HOW DOES PRINTED SOLDER PASTE VOLUME AFFECT SOLDER JOINT RELIABILITY?

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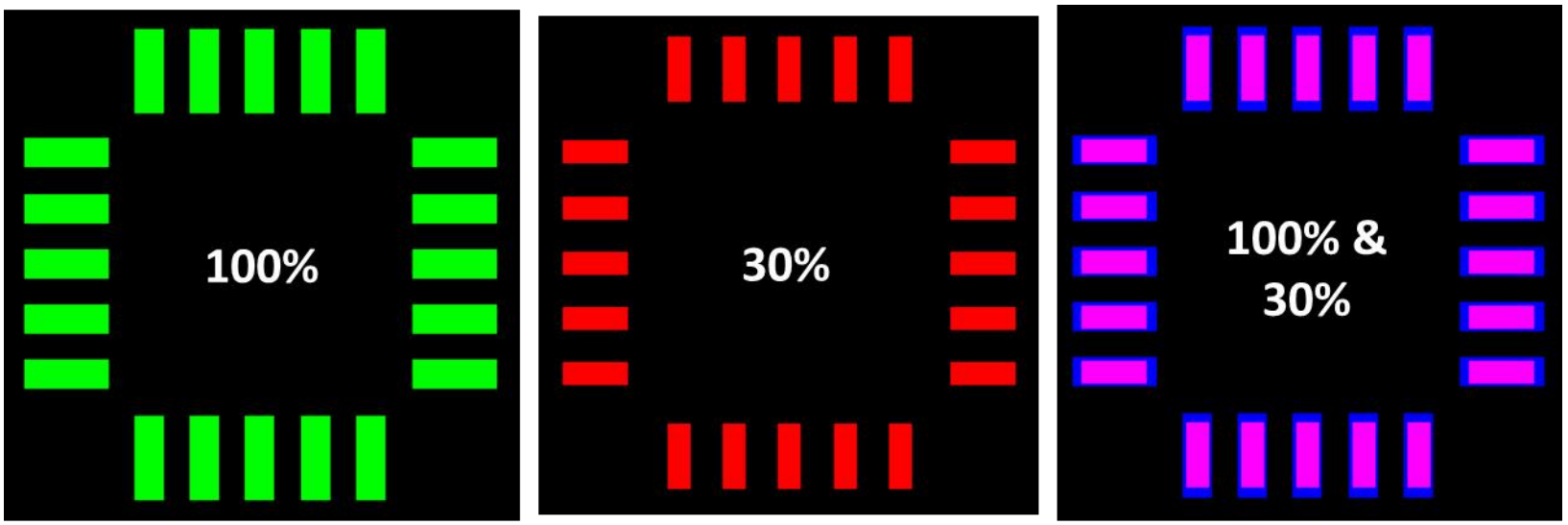
Originally presented at SMTA International 2018

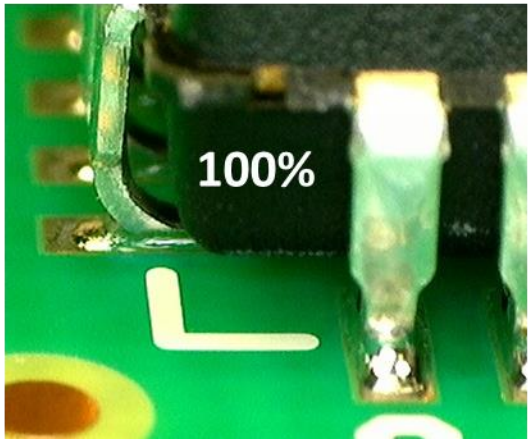
Outline / Agenda

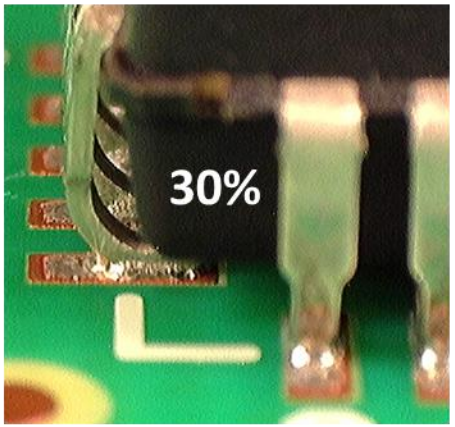
- Introduction
- Experimental Methodology
- Results & Discussion
- Conclusions & Recommendations
- Acknowledgements
- Question & Answer

Introduction

Solder Paste Volume Varies by Stencil Design







Introduction

How Does Volume Affect Solder Joint Reliability?

