Fill the Void III

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FCT Solder

- Introduction
- Factors that Influence Voiding
- Experimental Methodology
- Voiding Results
- Conclusions
- Future Work
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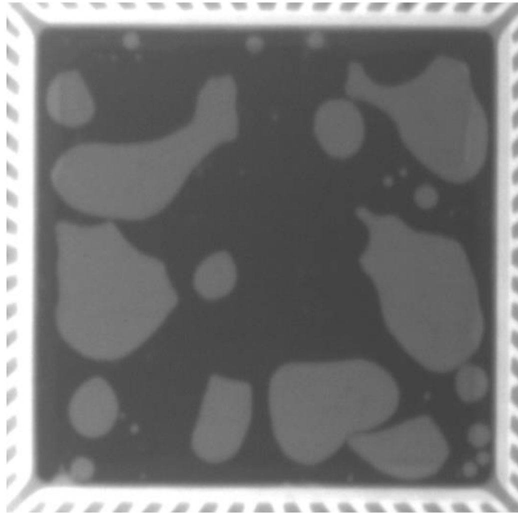
Introduction



Voids in QFN Thermal Pad Solder Joints

- Limit heat transfer
- Lower mechanical strength
- Can lead to long term reliability issues

Factors that Influence Voiding

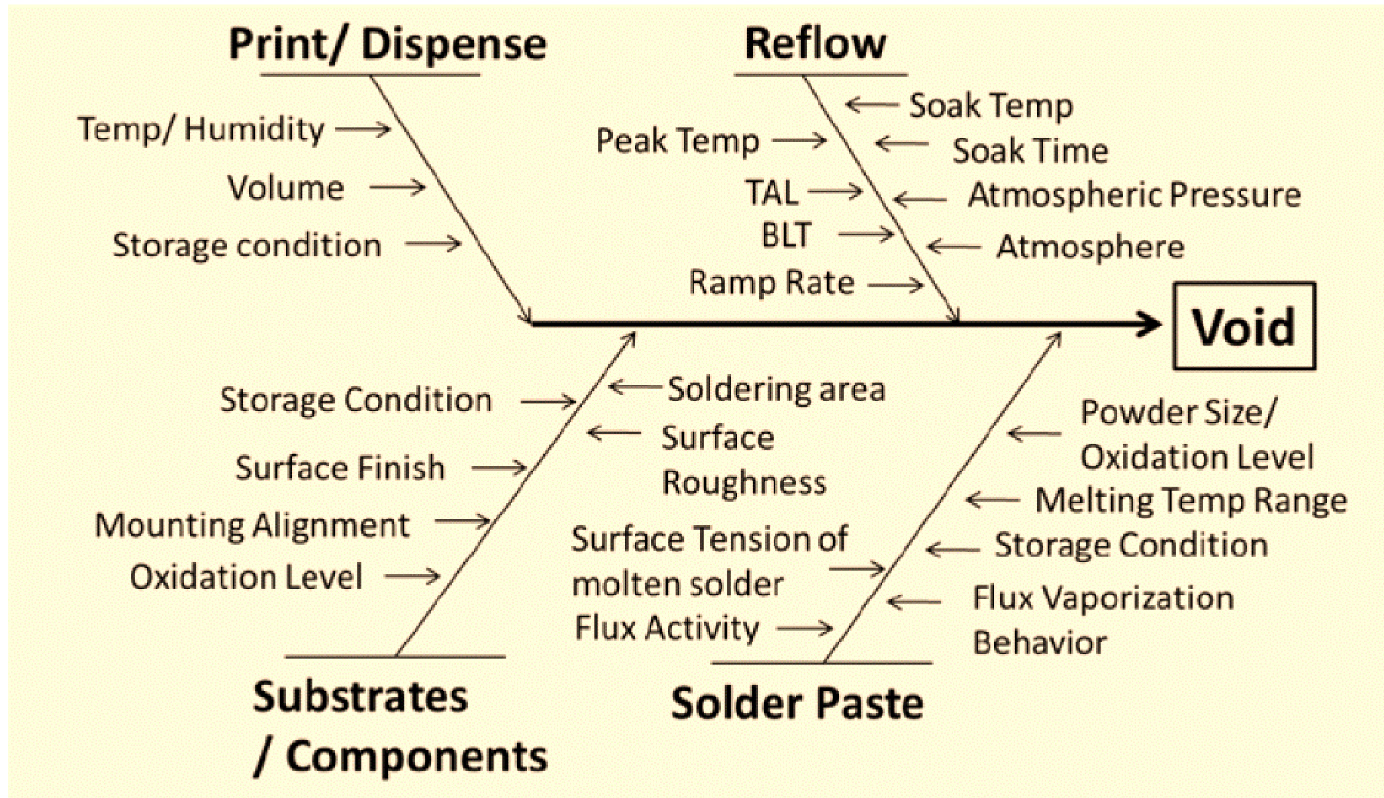
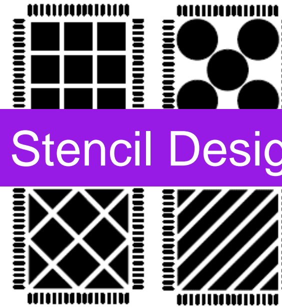


*Diagram from Nihon Superior, "Controlling the Voiding Mechanisms in the Reflow Soldering Process", Proceedings of IPC APEX Expo 2016.

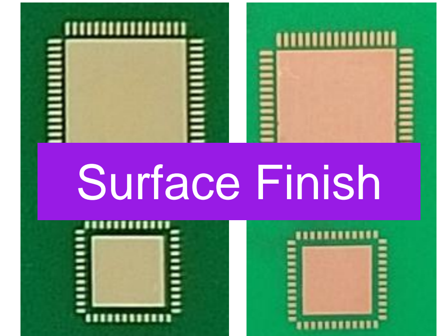
Voiding Factors That Were Studied Previously

