

How Does Surface Finish Affect Solder Paste Performance?

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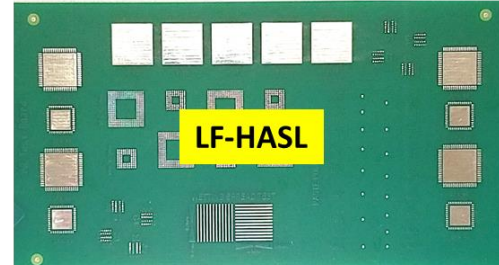
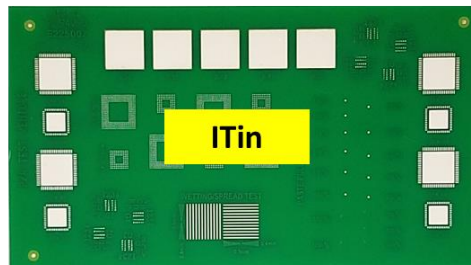
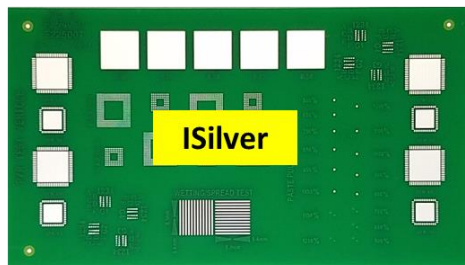
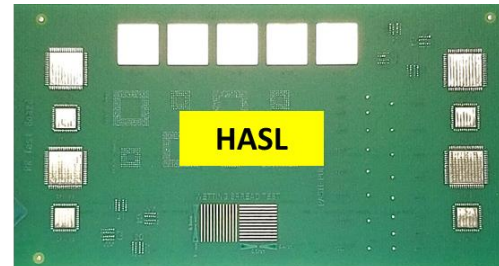
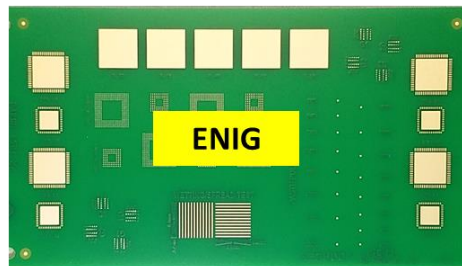
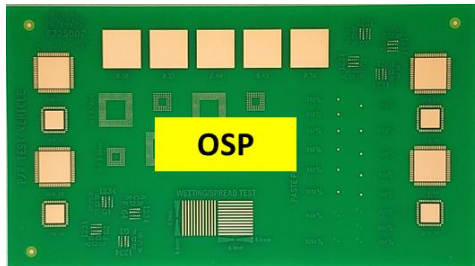
Outline/Agenda

- **Introduction**
- **Experimental Methodology**
- **Results & Discussion**
- **Conclusions**
- **Recommendations**
- **Future Work**
- **Question & Answer**

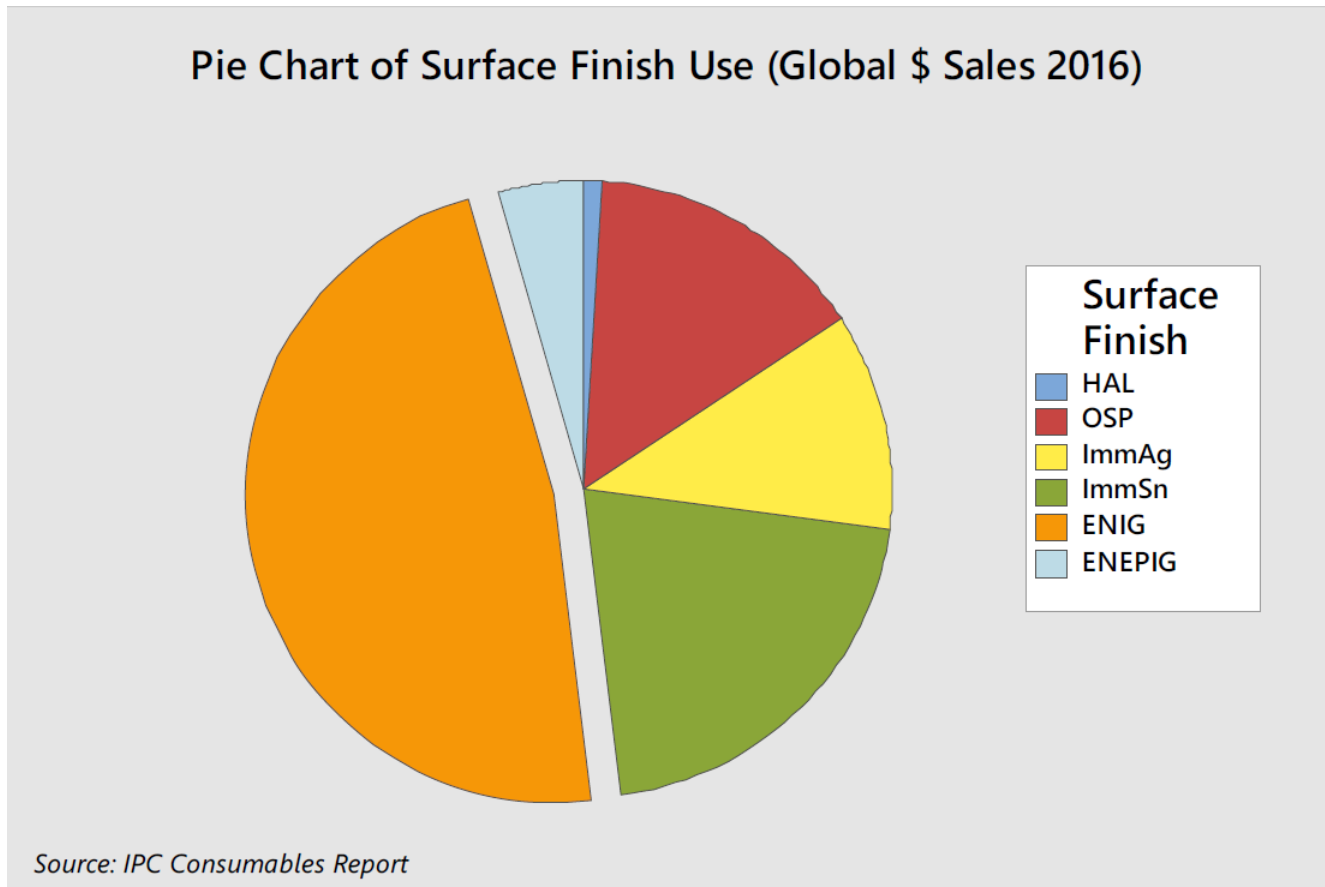
Introduction

Surface Finishes & Solder Pastes

- Must work together
- How does surface finish affect performance?



Surface Finishes Used on PCBs



*M. Bunce, L. Clark, J. Swanson, "Achieving A Successful ENIG Finished PCB Under Revision A Of IPC 4552 MacDermid Enthone", Proceedings of SMTA International, 2017

Experimental Methodology



Experimental Methodology

Surface Finish	Thickness
HASL (Sn63/Pb37)	1.6 - 8.4 μm solder
LF-HASL (SnCu0.7Ni0.06Ge)	2.8 - 3.3 μm solder
OSP (High Temp)	< 2 μm
ENIG	3.0 - 6.1 μm nickel 0.05 - 0.13 μm gold
ITin	1.7 - 1.8 μm tin
ISilver	0.15 - 0.38 μm silver

Experimental Methodology

Solder Pastes

Solder Paste Flux	J-STD-004 Class	Solder Alloy	Code
Water-Soluble	ORH0	Sn63/Pb37	WS 63-37
No-Clean	ROL0	Sn63/Pb37	NC 63-37
Water-Soluble	ORH1	SAC305	WS SAC
No-Clean	ROL0	SAC305	NC SAC

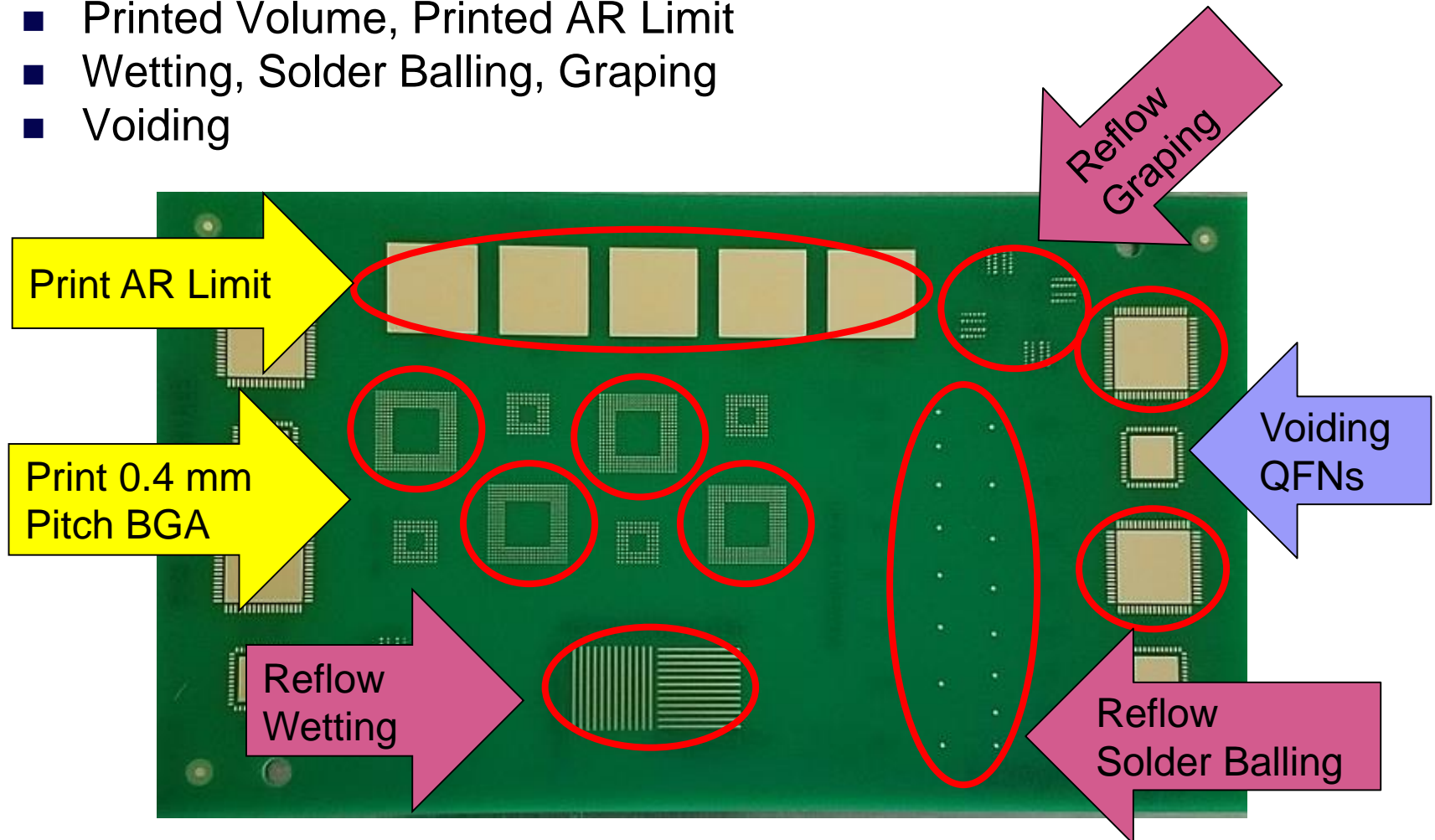


**Solder Powder Size:
IPC Type 4 (20-38 μm)**

Experimental Methodology

PR Test Board Measures:

