An Investigation into the Use of Nano-Coated Stencils to Improve Solder Paste Printing with Small Stencil Aperture Area Ratios

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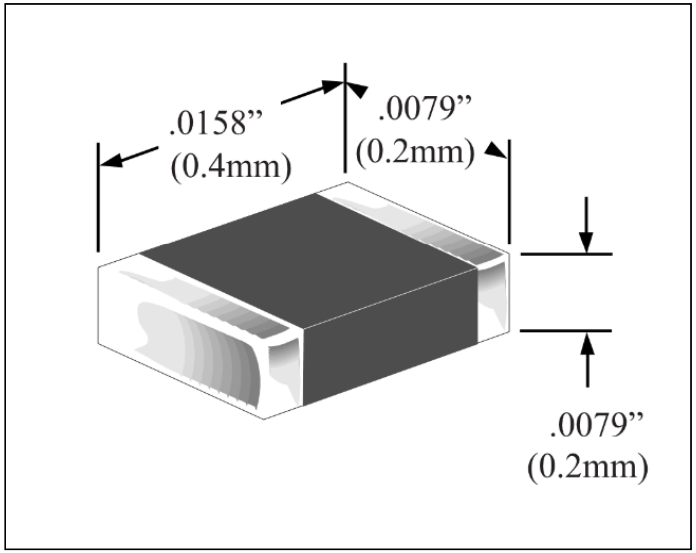
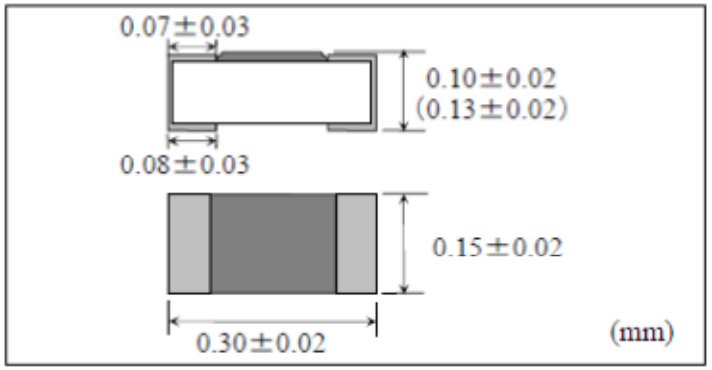
01005 and smaller components are a challenge due to their size

