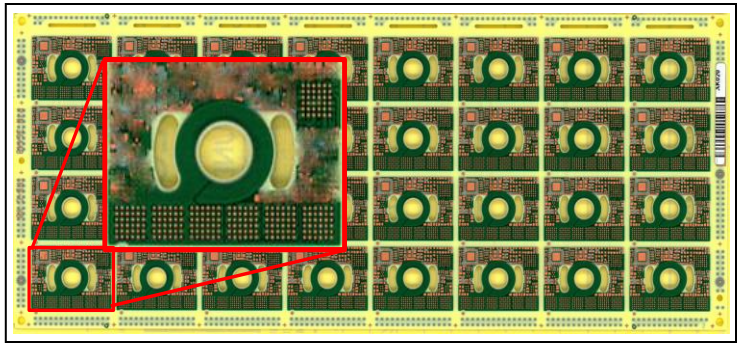
Ray Whittier
Vicor Corporation – VI Chip Division
rwhittier@vicr.com

Agenda

- Background
- Overview of Four Experiments
- Measurement and Analysis Methods
- Results & Discussion
- Questions

Background

- 2011 study on materials
  - Fine grain stainless steel (FG) as the best stencil foil material for the application
    - All SS performed better than electroformed or laser-cut nickel
  - Nanocoating (Wipe-on SAMP coating) dramatically improved yields on all stencil types
    - Raised overall print yields 5% in production



Test Vehicle

- **Production PCB**
- **15,000 apertures in 3x7” area**
- **8500 uBGA apertures per print**
- **1900 0201 apertures per print**

Four Experiments

#1: **Laser cutting parameters**

- Supplier used Process of Record (POR) and three other settings
- Produced two of each stencil – one nanocoated, one not
- Foil material: FG (POR)
- Nanocoating: 1st generation SAMP (POR)

#2: **Materials**

- FG, Experimental SS, Experimental EF
- 1st and 2nd generation SAMP Nanocoating

#3: **µBGA aperture shapes**

- Round, Square (rounded corners)

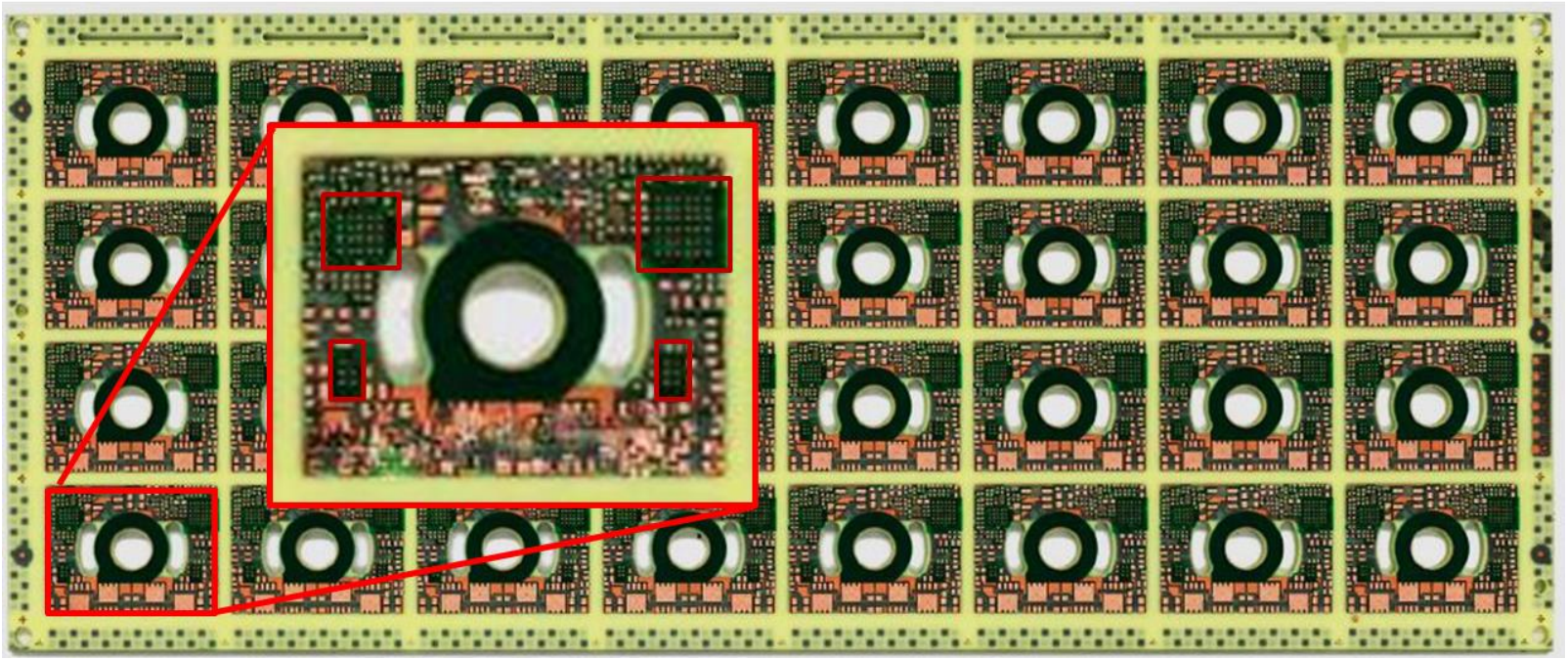
#4: **Stencil under wipe frequency**

- Every print, 10 prints/wipe

All experiments used 10-print test

New Test Vehicle

- Update to Production PCB
- 32-up panel
- 3” x 7”
- 9476 pads
- 2176 µBGA pads
- 3712 0201 pads



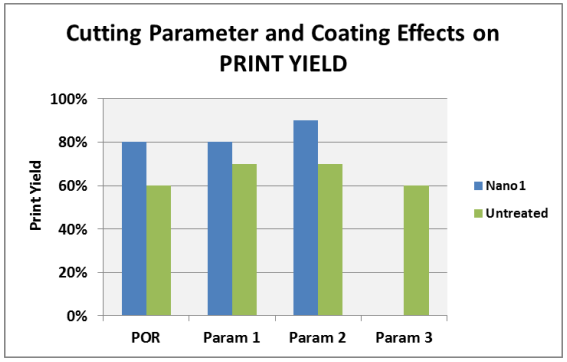
(non-BGA pads intentionally blurred)