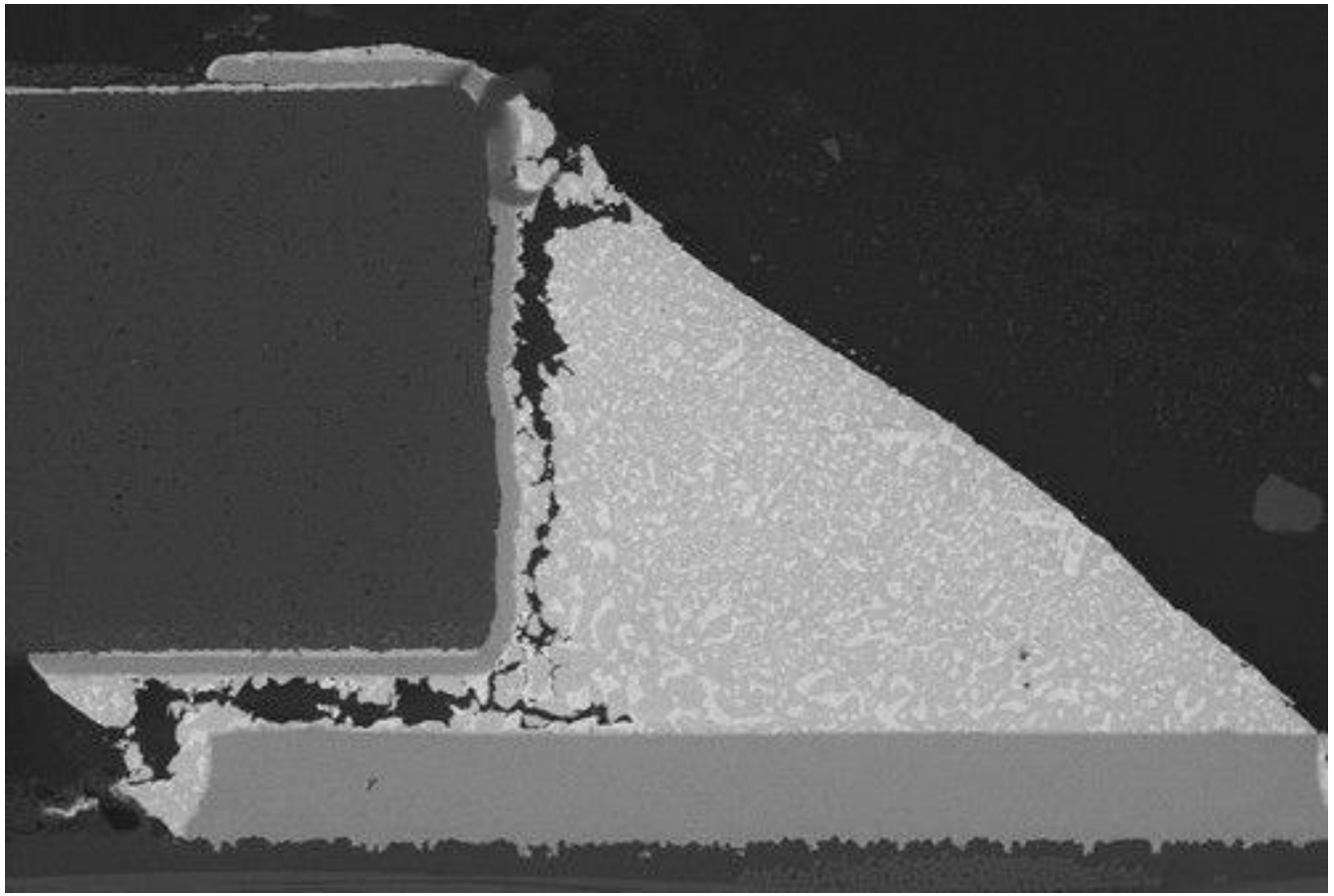