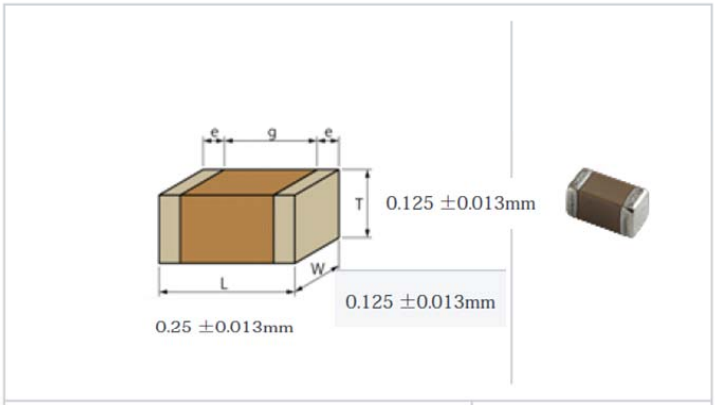
01005 Imperial (0402 Metric) Size

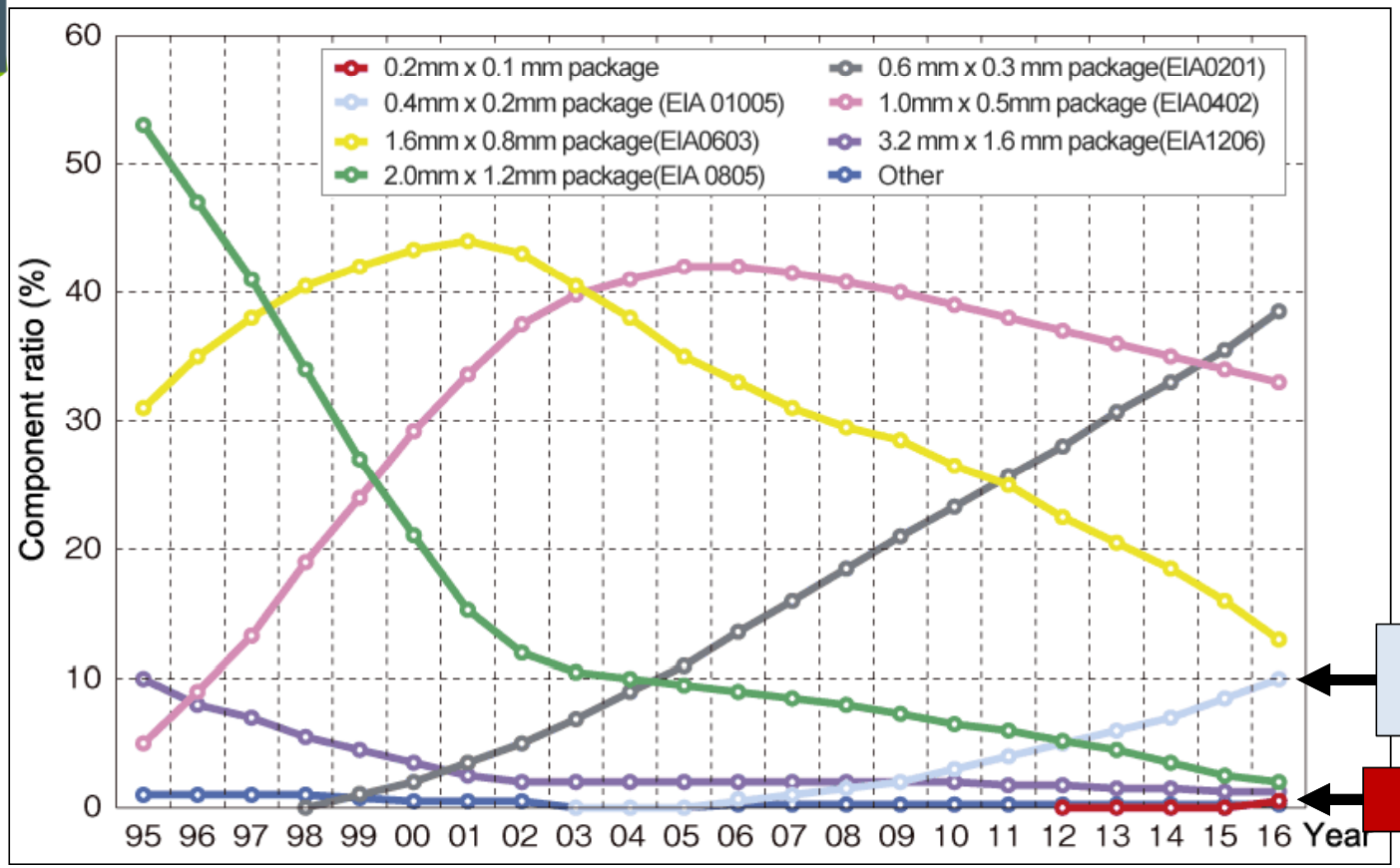


03015 Metric Size



0201 Metric Size



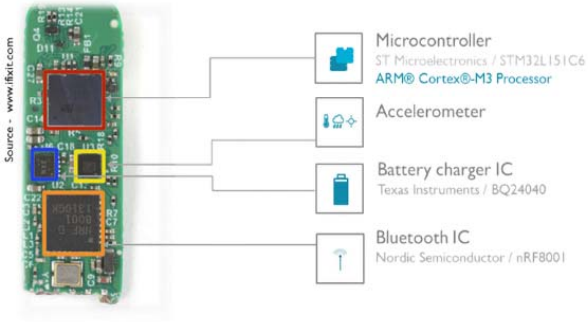


01005 Imperial
(0402 Metric)

0201 Metric

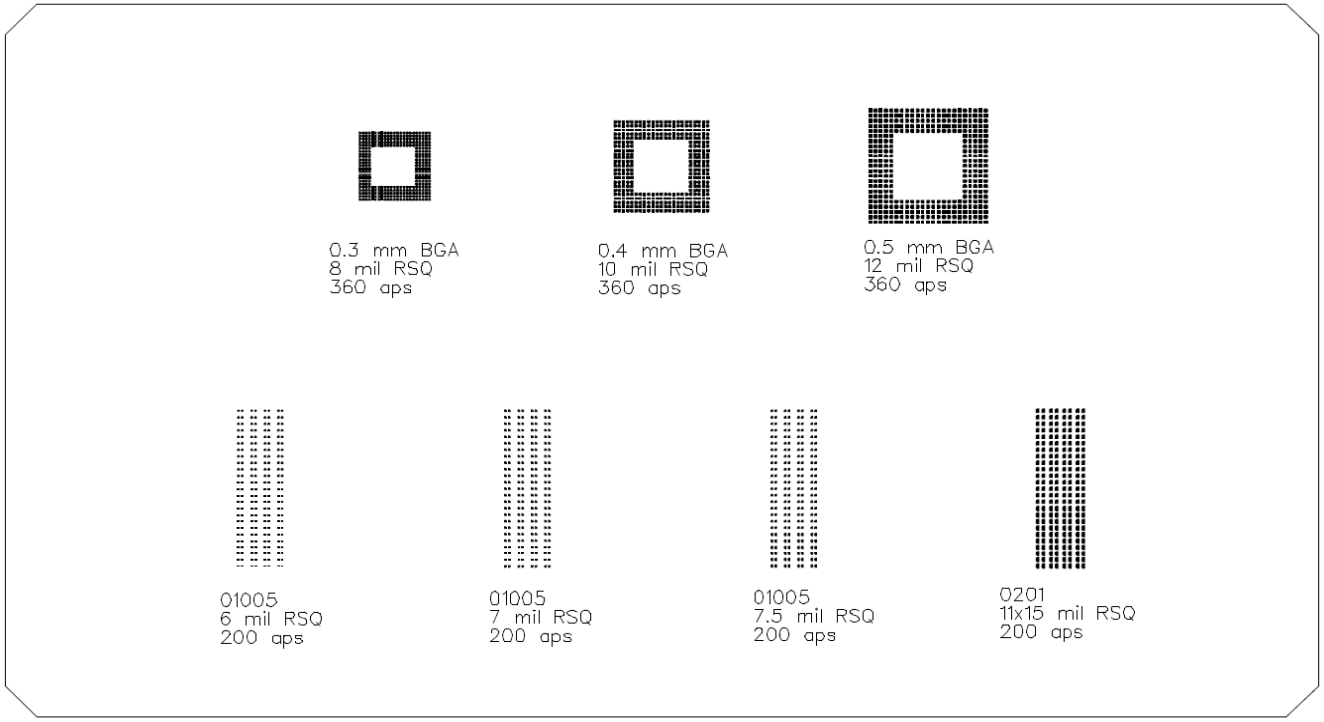
Reference: **Murata Manufacturing Company
http://www.murata.com/products/article/pp09e1/3.html

Why Use 01005 and Smaller Components?



Miniaturization with the need for solder paste printing of small features and large features with the same stencil on a product board are driving the need to increase solder paste transfer efficiency across all product segments

Solder Paste Printing is a Challenge



01005 Imperial Test Stencil
Developed to address this need

01005 Imperial Stencil Layout

					5 mil stencil		4 mil stencil		3 mil stencil	
Component Type	Aperture Size (mils)	Aperture Shape	Aperture Area (sq. mils)	# Paste Deposits Scanned Per print	Theoretical vol (cu. mils)	AR	Theoretical vol (cu. mils)	AR	Theoretical vol (cu. mils)	AR
0.5 mm BGA	12 x 12	RSQ	144	140	720	0.60	576	0.75	432	1.00
0.4 mm BGA	10 x 10	RSQ	100	150	500	0.50	400	0.63	300	0.83
0.3 mm BGA	8 x 8	RSQ	64	150	320	0.40	256	0.50	192	0.67
01005 6 mil	6 x 6	RSQ	36	144	180	0.30	144	0.38	108	0.50
01005 7 mil	7 x 7	RSQ	49	144	245	0.35	196	0.44	147	0.58
01005 7.5 mil	7.5 x 7.5	RSQ	56	144	281	0.38	225	0.47	169	0.63
0201 Imperial	11 x 15	RSQ	165	144	825	0.63	660	0.79	495	1.06