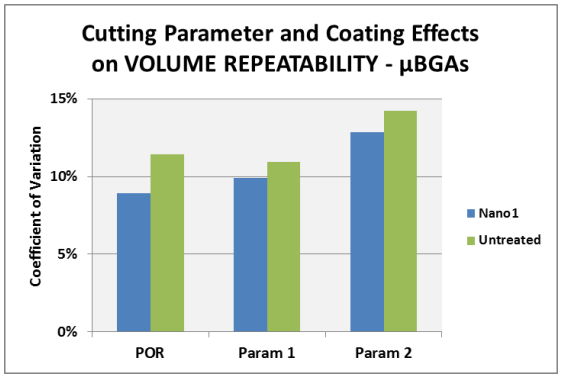
Test Info

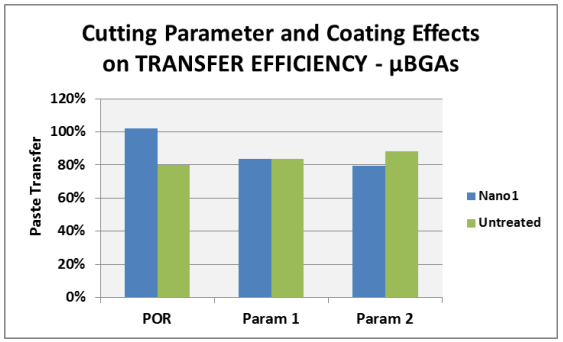
- Printed on DEK Horizon on NPI line
- Vac/Dry/Vac wipe every print
- Indium 3.2HF water soluble, lead-free, halogen-free solder paste
- 17 stencils tested over 9 runs
- Temp/humidity monitored & recorded
- Apertures measured with Microvue CMM
- Thicknesses measured near print area with micrometer
- Area Ratios (ARs) and volumes calculated for each aperture type in each stencil
- Print yields, volumes and positional offsets collected on Koh Young 3020VAL SPI
- Transfer Efficiencies (TEs) and Coefficients of Variation (CVs) calculated and plotted in Excel

Results

Exp #1 Cutting Parameters







Print Yields Ranging From 60-90%

- No clear advantage in cutting parameters
- Stencils treated with Nano1 consistently gave better yields
- Stencil in set 3 had 0% yield due to blocked aperture
- Yields historically higher

Volume Repeatability **(Lower CV is better)**

- POR parameter set shows best repeatability
- Stencils treated with Nano1 consistently give better repeatability

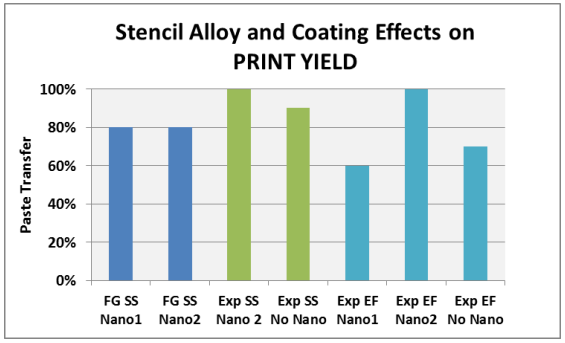
Transfer Efficiency

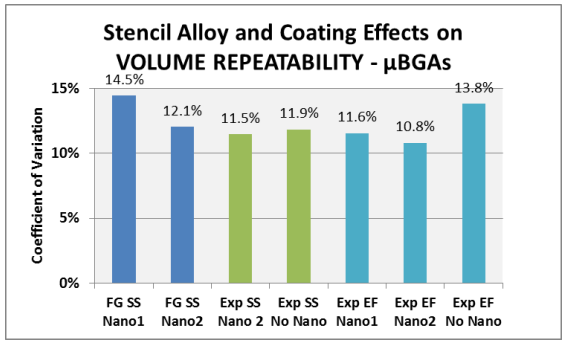
- Typically around 80% for this aperture
- 100% indicates error in system

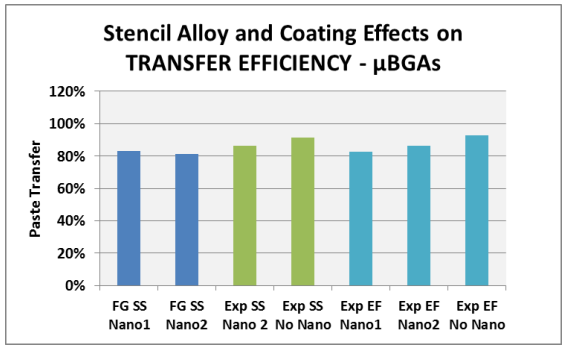
Items to Investigate

- Lower Yields
- Blocked aperture
- 100% TE

Exp #2 Stencil Materials







Print Yields Ranging From 60-100%

- FG steady at 80%, Exp SS shows promise, Experimental Electroform very erratic
- Stencils treated with Nano2 equaled or outperformed Nano1 or No Nano

Volume Repeatability **(Lower CV is better)**

- Goal is 10% or less; all somewhat high
- Stencils treated with Nano2 consistently give better repeatability than Nano1 or No Nano

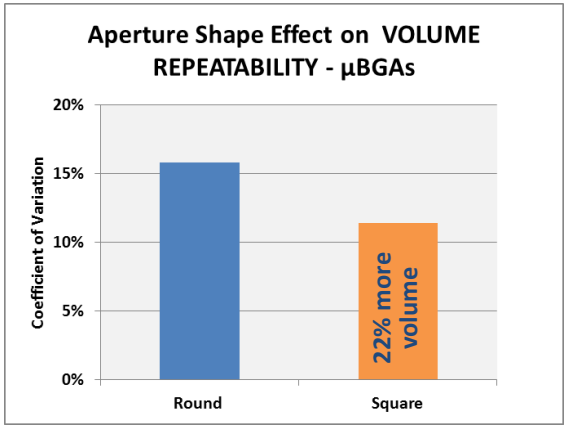
Transfer Efficiency

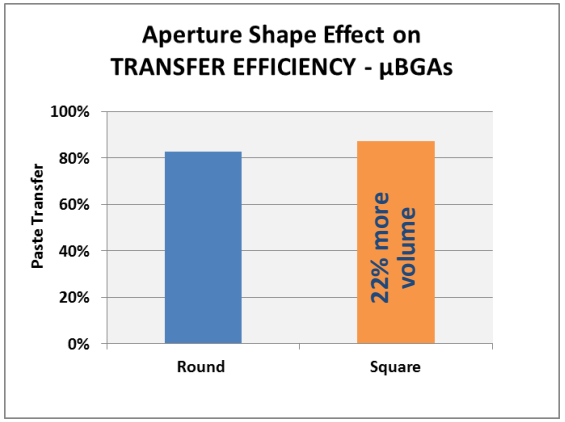
- Typically around 80% for this aperture
- Experimental SS may have slight advantage
- Nano shows lower TEs than No Nano