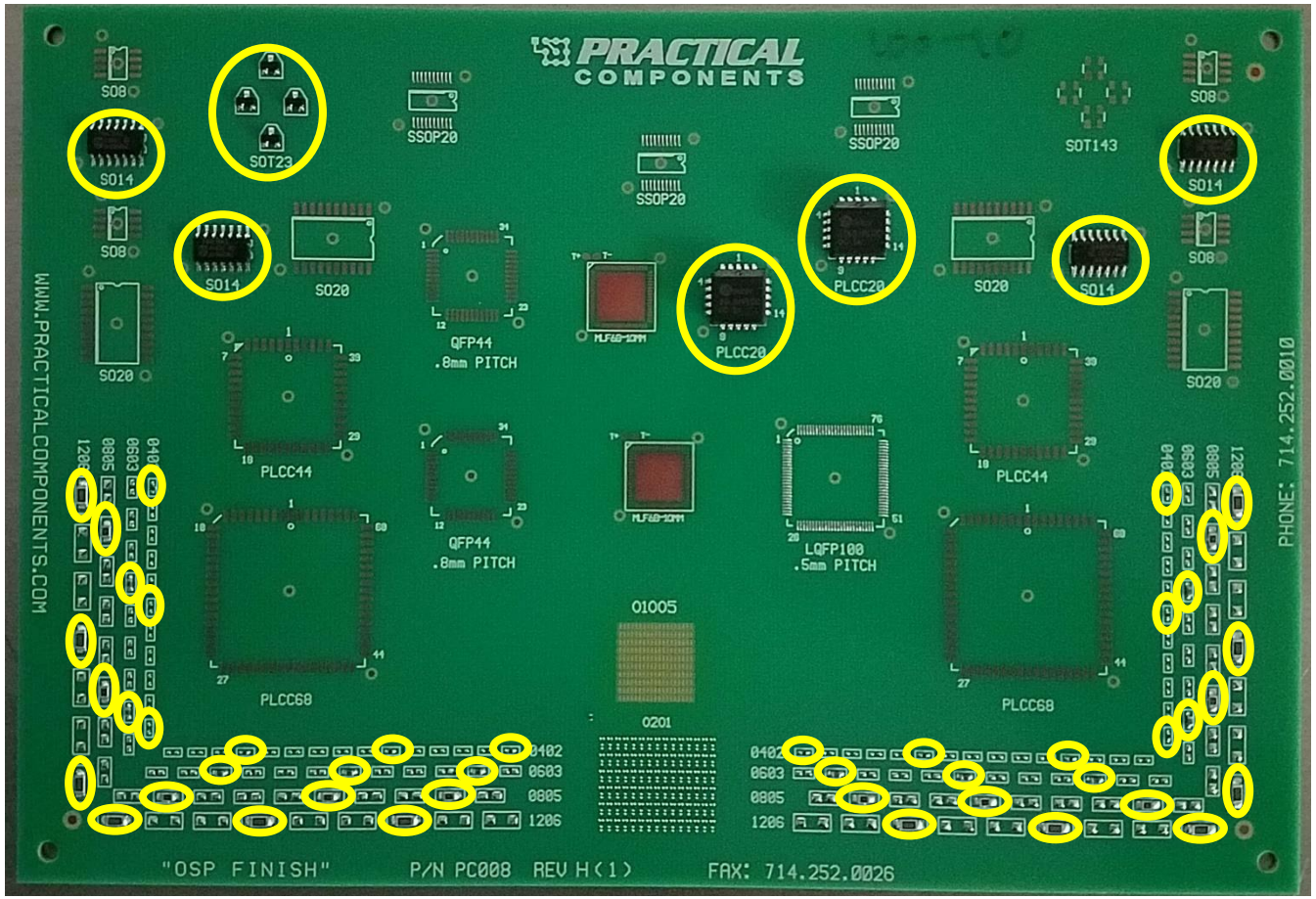