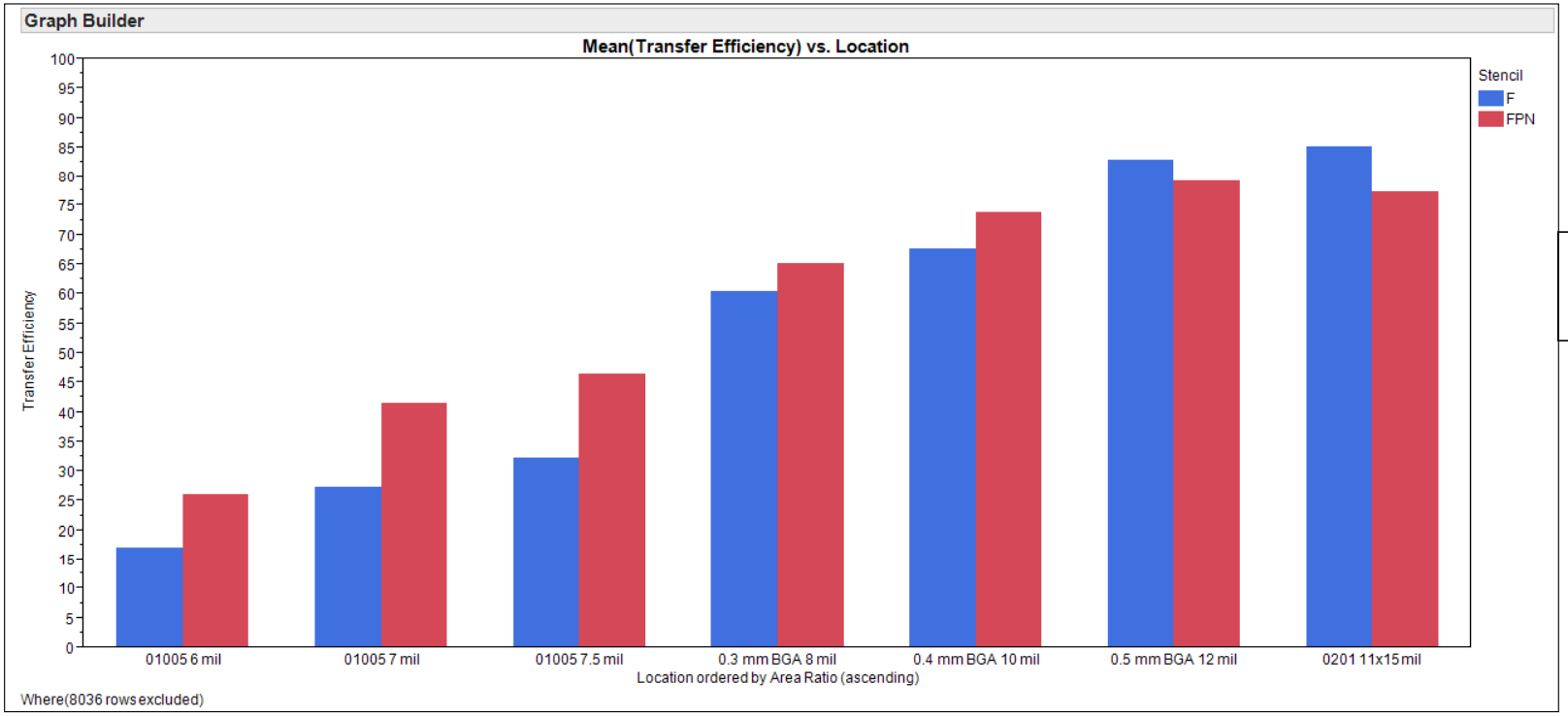
Print Study Details

- 10 print study for each combination of stencil and solder paste
- Solder paste volumes were measured for each component
- 1400 to 1900 data points were generated for each component within each combination
- Mean transfer efficiencies were calculated

01005 Test Stencil Variables Evaluated

Stencil thickness: 3 mil (75 µm), 4 mil (100 µm), 5 mil (125 µm)
Solder paste: No clean lead-free SAC 305 Type 3 (25-45 µm), Type 4 (20-38 µm), Type 5 (15-25 µm)
Coating: Un-coated, Polymer Nano-coating

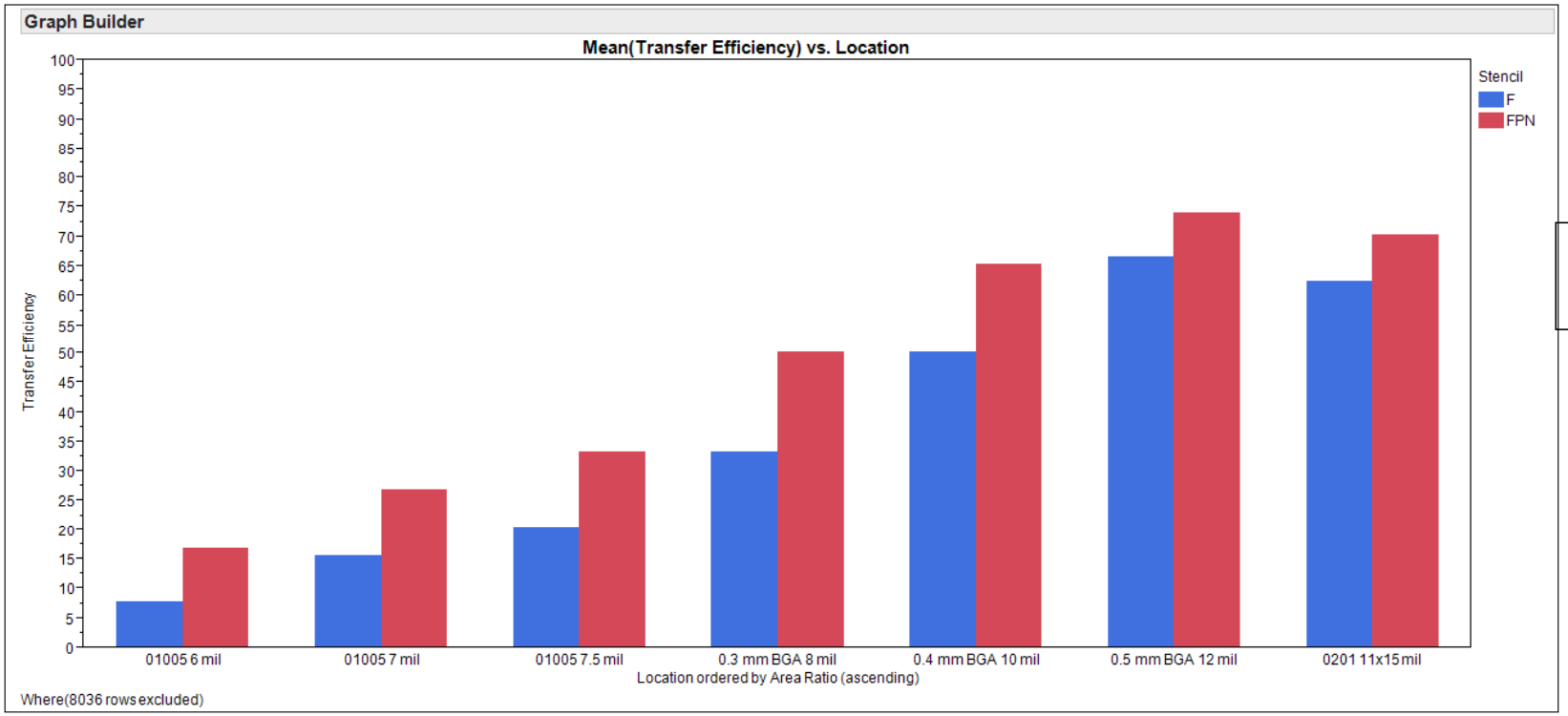
01005 Test Stencil (TS)- 3 Mil Thick Stencils



F = Uncoated
FPN = Nano-coated

TE% increases with increasing AR (left to right)
Polymer Nano-coating increases TE% by around 5 to 15% except for 0.5 mm BGA and 0201 Imperial Components

