Can Nano-Coatings Really Improve Stencil Performance?

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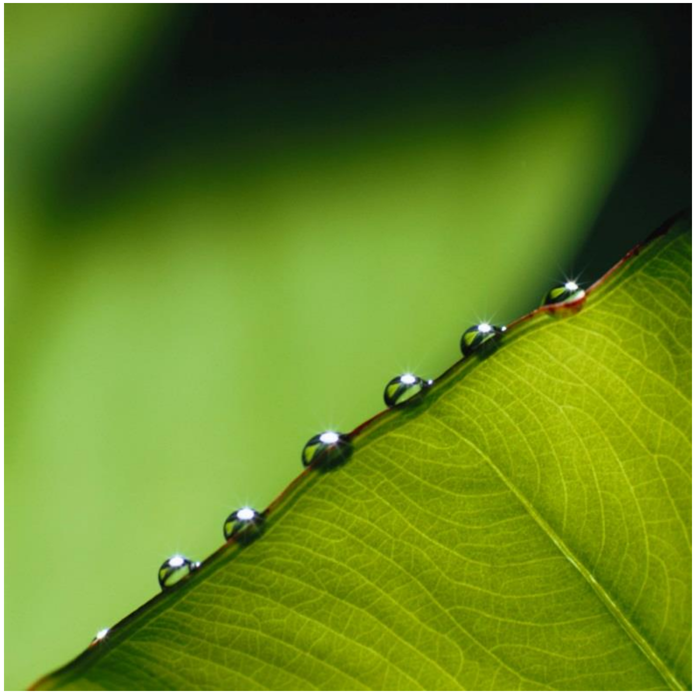
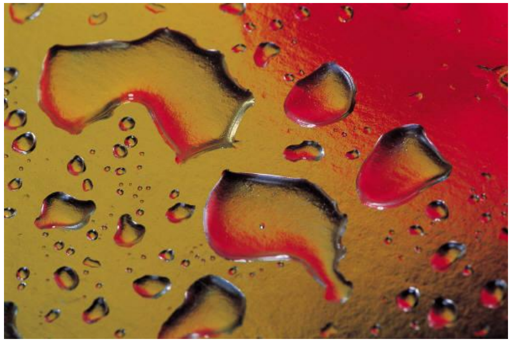
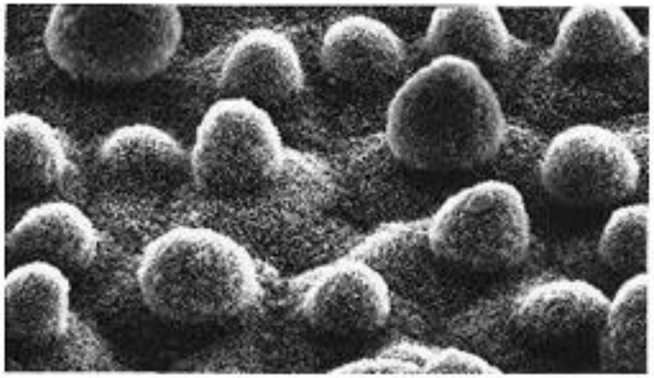
Outline/Agenda

- Introduction
- Claims & questions about coatings
- Experiment design
- Results of coating performance
- Return on investment
- Benefits and negative impact
- Q & A



Natural Superhydrophobic Surfaces



- **Lotus leaf is superhydrophobic.**
  - Water beads up on surface.
  - Waxy hydrophobic material.
  - Nanoscale and microscale structure.

Properties of Nano-Coatings

- Hydrophobic
- Oleophobic
- “Fluxophobic”

Claims About Nano-Coatings

- Reduced underside cleaning
- Reduced bridging
- Improved solder paste release
- Improved yield

Questions About Nano-Coatings

- How to measure performance?
- How robust are the coatings?
- What is the return on investment?
- What are the hidden benefits?
- What are the negative impacts?

Test Procedure

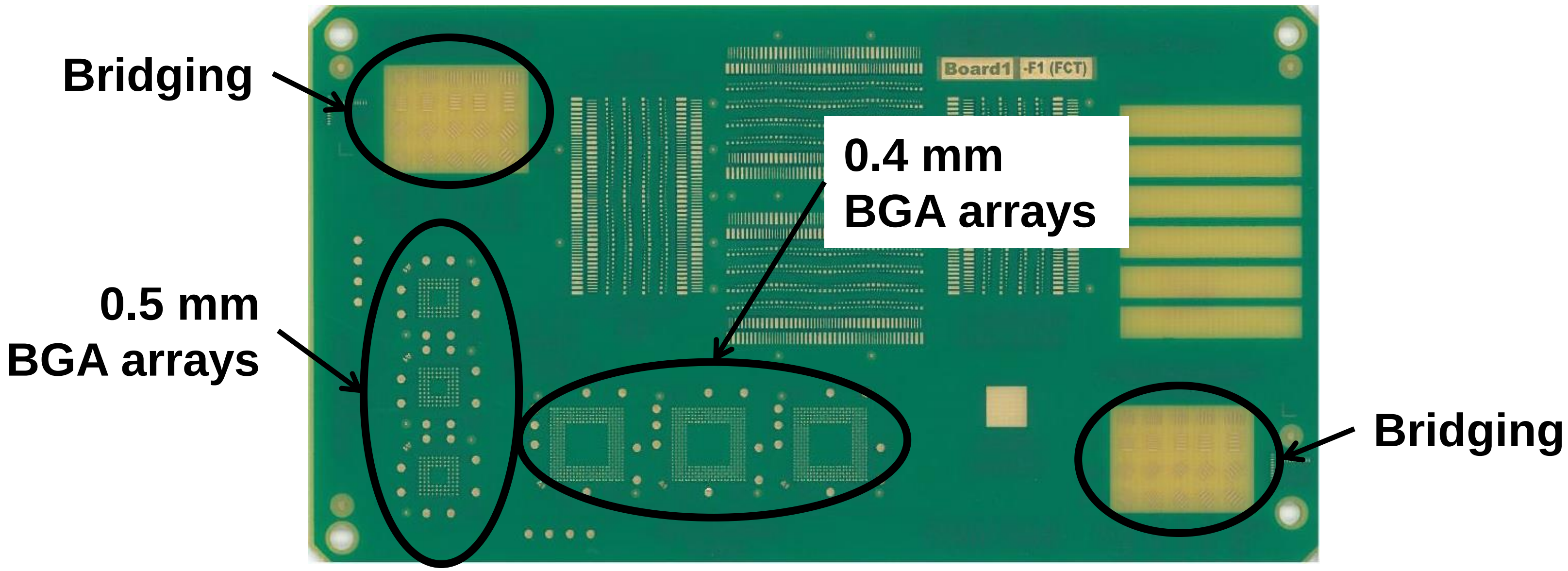
1. Stencils made and nano-coated
2. Measured contact angle, abrasion and chemical resistance
3. Printed 20 boards with no cleaning
4. Measured solder paste volume
5. Inspected bridging areas
6. Inspected underside of stencils

Experiment
Equipment and Materials

- **Essemtec printer**
  - 20 mm/sec, 0.18 Kg/cm, 1.5 mm/sec
- **ASC International SPI**
  - AP212 with VM150 sensor
- **Solder paste**
  - No clean, lead free, SAC305 Type 3
- **Stencils, 304 SS**
  - 0.005" (127 microns) thick Datum PhD

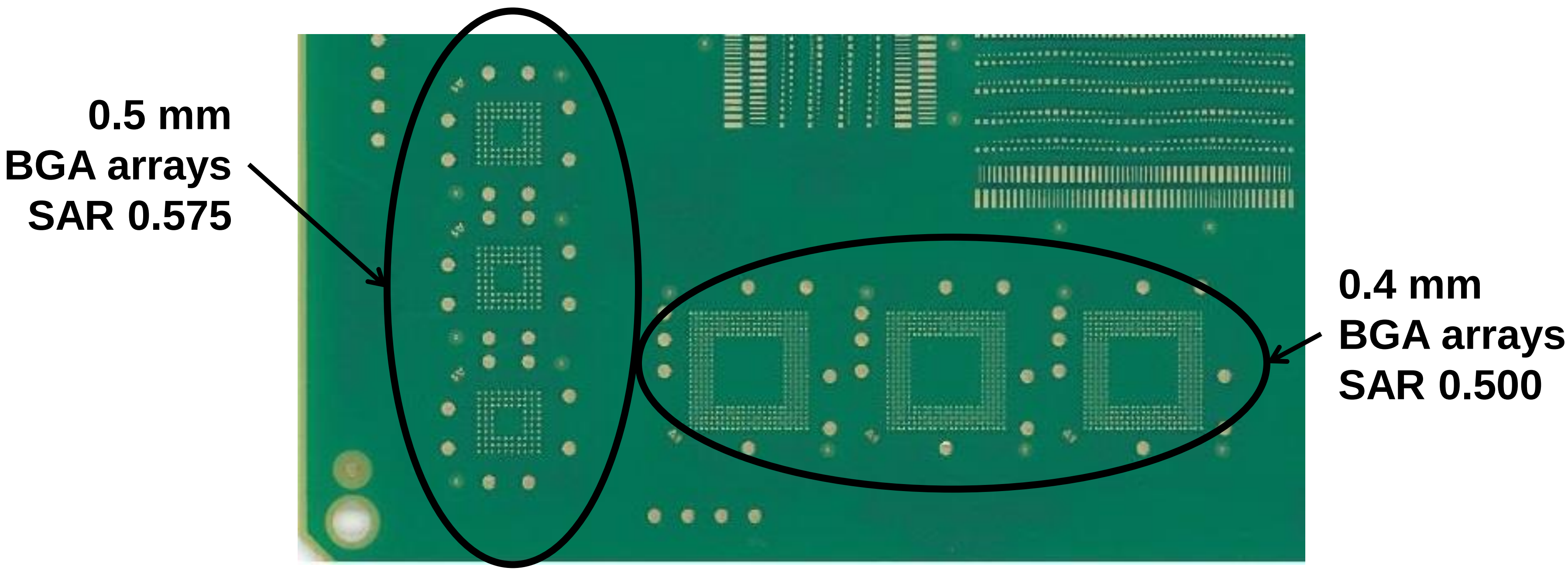
Experiment
Equipment and Materials

- **Test Board F1**
  - Paste release in 6 BGAs
  - Bridging in 2 areas



Experiment
Equipment and Materials

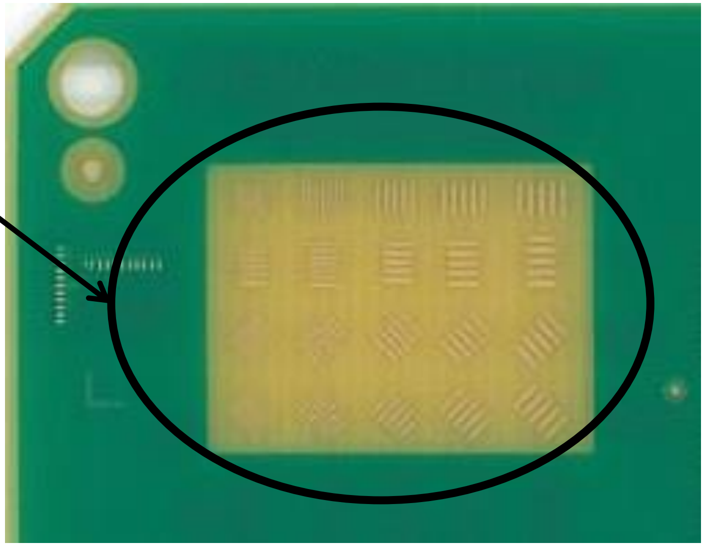
- **BGA areas**
  - 3 x 0.5 mm arrays, SAR 0.575, 252 pads/board
  - 3 x 0.4 mm arrays, SAR 0.500, 1080 pads/board