Image Source: http://www.failure-analysis-durability.com/electronics-failure-analysis.htm

Experimental Methodology

Experimental Methodology

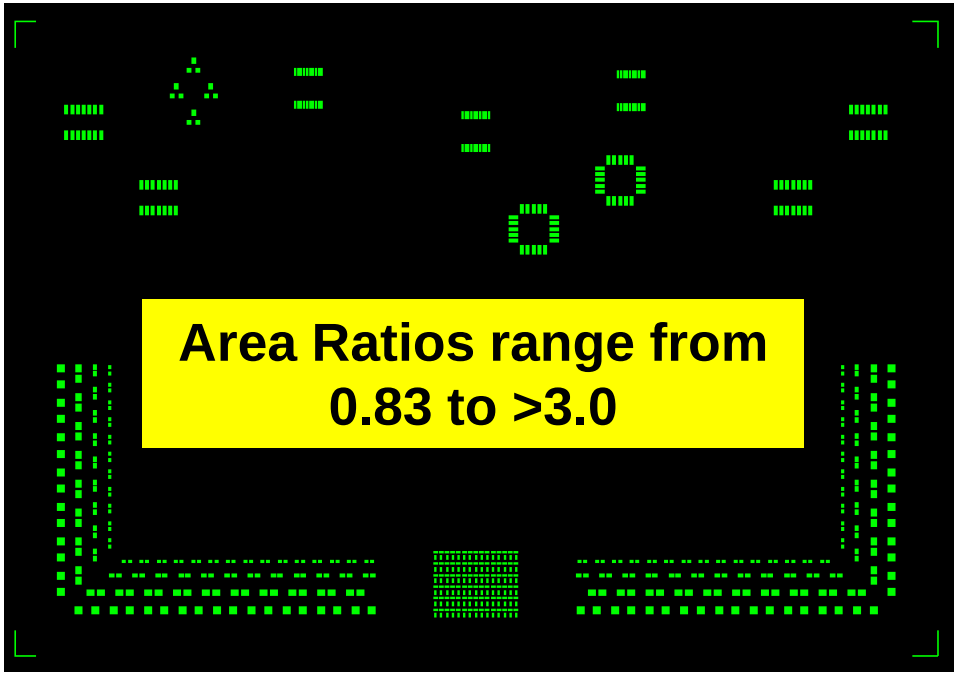


Comp	# Placed
SOT23	4
SO14	4
PLCC20	2
1206	12
0805	10
0603	10
0402	12

OSP-HT Surface Finish

Experimental Methodology

Solder Paste Volume	Stencil Thickness in µm (mils)	Stencil Design Based on 100%
125%	102 (4)	Apertures enlarged to 125%
100%	102 (4)	Stencil data used as received
75%	76 (3)	Reduced thickness
50%	51 (2)	Reduced thickness
40%	51 (2)	Reduced thickness & apertures
30%	51 (2)	Reduced thickness & apertures
25%	51 (2)	Reduced thickness & apertures