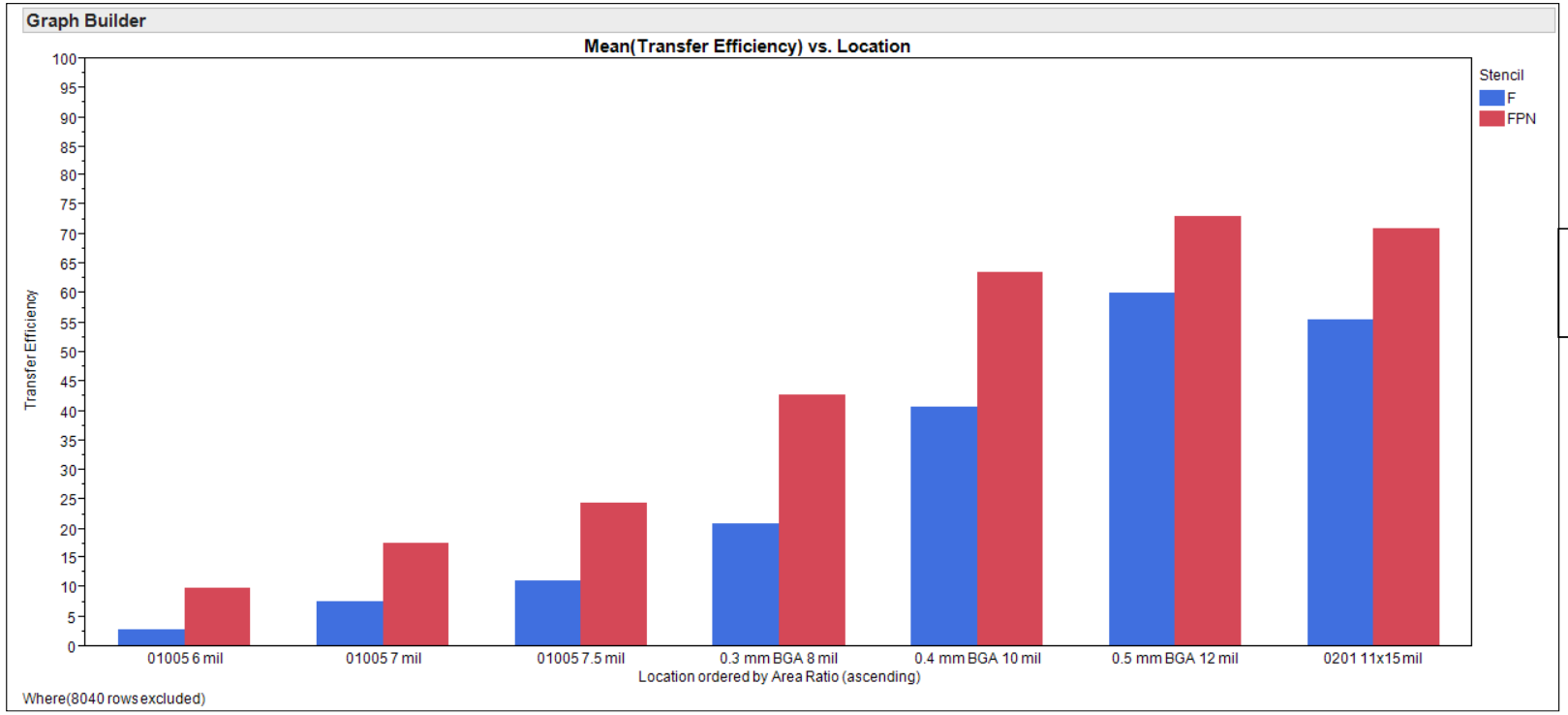
01005 TS - 4 Mil Thick Stencils



F = Uncoated
FPN = Nano-coated

TE% increases with increasing AR (left to right)
Polymer Nano-coating increases TE% by around 10 to 15%

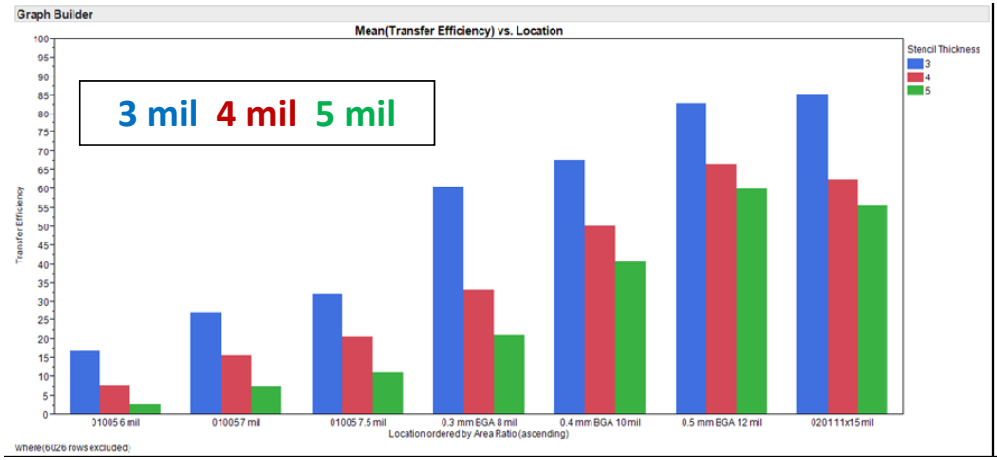
01005 TS - 5 Mil Thick Stencils



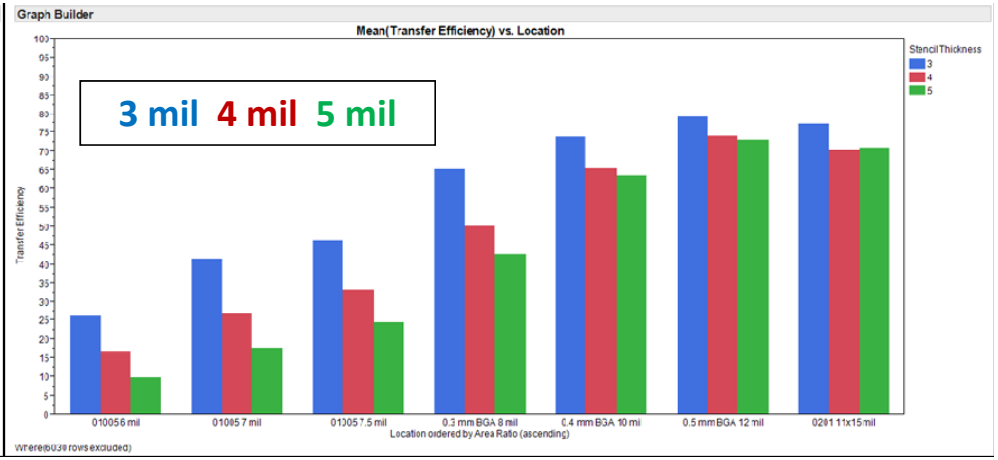
F = Uncoated
FPN = Nano-coated

TE% increases with increasing AR (left to right)
Polymer Nano-coating increases TE% by around 7 to 23%
01005 TE%s are low with this stencil thickness of 5 mils