Experiment
Equipment and Materials

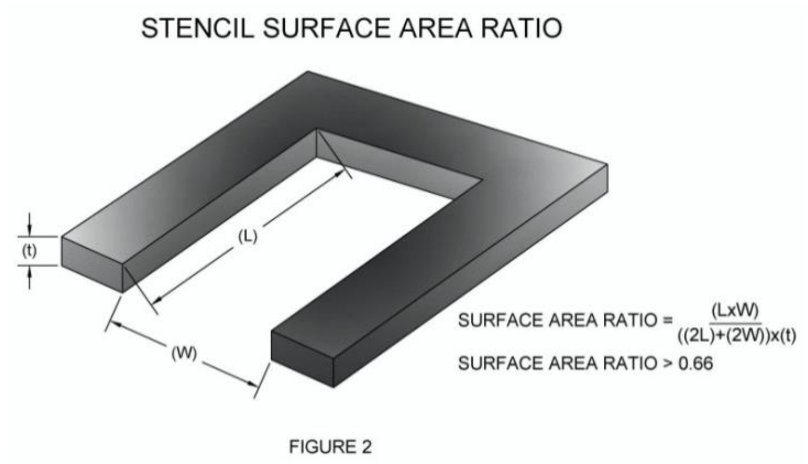
- **Bridging areas (2)**
  - 160 possible bridges per board

Bridging



Experiment
Surface Area Ratio Calculation

- **0.5 mm BGA arrays**
  - Stencil thickness = 5.0 mils (127 µm)
  - Aperture = 11.5 mils (292 µm) square
  - SAR = 0.575
- **0.4 mm BGA arrays**
  - Aperture = 10.0 mils (254 µm) square
  - SAR = 0.500



Experiment
*Surface Area Ratio by Pad

- **0.5 mm BGA arrays**
  - Pad = 9 mils (229 µm) round
  - SAR by pad = 0.275
- **0.4 mm BGA arrays**
  - Pad = 8 mils (203 µm) round
  - SAR by pad = 0.250

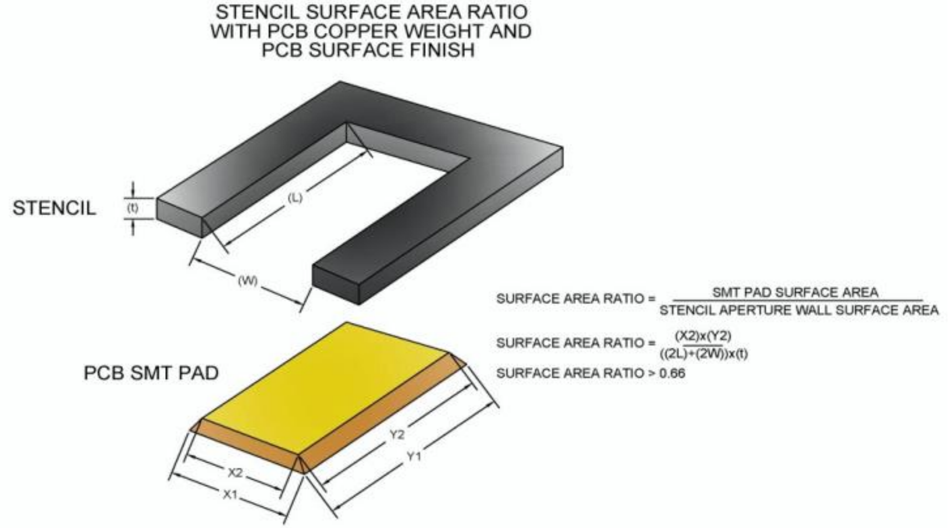
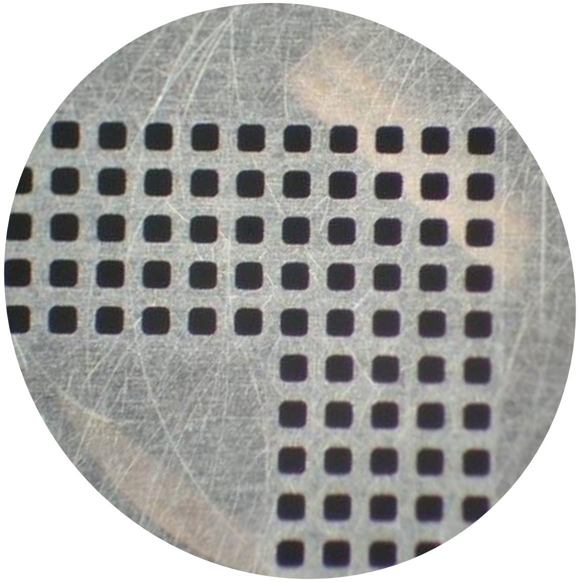


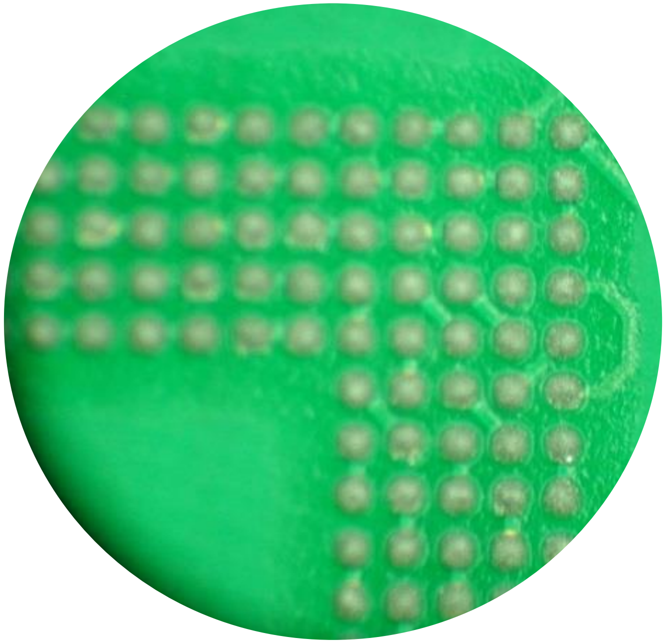
FIGURE 4

*Successful Stencil Printing: Performance is on the Surface
Robert Dervaes, V.P. Technology, FCT Assembly