Solder Paste

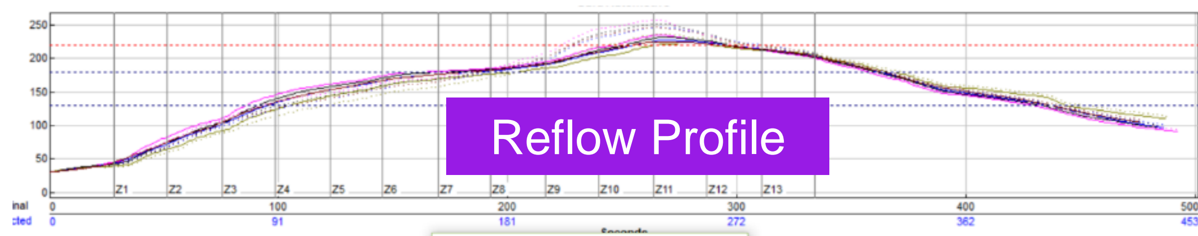
Solder Powder



Stencil Design



Surface Finish



Reflow Profile

Nitrogen Reflow

Vapor Phase - Vacuum

Voiding Factors in This Presentation

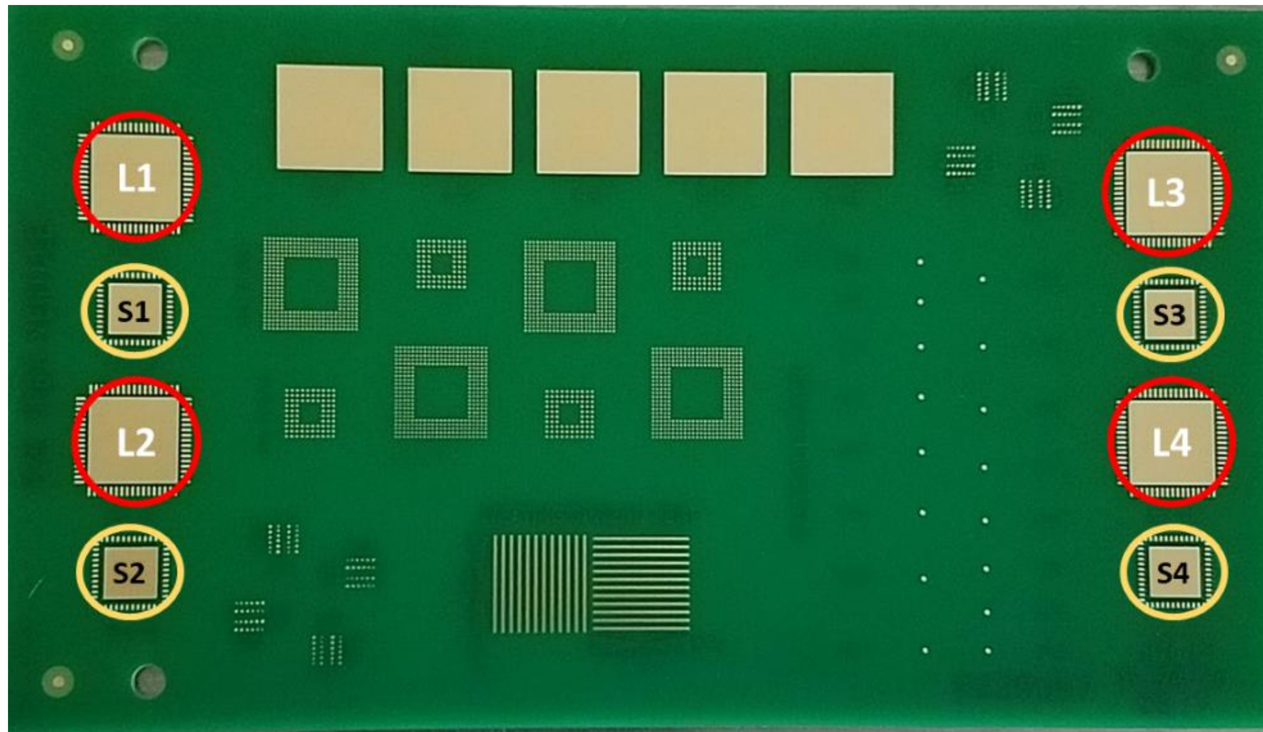
- Solder Powder Size (T3, T4, T5 – SAC305)
- Solder Paste
  - B = Water Soluble Lead-Free
  - C = No Clean Lead-Free
  - E = Water Soluble Lead-Free
  - F = New “Low Voiding” No Clean Lead-Free
- Solder Alloy
  - SAC305 (Sn/3.0Ag/0.5Cu)
  - SN100C (Sn/0.7Cu/0.05Ni/0.005Ge)
  - SN100CV (Sn/0.7Cu/0.05Ni + Bi)
  - AT Mix: 90% SAC305 + 10% SN100C (Sn/2.7 Ag/0.52 Cu/0.006 Ni)
- Surface Finish (ENIG and OSP)
- Stencil Design (50 to 80% Area Coverage)

Experimental Methodology

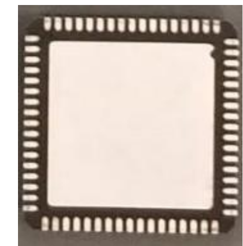
Experimental Methodology

PR Test Board has Two Sizes of QFNs

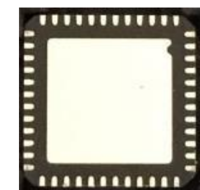
- QFN 10 = 10 mm body, 68 lead, 8.3 mm thermal pad
- QFN 7 = 7 mm body, 48 lead, 4.9 mm thermal pad



QFN 10
10 mm body
Tin finish



QFN 7
7 mm body
Tin finish



Most tests: 80 void measurements = 20 boards x 4 components ea.

Experimental Methodology

Solder Pastes

Solder Paste	Attributes	J-STD-004 Class
B	Water Soluble Lead Free. Relatively High Voiding	ORH1
E	Water Soluble Lead Free. Relatively Low Voiding	ORH1
C	No Clean Lead Free. Typically Low Voiding	ROL0
F	No Clean Lead Free. “Ultra-Low” Voiding	ROL0