01005 TS: 3, 4, 5 Mil Thick Stencils



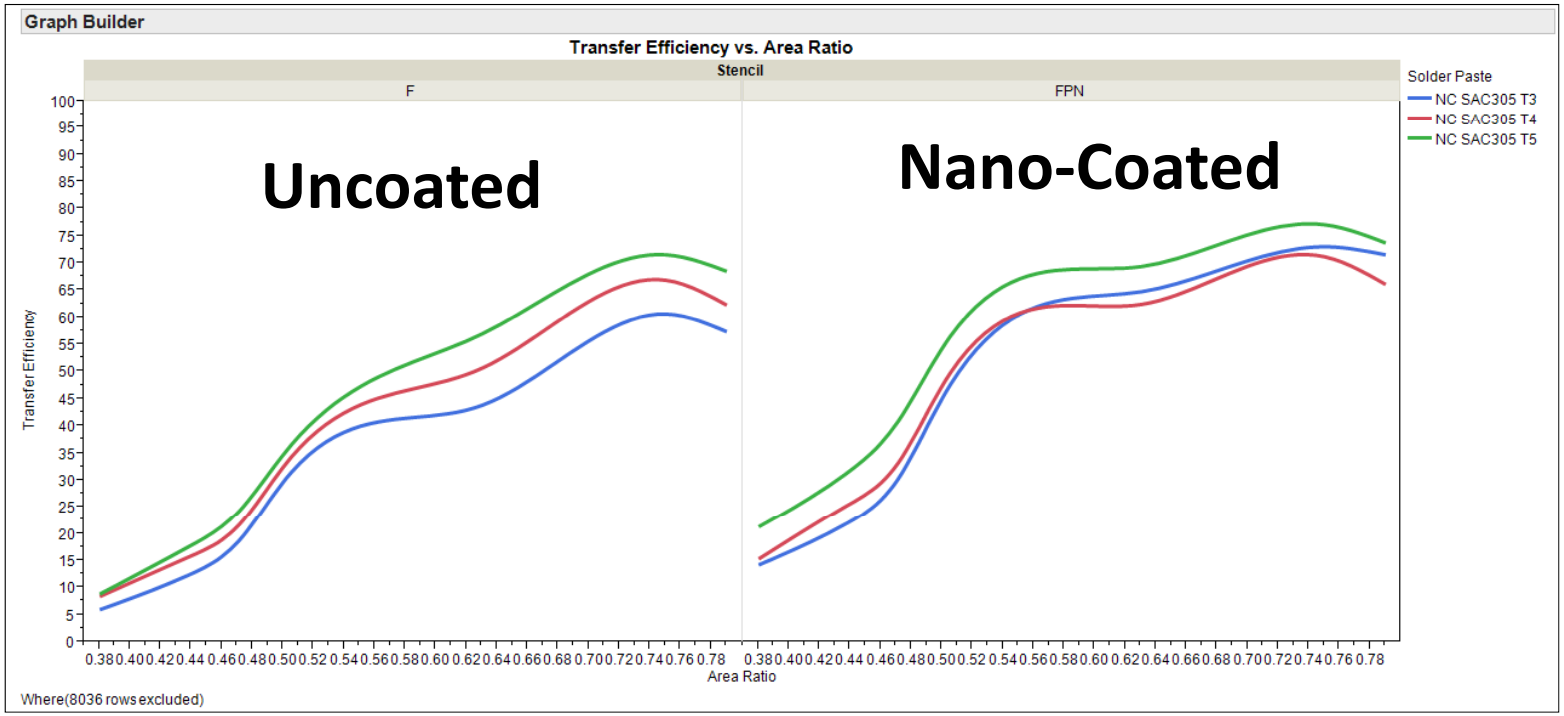
Uncoated stencils



Polymer nano-coated stencils

TE% increases with decreasing stencil thickness: 3 mil TE% > 4 mil > 5 mil
The Polymer nano-coating levels this trend out with larger ARs (0.4 mm and 0.5 mm pitch BGAs and 0201 Imperial components)

01005 TS: Solder Paste Type 3, Type 4, Type 5 (4 mil Thick Stencil)



Type 3
Type 4
Type 5

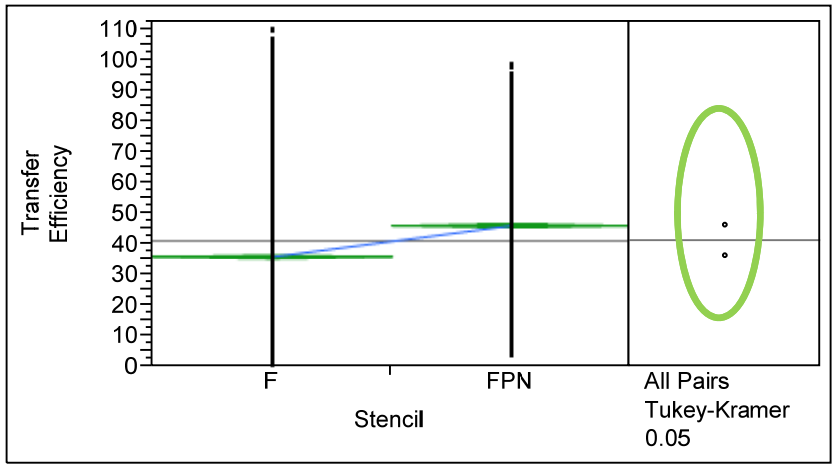
TE% does not increase linearly with AR

The polymer nano-coating helps T3 paste TE% to match the TE% of T4

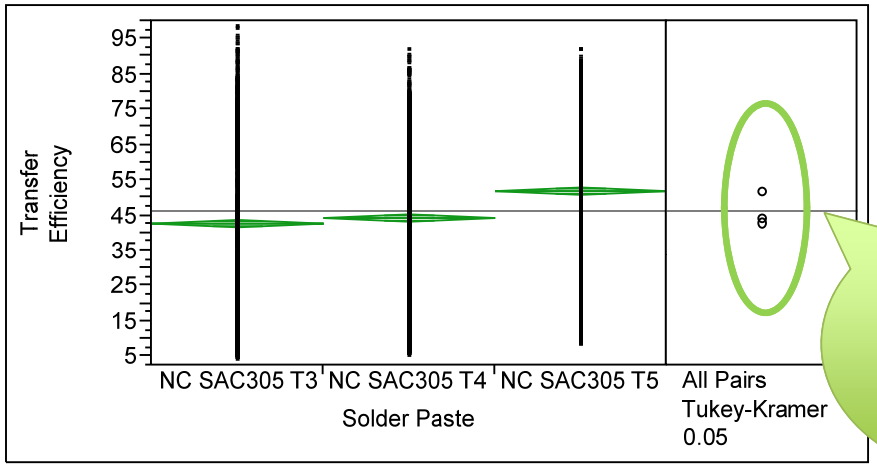
01005 Test Stencil General Observations

- Transfer efficiencies increase with decreasing stencil thickness: 5 mil < 4 mil < 3 mil
- The polymer nano-coating increases the mean TE% by 5 – 30% over the uncoated stencil depending upon area ratio
- The polymer nano-coating increases the mean TE% allowing higher stencil thicknesses to be used adding solder paste volume.
- As expected, solder paste type affects TE%: Type 5 > Type 4 > Type 3.
- The effect of the polymer nano-coating on TE% causes the TE% for Type 3 solder paste to nearly match that of Type 4.

01005 Test Stencil Statistical Significance
Tukey-Kramer HSD Analysis



Uncoated (F) / Nano-Coated Stencils (FPN)
Difference in means are statistically different



HSD comparison shows differences in the means

Solder Paste Types 3, 4, 5
Means for Type 3 and 4 are not statistically different, but Type 5 is significantly higher

01005 TS Statistical Significance Tukey-Kramer HSD

Variables Compared	Effect on TE% (0 = no effect / baseline + = increase ++ = increase over 0 and +)
Uncoated stencils (F)	**0**
Nano-coated stencils (FPN)	**+**
Type 3 paste	**0**
Type 4 paste	**+**
Type 5 paste	**++**
Uncoated stencils (F) with	
Type 3 paste	**0**
Type 4 paste	**+**
Type 5 paste	**++**
Nano-coated stencils (FPN) with	
Type 3 paste	**0**
Type 4 paste	**0**
Type 5 paste	**+**