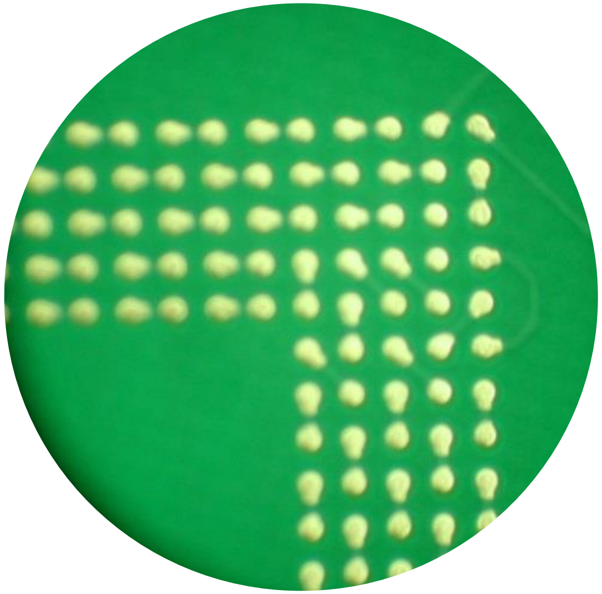
Experiment



Stencil apertures
10.0 mil square
SAR 0.500



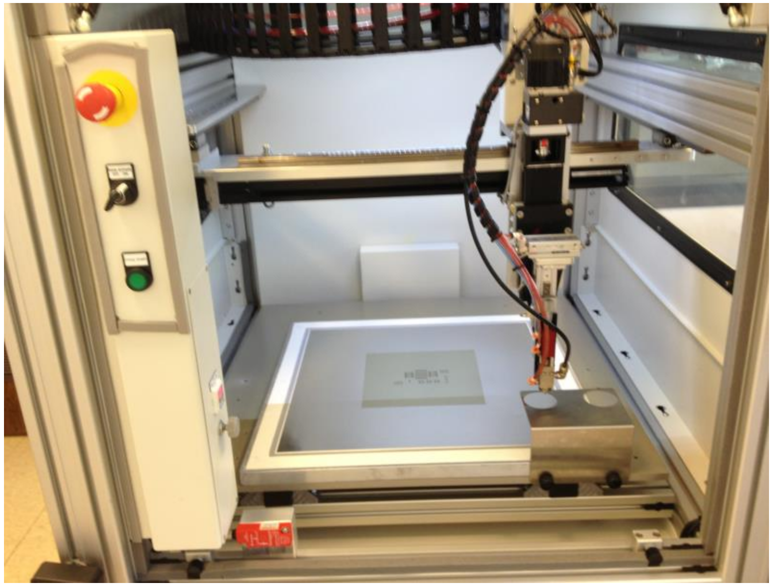
Printed paste



Pads on circuit board
8.0 mil round
SAR 0.250 by pad area

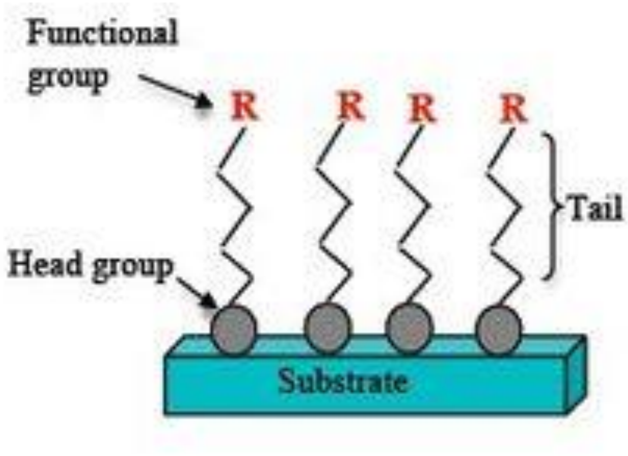
Coating Application

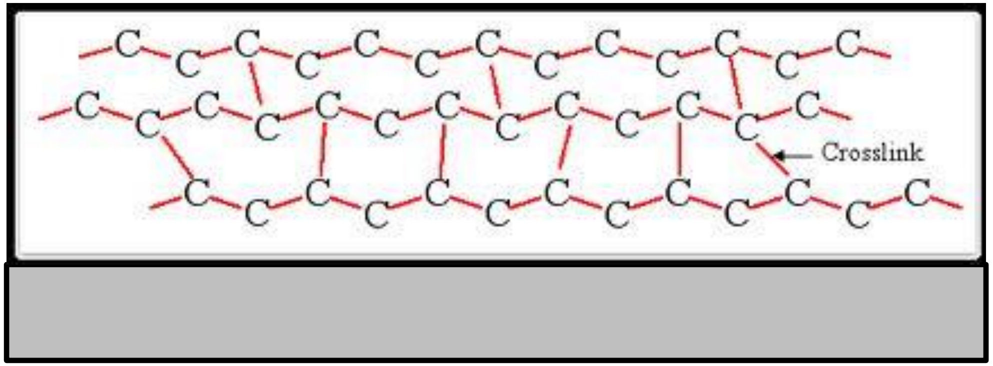
<u>Wipe on</u>
Coating B
Coating C



<u>Spray coat and cure</u>
Coating A
Coating D

Coating Chemistry





Self Assembled Monolayer
Coating B
Coating C

Polymer – Cross Link
Coating A
Coating D

Coating Thickness

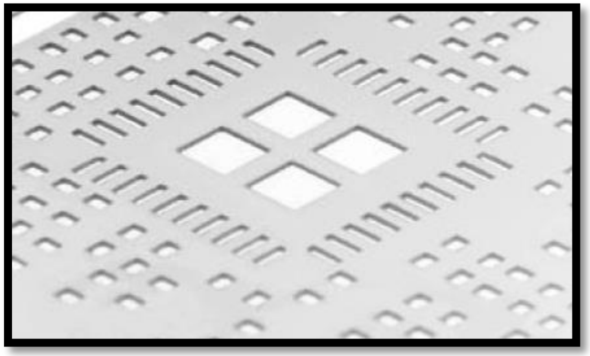
Coating	Thickness
Uncoated	0
Coating A	1000 – 2000 nm (1 – 2 microns)
Coating B	2 – 4 nm
Coating C	2 – 4 nm
Coating D	2000 – 4000 nm (2 – 4 microns)

Questions About Nano-Coatings

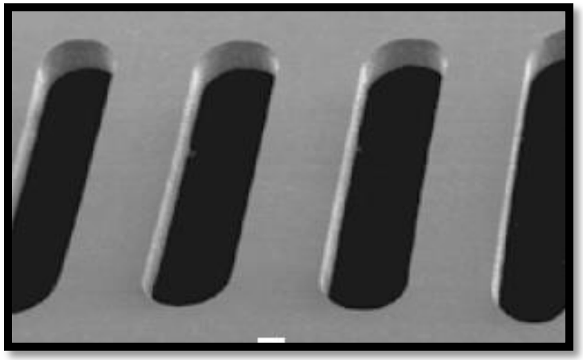
- **How to measure performance?**
- How robust are the coatings?
- What is the return on investment?
- What are the hidden benefits?
- What are the negative impacts?

Performance Measurement

- **SURFACE FUNCTION**
  - **Contact angle**
  - Underside cleaning
  - Bridging

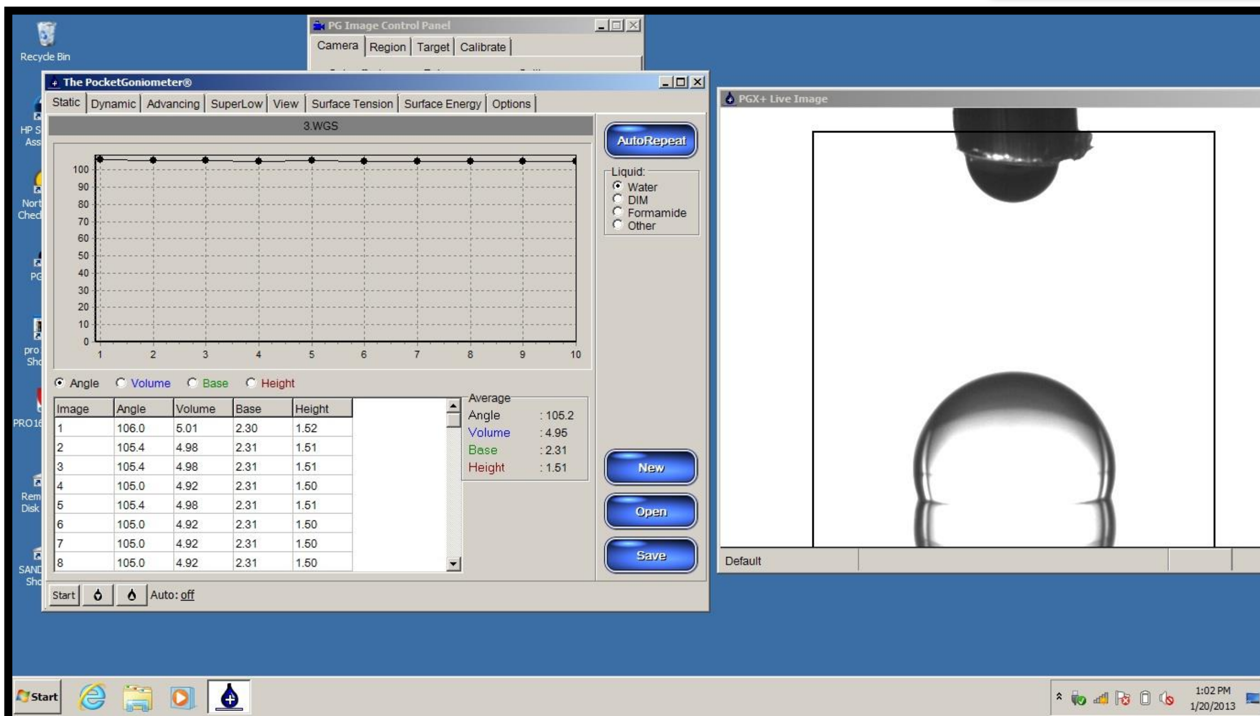


- **APERTURE FUNCTION**
  - Solder paste release
  - Transfer efficiency



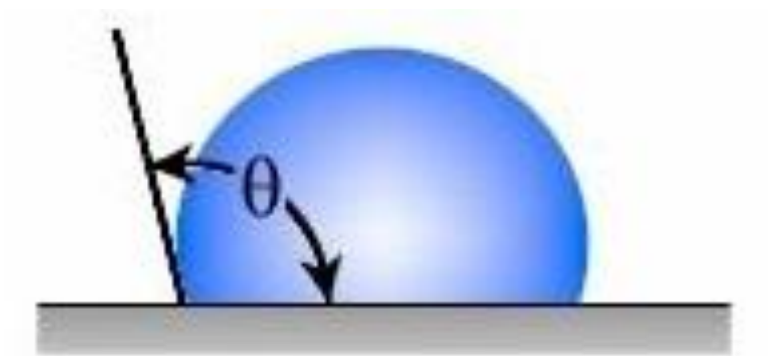
How to Measure Contact Angle

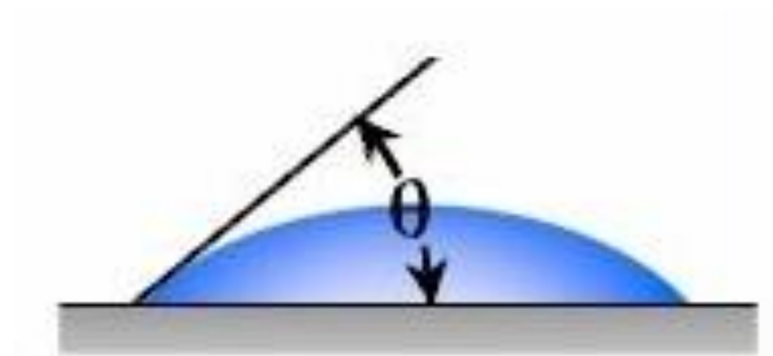
GONIOMETER



Surface Function - Contact Angle

Hydrophobic Surface		**Hydrophilic Surface**
High	**Contact Angle**	Low
Poor	**Adhesiveness**	Good
Poor	**Wettability**	Good
Low	**Surface Energy**	High





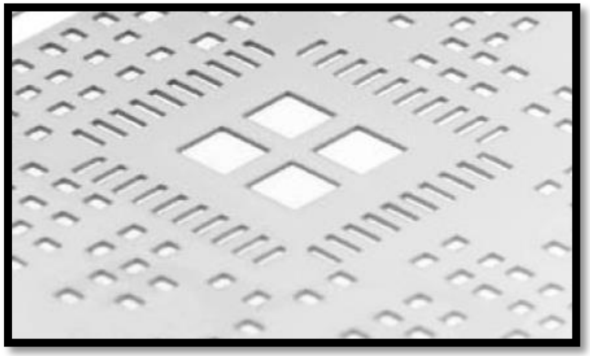
Surface Function – Contact Angle

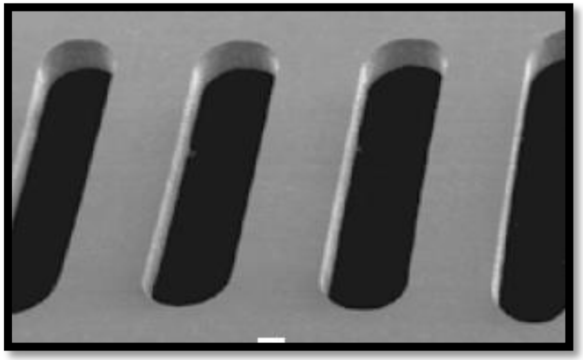
Coating	CA Water	CA n-Hexadecane
Uncoated	54	9
Coating A	103	60
Coating B*	101	66
Coating C*	109	70
Coating D	105	64