Items to Investigate

- CVs>10%
- Lower TEs with Nano (common trend)

Exp #3 µBGA Aperture Shapes



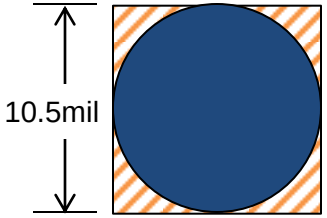


Volume Repeatability

- Square aperture better than round

Transfer Efficiency

- Square better than round

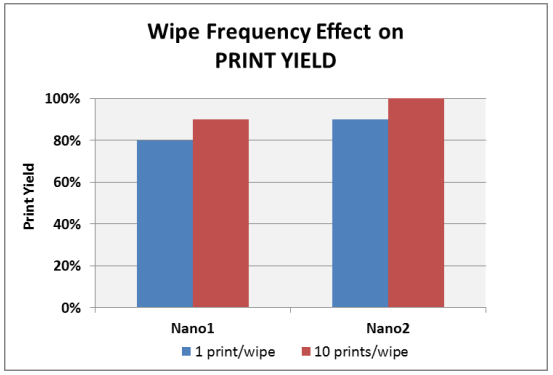


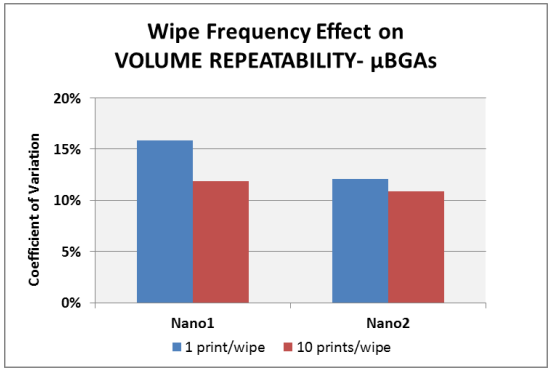
22% more volume available from corners

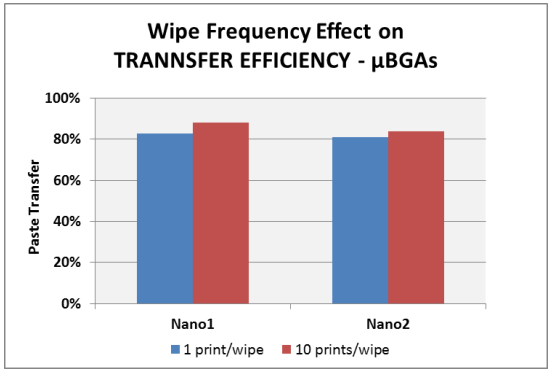
Items to Investigate

- Compatibility with NSMD pads (all SMD in this study)
- Reflow behavior – bridging, balling

Exp #4 Wipe Frequency







Print Yields Ranging From 80-100%

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

Volume Repeatability **(Lower CV is better)**

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

Transfer Efficiency

- Typically around 80% for this aperture
- Slightly more paste at 10 prints/wipe

Items to Investigate

- Why does extending the wipe interval from ONE to TEN improve yield and volume repeatability?
- Devised experiment to find out

Findings So Far…

- POR stencil cutting parameters appear best (but numbers don’t agree with benchmarks)
- Nanocoating improves yields & variation
- Nanocoating tends to reduce TE by a few %
- New generation of nanocoating outperforms original
- Square apertures offer more volume, better TE and volume repeatability than circles
- When using nanocoating, extending stencil underwipe intervals improved yields and repeatability

Items to Investigate

#1: **Laser cutting parameters**

- Blocked aperture
- 100%TE
- Lower overall yields

#2: **Materials**

- CVs>10%,
- Lower TEs with Nano (common trend)

#3: **µBGA aperture shapes**

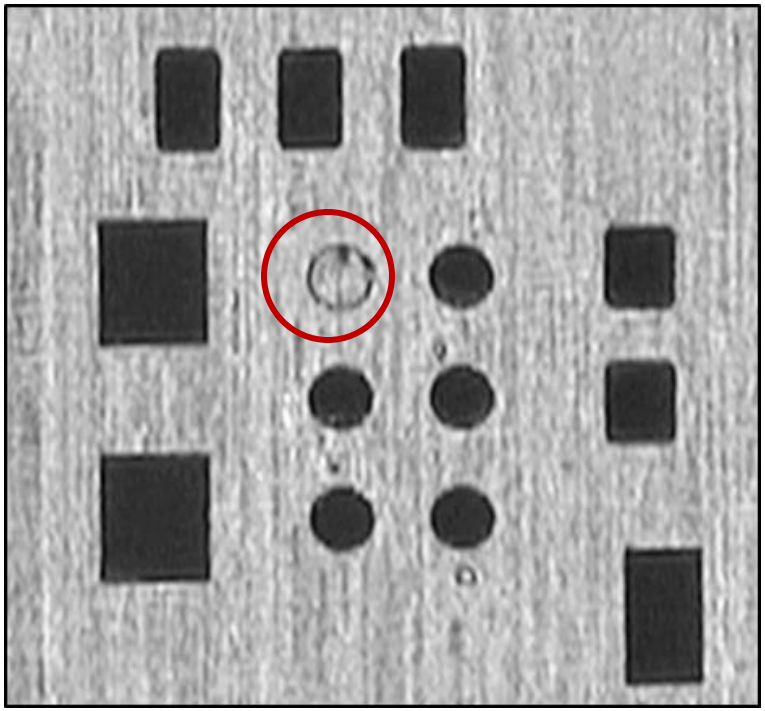
- Print quality of square apertures on round NSMD pads
- Reflow properties of square apertures

#4: **Stencil under wipe frequency**

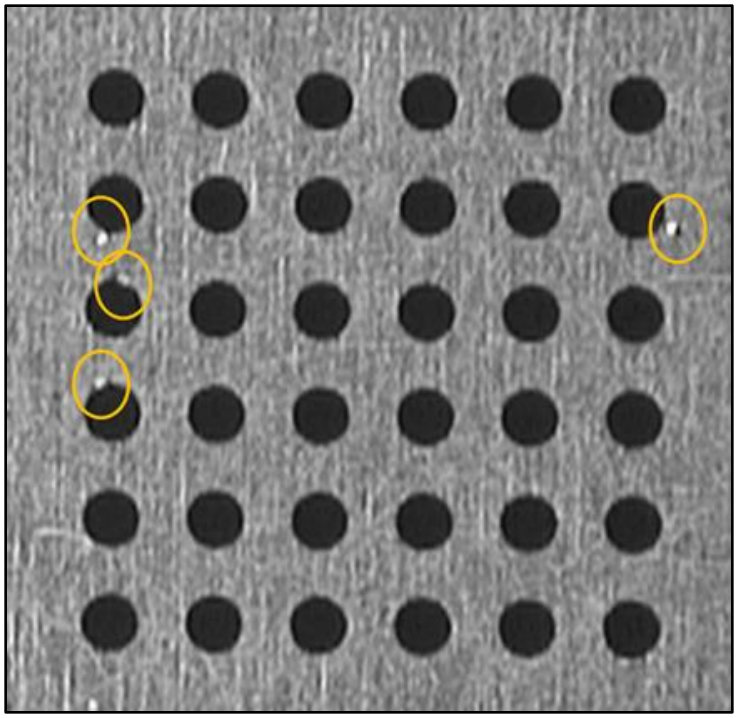
- Improved performance at 10X wipe intervals