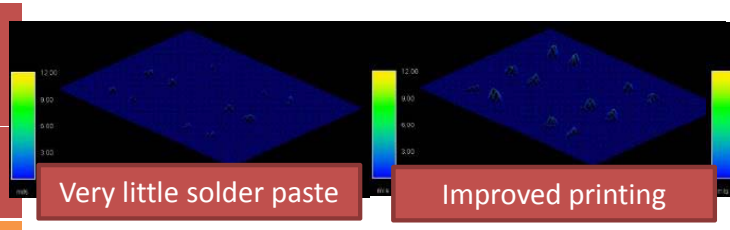
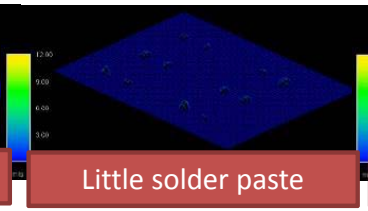
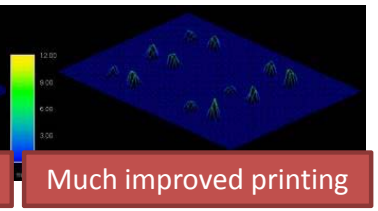
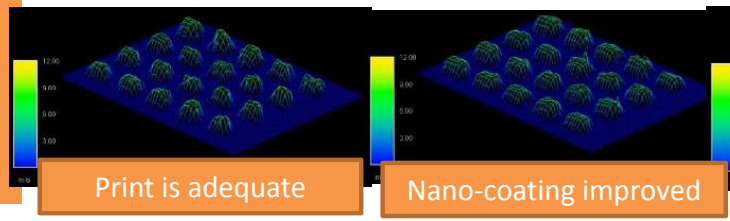
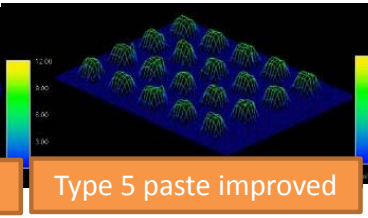
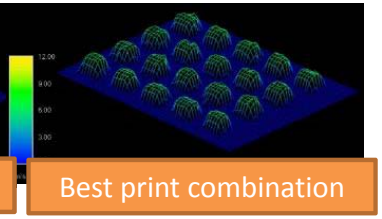
Nano-coating increases TE% statistically

TE increases statistically with paste type

Uncoated stencils: TE increases statistically with paste type (Type 5>Type 4>Type 3)

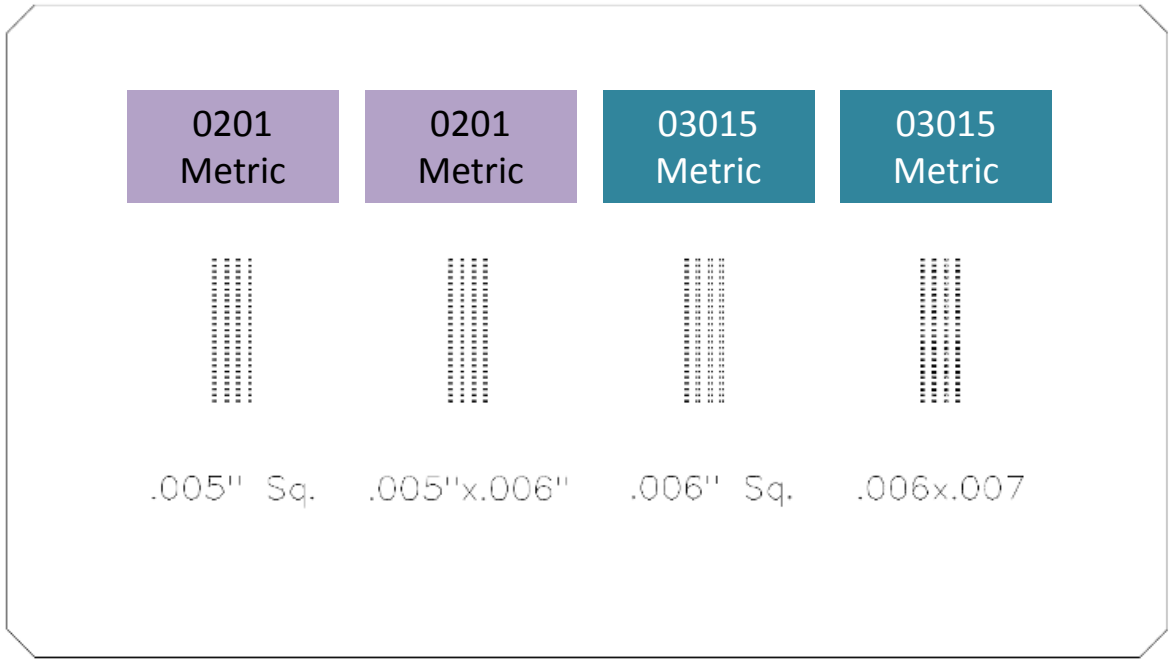
Nano-coated stencils: TE increases statistically only with Type 5 paste

Solder Paste Brick Definition Improvements

	Type 3 Paste 5 mil Uncoated	Type 3 Paste 5 mil Nano-coated	Type 5 Paste 5 mil Uncoated	Type 5 Paste 5 mil Nano-coated
0.35 AR	 Very little solder paste	Improved printing	 Little solder paste	 Much improved printing
0.60 AR	 Print is adequate	Nano-coating improved	 Type 5 paste improved	 Best print combination

All images are prints from the 5 mil thick stencils and Types 3 and 5 solder paste.
Improvements with nano-coated stencil and solder paste type (Type 5> Type 3)

03015 Metric Test Stencil Design



03015 Metric Test Stencil Layout

					4 mil stencil		3 mil stencil	
Component Type	Aperture Size (mils)	Aperture Shape	Aperture Area (sq. mils)	# Paste Deposits Scanned Per print	Theoretical vol (cu. mils)	AR	Theoretical vol (cu. mils)	AR
0201 metric	5 x 5	Square	25	192	100	0.31	75	0.42
0201 metric	5 x 6	Rectangle	30	192	120	0.34	90	0.45
03015 metric	6 x 6	Square	36	192	144	0.38	108	0.50
03015 metric	6 x 7	Rectangle	42	192	168	0.40	126	0.54