Stencil Material: Fine grain SS 2-5 µm
No coatings

Experimental Methodology

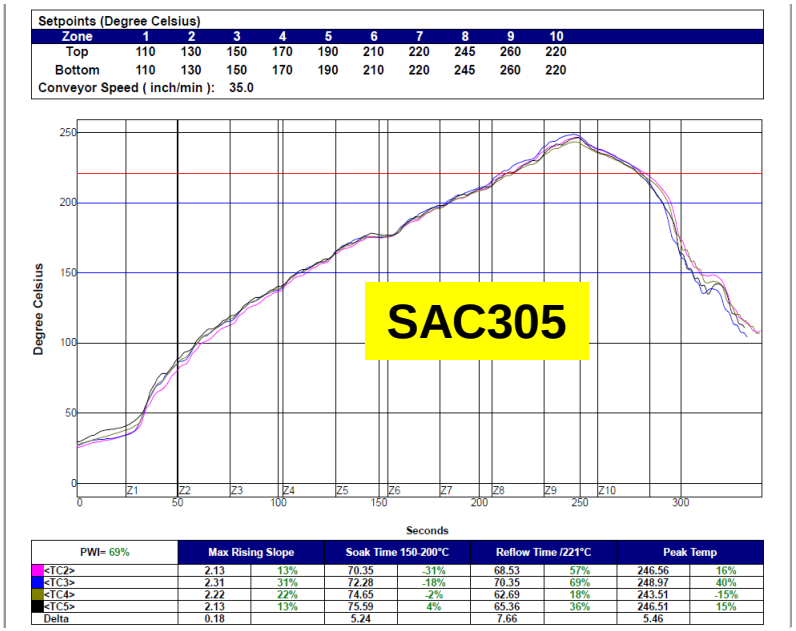
Print Parameters

Print Speed	30 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

Solder Paste =
No Clean
SAC305 T4
ROL0

Experimental Methodology

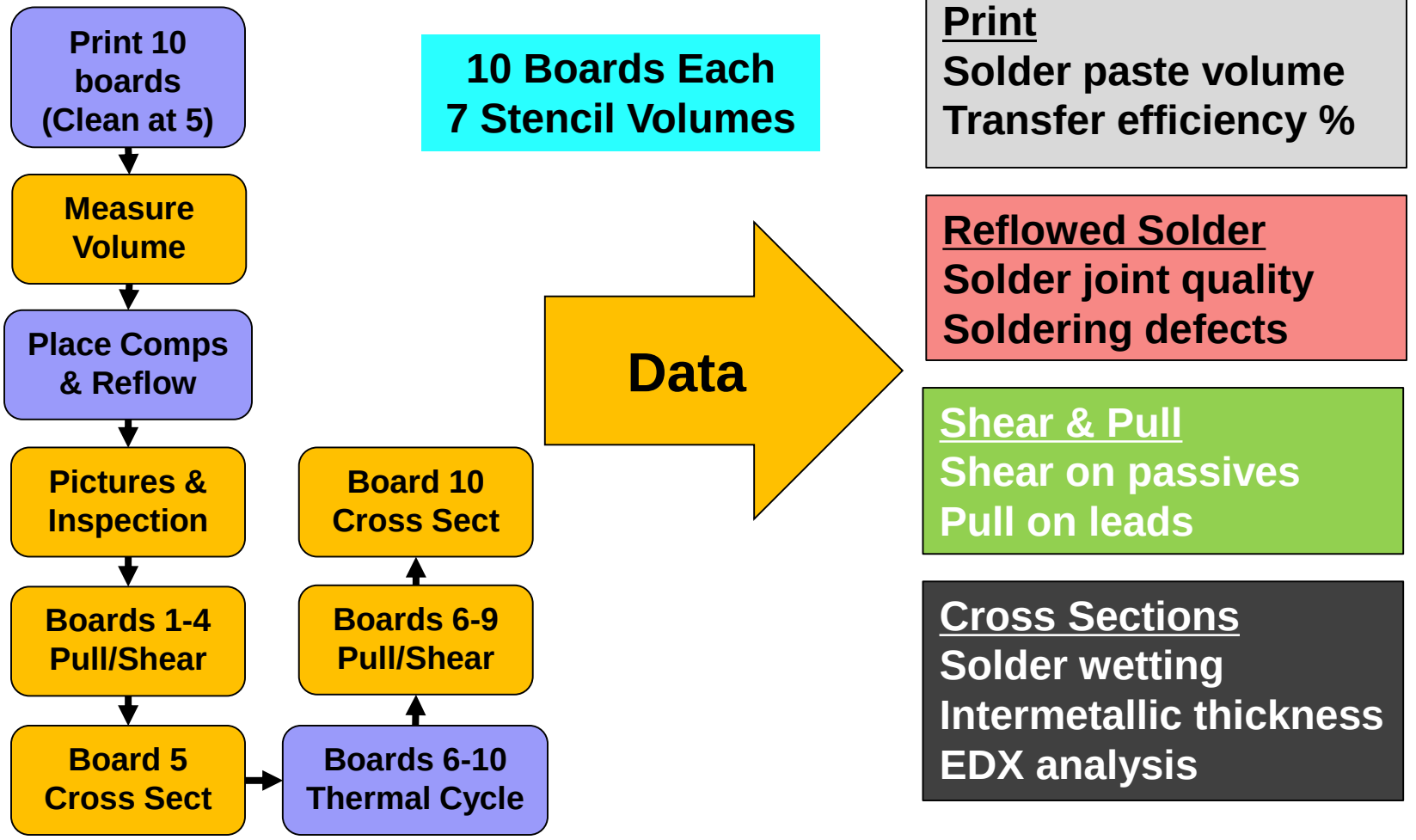
Reflow Profile



Setting	SAC305 Profile
Soak Time (150 to 200 °C)	70 - 75 sec
TAL (Reflow time)	63 – 70 sec > 221°C
Peak temperature	243 to 249 °C
Profile length (25 °C to peak)	4.1 minutes