***Inconsistent performance lot to lot**

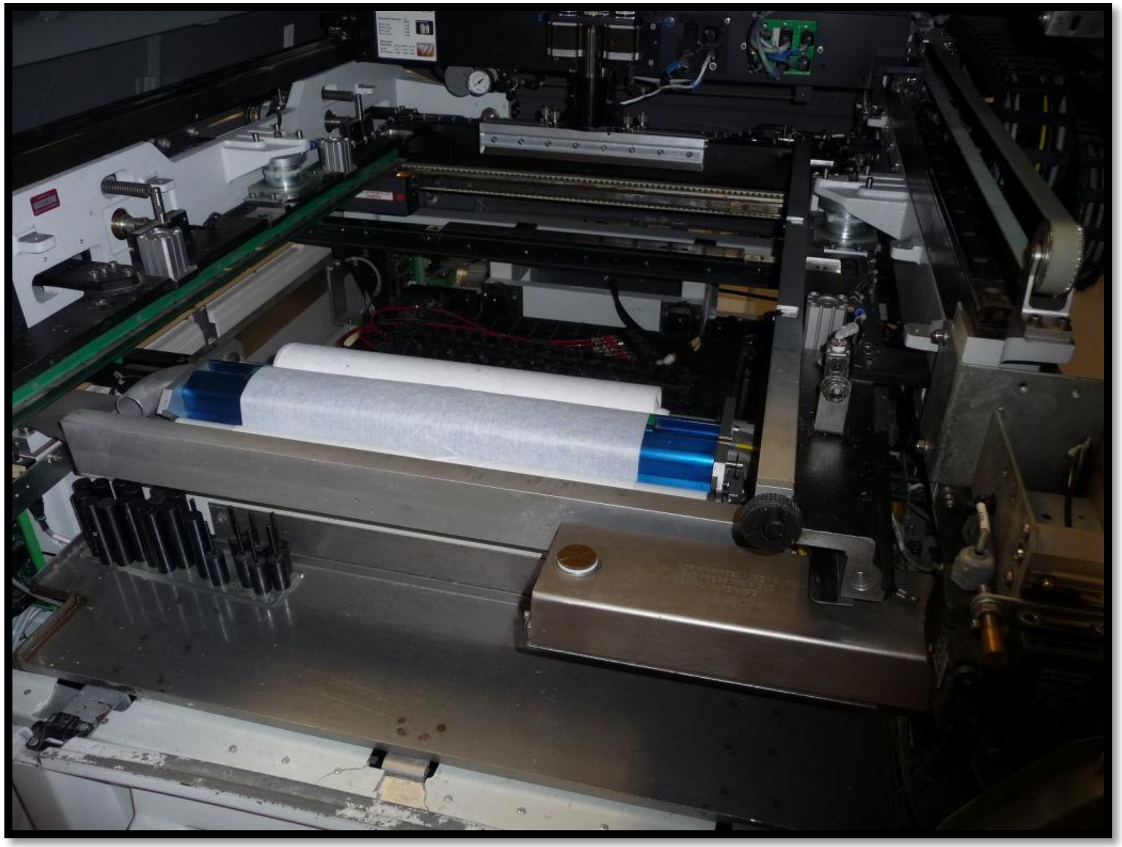
Performance Measurement

- **SURFACE FUNCTION**
  - Contact angle
  - **Underside cleaning**
  - **Bridging**
- **APERTURE FUNCTION**
  - Solder paste release
  - Transfer efficiency

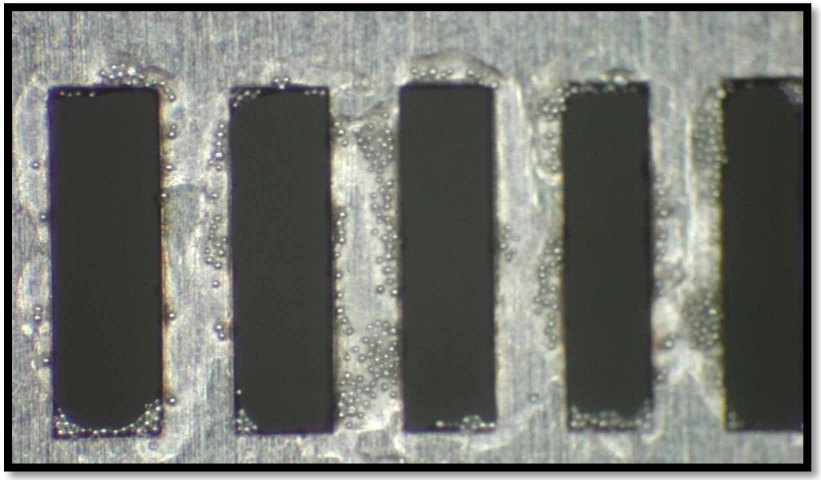




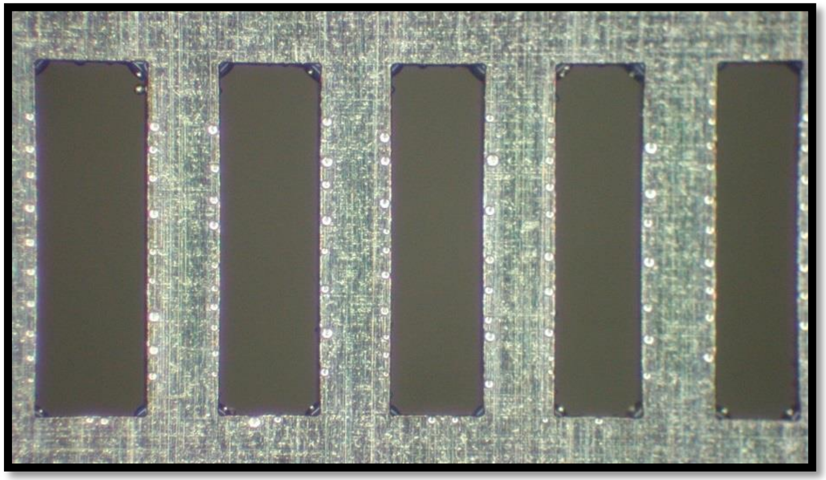
Surface Function – Underside Cleaning



Surface Function – Underside Cleaning



Uncoated stencil

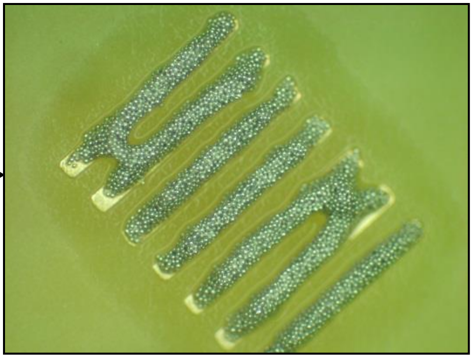


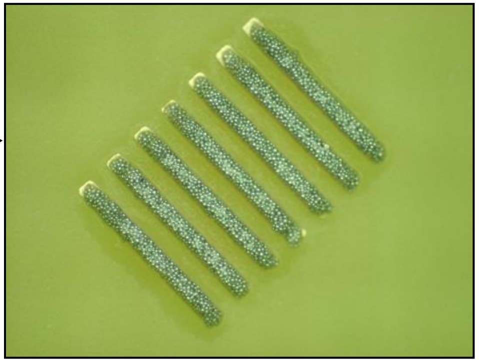
Nano-coated stencil
Coatings A, B, C, D

After 20 prints with no underside cleaning

Surface Function – Bridging

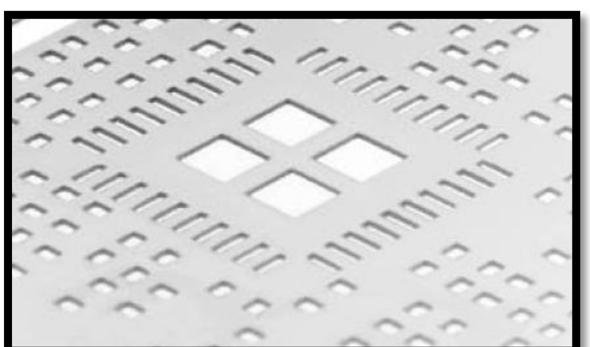
Coating	Bridging	Profile Shape
Uncoated	174	Deteriorates
Coating A	0	Consistent
Coating B	2	Consistent
Coating C	0	Consistent
Coating D	0	Consistent



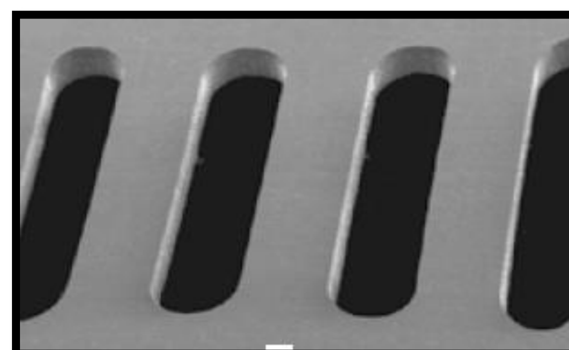


Performance Measurement

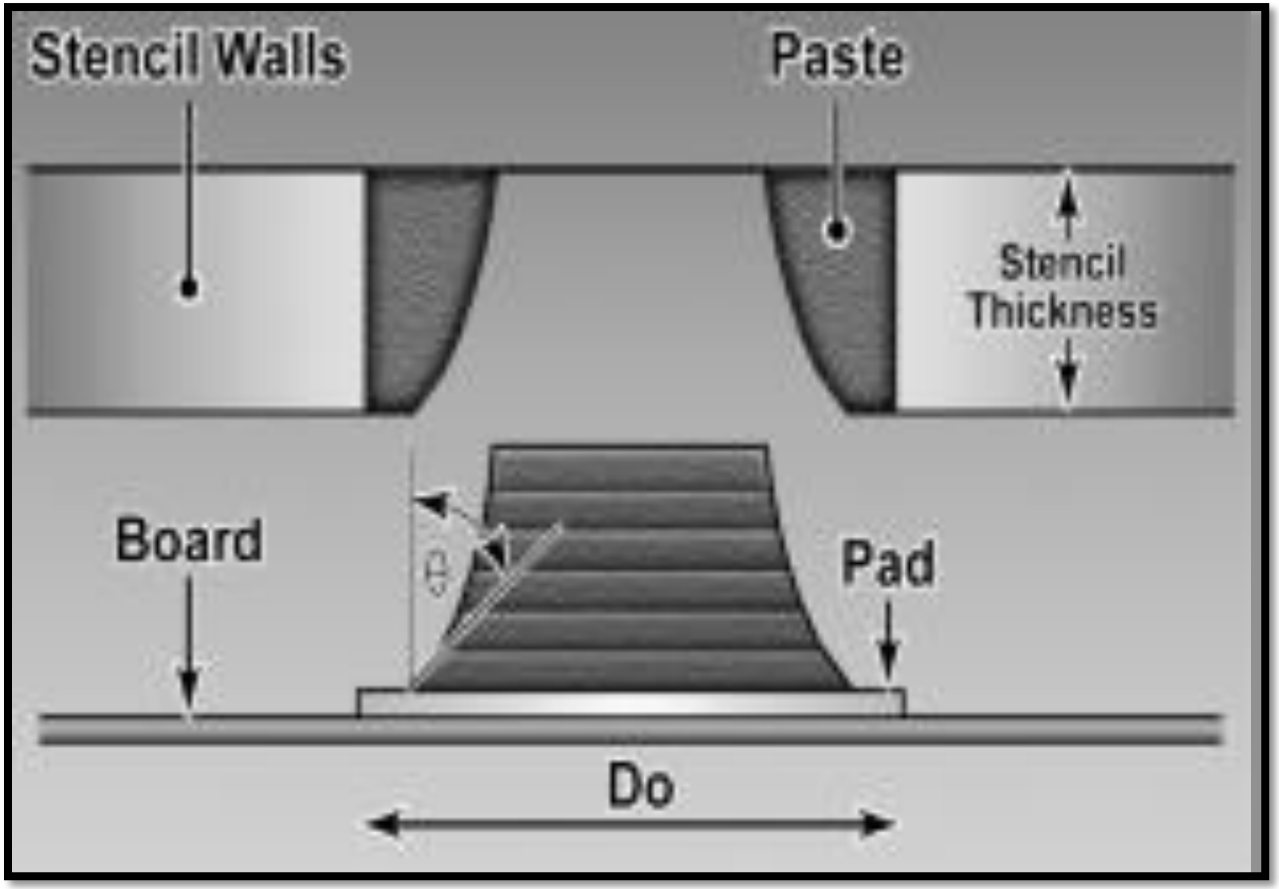
- **SURFACE FUNCTION**
  - Contact angle
  - Underside cleaning
  - Bridging