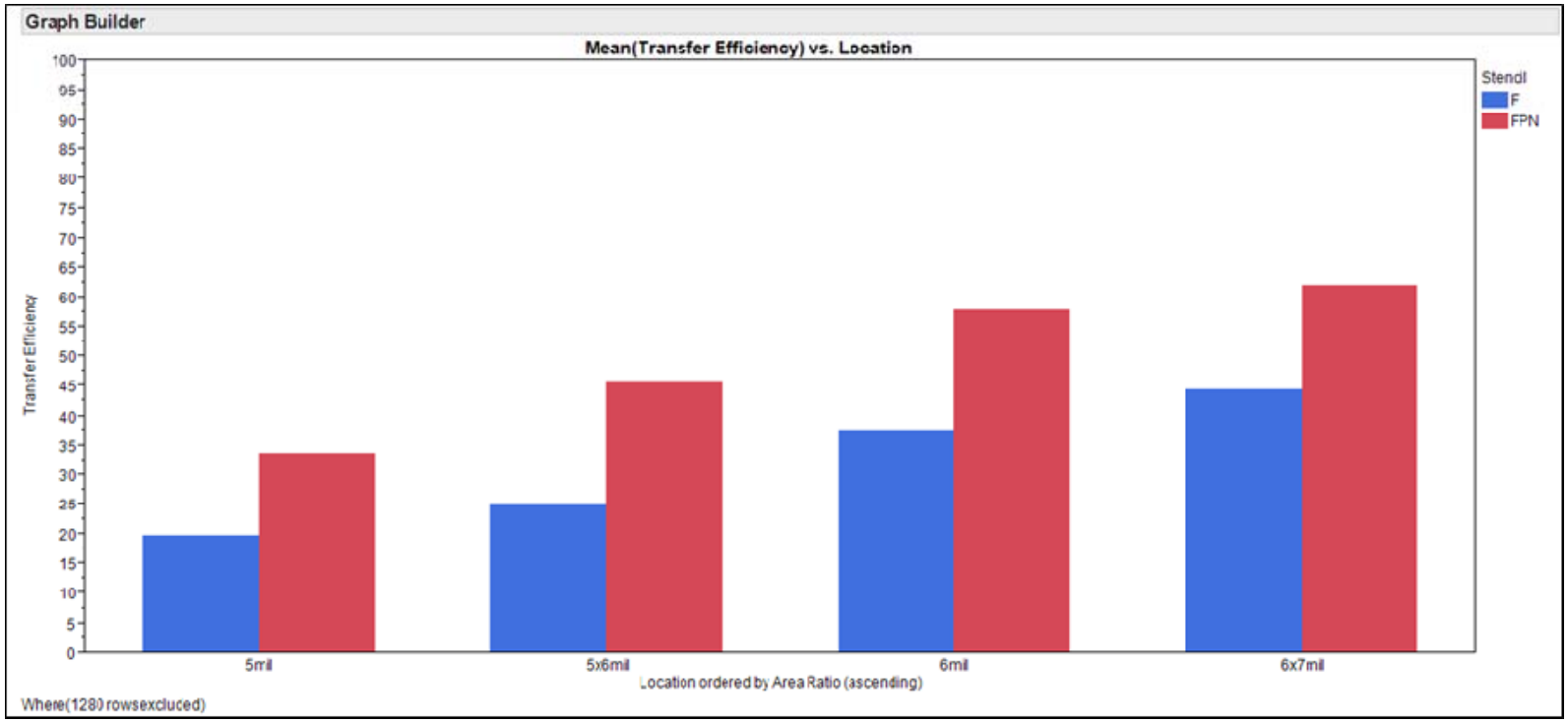
03015 Test Stencil (TS) Variables Evaluated

Stencil thickness: 3 mil (75 µm), 4 mil (100 µm)

Solder paste: No clean lead-free SAC 305 Type 4 (20-38 µm), Type 5 (15-25 µm)

Coating: Un-coated, Polymer Nano-coating

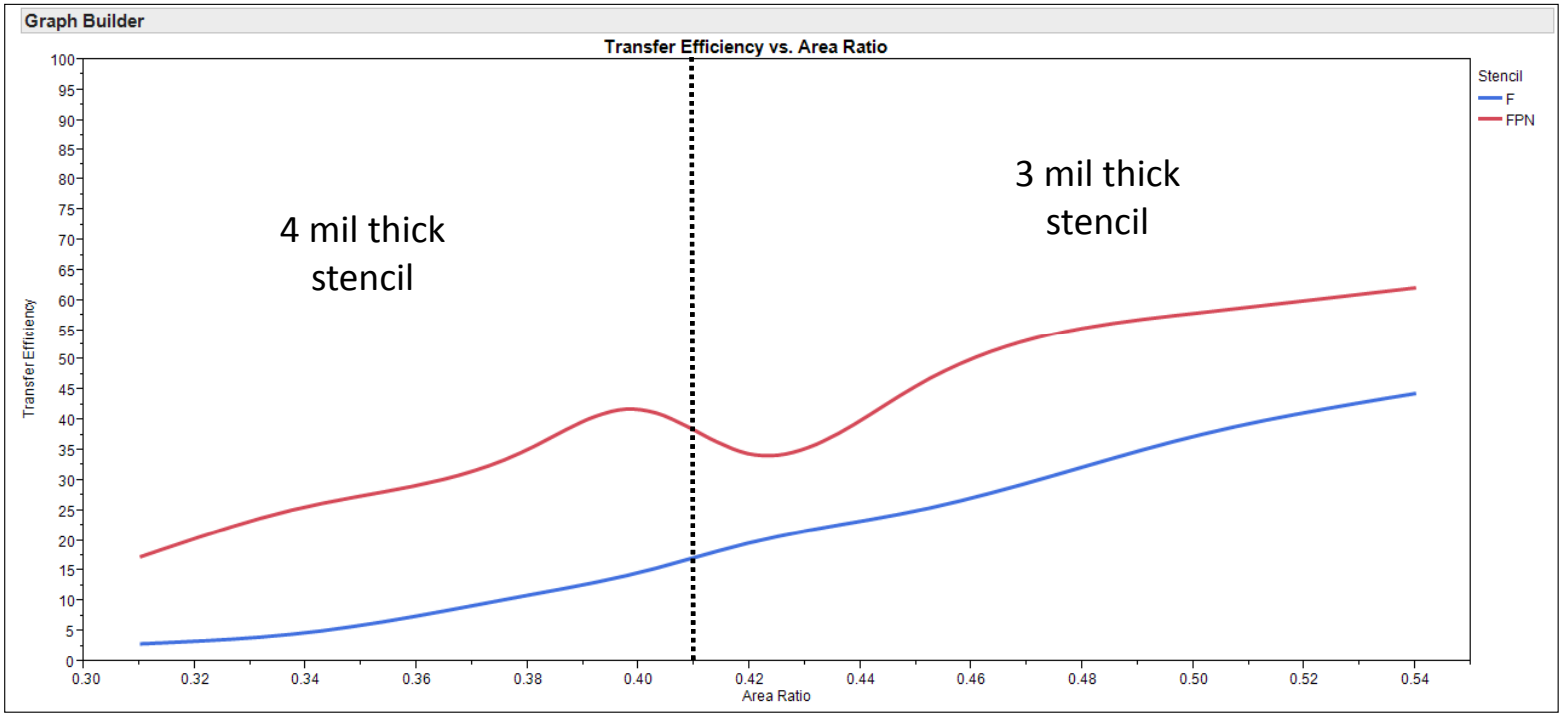
03015 Metric Stencil Transfer Efficiency (Type 5 paste, 3mil thick stencil)



F = Uncoated
FPN = Nano-coated

Type 5 Paste, 3 Mil Thick Stencil
TE% increases by around 15 to 25% from uncoated to nano-coated stencil