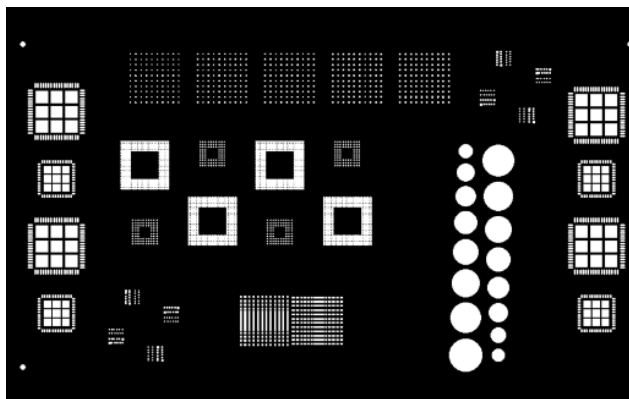
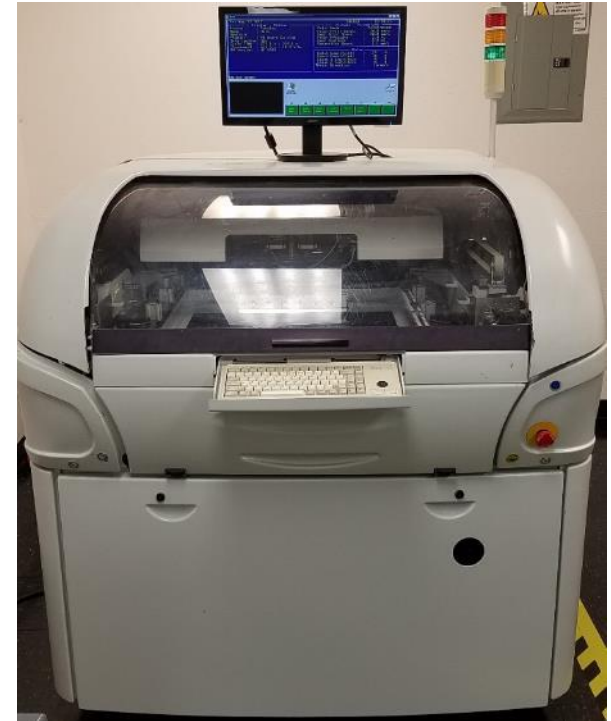
- Printed Volume, Printed AR Limit
- Wetting, Solder Balling, Graping
- Voiding



Experimental Methodology

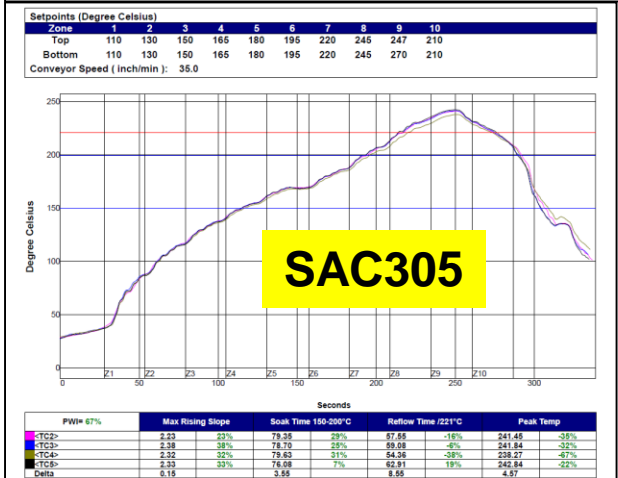
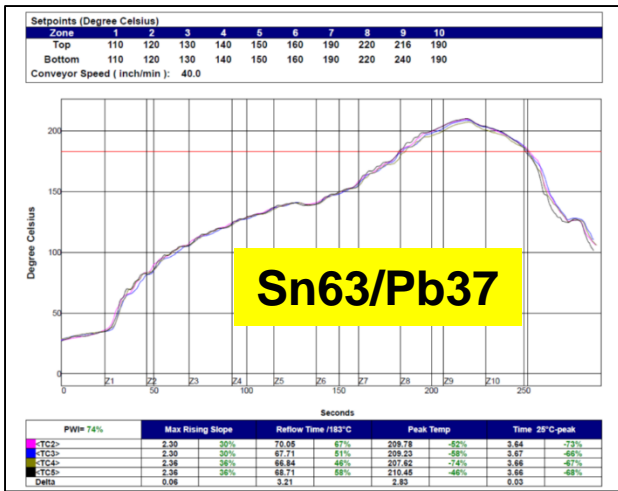
Print and Stencil Parameters

Print Speed	50 mm/sec
Blade Length	300 mm
Blade Pressure	5.0 kg (0.17 kg/cm)
Separation Speed	3.0 mm/sec
Separation Distance	2.0 mm
Stencil Thickness	127 μm (5 mil)
Stencil Material	Fine grain SS 2-5 μm

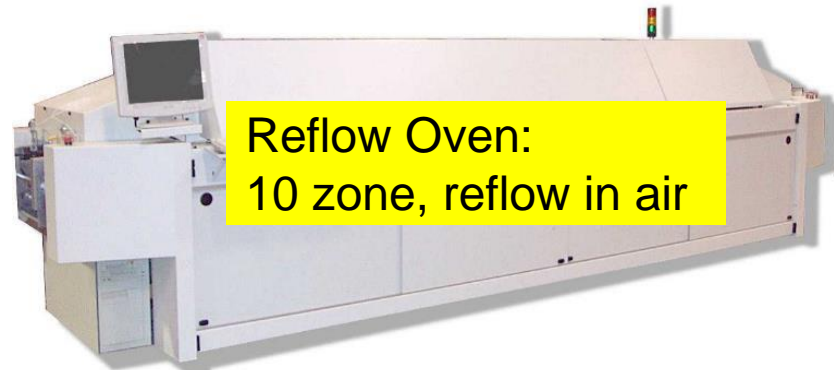


Experimental Methodology

Reflow Profiles

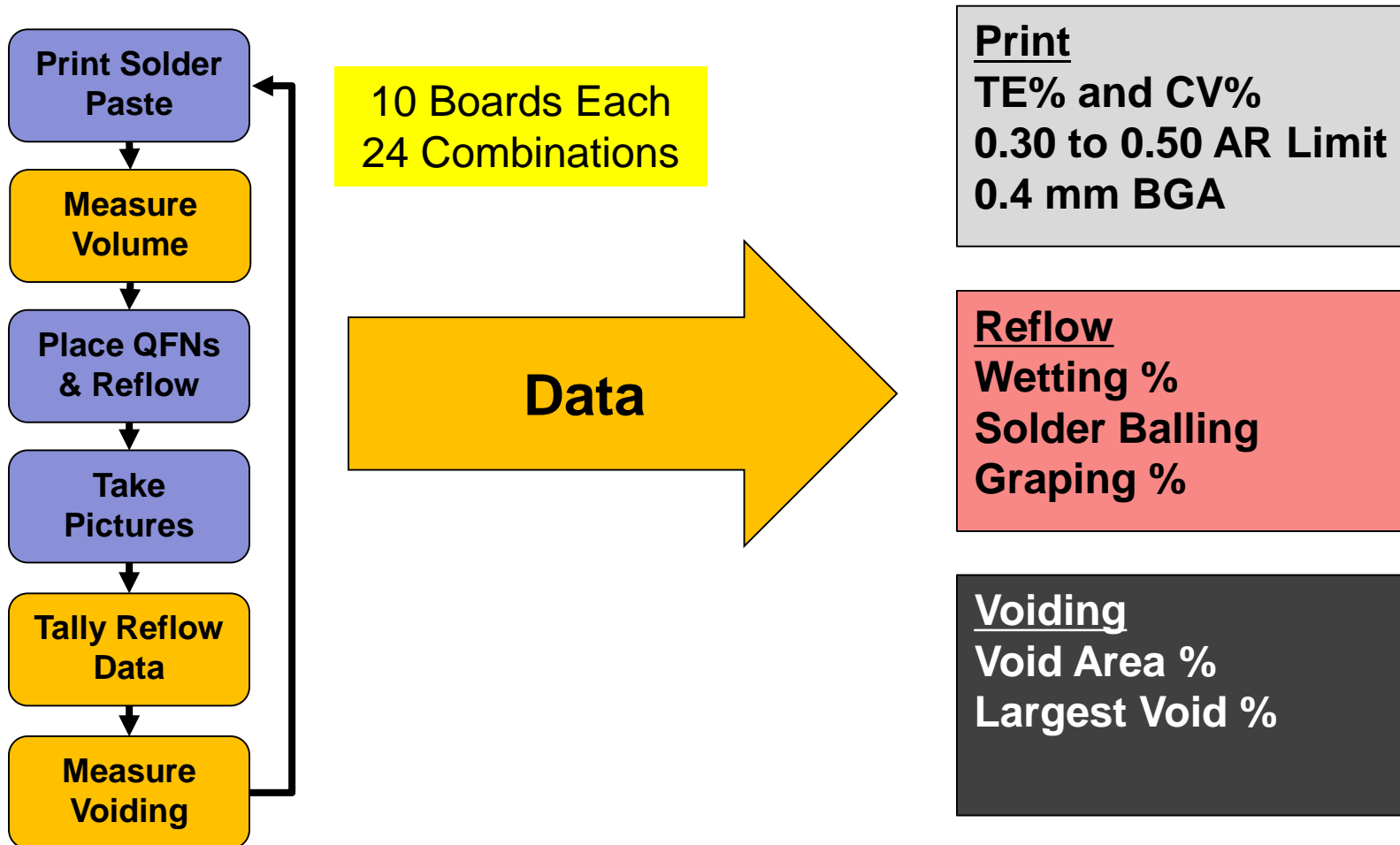


Setting	Sn63/Pb37 Profile	SAC305 Profile
Max Rising Slope	2.3 – 2.4 °C/sec	2.2 – 2.4 °C/sec
TAL (Reflow time)	67 – 70 sec > 183°C	54 – 63 sec > 221°C
Peak temperature	208 to 210 °C	238 to 243 °C
Profile length (25 °C to peak)	3.6 minutes	4.1 minutes