Blocked Aperture & 100% TE

Root cause is in manufacturing issues

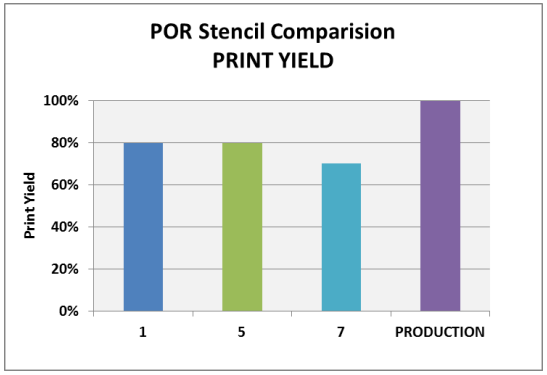


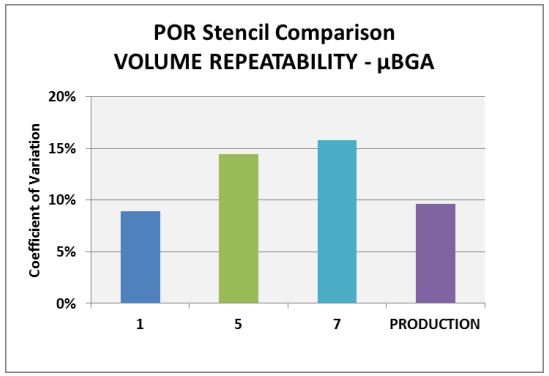
Stencil #4, missing aperture

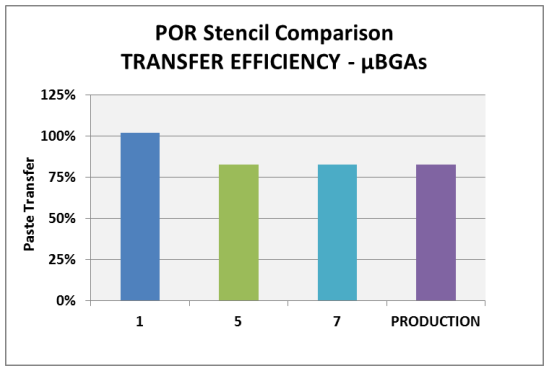


Stencil #1, bumps on PCB side

Exp #5:Lower Yields, Higher CVs







Compared results from experiment with current production stencil & data

Stencils 1, 5, 7 and PRODUCTION all cut under identical parameter sets

Print Yields

- Production stencil 100%, test stencils 80% or less

Volume Repeatability

- Production <10%, test stencils near 15%
- Test stencil #1 disqualified due to PCB side topography

Transfer Efficiency

- Typically around 80% for this aperture
- Test stencil #1already discussed

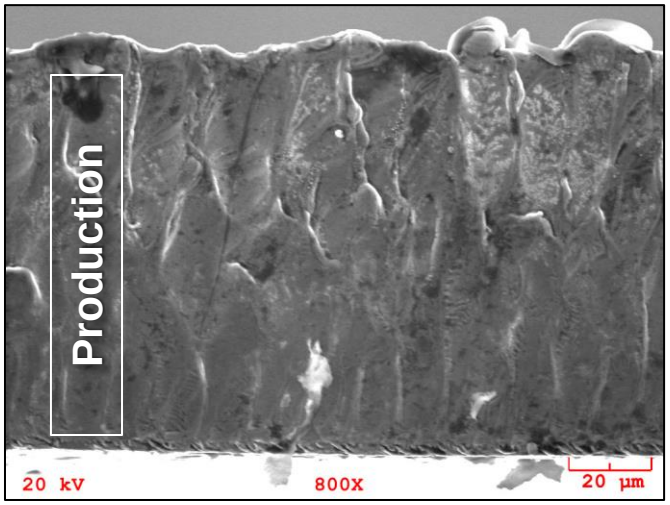
Test Stencils 1, 5, 7 cut at different facility than PRODUCTION stencil

Stencil Wall SEMs

Revealed major differences in wall finishes

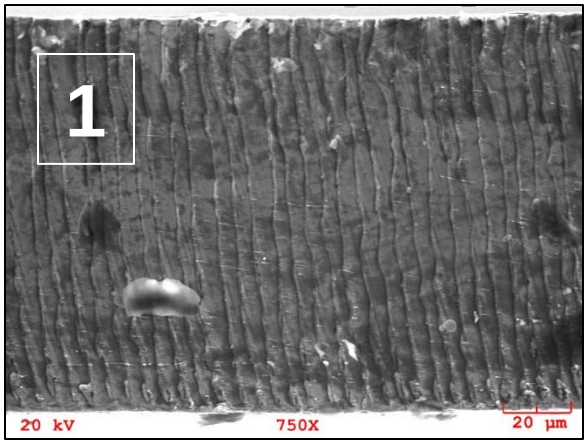
All stencils cut using Process of Record parameters

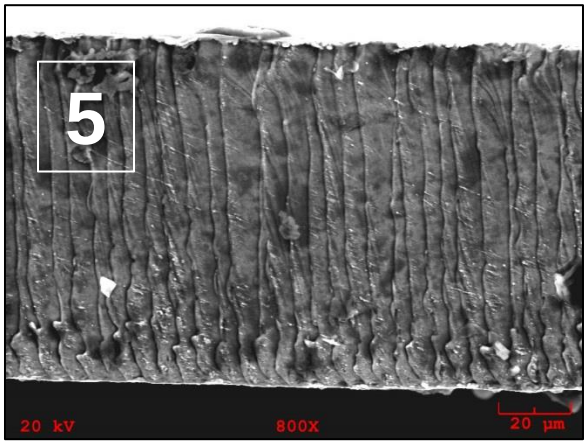
Cut at usual facility:

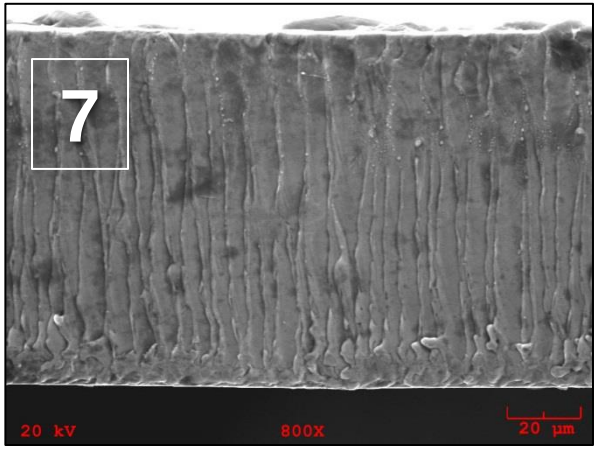


Conclusion:
Considerable differences in the outputs of the two different facilities

Cut at alternate facility:







Investigation Progress

#1: **Laser cutting parameters**

- ☑ Missing aperture
- ☑ 100%TE
- ☑ Lower overall yields

#2: **Materials**

- ☑ CVs>10%,
- ☐ Lower TEs with Nano (common trend) – partial info available

#3: **µBGA aperture shapes**

- ☐ Print quality of square apertures on round NSMD pads – no info
- ☐ Reflow properties of square deposits – no info yet

#4: **Stencil under wipe frequency**

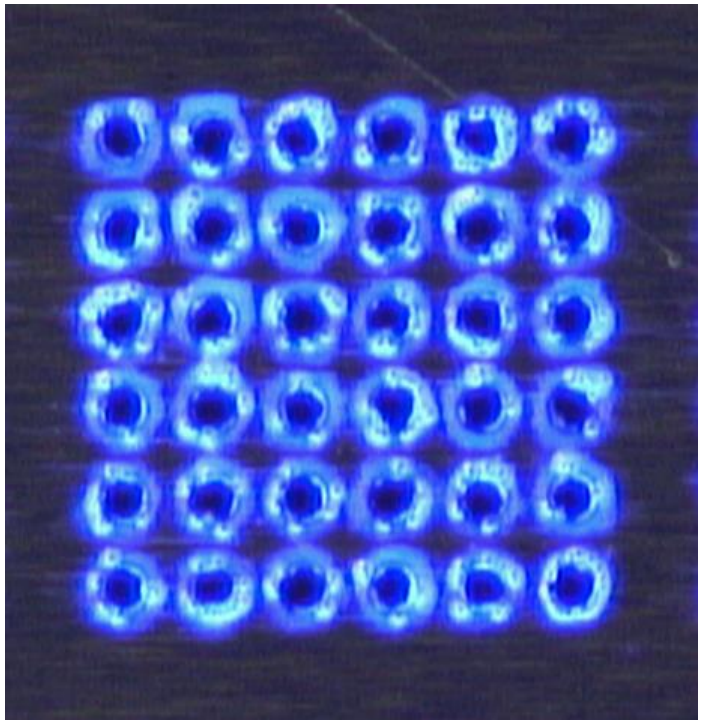
- ☐ Improved performance at 10X wipe intervals – *additional experiment completed!*

New Experiment

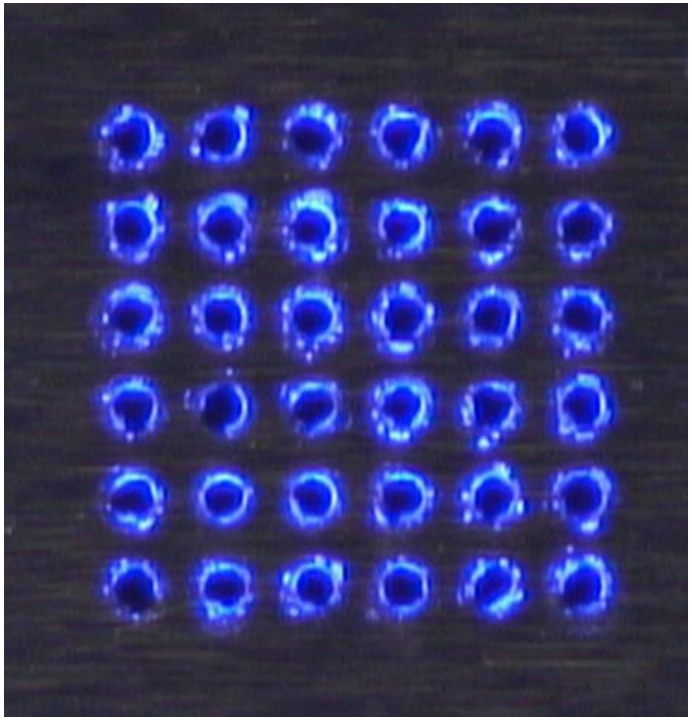
- Nanocoat ½ of stencil's print area
- Get UV tracer dye added to solder paste
- Run head-to-head comparisons off of same print
- Photodocument differences with digital microscope & UV flashlight
- ***Share at SMTAI!!!***