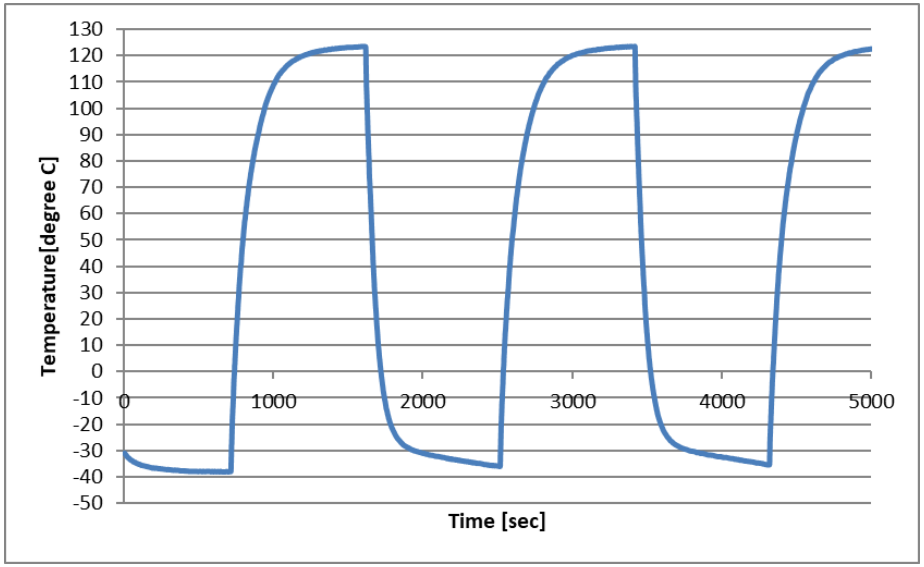
Experimental Methodology

Process and Data



Experimental Methodology

Thermal Cycling and Shear & Pull Parameters



Parameter	Value
Temperature Range	-40 to 125°C
Ramp Time	5 min
Dwell Time	10 min
# Cycles	1000

Component	Test Type	Stroke Speed	Clearance
0402	Chip Shear	0.5mm/sec	Below 1/4 of component width
0603	Chip Shear	0.5mm/sec	Below 1/4 of component width
0805	Chip Shear	0.5mm/sec	Below 1/4 of component width
1206	Chip Shear	0.5mm/sec	Below 1/4 of component width
SOT23	0° Lead Pull	0.12mm/sec	~
SO14	90° Lead Pull	0.12mm/sec	~
PLCC20	90° Lead Pull	0.12mm/sec	~

Solder Paste Volume and TE%

Target Solder Paste Volumes

	Stencil						
Component	**25%**	**30%**	**40%**	**50%**	**75%**	**100%**	**125%**
0402	500	600	800	1000	1500	2000	2500
0603	1200	1440	1920	2400	3600	4800	6000
0805	3000	3600	4800	6000	9000	12000	15000
1206	3600	4320	5760	7200	10800	14400	18000
PLCC20	1875	2250	3000	3750	5625	7500	9375
SO14	1875	2250	3000	3750	5625	7500	9375
SOT23	1225	1470	1960	2450	3675	4900	6125
SOT23 L	1750	2100	2800	3500	5250	7000	8750

All Values Are in Cubic Mils

Measured Mean Solder Paste Volumes

	Stencil						
Component	**25%**	**30%**	**40%**	**50%**	**75%**	**100%**	**125%**
0402	628	777	1000	1076	1709	2197	2752
0603	1556	1884	2379	2484	4026	5616	7589
0805	3601	4355	5692	5402	9805	13884	18638
1206	4825	5951	7448	7455	13097	17087	23845
PLCC20	1861	2510	3210	4330	6519	8502	11150
SO14	2074	2352	3004	4509	6061	8434	14020
SOT23	1402	1772	2184	2662	4034	5487	7151
SOT23 L	2267	2773	3376	4638	6402	8527	9939