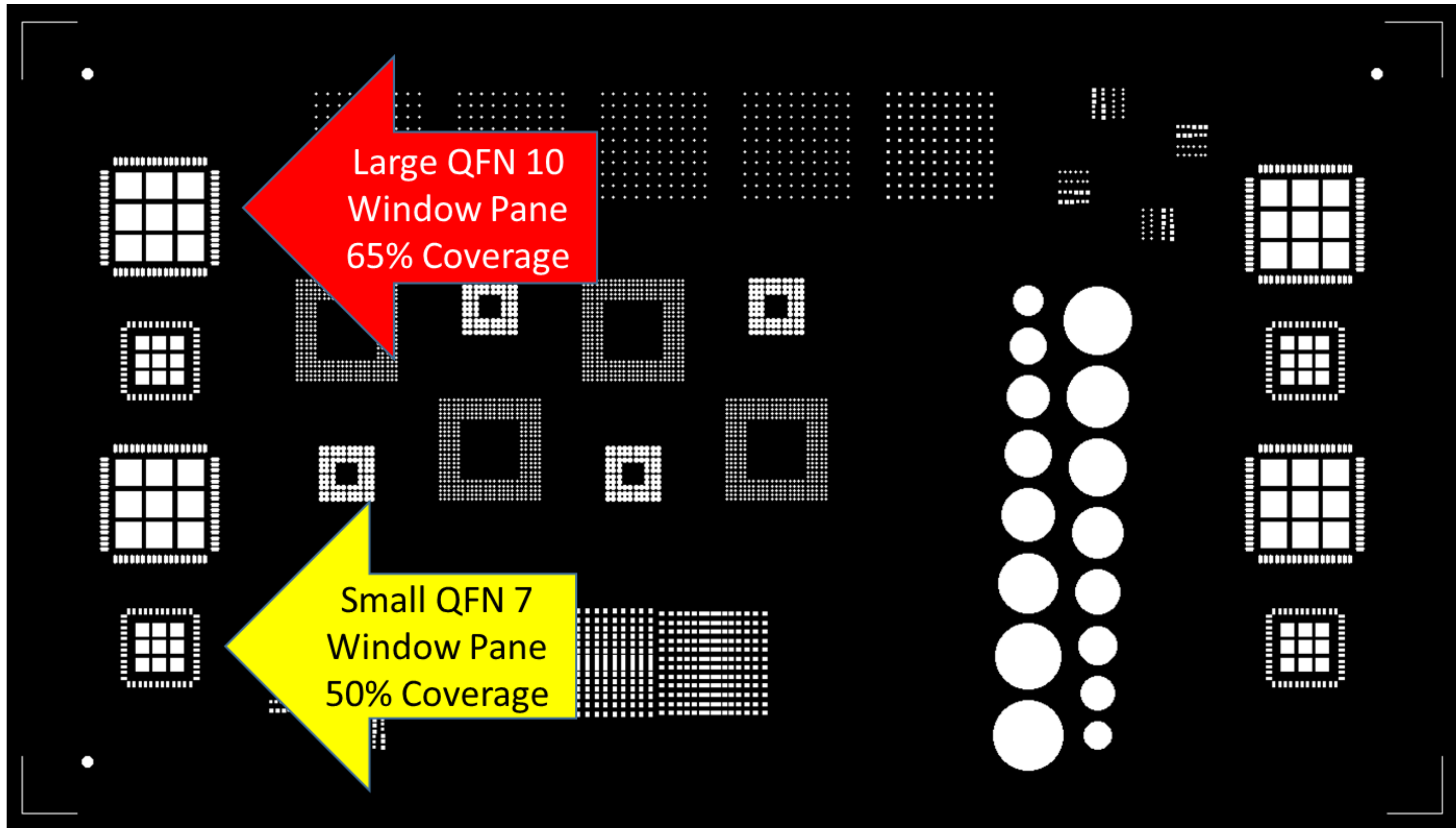
Experimental Methodology

Solder Alloys Used

Alloy	Composition (% wt)	Melting Range (°C)
SN100C	Sn / 0.7 Cu / 0.06 Ni / 0.005 Ge	227 (eutectic)
SAC305	Sn / 3.0 Ag / 0.5 Cu	217 - 220
SN100CV	Sn / 1.5 Bi / 0.7 Cu / 0.06 Ni	221 - 225
(AT) SAC305 90% SN100C 10%	Sn / 2.7 Ag / 0.52 Cu / 0.006 Ni	217 - 227

Experimental Methodology

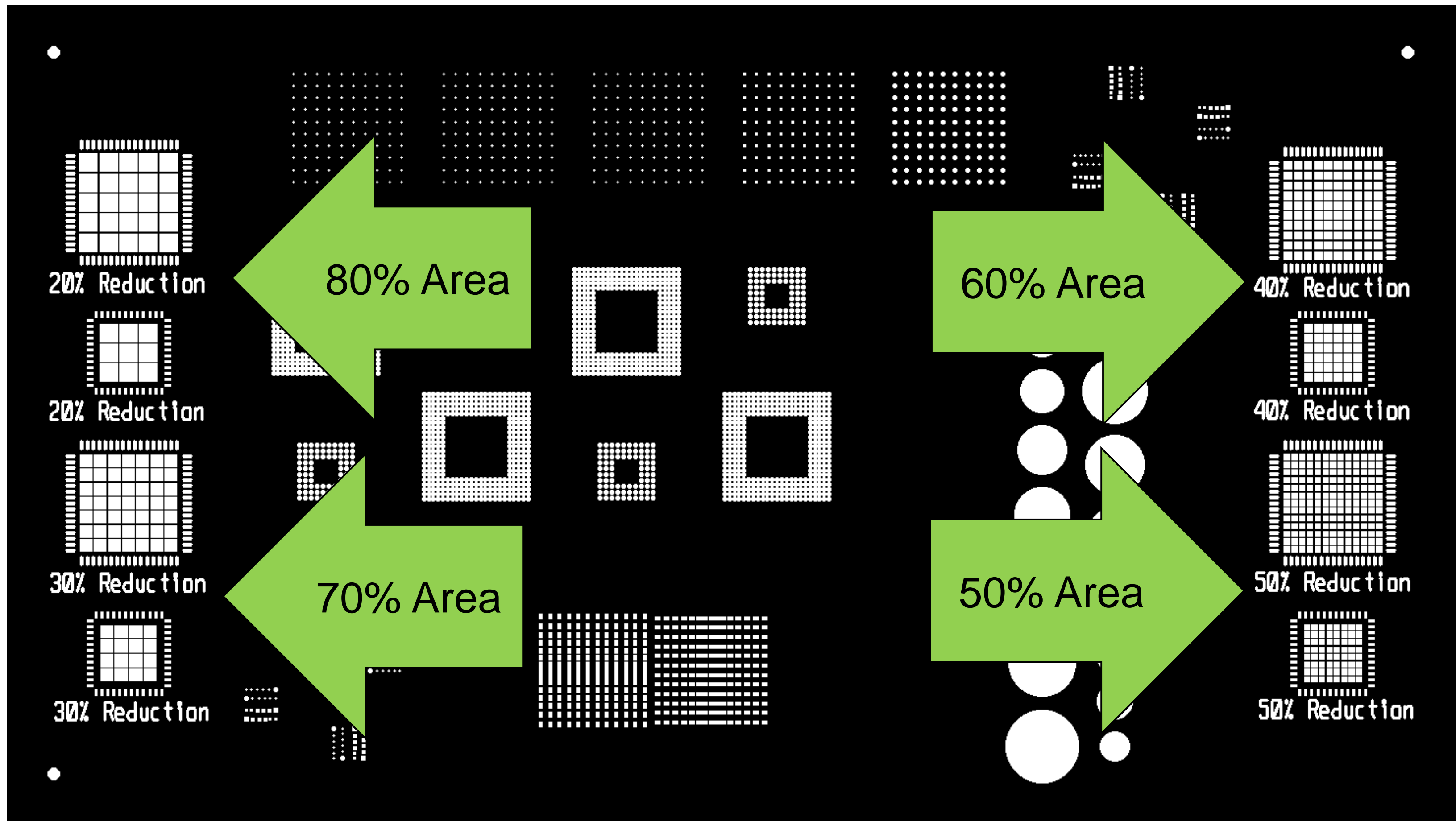
Stencil Design #1 – Standard for the PR Board