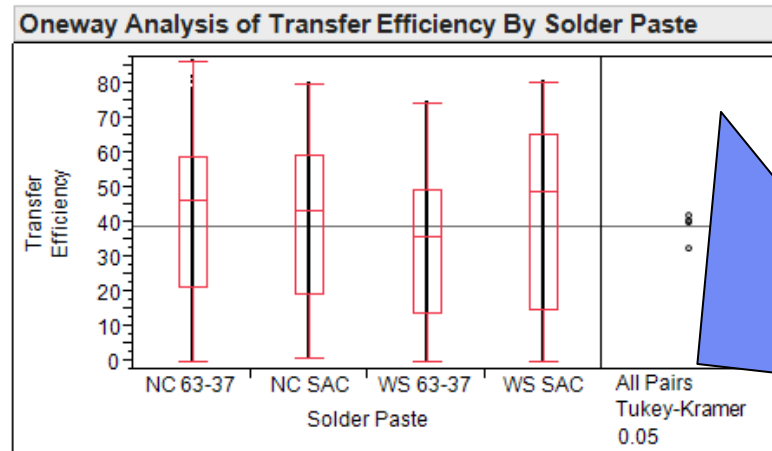
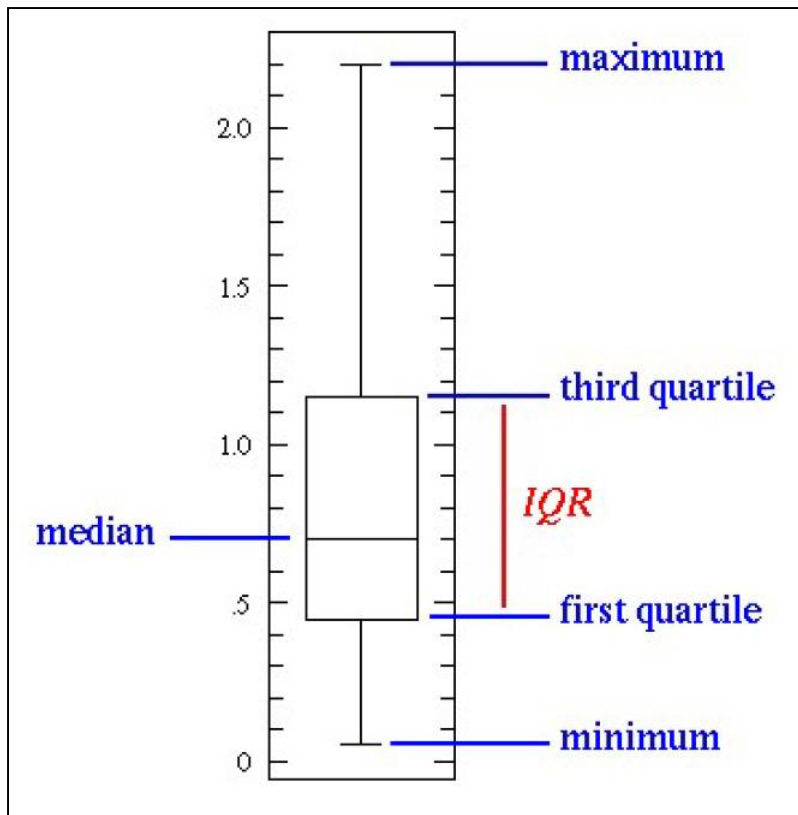
Experimental Methodology

Process and Data



Experimental Methodology

Box Plots & Tukey-Kramer Honest Significant Difference



Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

Connecting Letters Report

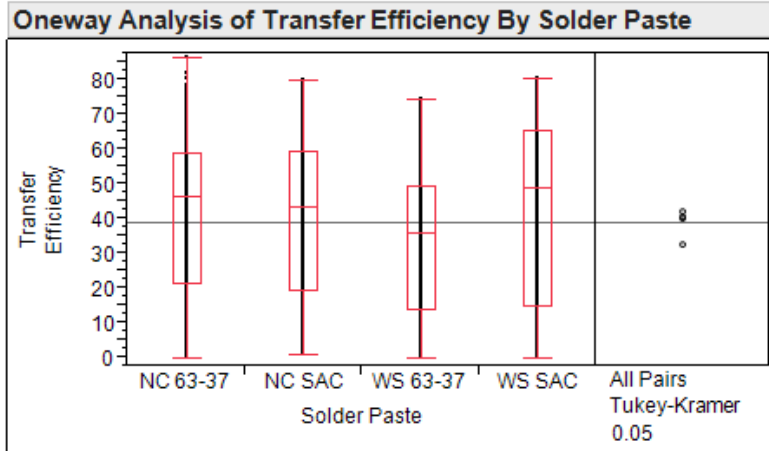
Level	Mean
WS SAC A	42.1
NC 63-37 B	40.7
NC SAC B	40.0
WS 63-37 C	32.7

Levels not connected by same letter are significantly different.

Connecting Letters Shows Differences



Print: Transfer Efficiency Overview



Means Comparisons

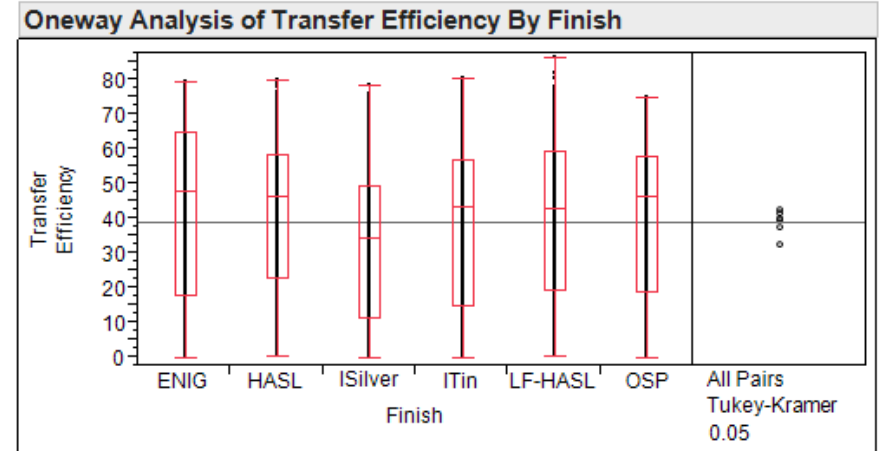
Comparisons for all pairs using Tukey-Kramer HSD

Connecting Letters Report

Level	Mean
WS SAC A	42.1
NC 63-37 B	40.7
NC SAC B	40.0
WS 63-37 C	32.7

Levels not connected by same letter are significantly different.

SOLDER PASTE



Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

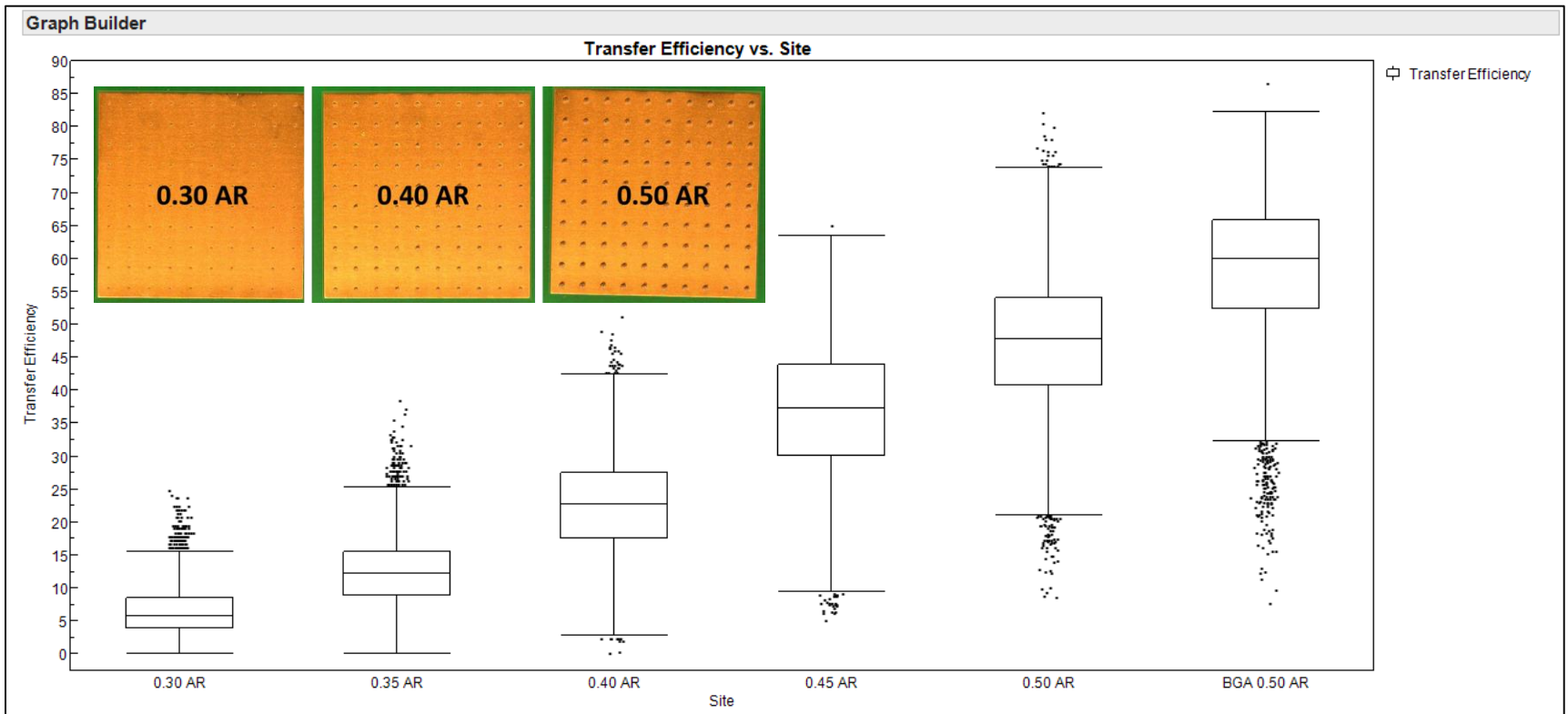
Connecting Letters Report

Level	Mean
ENIG A	42.3
HASL A	41.6
LF-HASL B	39.8
OSP B	39.7
ITin C	37.4
ISilver D	32.6

Levels not connected by same letter are significantly different.