- **APERTURE FUNCTION**
  - **Solder paste release**
  - **Transfer efficiency**

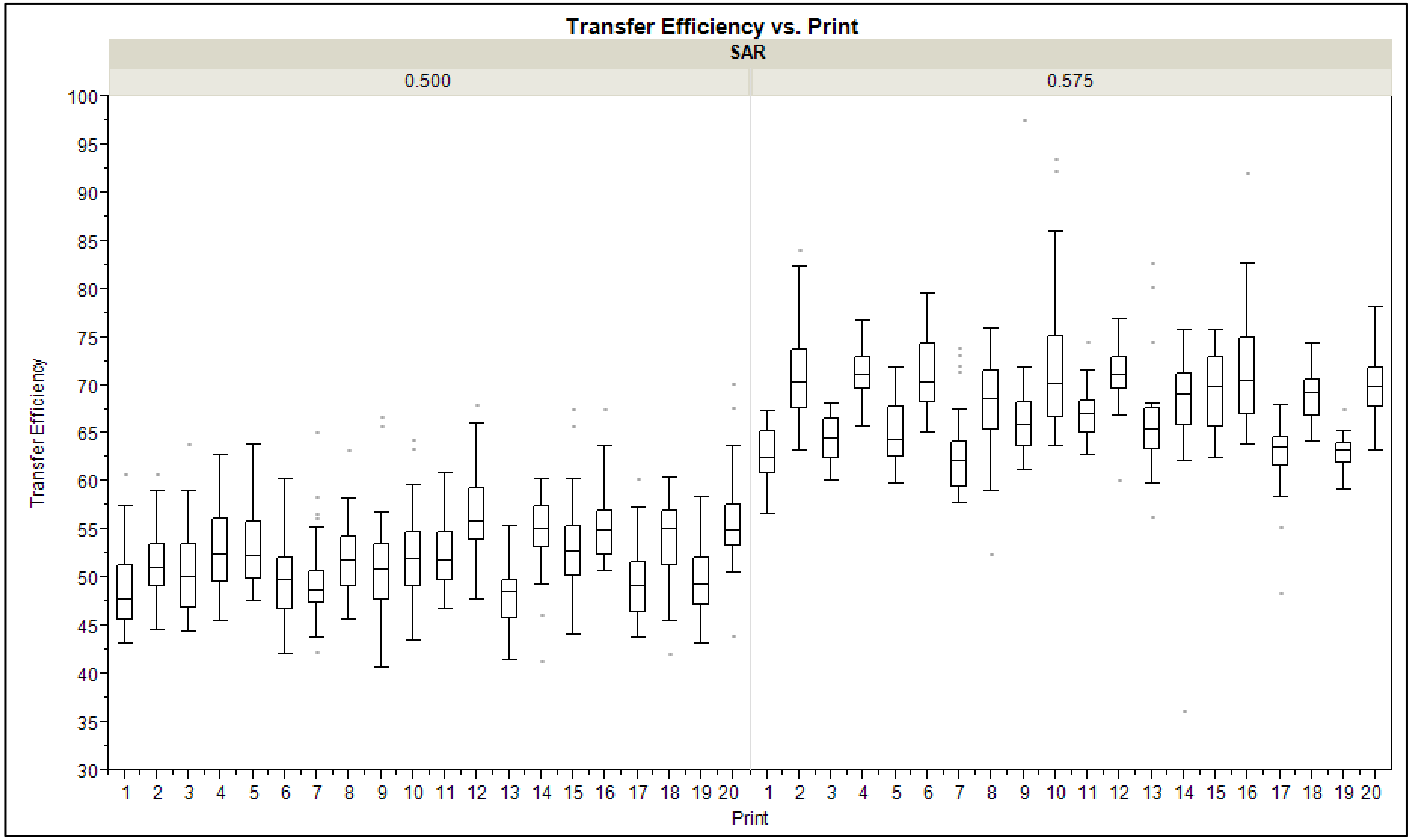


Aperture Function – Solder Paste Release



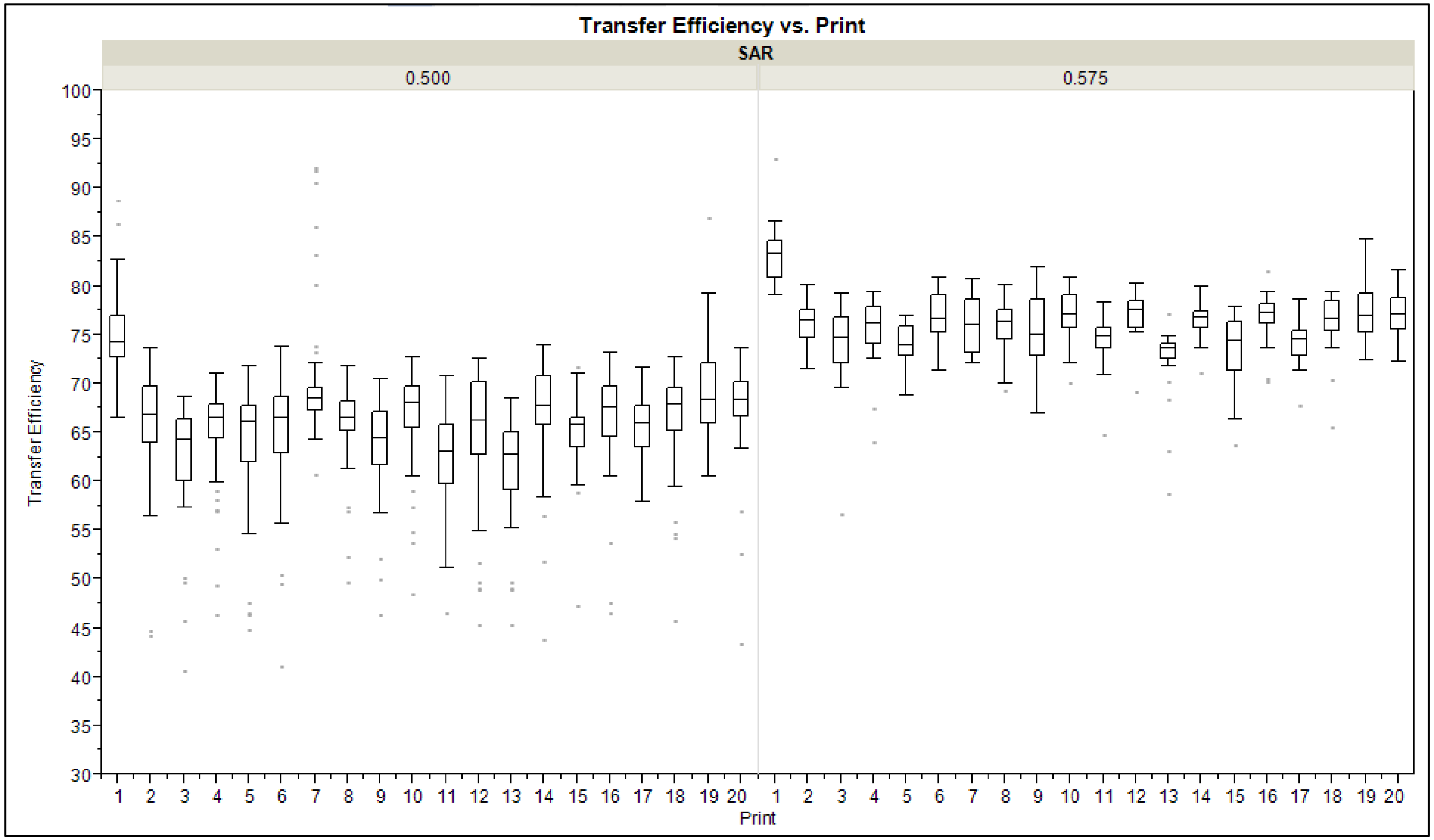
Journal of SMT Volume 16 Issue 1, 2003. REAL TIME VISUALIZATION AND PREDICTION OF SOLDER PASTE FLOW IN THE CIRCUIT BOARD PRINT OPERATION. Dr. Gerald Pham-Van-Diep, Srinivasa Aravamudhan, and Frank Andres