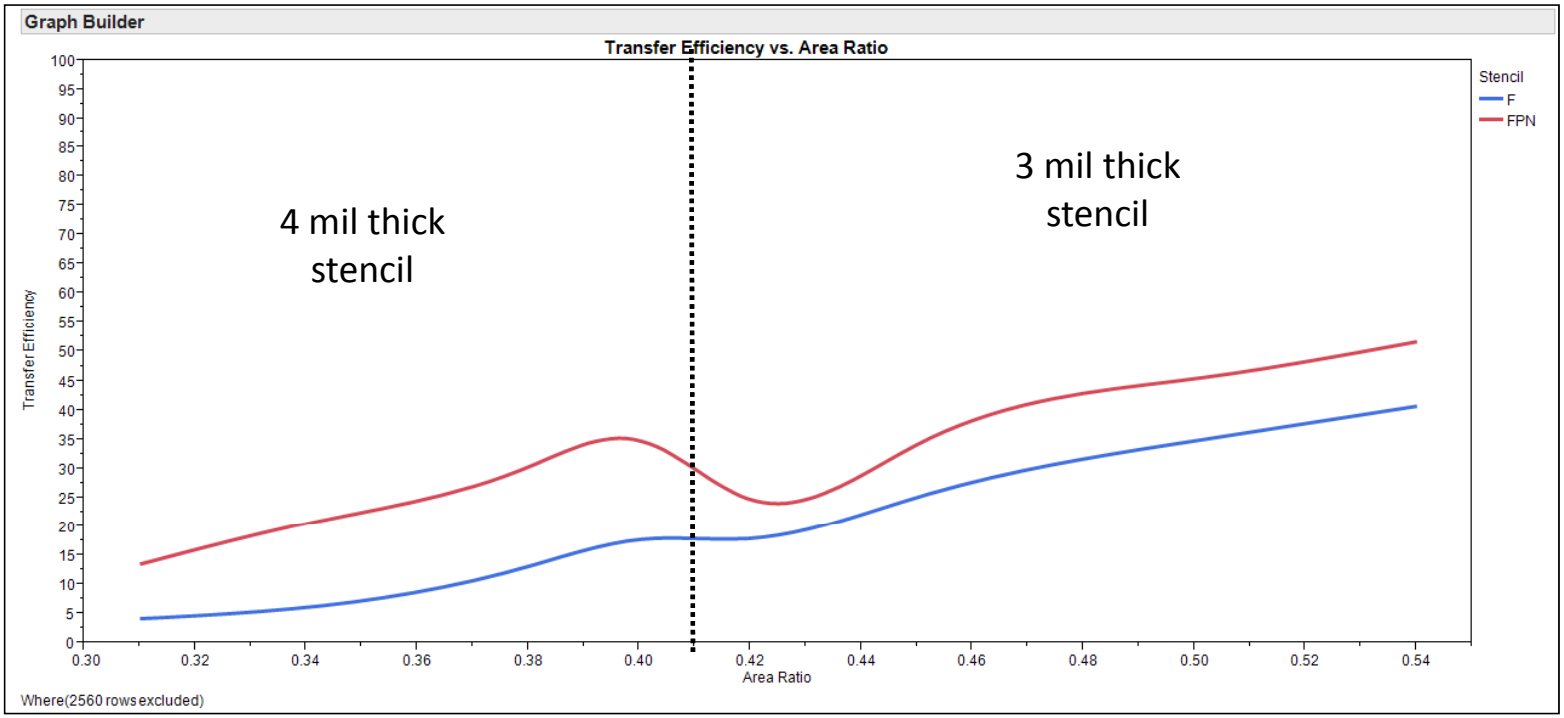
03015 Metric Stencil Transfer Efficiency (Type 5 paste with 3 and 4 mil Thick Stencils)



F = Uncoated
FPN = Nano-coated

At these low ARs, TE% increases nearly linearly with AR
Polymer nano-coating gives a clear increase in TE% by around 15 to 25%

03015 Metric Stencil Transfer Efficiency (Type 4 paste with 3 and 4 mil Thick Stencils)

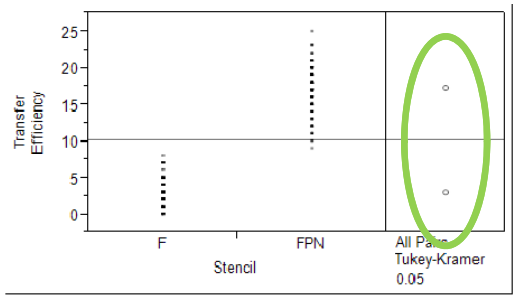


F = Uncoated
FPN = Nano-coated

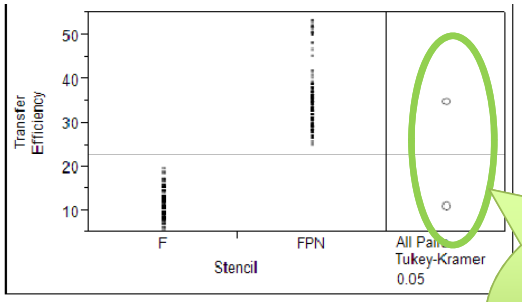
Type 4 paste gives overall lower TE% thanType 5 paste.
Polymer nano-coating with Type 4 paste increases TE% by around 10 to 20%

03015 Metric Stencil Tukey-Kramer HSD Statistical Analysis

F = Uncoated
FPN = Nano-coated

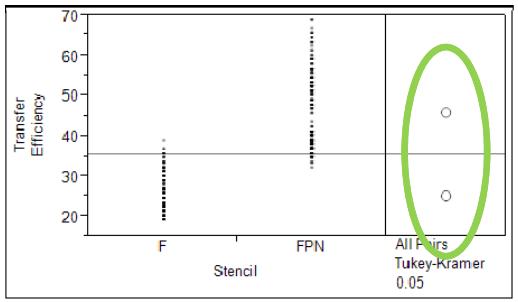


AR = 0.31

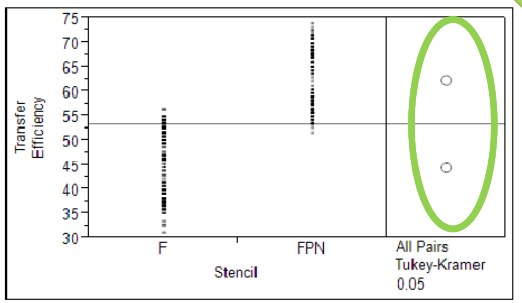


AR = 0.38

HSD comparison shows clear differences in the means



AR = 0.45



AR = 0.54

The Polymer Nano-coating statistically increases TE% compared with non-coated stencils for all ARs tested.

General Recommendations by Component

Component Type	Stencil Thickness	Solder Paste	Polymer Nano-Coating
0.3 mm CSP	3 mil	Types 4, 5	Uncoated
	3 mil	Types 3, 4, 5	Nano-coated
0.4 mm CSP	3, 4, 5 mil	Types 4, 5	Uncoated
	3, 4, 5 mil	Types 3, 4, 5	Nano-coated
0.5 mm CSP	3, 4, 5 mil	Types 3, 4, 5	Uncoated
	3, 4, 5 mil	Types 3, 4, 5	Nano-coated
0201 Imperial (0603 Metric)	3, 4, 5 mil	Types 3, 4, 5	Uncoated
	3, 4, 5 mil	Types 3, 4, 5	Nano-coated
01005 Imperial (0402 Metric)	3 mil	Type 5	Nano-coated
03015 Metric and 0201 Metric	3 mil	Type 5	Nano-coated

Nano-coated stencils are generally preferred due to increased printed paste volume

Conclusions

- It is possible to print solder paste for small components: 01005 Imperial, 03015 Metric, 0201 Metric, and 0.3 and 0.4 mm pitch CSPs
- Laser cut, fine-grain steel stencils can be used
- Type 4 or 5 solder pastes are generally recommended over Type 3 solder paste for 0.3 mm and 0.4 mm pitch CSPs
- Type 3, 4 or 5 solder pastes can be used with 0.5 mm pitch CSPs and 0201 Imperial components
- Solder paste with Type 5 solder powder is generally recommended for 01005 Imperial, 03015 Metric and 0201 Metric components with 3mil thick nano-coated stencils
- A polymer nano-coating is recommended for all component types with TE% increasing by 5 to 30% over non-coated stencils

Acknowledgments

- ✓ The authors would like to thank Fine Line Stencil for designing and manufacturing the stencils used in this investigation.
- ✓ The authors also thank Metal Etching Technology (MET) for their guidance and support with this investigation.

Questions?

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