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)
  - 144 possible bridges per board

Bridging

Pitch: 8, 12, 16, 18, 20 mils
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

Stencil apertures
10.0 mil square
SAR 0.500

Printed paste

Pads on circuit board
8.0 mil round
Coating Application

Wipe on
Coating B
Coating C

Spray coat and cure
Coating A
Coating D
Coating Chemistry

**Self Assembled Monolayer**
- Coating B
- Coating C

**Polymer – Cross Link**
- Coating A
- Coating D
# Coating Thickness

<table>
<thead>
<tr>
<th>Coating</th>
<th>Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uncoated</td>
<td>0</td>
</tr>
<tr>
<td>Coating A</td>
<td>1000 – 2000 nm (1 – 2 microns)</td>
</tr>
<tr>
<td>Coating B</td>
<td>2 – 4 nm</td>
</tr>
<tr>
<td>Coating C</td>
<td>2 – 4 nm</td>
</tr>
<tr>
<td>Coating D</td>
<td>2000 – 4000 nm (2 – 4 microns)</td>
</tr>
</tbody>
</table>
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

<table>
<thead>
<tr>
<th>Hydrophobic Surface</th>
<th>Hydrophilic Surface</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>Contact Angle</td>
</tr>
<tr>
<td>Poor</td>
<td>Adhesiveness</td>
</tr>
<tr>
<td>Poor</td>
<td>Wettability</td>
</tr>
<tr>
<td>Low</td>
<td>Surface Energy</td>
</tr>
<tr>
<td></td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>Good</td>
</tr>
<tr>
<td></td>
<td>Good</td>
</tr>
<tr>
<td></td>
<td>High</td>
</tr>
</tbody>
</table>
## Surface Function – Contact Angle

<table>
<thead>
<tr>
<th>Coating</th>
<th>CA DI Water</th>
<th>CA n-Hexadecane</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uncoated</td>
<td>54</td>
<td>9</td>
</tr>
<tr>
<td>Coating A</td>
<td>103</td>
<td>60</td>
</tr>
<tr>
<td>Coating B*</td>
<td>101</td>
<td>66</td>
</tr>
<tr>
<td>Coating C*</td>
<td>109</td>
<td>70</td>
</tr>
<tr>
<td>Coating D</td>
<td>105</td>
<td>64</td>
</tr>
</tbody>
</table>

*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

After 20 prints with no underside cleaning

Uncoated stencil

Nano-coated stencil
Coatings A, B, C, D
### Surface Function – Bridging

<table>
<thead>
<tr>
<th>Coating</th>
<th>Bridging</th>
<th>Profile Shape</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uncoated</td>
<td>174</td>
<td>Deteriorates</td>
</tr>
<tr>
<td>Coating A</td>
<td>0</td>
<td>Consistent</td>
</tr>
<tr>
<td>Coating B</td>
<td>2</td>
<td>Consistent</td>
</tr>
<tr>
<td>Coating C</td>
<td>0</td>
<td>Consistent</td>
</tr>
<tr>
<td>Coating D</td>
<td>0</td>
<td>Consistent</td>
</tr>
</tbody>
</table>
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

TE by Location for SAR 0.575
Aperture Function – Transfer Efficiency

TE by Location for SAR 0.500
Aperture Function – Transfer Efficiency

Average Transfer Efficiency
SAR 0.575 (0.5 mm BGA)
Aperture Function – Transfer Efficiency

Average Transfer Efficiency
SAR 0.500 (0.4 mm BGA)
Aperture Function – Stencils After 20 Prints

Coating A

Coating B

Coating D

Uncoated
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
Abrasion Test Procedure

1. Coating scrubbed for 2000 cycles
2. Contact angle measured every 500 cycles with DI water
3. Testing repeated with chemicals added
Robustness – Abrasion

A abrasion test was conducted on 100% cotton and water samples. The graphs show the change in contact angle over different cycle counts for samples D, B, and C.

- **Abrasions - 100% Cotton**: The contact angle remains relatively stable for all samples, with a slight decrease over the cycle count.
- **Abrasions - Water**: The contact angle decreases significantly for all samples, with sample D showing the least decrease and sample C showing the most decrease over the cycle count.
Robustness – Abrasion with Chemicals

Abrasions - IPA

Abrasions - 25% Rosin Flux
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?
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

Transfer Efficiency: 70%
Wasted Paste: 30%
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

*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

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

<table>
<thead>
<tr>
<th>Benefits</th>
<th>Nano-Coatings Tested</th>
</tr>
</thead>
<tbody>
<tr>
<td>Underside cleaning improved</td>
<td>All coatings – A, B, C, D</td>
</tr>
<tr>
<td>Bridging improved</td>
<td>All coatings – A, B, C, D</td>
</tr>
<tr>
<td>Transfer efficiency increased</td>
<td>Coatings A and D</td>
</tr>
<tr>
<td>Visible on the stencil</td>
<td>Coatings A and D</td>
</tr>
<tr>
<td>Re-apply by the user</td>
<td>Coatings B and C</td>
</tr>
</tbody>
</table>
Questions About Nano-Coatings

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# Negative Impact

<table>
<thead>
<tr>
<th>Negative Impacts</th>
<th>Nano-Coatings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coating wears through abrasion</td>
<td>Coatings B and C</td>
</tr>
<tr>
<td>Coating wear not visible</td>
<td>Coatings B and C</td>
</tr>
<tr>
<td>Transfer efficiency decreased</td>
<td>Coatings B and C</td>
</tr>
</tbody>
</table>
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?

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