All Values Are in Cubic Mils

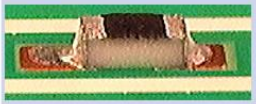
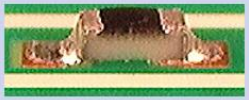
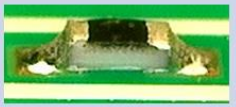
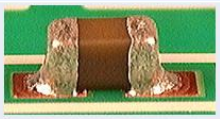
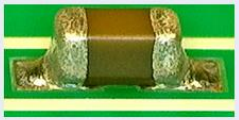
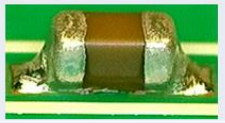
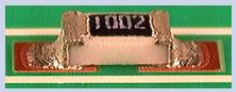
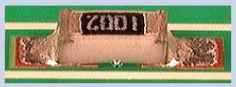
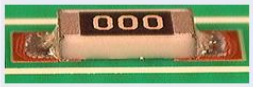
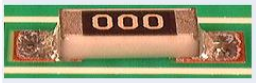
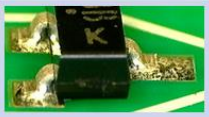
Measured Mean Transfer Efficiencies

	Stencil						
Component	**25%**	**30%**	**40%**	**50%**	**75%**	**100%**	**125%**
0402	31%	39%	50%	54%	85%	110%	138%
0603	32%	39%	50%	52%	84%	117%	158%
0805	30%	36%	47%	45%	82%	116%	155%
1206	34%	41%	52%	52%	91%	119%	166%
PLCC20	25%	33%	43%	58%	87%	113%	149%
SO14	28%	31%	40%	60%	81%	112%	187%
SOT23	29%	36%	45%	54%	82%	112%	146%
SOT23 L	32%	40%	48%	66%	91%	122%	142%

All Values Are Based on the 100% Volume Stencil

Solder Joint Inspection

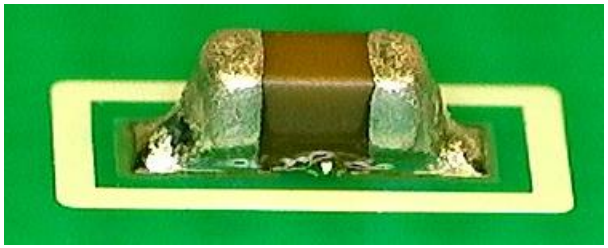
Solder Joint Inspection
IPC-A-610 & J-STD-001

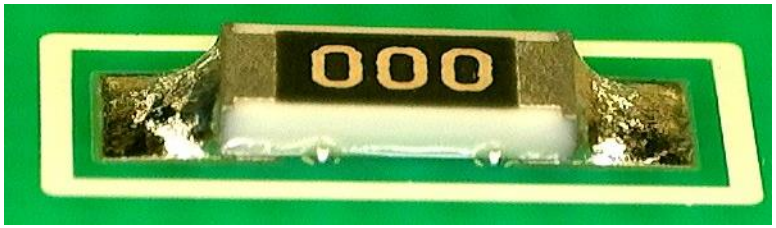
Component	Stencil 30%	Stencil 40%	Stencil 50%	Stencil 75%	Stencil 100%	Stencil 125%
0402						
0603						
0805						
1206						
PLCC20						
SO14						
SOT23						

Solder Joint Defects
IPC-A-610 & J-STD-001

	SO14	SOT23		PLCC20	1206		0805		0603		0402	
Stencil		Missing	SB		MCB	SKOP	MCB	SKOP	MCB	SKOP	MCB	SKOP
30%	0%	33%	0%	0%	23%	1%	3%	0%	5%	0%	0%	17%
40%	0%	-	0%	0%	29%	0%	13%	0%	21%	0%	0%	12%
50%	0%	35%	0%	0%	63%	3%	48%	0%	45%	0%	0%	8%
75%	0%	18%	25%	0%	73%	0%	63%	0%	45%	0%	10%	8%
100%	0%	15%	10%	0%	87%	0%	80%	0%	50%	0%	1%	6%
125%	0%	8%	15%	0%	99%	0%	80%	0%	79%	0%	27%	3%