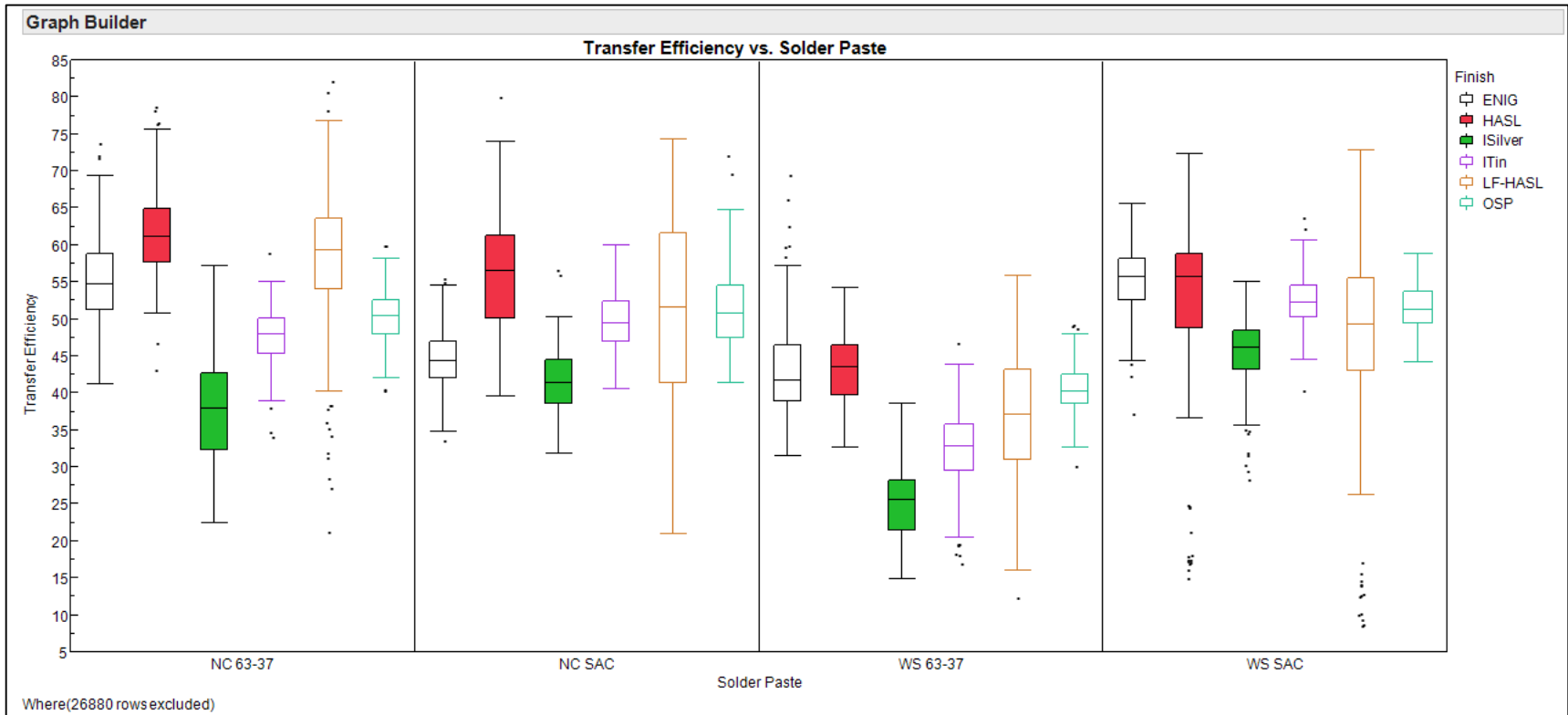
SURFACE FINISH

Print: TE 0.30 - 0.50 AR Limit Patterns



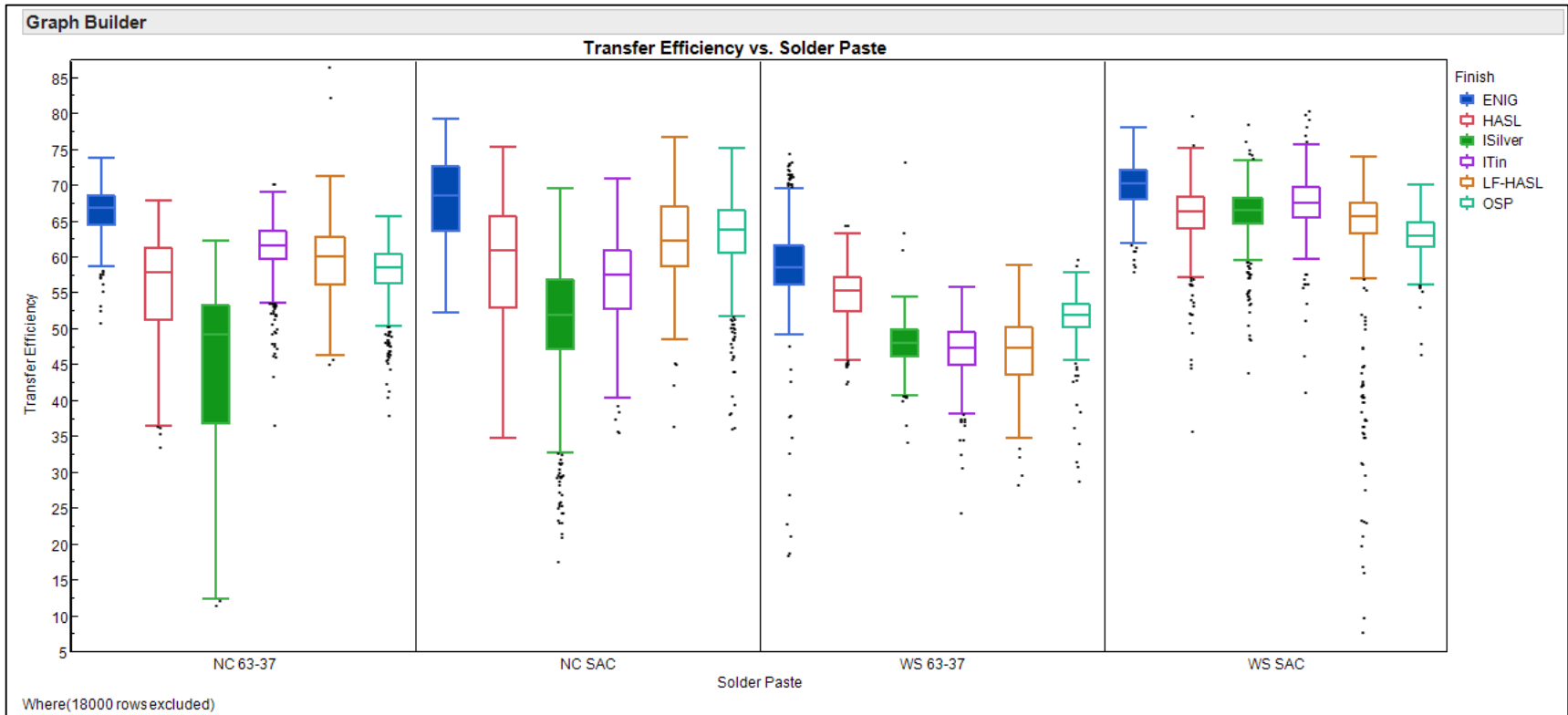
Some Solder Pastes Will Not Print at Low ARs

Print: TE 0.50 AR Limit Patterns



WS SAC Paste Prints More Uniformly
HASL Gave Highest TEs. ISilver Gave Lowest TEs

Print: TE 0.4 mm Pitch BGA (0.50 AR)



WS SAC Paste Prints Equally Well on all Finishes
Other Pastes: ENIG Gave Highest TEs. ISilver Gave Lowest TEs

Print: TE% and CV% Summary

0.4 mm Pitch BGA

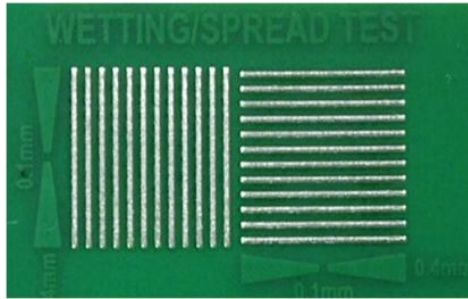
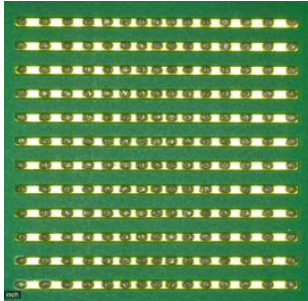
Surface Finish	Mean TE%	Standard Deviation of TE%	CV (%)
ENIG	65.9	6.4	9.7
HASL	58.9	7.5	12.7
ISilver	52.5	11.2	21.3
ITin	58.1	8.8	15.1
LF-HASL	58.1	9.3	16.0
OSP	58.9	6.3	10.7

Coefficient of Variation of Less Than 10% is the Goal

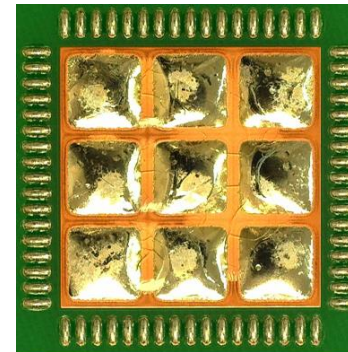
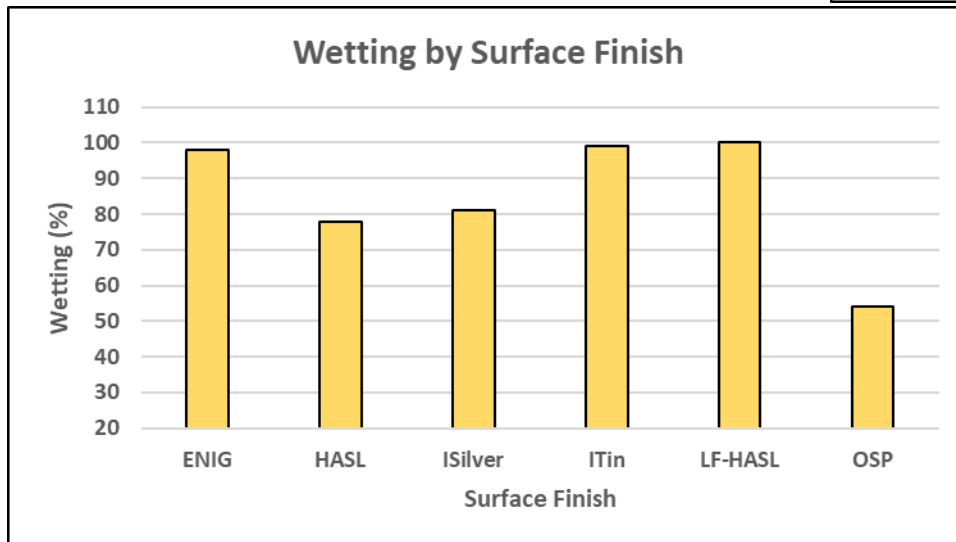
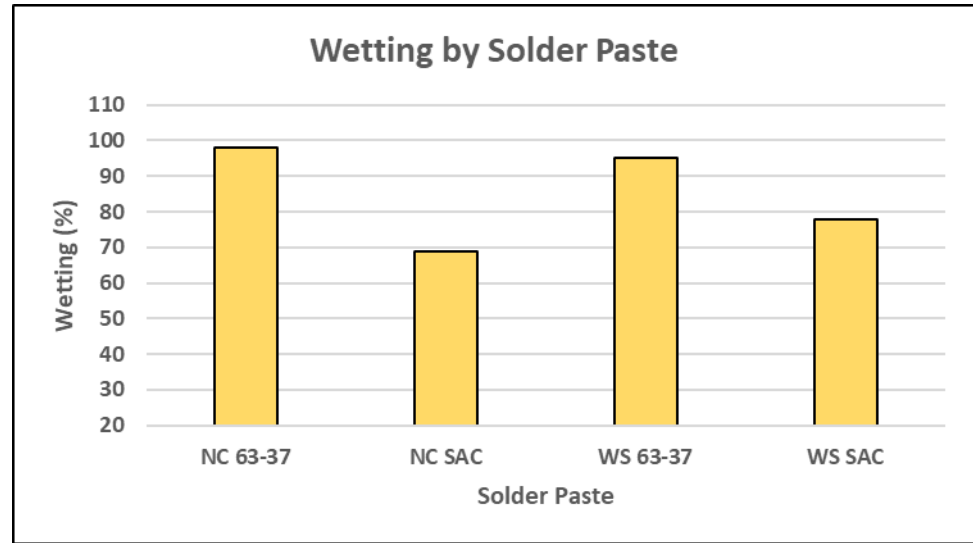
Reflow Results