Aperture Function – Transfer Efficiency



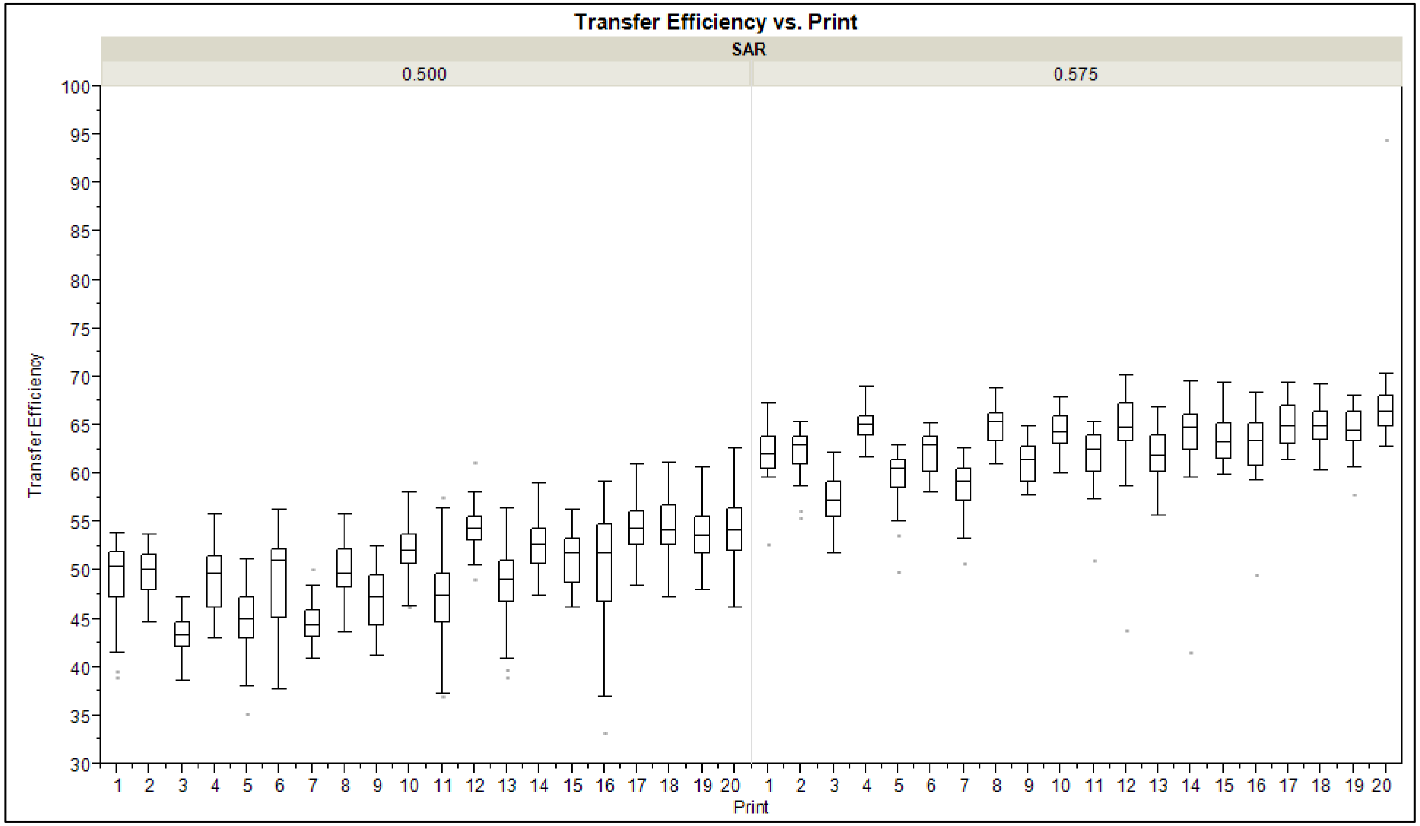
Uncoated: Transfer Efficiency by SAR and Print

Aperture Function – Transfer Efficiency



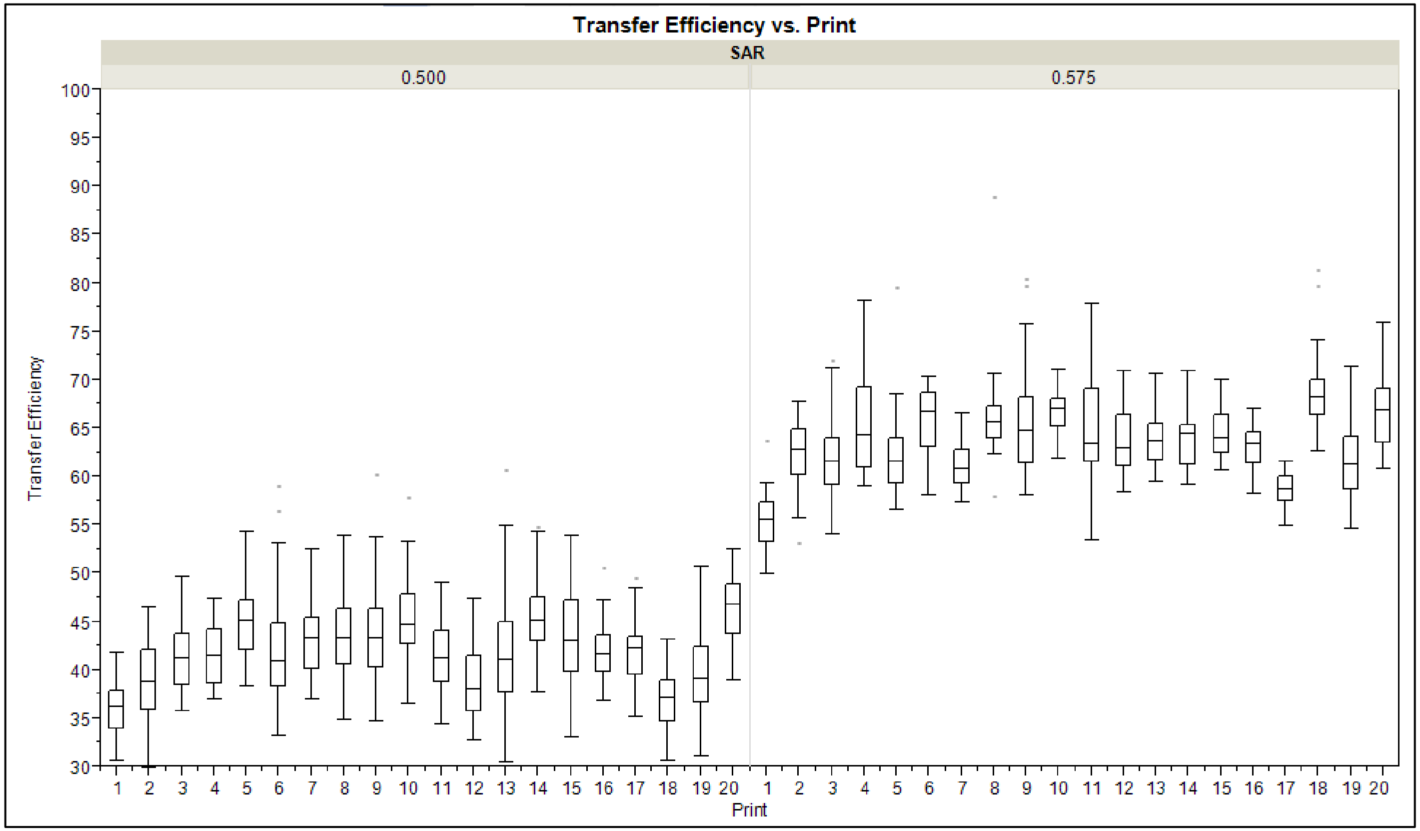
Coating A: Transfer Efficiency by SAR and Print

Aperture Function – Transfer Efficiency



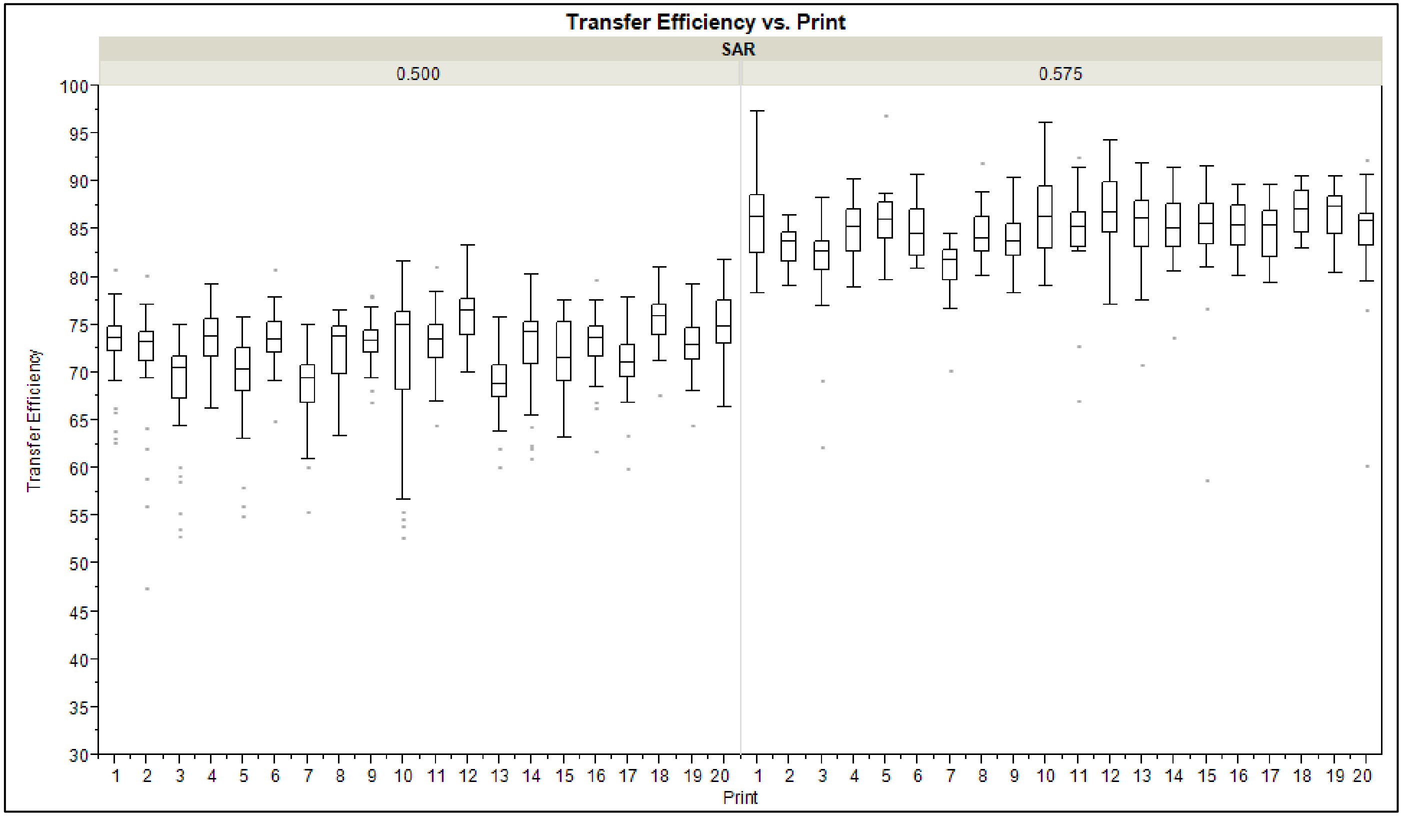
Coating B: Transfer Efficiency by SAR and Print