0.5mm BGA

10 prints with no wipe



Untreated

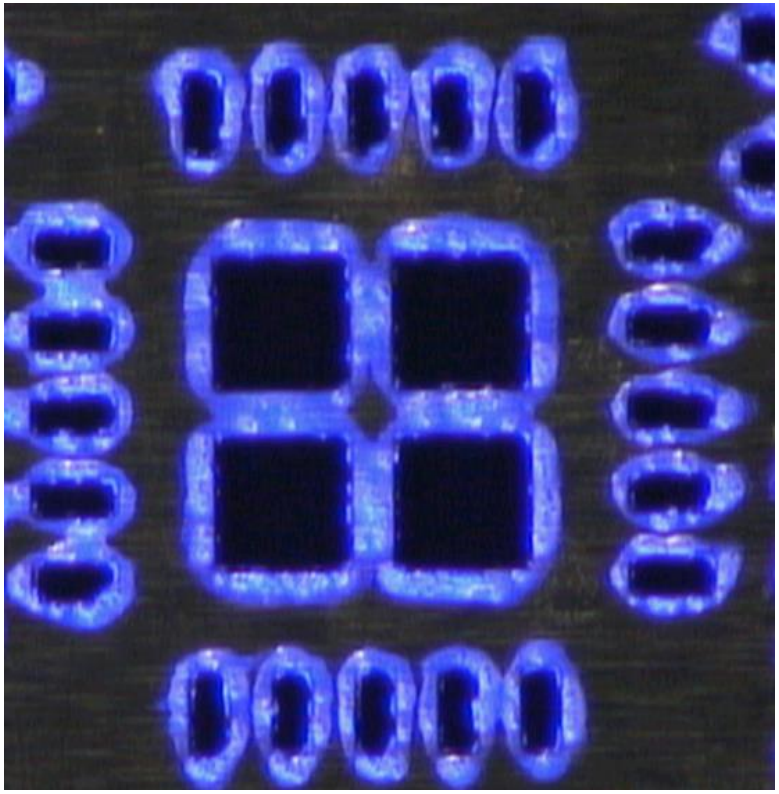


Nanocoated

Detailed information to be published at APEX 2014

QFN

10 prints with no wipe



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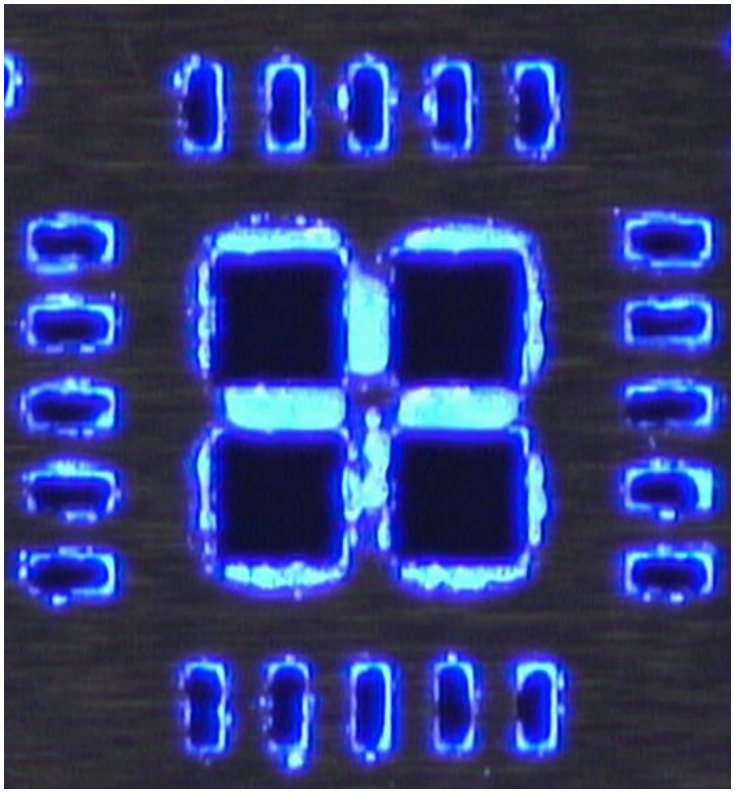
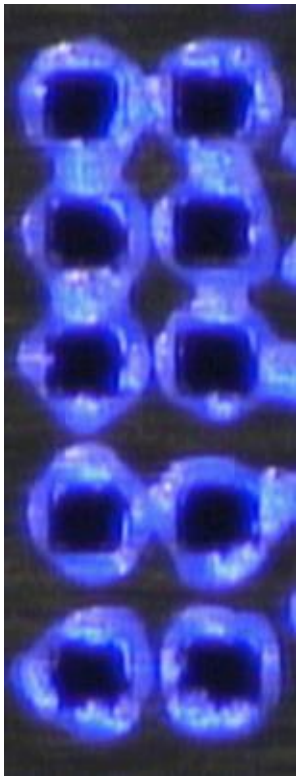


Nanocoated

Detailed information to be published at APEX 2014

0201s

10 prints with no wipe



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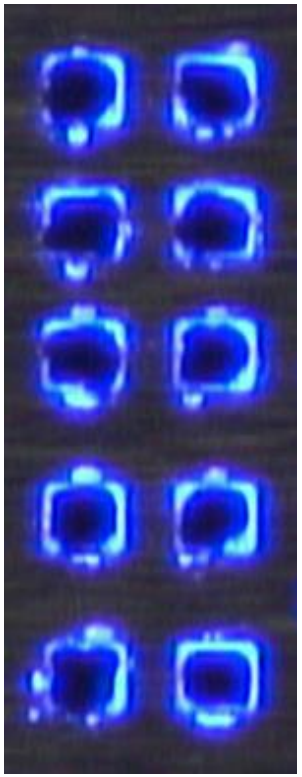
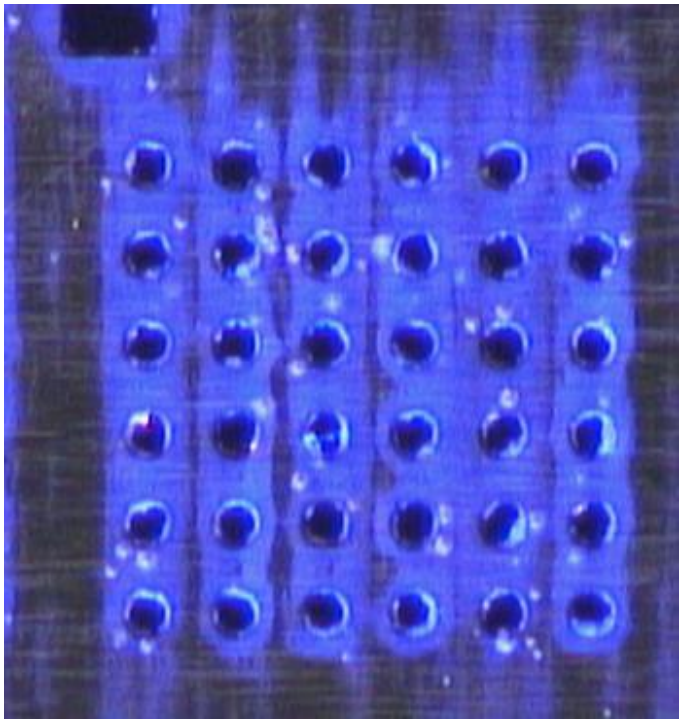