Used for all tests unless otherwise noted

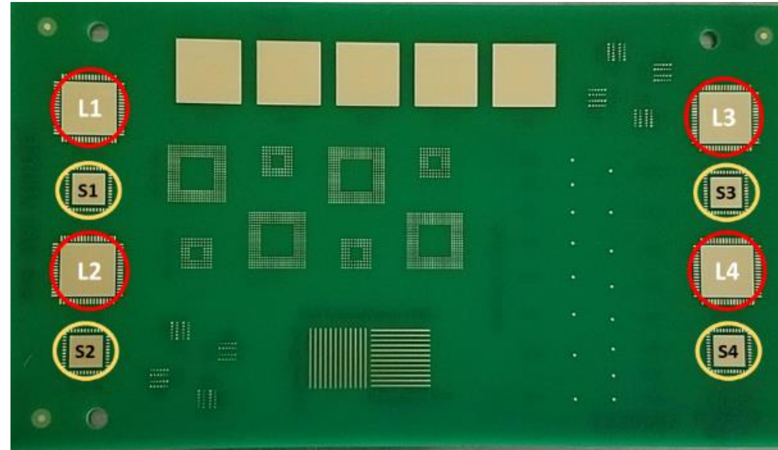
Experimental Methodology

Stencil Design #2 – Custom for this Experiment



Experimental Methodology

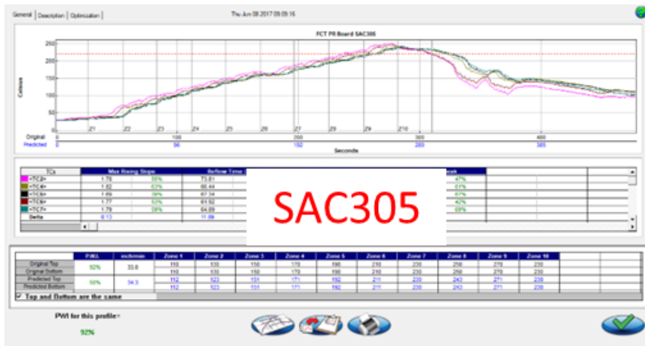
Stencil Design #2 Custom Test

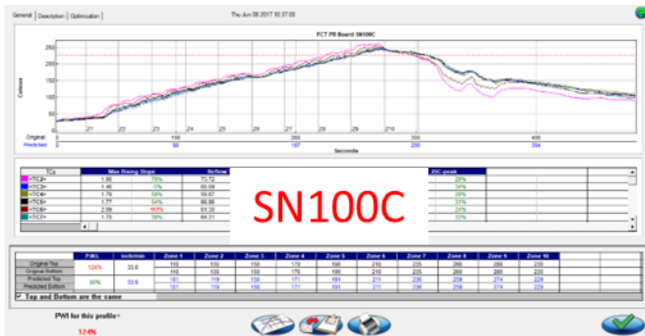


Location	Number of Windows	Window Size in mm (mils)	Web Spacing in mm (mils)	Paste Coverage Area (%)
L1	25	1.47 (58)	0.20 (8)	80
L2	49	1.00 (39)	0.20 (8)	70
L3	100	0.64 (25)	0.20 (8)	60
L4	169	0.44 (17.5)	0.20 (8)	50
S1	9	1.47 (58)	0.20 (8)	80
S2	16	1.02 (40)	0.20 (8)	70
S3	36	0.64 (25)	0.20 (8)	60
S4	64	0.43 (17)	0.20 (8)	50

Experimental Methodology

Reflow Profiles





Setting	SAC305 Profile	SN100C Profile
Ramp rate	1.7 – 1.8 °C/sec	1.5 – 2.0 °C/sec
TAL (Reflow time)	61 – 67 sec > 220°C	60 – 67 sec > 227°C
Peak temperature	241 to 248 °C	245 to 256 °C
Profile length (25 °C to peak)	4.7 minutes	4.5 minutes
Alloys used	SAC305 and AT Mix	SN100C and SN100CV