Aperture Function – Transfer Efficiency



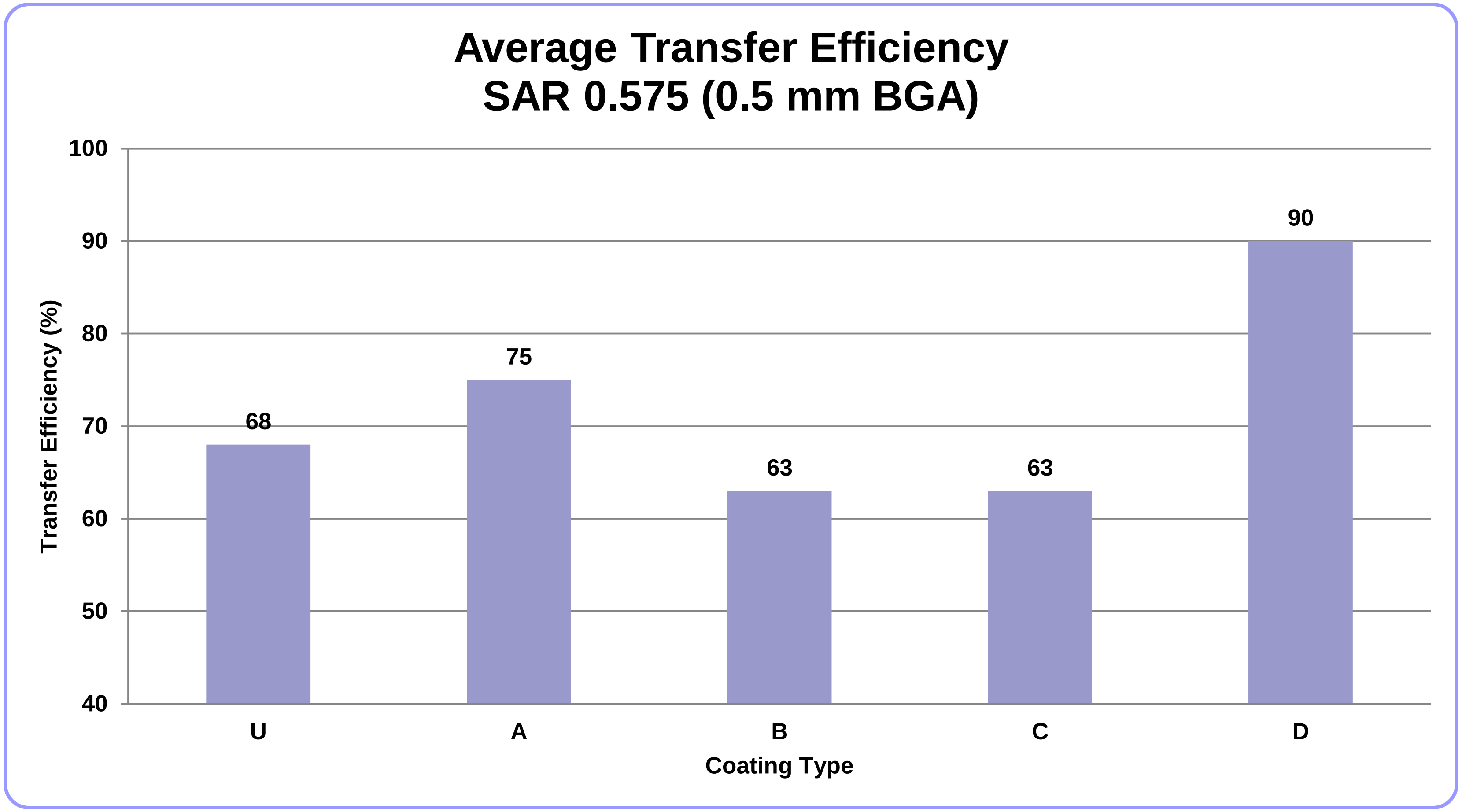
Coating C: Transfer Efficiency by SAR and Print

Aperture Function – Transfer Efficiency

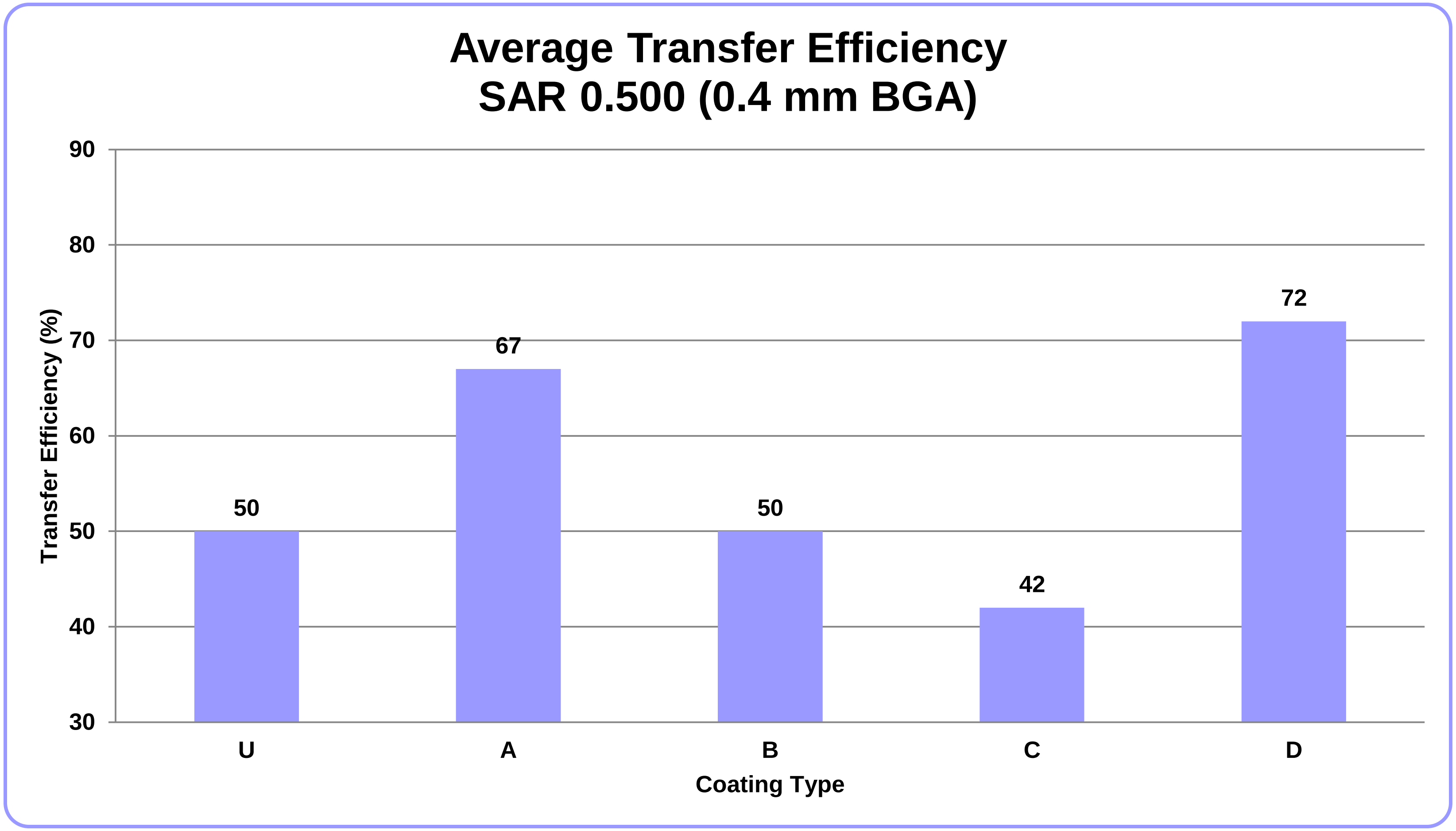


Coating D: Transfer Efficiency by SAR and Print

Aperture Function – Transfer Efficiency



Aperture Function – Transfer Efficiency



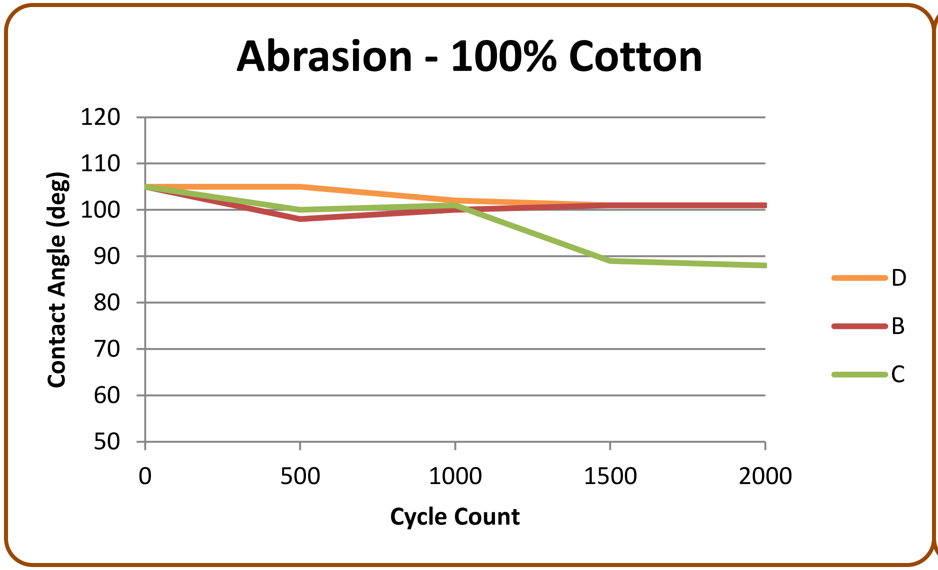
Questions About Nano-Coatings

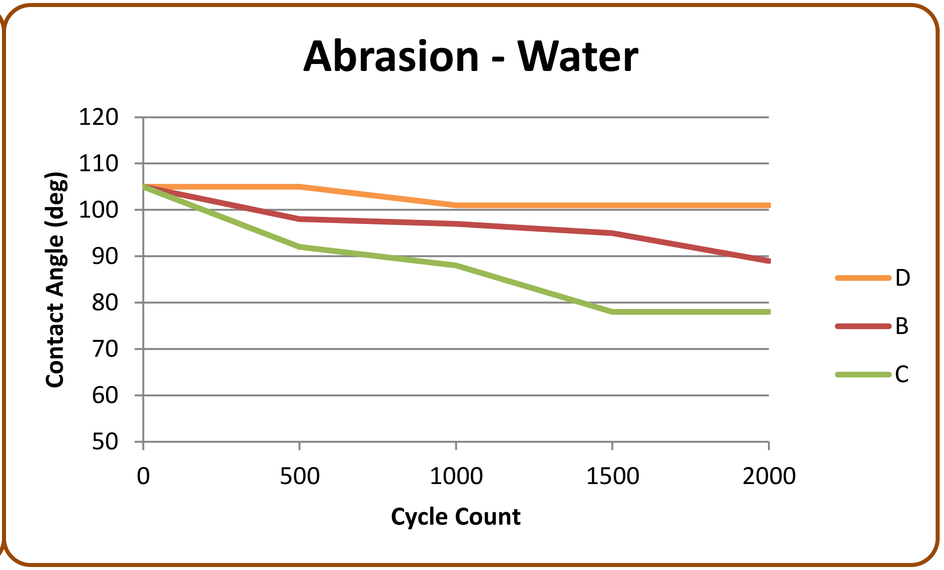
- How to measure performance?
- **How robust are the coatings?**
- What is the return on investment?
- What are the hidden benefits?
- What are the negative impacts?