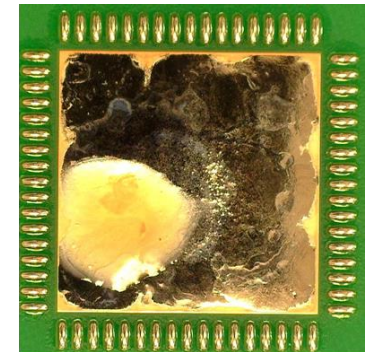
Reflow: Wetting



15 Bricks of Paste on Each Line
Pitch varies 0.4 to 0.1 mm
Goal = 100% Spread

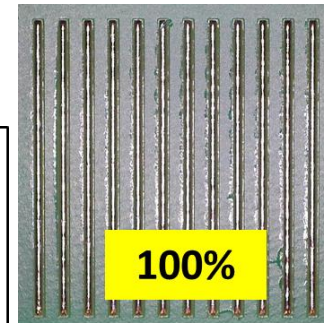
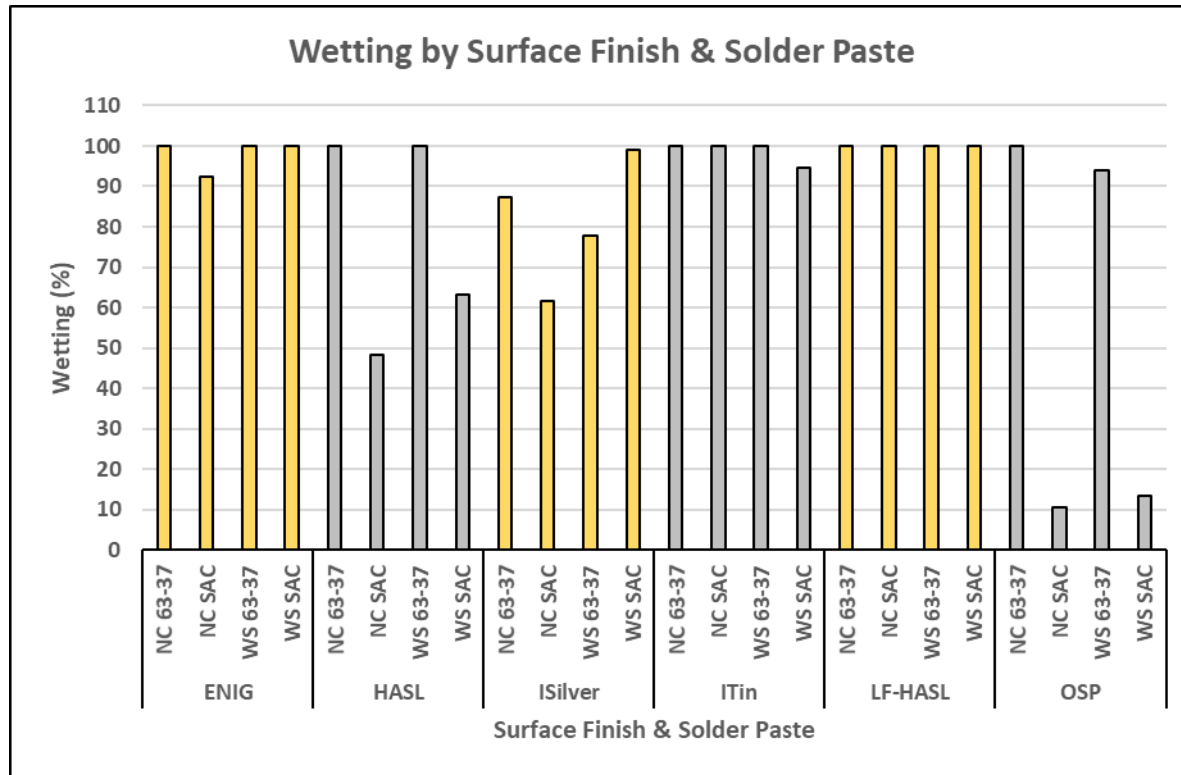