Equipment

<u>Printer parameters</u>

30 mm/sec print speed

0.18 kg/cm (1.0 lb/in) blade pressure

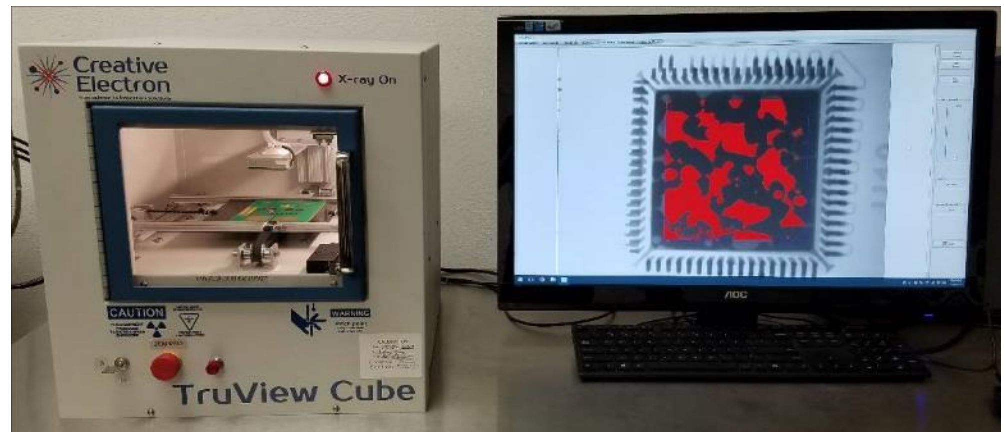
3.0 mm/sec separation

Pick and Place

Equipment

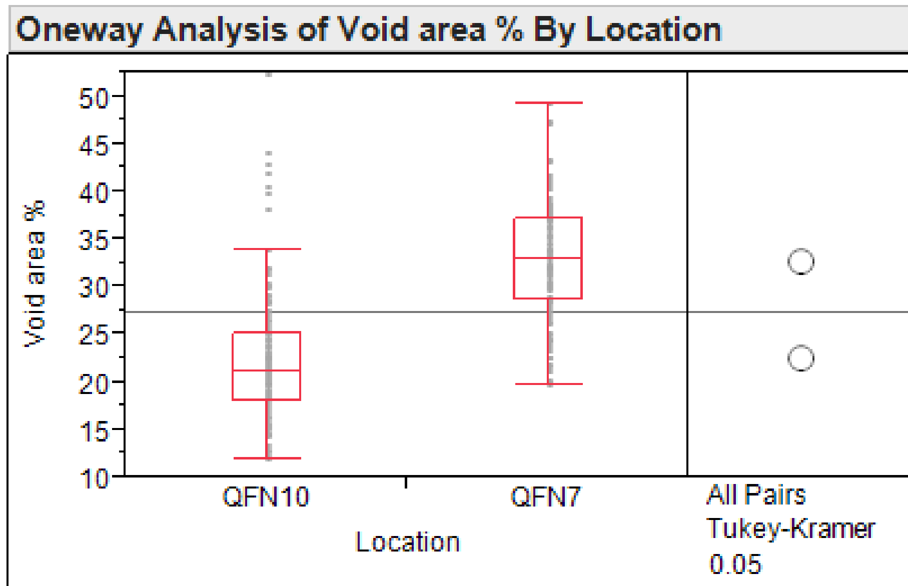
Reflow Oven:
10 zone, reflow in air

X-Ray: voltage 70 kV,
current 400 μA



Voiding Results

Voiding Results – Component Size



Excluded Rows 480

Means Comparisons

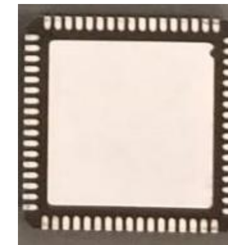
Comparisons for all pairs using Tukey-Kramer HSD

Connecting Letters Report

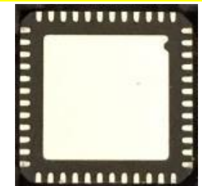
Level			Mean
QFN7	A		32.674167
QFN10		B	22.431667

Levels not connected by same letter are significantly different.

QFN 10
65% area

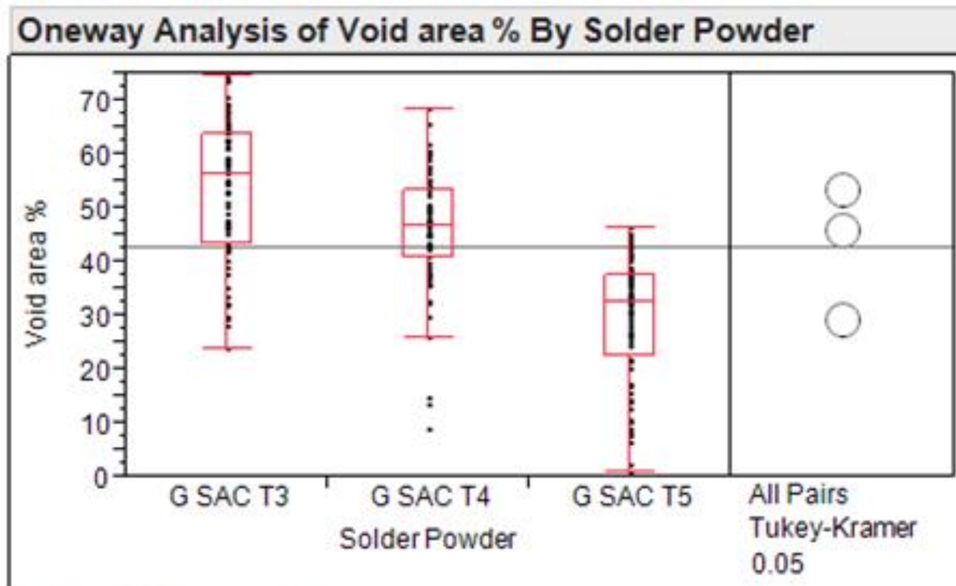


QFN 7
50% area



NC Solder Paste C
SAC305 Profile

Voiding Results – Solder Powder Size



Excluded Rows 1616

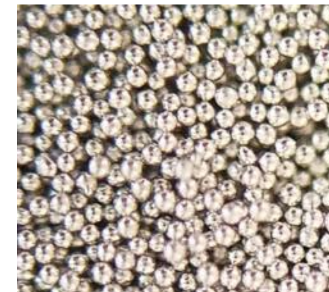
Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

Connecting Letters Report

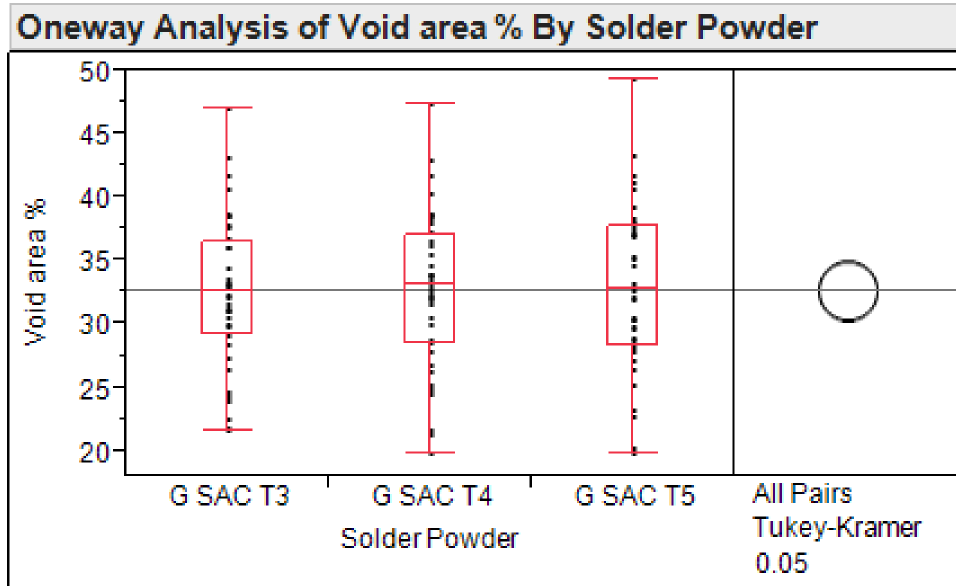
Level				Mean
G SAC T3	A			53.348750
G SAC T4		B		46.000000
G SAC T5			C	29.266250

Levels not connected by same letter are significantly different.