Robustness of Nano-Coatings

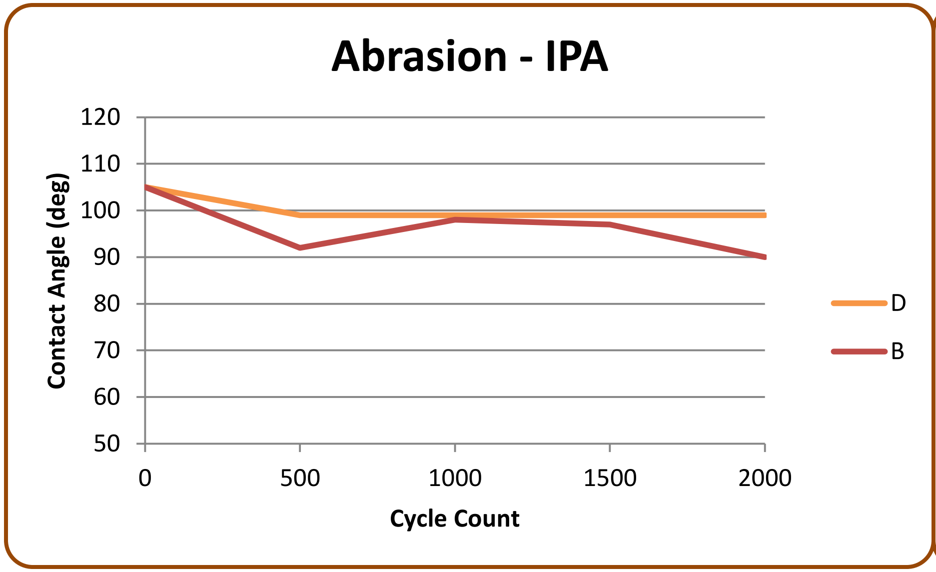
ASTM D2486 Abrasion Tester

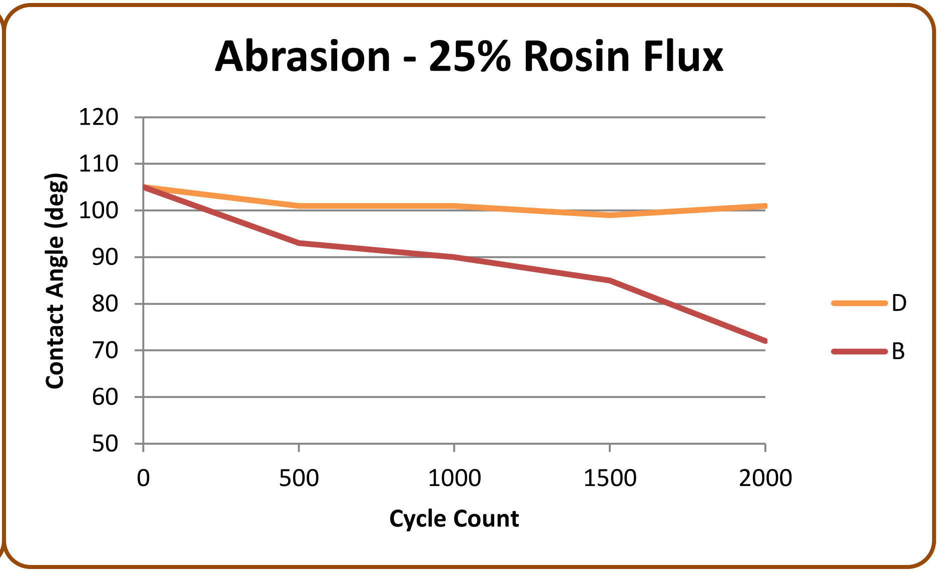
Robustness – Abrasion





Robustness – Abrasion with Chemicals





Questions About Nano-Coatings

- How to measure performance?
- How robust are the coatings?
- **What is the return on investment?**
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- What are the negative impacts?

Return on Investment

Cost of Printing

- Cycle time - productivity
- Cleaning material usage
- Waste of solder paste
- Yield loss
- Rework time and materials

Return on Investment – Cycle Time

Clean Every Print - Uncoated Stencil

- Typical for small SAR <0.55
- Print 1 board every 60-70 seconds

Clean Every 20 Prints - Nano-Coating

- Print 1 board every 25-35 seconds
- Doubles print productivity

Return on Investment – Cleaning Material Usage

Clean Every Print – Uncoated Stencil

- Fabric usage = 3 inch x $0.04/in = $0.12
- Solvent usage = 10 mL x $0.008/mL = $0.08
- Total = $0.20 per circuit board

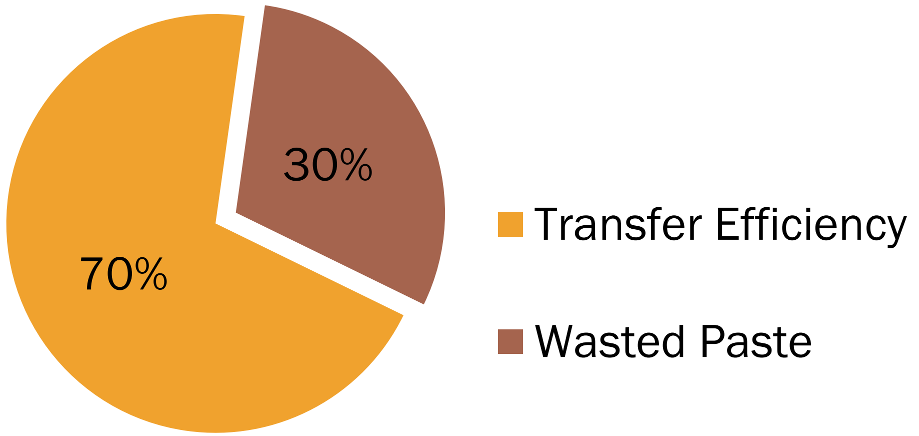
Clean Every 20 Prints - Nano-Coating

- Total = $0.01 per circuit board

Return on Investment – Solder Paste Waste

Uncoated Stencil

- Solder paste is cleaned from stencil bottom
- 0.4 to 0.7 grams of paste cleaned from stencil
- Waste of $0.04 to $0.07 per board



Return on Investment – Solder Paste Waste

Nano-Coated Stencil

- Solder paste is NOT cleaned from stencil bottom
- No waste of solder paste, save $$$

Return on Investment – Yield Loss

Print Issues Account for the Majority of Defects

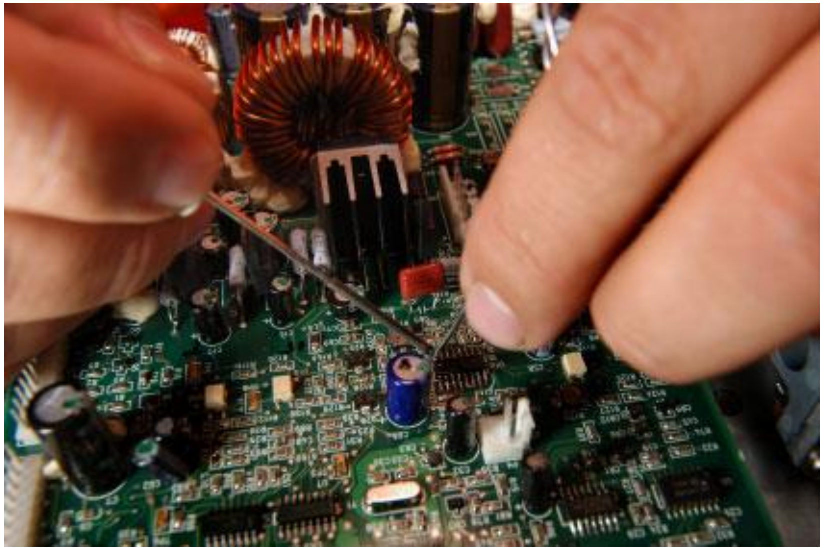
- Nano-coating yield improvements of 10 – 70% reported by Shea, Zubrick, and Whittier*
- Increased TE can improve these defects: insufficient solder, solder balling, graping
- If a circuit board costs $100, preventing scrap pays for most nano-coatings
- Savings in terms of yield is potentially huge

*SMTA 2011, USING SPI TO IMPROVE PRINT YIELDS. C. Shea, M. Zubrick, R. Whittier

Return on Investment – Rework Time and Materials

What is the Impact of Nano-Coatings on Rework?

- First pass yield improvement
- Eliminate rework and improve cycle time
- Save materials and labor cost



Return on Investment

Item	Cost Savings ($)
Improved print cycle time	2 boards per minute instead of 1
Cleaning material savings	Save $0.18 – 0.20 per board
Solder paste waste reduction	Save $0.04 – 0.07 per board
Yield improvement	Savings inestimable
Save on rework costs	Savings inestimable
If Nano-coating costs $40	**ROI is 150 to 180 boards**

Questions About Nano-Coatings

- How to measure performance?
- How robust are the coatings?
- What is the return on investment?
- **What are the hidden benefits?**
- What are the negative impacts?

Hidden Benefits

Benefits	Nano-Coatings Tested
Underside cleaning improved	All coatings – A, B, C, D
Bridging improved	All coatings – A, B, C, D
Transfer efficiency increased	Coatings A and D
Visible on the stencil	Coatings A and D
Re-apply by the user	Coatings B and C

Questions About Nano-Coatings

- How to measure performance?
- How robust are the coatings?
- What is the return on investment?
- What are the hidden benefits?
- **What are the negative impacts?**

Negative Impact

Negative Impacts	Nano-Coatings
Coating wears through abrasion	Coatings B and C
Coating wear not visible	Coatings B and C
Transfer efficiency decreased	Coatings B and C

Conclusions

- Nano-coatings provide benefits, but coatings differ in performance.

- The cost of most coatings is negligible compared to the costs of cleaning materials, solder paste waste, defects, yield loss and rework.

- If you use a nano-coating, be sure to choose the right one.

Thank You for Your Attention!

Any questions?

Tony Lentz
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