OSP NC SAC

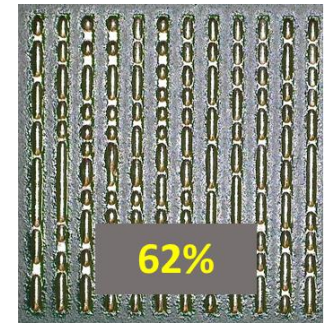


OSP NC 63-37

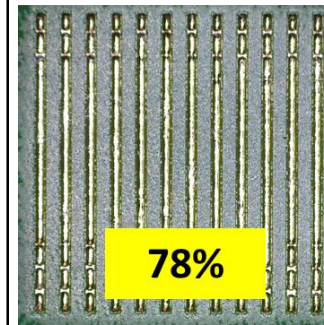
Reflow: Wetting



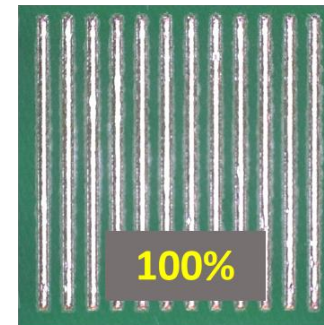
ENIG NC 63-37



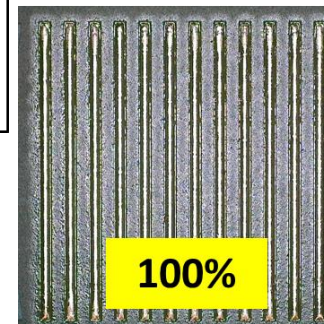
HASL WS SAC



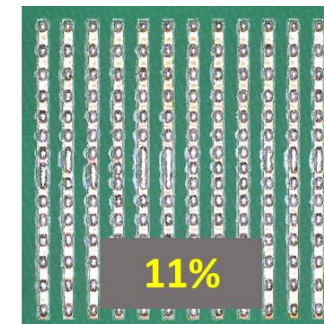
ISilver WS 63-37



ITin NC SAC

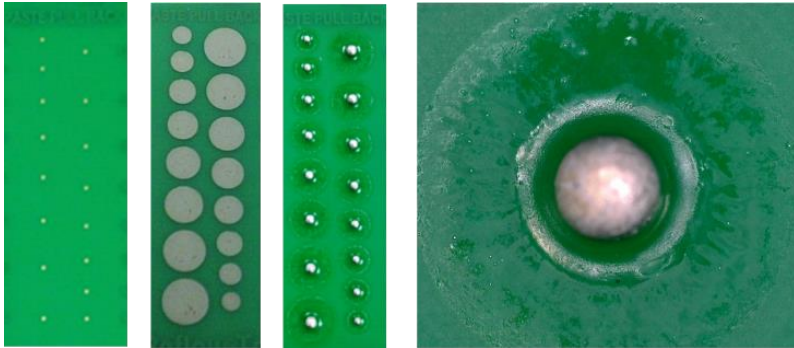


LF-HASL WS SAC

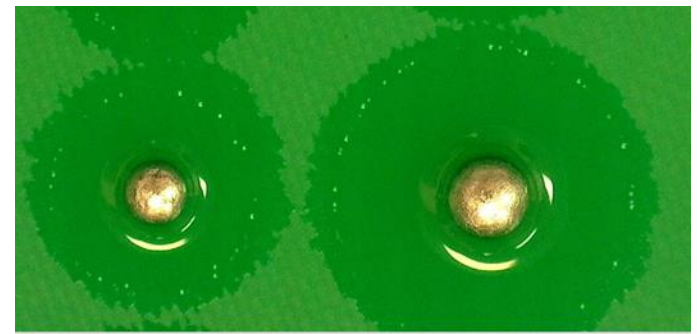
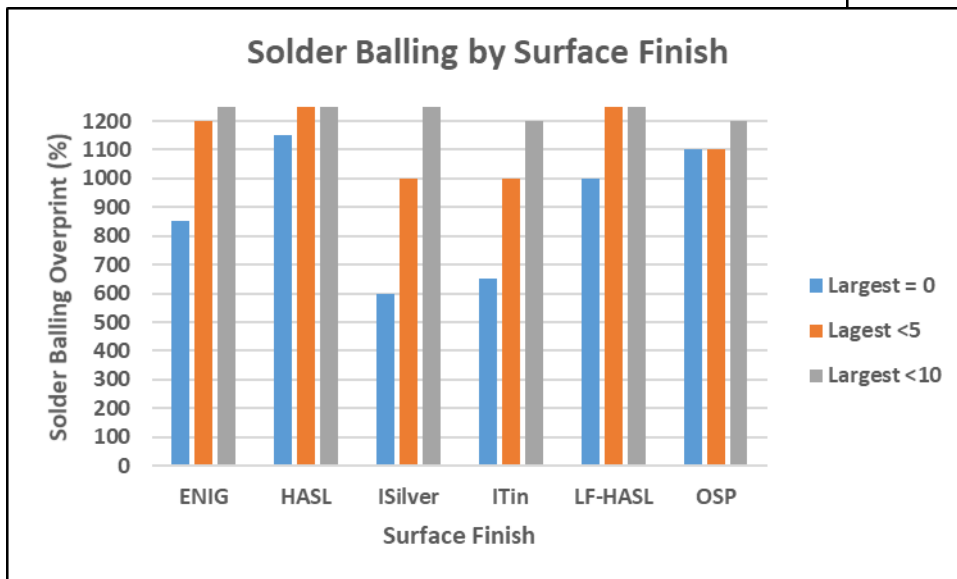
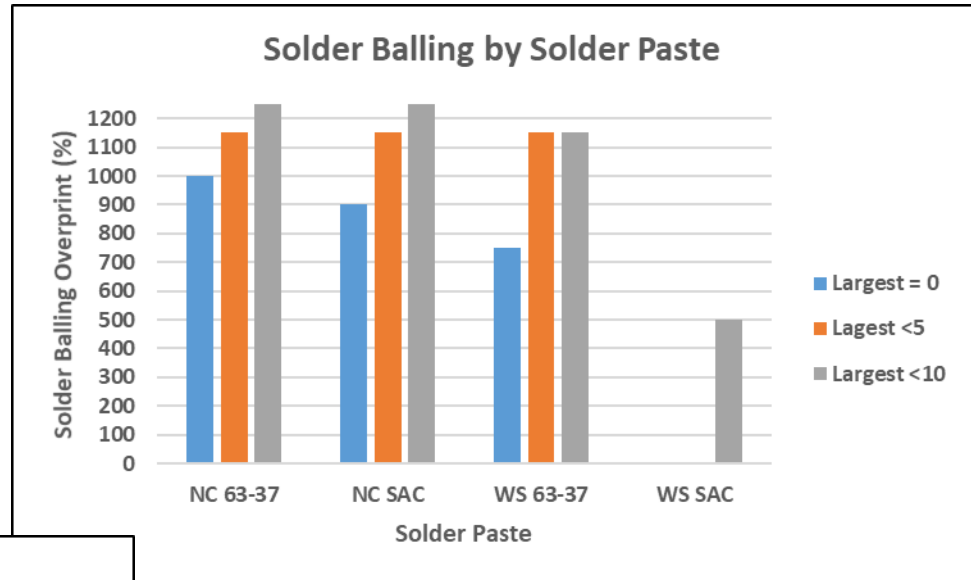


OSP NC SAC

Reflow: Solder Balling

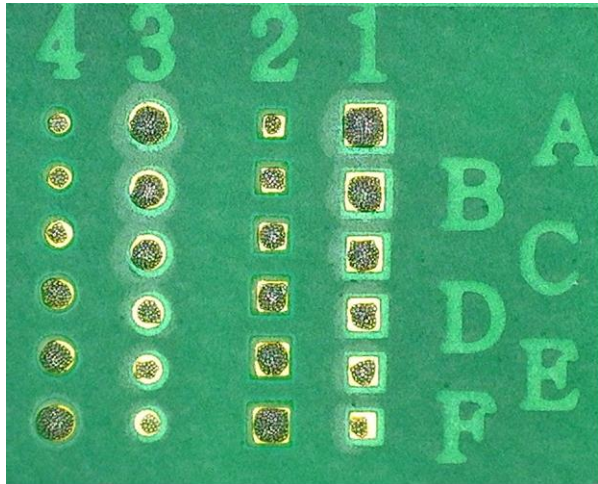


Overprint 500% to 1250%
Goal = 1250% Overprint



OSP WS 63-37

Reflow: Graping



5 mil thick stencil

A = 7 mil (0.35 AR)

B = 8 mil (0.40)

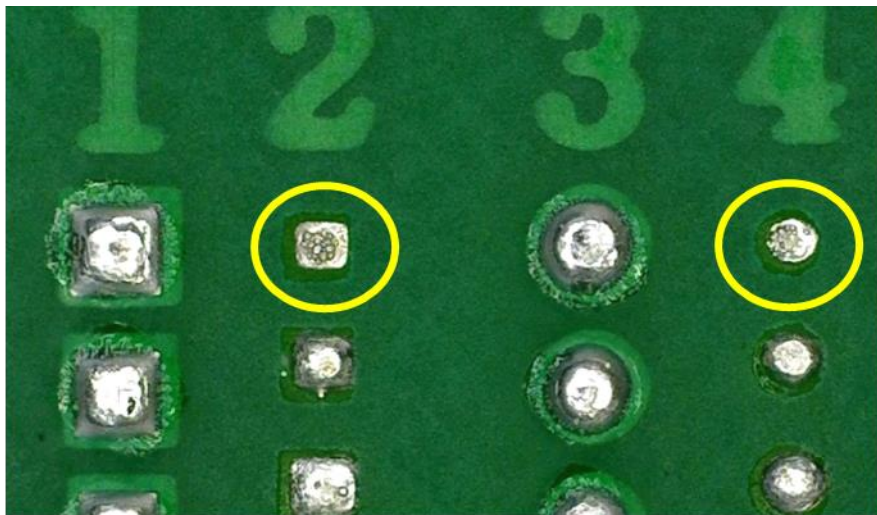
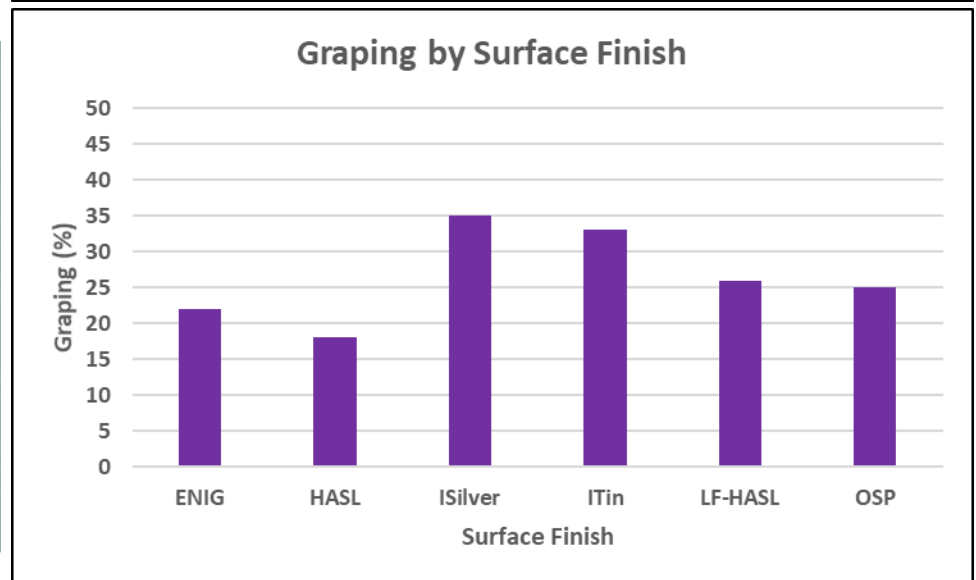
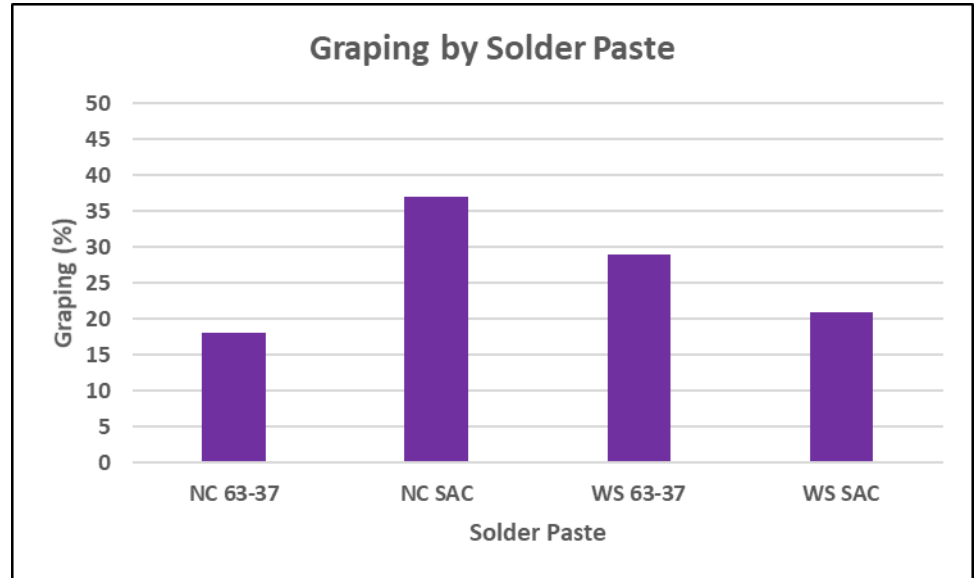
C = 9 mil (0.45)

D = 10 mil (0.50)

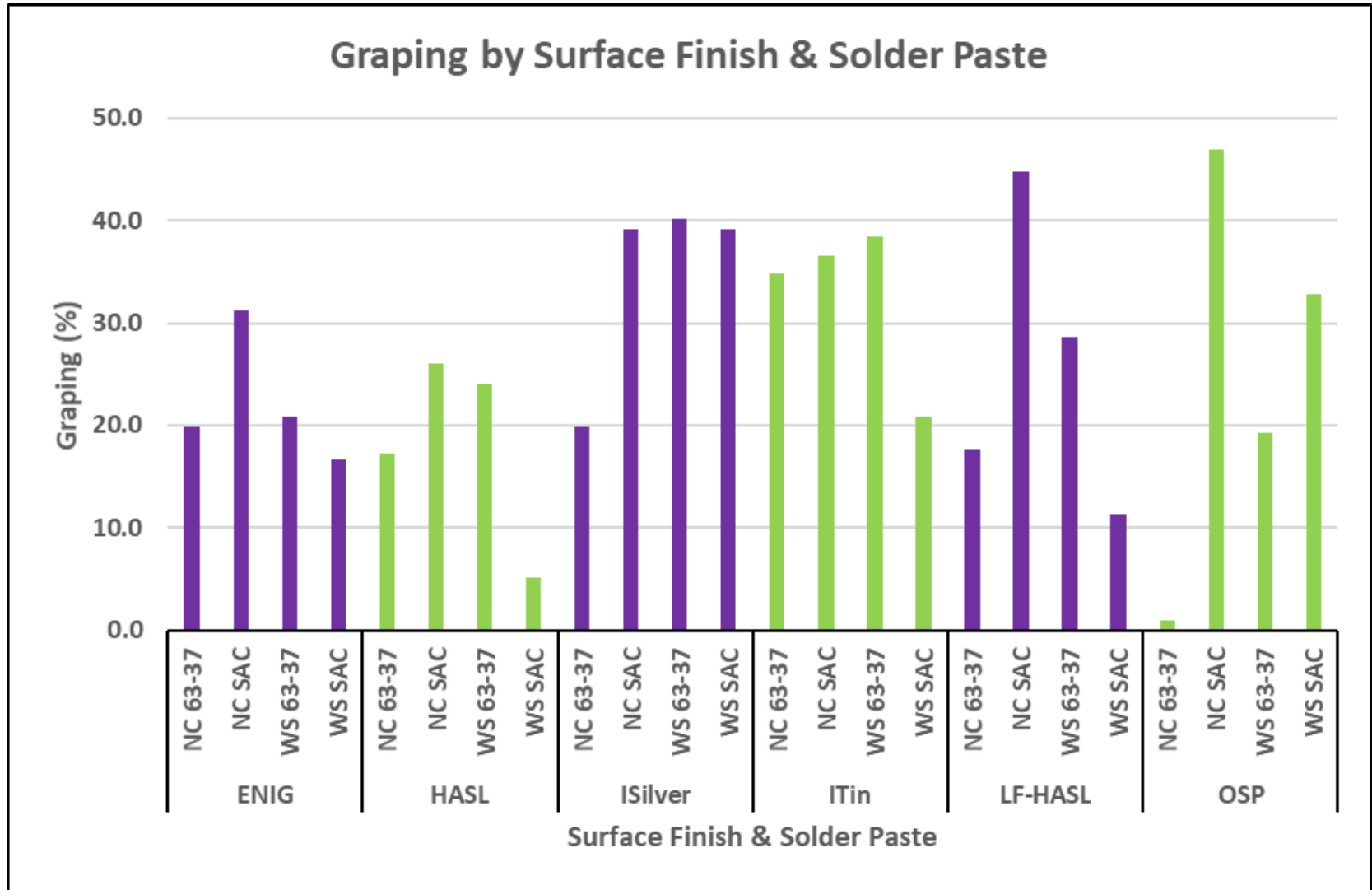
E = 11 mil (0.55)