WS Solder Paste B
SAC305 Profile
QFN 10

Voiding Results – Solder Powder Size



Excluded Rows 600

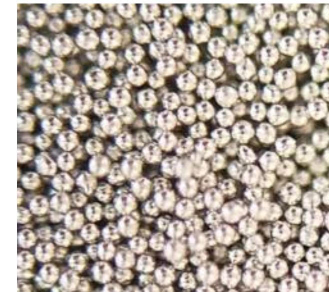
Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

Connecting Letters Report

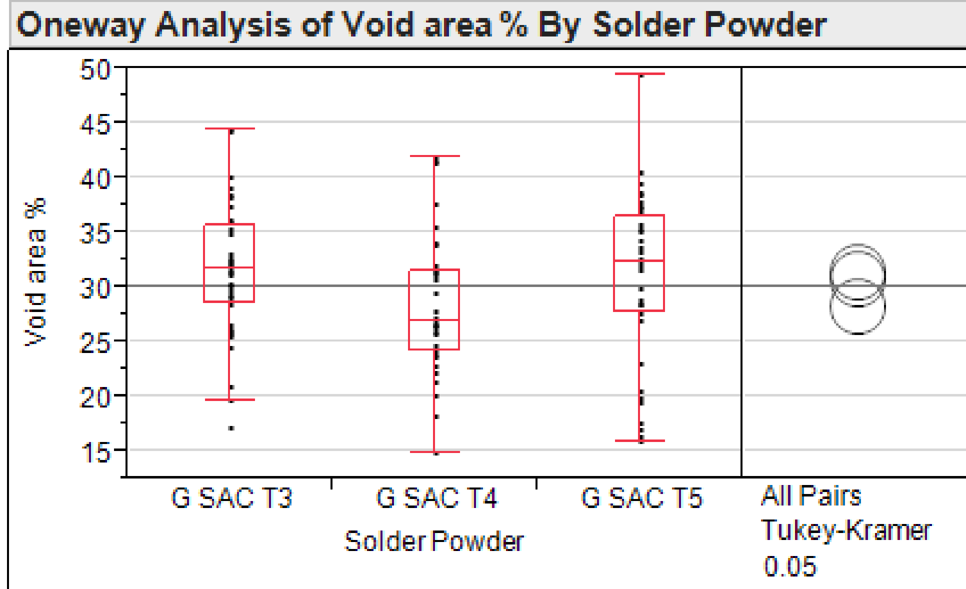
Level		Mean
G SAC T4	A	32.772500
G SAC T5	A	32.745000
G SAC T3	A	32.505000

Levels not connected by same letter are significantly different.



NC Solder Paste C
SAC305 Profile
QFN 7

Voiding Results – Solder Powder Size



Excluded Rows 480

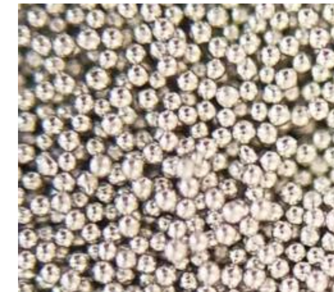
Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

Connecting Letters Report

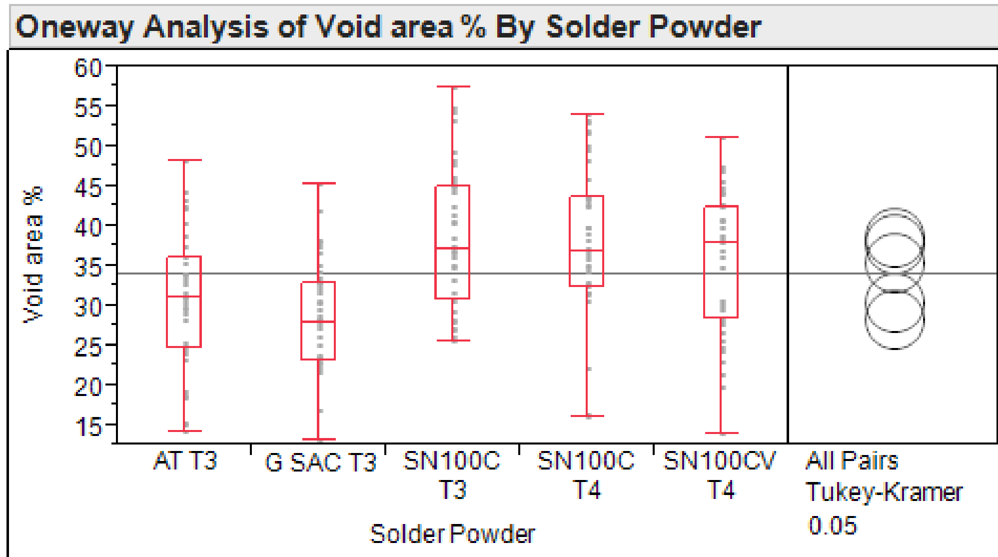
Level		Mean
G SAC T3	A	31.560000
G SAC T5	A	30.732500
G SAC T4	A	28.230000

Levels not connected by same letter are significantly different.



NC Solder Paste F
SAC305 Profile
QFN 7

Voiding Results – Solder Alloy



WS Solder Paste B
Appropriate profile
QFN 7

Excluded Rows 520

Means Comparisons

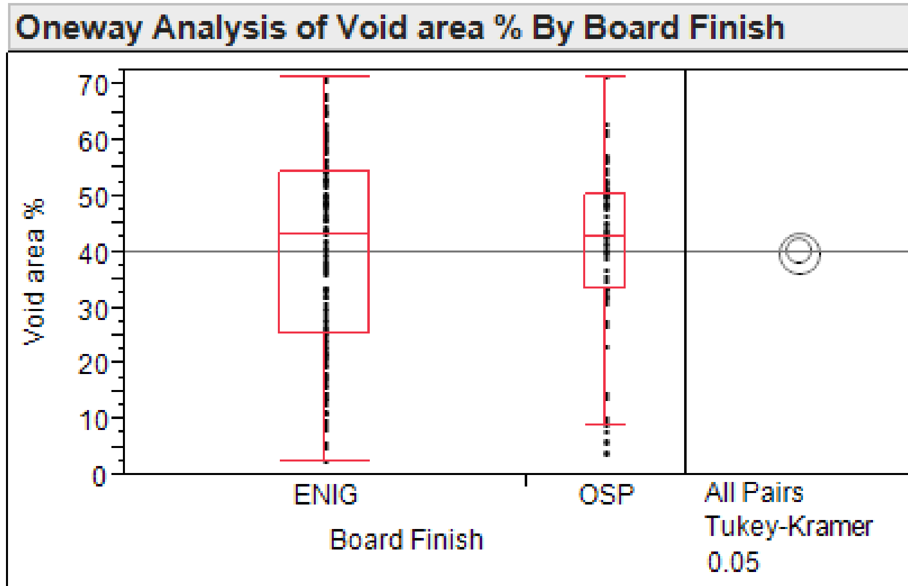
Comparisons for all pairs using Tukey-Kramer HSD

Connecting Letters Report

Level				Mean
SN100C T3	A			38.512500
SN100C T4	A			37.955000
SN100CV T4	A	B		35.382500
AT T3		B	C	30.500000
G SAC T3			C	28.440000

Levels not connected by same letter are significantly different.