Nanocoated

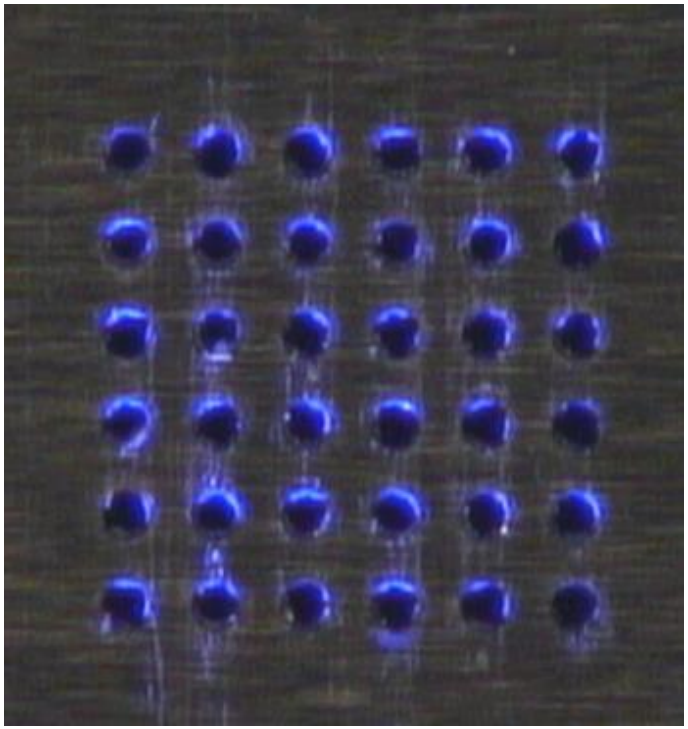
Detailed information to be published at APEX 2014

0.5mm BGA

10 prints with1 wipe (vac-dry-vac)