F = 12 mil (0.60)

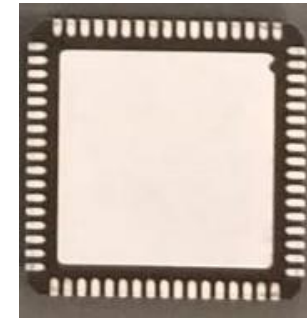
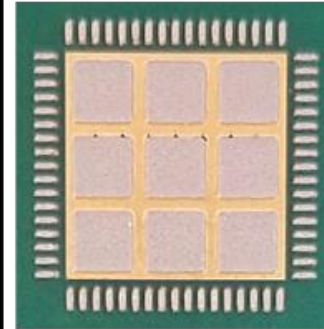
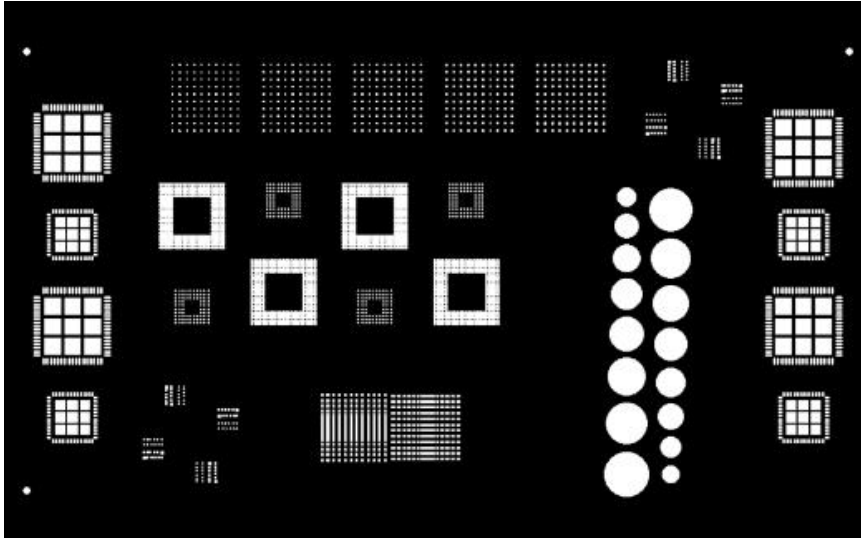
Goal = 0% Graping



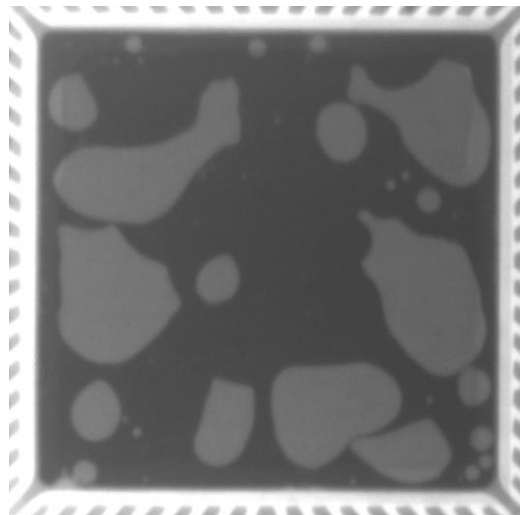
Reflow: Graping



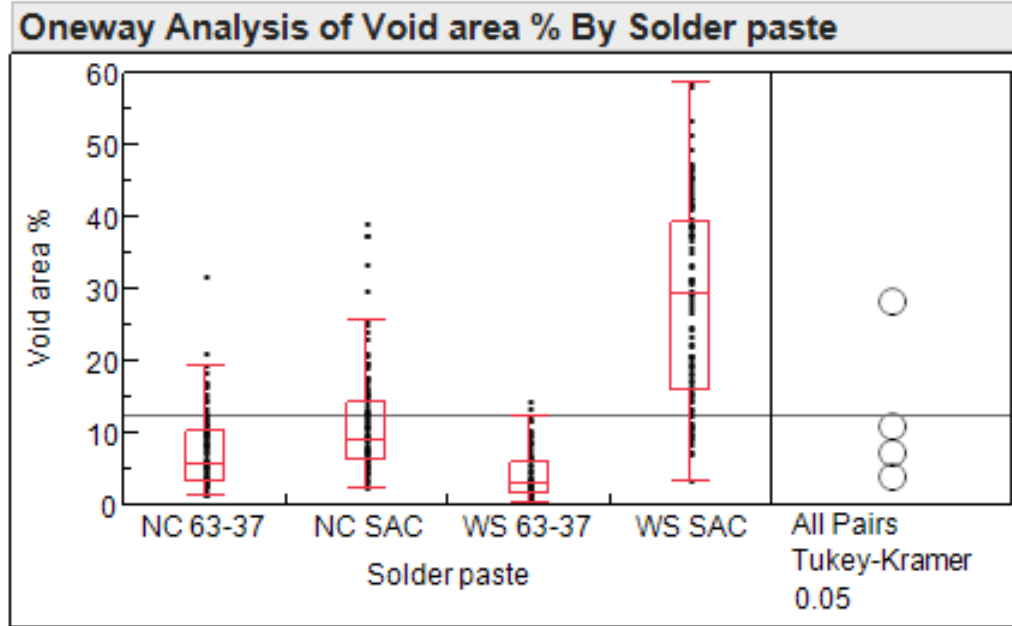
Voiding Results



Goal = 0% Void Area



Voiding: Solder Paste



Clear Differences in Void Performance

Means Comparisons

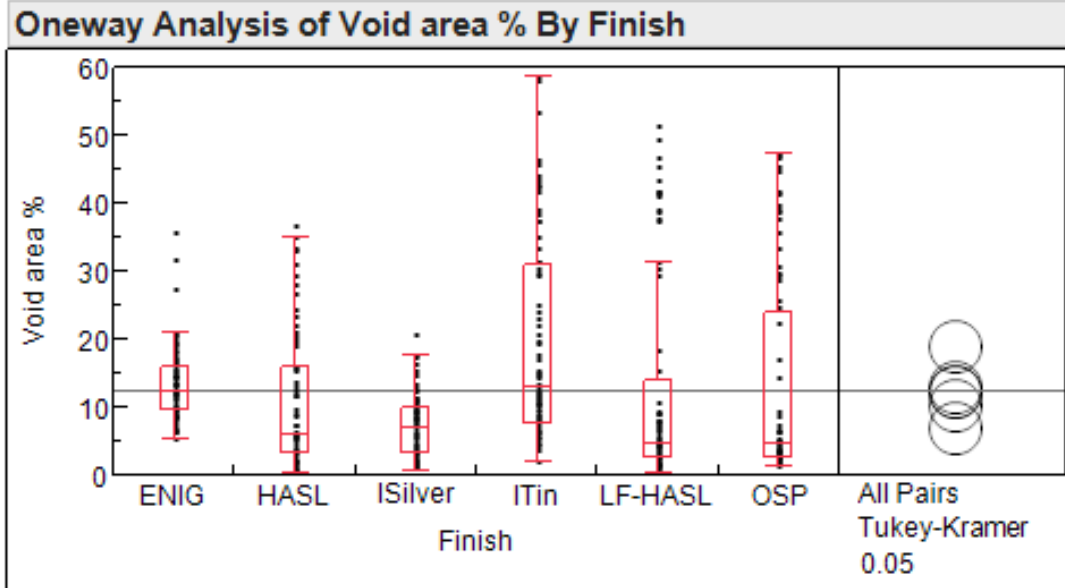
Comparisons for all pairs using Tukey-Kramer HSD

Connecting Letters Report

Level	Mean
WS SAC A	28.3
NC SAC B	11.2
NC 63-37 C	7.2
WS 63-37 D	4.1

Levels not connected by same letter are significantly different.