Voiding Results – Surface Finish



Excluded Rows 1576

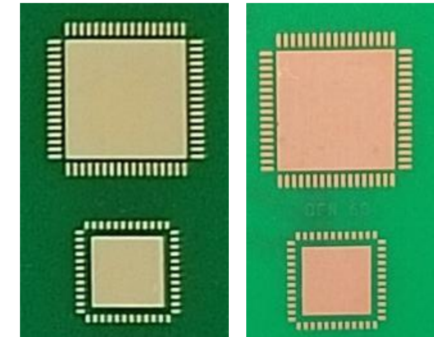
Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

Connecting Letters Report

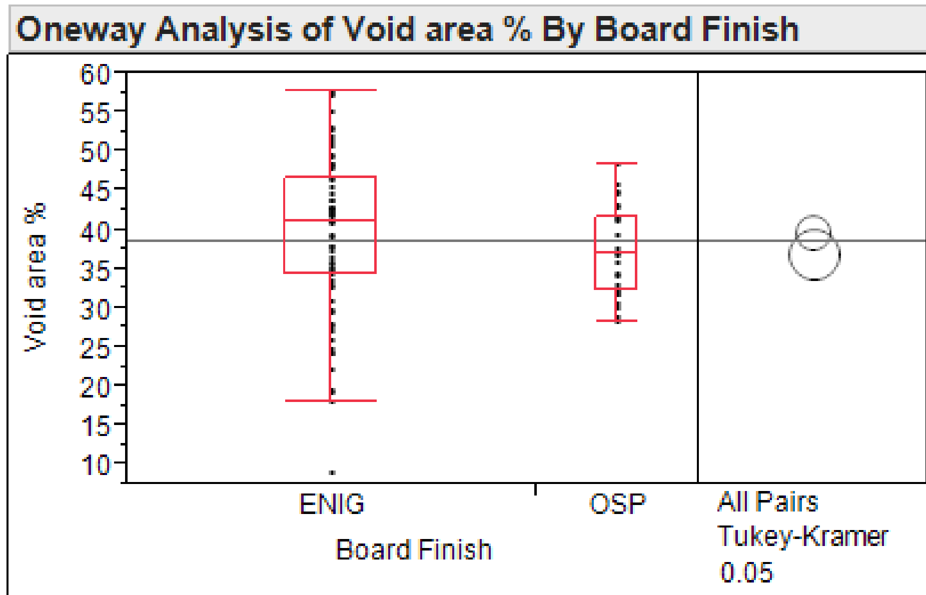
Level		Mean
ENIG	A	40.151500
OSP	A	40.056250

Levels not connected by same letter are significantly different.



WS Solder Paste B
SAC305 Profile
QFN 10

Voiding Results – Surface Finish



Excluded Rows 1744

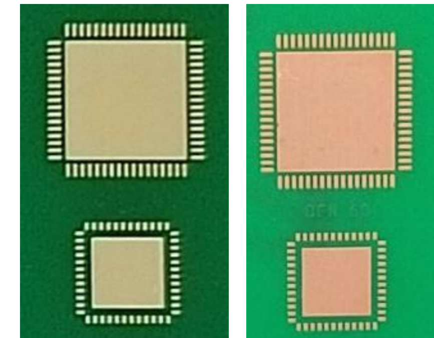
Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

Connecting Letters Report

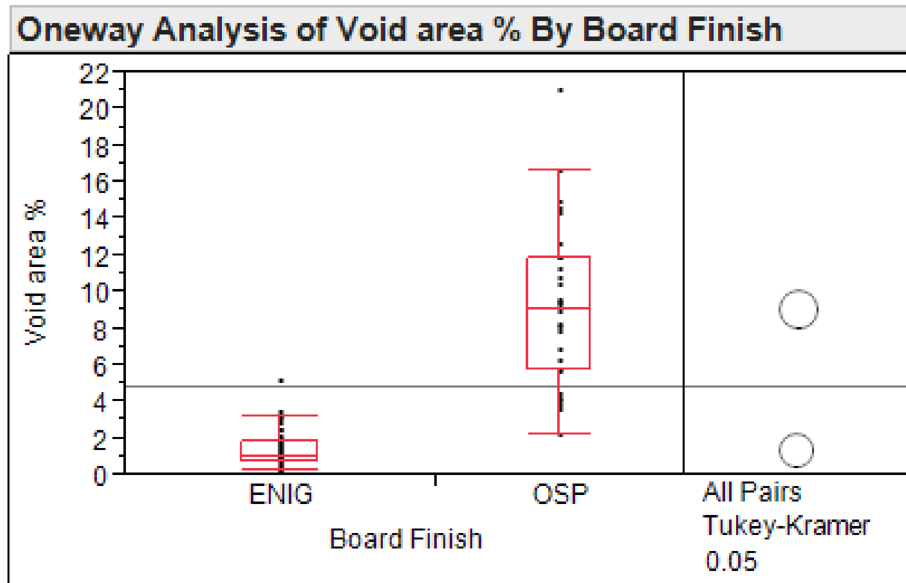
Level		Mean
ENIG	A	39.597500
OSP	A	36.943750

Levels not connected by same letter are significantly different.