Untreated

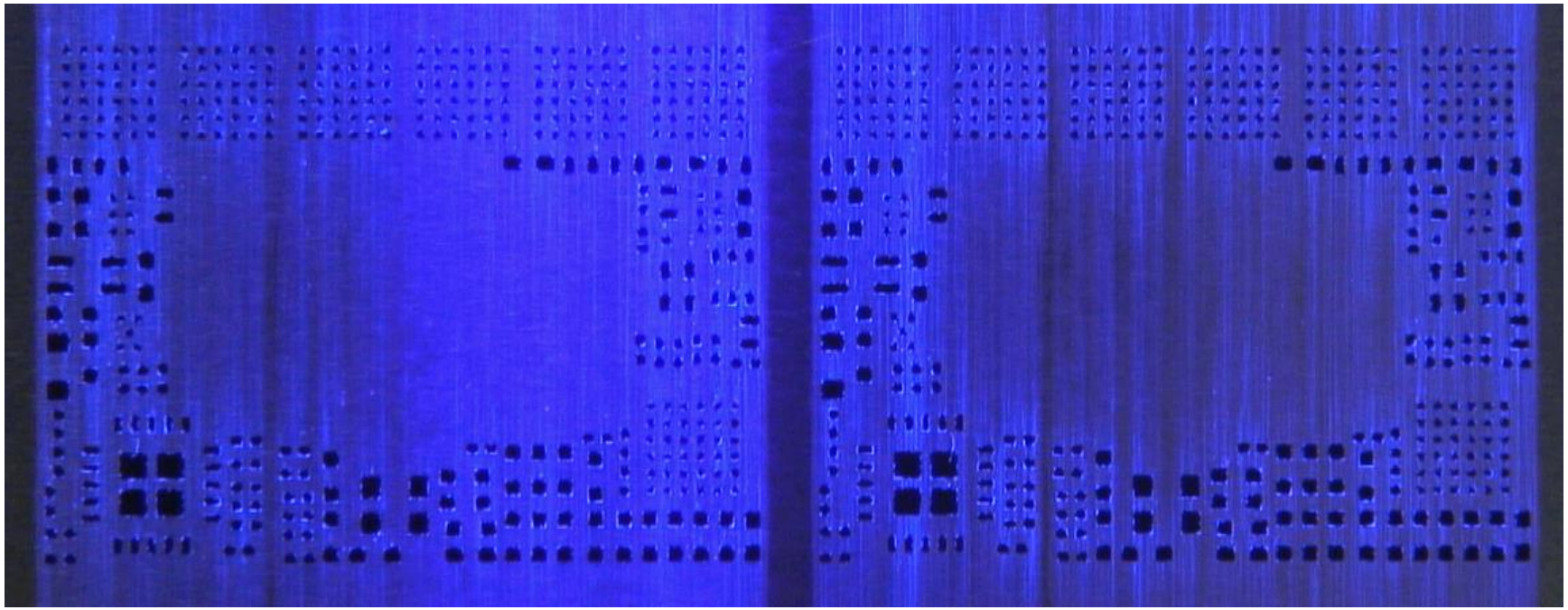


Nanocoated

Nanocoating and under wiping subject of ongoing research

Stencil Underside

10 prints with1 wipe (vac-dry-vac) every print

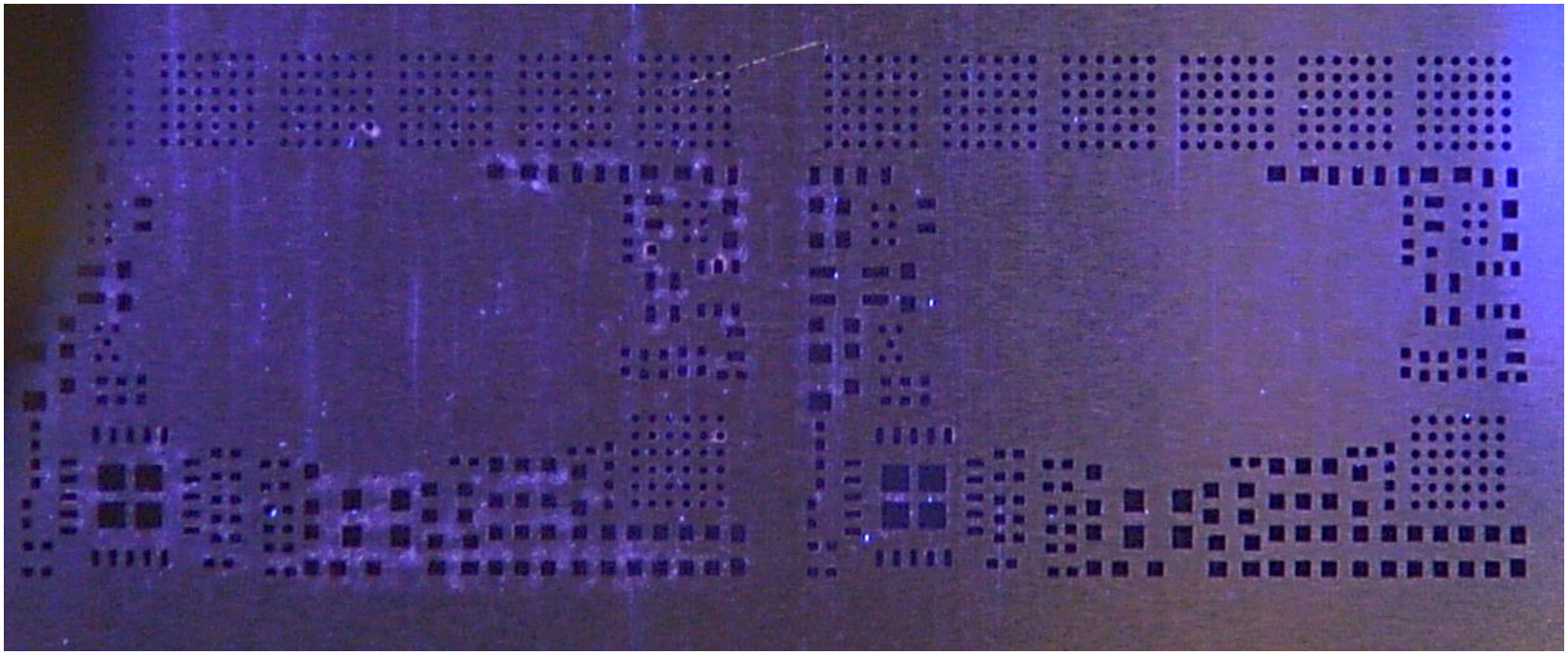


Untreated **Nanocoated**

Nanocoated area shows less buildup on stencil surface and in apertures

Stencil Underside

10 prints with1 wipe (vac-dry-vac) every print
Followed by solvent underwipe



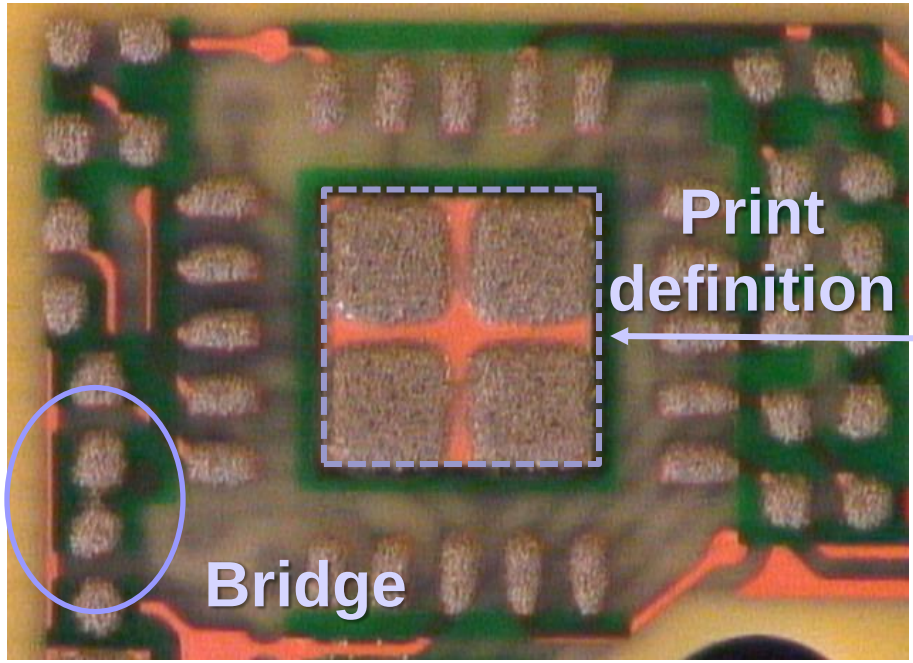
Untreated **Nanocoated**

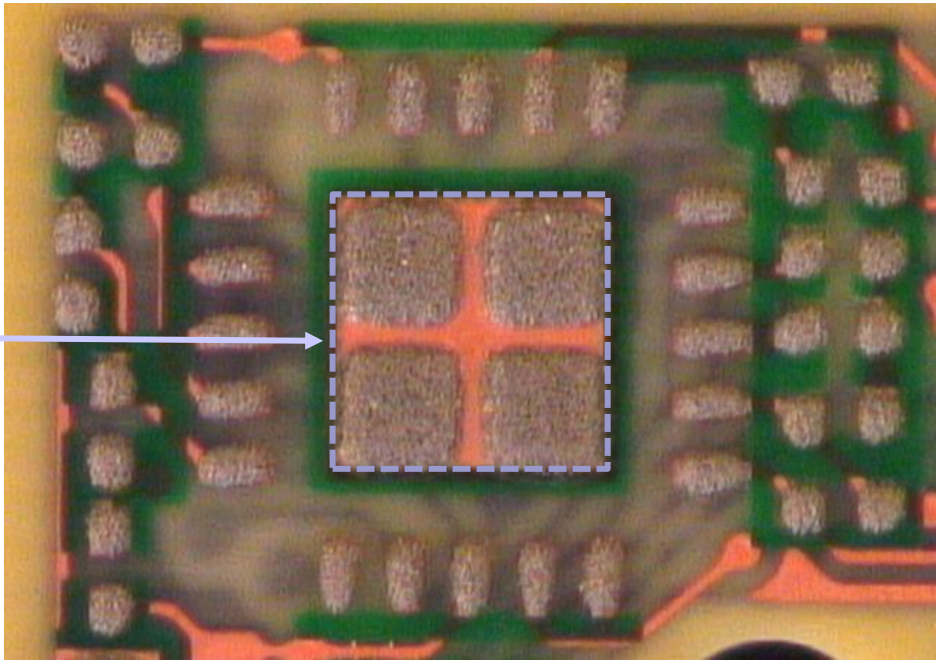
Solvent wipe is more effective on nanocoated area

Print Definition Improvements

QFN and 0201s after 10 prints with no wipe

Same board, same stencil, same print stroke





No Nano

Nano

Results & Discussion

- Experiments 1 & 2 had noise induced by stencil manufacturing process; results did not correlate with prior test results or production data.
  - Trend on nanocoating was clear in both experiments:
    - **Treated stencils performed better than untreated**
    - **Stencils treated with Nano2 performed better than those treated with Nano1**
- Experiment 3 agreed with published data that square BGA apertures release better than round
  - Tested on SMD pads only
  - Change not implemented in production yet
  - Open questions on reflow compatibility

Results & Discussion

- Experiment 4 showed better print quality with extended underwipe intervals
  - Better yields, better volume repeatability
    - **Both generations of nanocoating improved print quality at extended intervals**
    - **Nano2 overall better than Nano1**
  - Spurred new test to visualize flux-stencil interaction
- New Experiment (to be documented in upcoming paper)
  - Nanocoated area limited flux spread considerable more than untreated area
  - Nanocoated area cleaned more easily than untreated area
  - Limiting flux flow under stencil limits sphere flow under stencil and improves gasketing
  - Visible improvement in print definition on QFN and 0201

Thank You!

Questions?

Chrys Shea
chrys@sheaengineering.com

Ray Whittier
rwhittier@vicr.com