Voiding: Surface Finish



Less Clear Differences in Void Performance

Means Comparisons

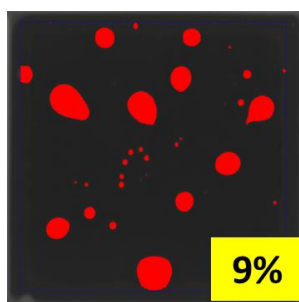
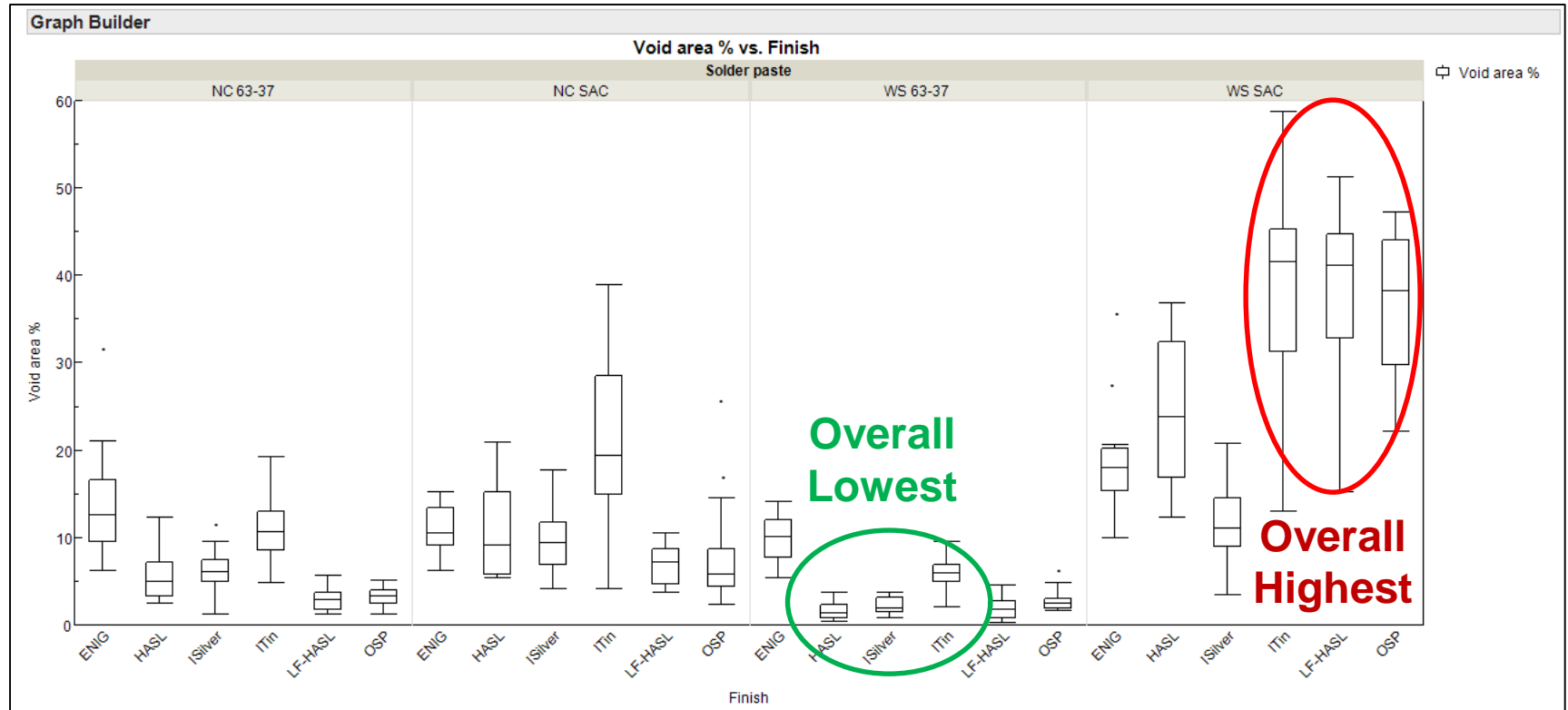
Comparisons for all pairs using Tukey-Kramer HSD

Connecting Letters Report

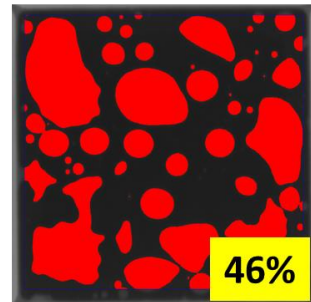
Level	Mean
ITin A	19.4
ENIG B	13.2
OSP B C	12.7
LF-HASL B C	12.5
HASL B C	10.7
ISilver C	7.5

Levels not connected by same letter are significantly different.

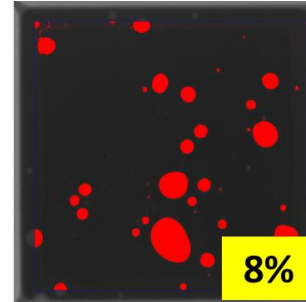
Voiding: Surface Finish & Solder Paste



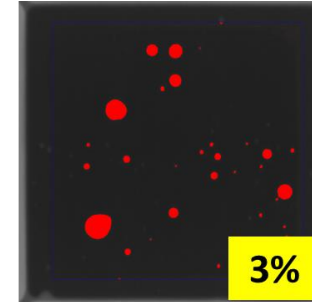
ITin WS 63-37



ITin WS SAC



ISilver WS SAC



ISilver WS 63-37

Scoring System



Scoring System

Category	Performance Metric	Possible Score
Print	Transfer Efficiency % in the 0.4 mm BGA Arrays	5
Print	Coefficient of Variation (TE) in the 0.4 mm BGA Arrays	5
Print	Transfer Efficiency % in the 0.50 AR Pattern	5
Print	Coefficient of Variation (TE) in the 0.50 AR Pattern	5
Reflow	Wetting or Spread %	5
Reflow	Solder Balling	5
Reflow	Graping %	5
Voiding	Void Area %	5
Voiding	Largest Void %	5
	Total Possible Score	45

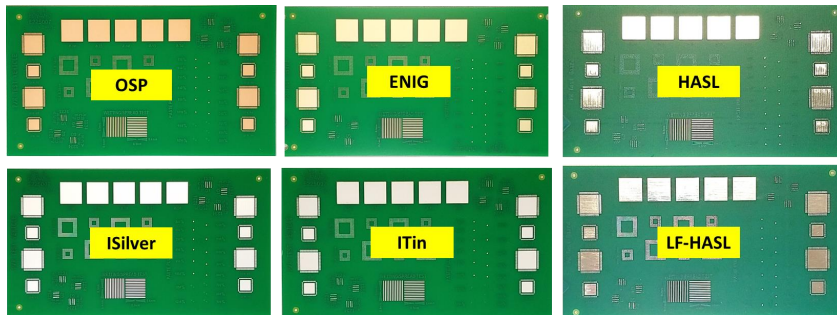
Scoring System

Score	Print 0.4 mm BGA		Print 0.50 AR Pattern		Reflow			Voiding	
	TE%	CV%	TE%	CV%	Wetting %	Solder Balling	Graping %	Void Area %	Largest Void %
1	<50	>15	<40	>20	0-20	none	41-50	>25	>5.0
2	51-57	10-14	41-45	16-20	21-40	500-650	31-40	16-25	3.1-5.0
3	58-64	8-9	46-50	11-15	41-60	700-850	21-30	11-15	2.1-3.0
4	65-70	6-7	51-55	8-10	61-80	900-1050	11-20	6-10	1.1-2.0
5	>70	0-5	>55	<8	81-100	1100-1250	0-10	1-5	0-1.0

Scores Overall

Surface Finish	Total (180 poss)
ENIG	131
HASL	128
OSP	123
LF-HASL	117
ITin	113
ISilver	107

Solder Paste	Total (270 poss)
NC 63-37	207
WS 63-37	178
NC SAC	174
WS SAC	160



Scores: All Combinations

Top 10
7 63-37 pastes
3 ENIG
3 HASL













Bottom 10
7 SAC pastes
3 ITin
3 ISilver

Surface Finish	Solder Paste	Print Score (20 poss)	Reflow Score (15 poss)	Void Score (10 poss)	Total (45 poss)
OSP	NC 63-37	15	15	10	40
ENIG	NC 63-37	17	14	6	37
LF-HASL	NC 63-37	13	14	10	37
HASL	NC 63-37	13	14	8	35
HASL	WS 63-37	12	13	10	35
ENIG	WS SAC	18	11	5	34
ITin	NC 63-37	14	11	7	32
OSP	WS 63-37	11	11	10	32
ENIG	NC SAC	13	11	7	31
HASL	NC SAC	13	11	7	31
LF-HASL	NC SAC	11	11	9	31
ENIG	WS 63-37	10	12	7	29
OSP	NC SAC	13	7	8	28
ISilver	WS 63-37	8	10	10	28
LF-HASL	WS 63-37	5	13	10	28
ITin	WS SAC	17	9	2	28
ITin	NC SAC	12	11	4	27
HASL	WS SAC	13	10	4	27
ISilver	WS SAC	13	8	6	27
ISilver	NC 63-37	5	13	8	26
ISilver	NC SAC	9	10	7	26
ITin	WS 63-37	7	11	8	26
OSP	WS SAC	17	4	2	23
LF-HASL	WS SAC	8	11	2	21

Scores: Sorted by Finish

Surface Finish	Solder Paste	Print Score (20 poss)	Reflow Score (15 poss)	Void Score (10 poss)	Total (45 poss)
ENIG	NC 63-37	17	14	6	37
ENIG	WS SAC	18	11	5	34
ENIG	NC SAC	13	11	7	31
ENIG	WS 63-37	10	12	7	29
HASL	NC 63-37	13	14	8	35
HASL	WS 63-37	12	13	10	35
HASL	NC SAC	13	11	7	31
HASL	WS SAC	13	10	4	27
ISilver	WS 63-37	8	10	10	28
ISilver	WS SAC	13	8	6	27
ISilver	NC 63-37	5	13	8	26
ISilver	NC SAC	9	10	7	26
ITin	NC 63-37	14	11	7	32
ITin	WS SAC	17	9	2	28
ITin	NC SAC	12	11	4	27
ITin	WS 63-37	7	11	8	26
LF-HASL	NC 63-37	13	14	10	37
LF-HASL	NC SAC	11	11	9	31
LF-HASL	WS 63-37	5	13	10	28
LF-HASL	WS SAC	8	11	2	21
OSP	NC 63-37	15	15	10	40
OSP	WS 63-37	11	11	10	32
OSP	NC SAC	13	7	8	28
OSP	WS SAC	17	4	2	23

Surface Finish Performance

Surface Finish	Printing	Reflow	Voiding
ENIG			
HASL	OK	OK	OK
ISilver			
ITin	OK	OK	
LF-HASL			
OSP			OK

Conclusions





Conclusions

- ✓ No Clean Sn63/Pb37 Solder Paste Works Well with Most Surface Finishes
- ✓ No Clean SAC305 Solder Paste is a Good Lead-Free Option
- ✓ ENIG and HASL (63/37) Work Well with Most Solder Pastes
- ✓ Immersion Tin and Immersion Silver Did Not Perform as Well as the Other Surface Finishes
- ✓ OSP and Lead-Free HASL Showed a Wide Range of Performance Depending upon Solder Paste

Performance Depends upon the Solder Paste and Surface Finish Combinations

Recommendations

- Run a Similar Evaluation in Your Process
- Choose Surface Finish and Solder Paste Combinations that Work Well:
 - ENIG - NC 63/37 or WS SAC
 - HASL - NC 63/37 or NC SAC
 - ISilver - WS 63/37 or WS SAC
 - ITin - NC 63/37 or WS SAC
 - LF-HASL - NC 63/37 or NC SAC
 - OSP - NC 63/37 or NC SAC



RECOMMENDED

Future Work

Exploring Several Combinations of Surface Finish and Solder Paste in More Detail

- Include other lead free alloys
- Print parameters varied
- Reflow profiles varied
- Reflow measured on 2nd cycle





Thank You!

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