WS Solder Paste E
SAC305 Profile
QFN 10

Voiding Results – Surface Finish



Excluded Rows 1784

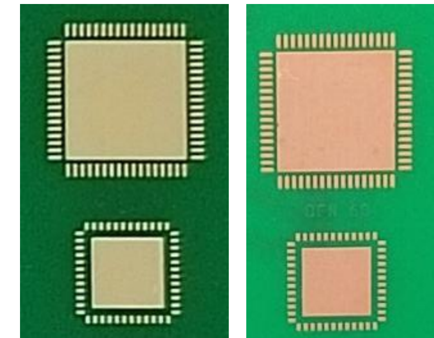
Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

Connecting Letters Report

Level			Mean
OSP	A		9.2031250
ENIG		B	1.3575000

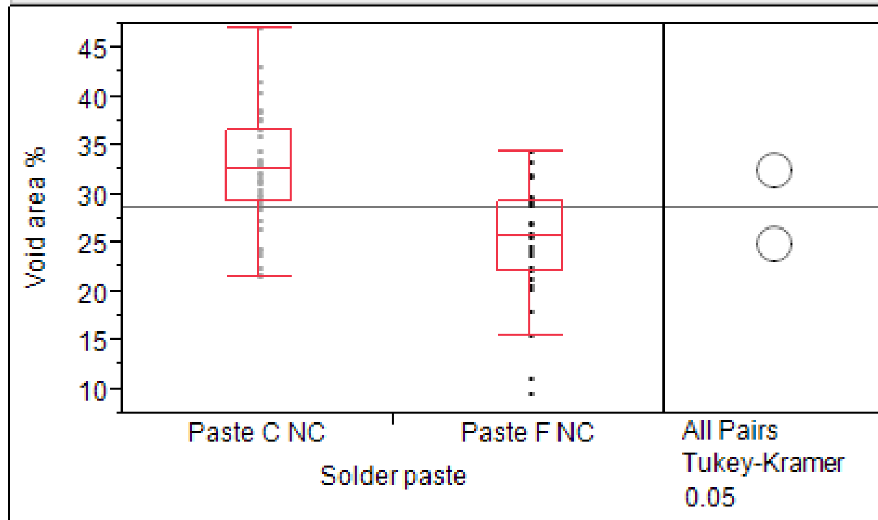
Levels not connected by same letter are significantly different.



NC Solder Paste C
SAC305 Profile
QFN 10

Voiding Results – Solder Paste

Oneway Analysis of Void area % By Solder paste Location=QFN7



Excluded Rows 240

Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

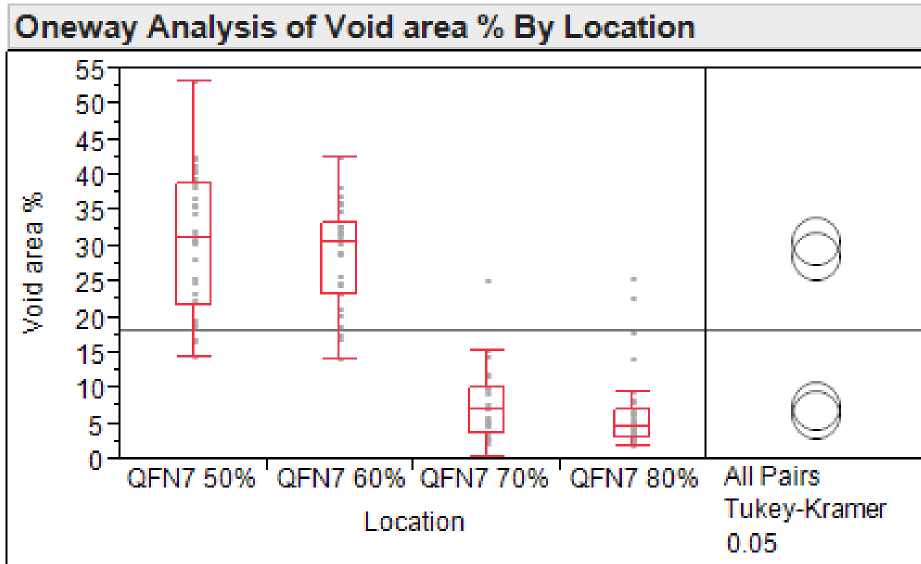
Connecting Letters Report

Level			Mean
Paste C NC	A		32.505000
Paste F NC		B	25.070000

Levels not connected by same letter are significantly different.

NC Solder Pastes C & F
SAC305 Profile
QFN 7

Voiding Results – Custom Stencil Design



Excluded Rows 600

Means Comparisons

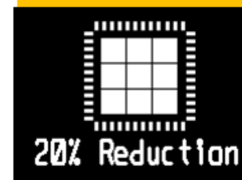
Comparisons for all pairs using Tukey-Kramer HSD

Connecting Letters Report

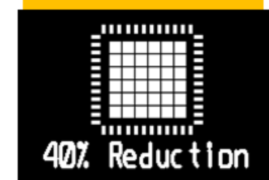
Level			Mean
QFN7 50%	A		30.720000
QFN7 60%	A		28.750000
QFN7 70%		B	7.633333
QFN7 80%		B	6.493333

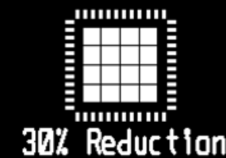
Levels not connected by same letter are significantly different.

80% area



60% area





70% area

50% area

NC Solder Paste F
SAC305 Profile
QFN 7

Conclusions

What Have We Learned About Voiding?

Factor	Conclusion
Component size	• The 7 mm QFN gave higher voiding than the 10 mm QFN. This was likely affected by the stencil design.
Solder powder size	• Decreasing solder powder size gave lower voiding for Paste B (WS) but not Pastes C or F (NC)
Solder paste	• Water soluble lead free pastes tend to give higher voiding than no clean lead free pastes. • New “low voiding” solder pastes can help to reduce the potential for voiding.
Solder alloy	• As the melting range of the solder alloy widens then the voiding tends to decrease.
Surface finish	• OSP surface finish gave higher voiding than ENIG with a no clean paste. Two water soluble pastes showed similar voiding with OSP and ENIG.
Stencil design	• Increasing the printed paste area tends to reduce voiding on QFN thermal pads.

How to Fill the Void

- ✓ Decreasing the solder powder size can reduce voiding with certain solder pastes.
- ✓ Specific solder alloys may help mitigate voiding.
- ✓ Use a solder paste that works well with the surface finish to minimize voiding.
- ✓ “Low voiding” solder pastes can be used to reduce the overall potential for voiding.
- ✓ Optimize the stencil design for the components to allow for complete wetting and gas escape routes.

Future Work

Voiding is prevalent for via-hole in pad designs. Mitigation methods are being tested including:

- Via hole plugging options
  - No plug – open via hole
  - Solder mask tent
  - Complete via fill
- Stencils designs
  - Print around holes
  - Gas escape routes

I would like to thank Greg Smith (Blue Ring Stencils) for his help designing the stencils used in this work.

I also appreciate the efforts of Andrea Motley, a summer intern, who performed much of the testing.

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