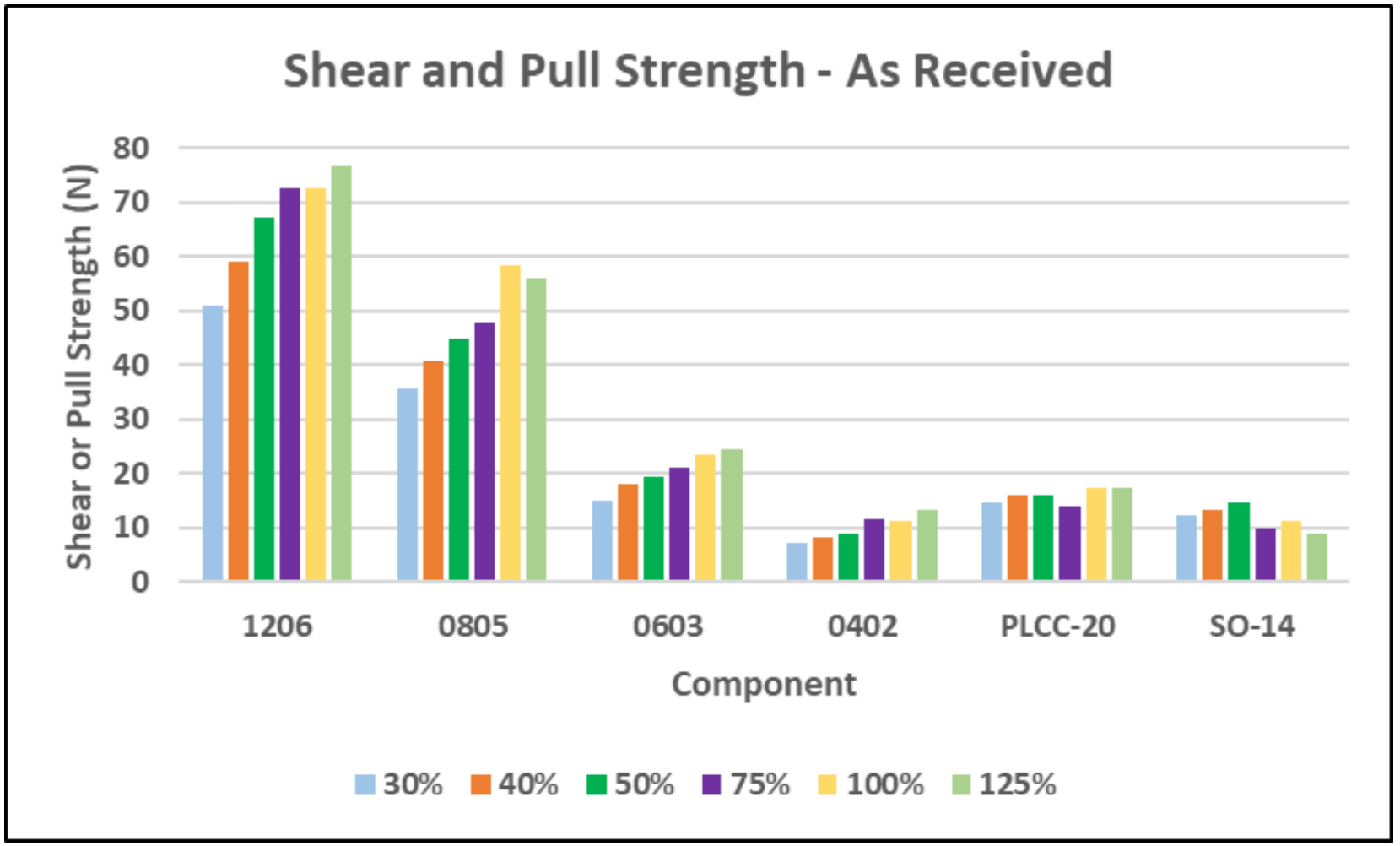
SB = Solder Balls
MCB = Mid Chip Beading
SKOP = Skew Off Pad



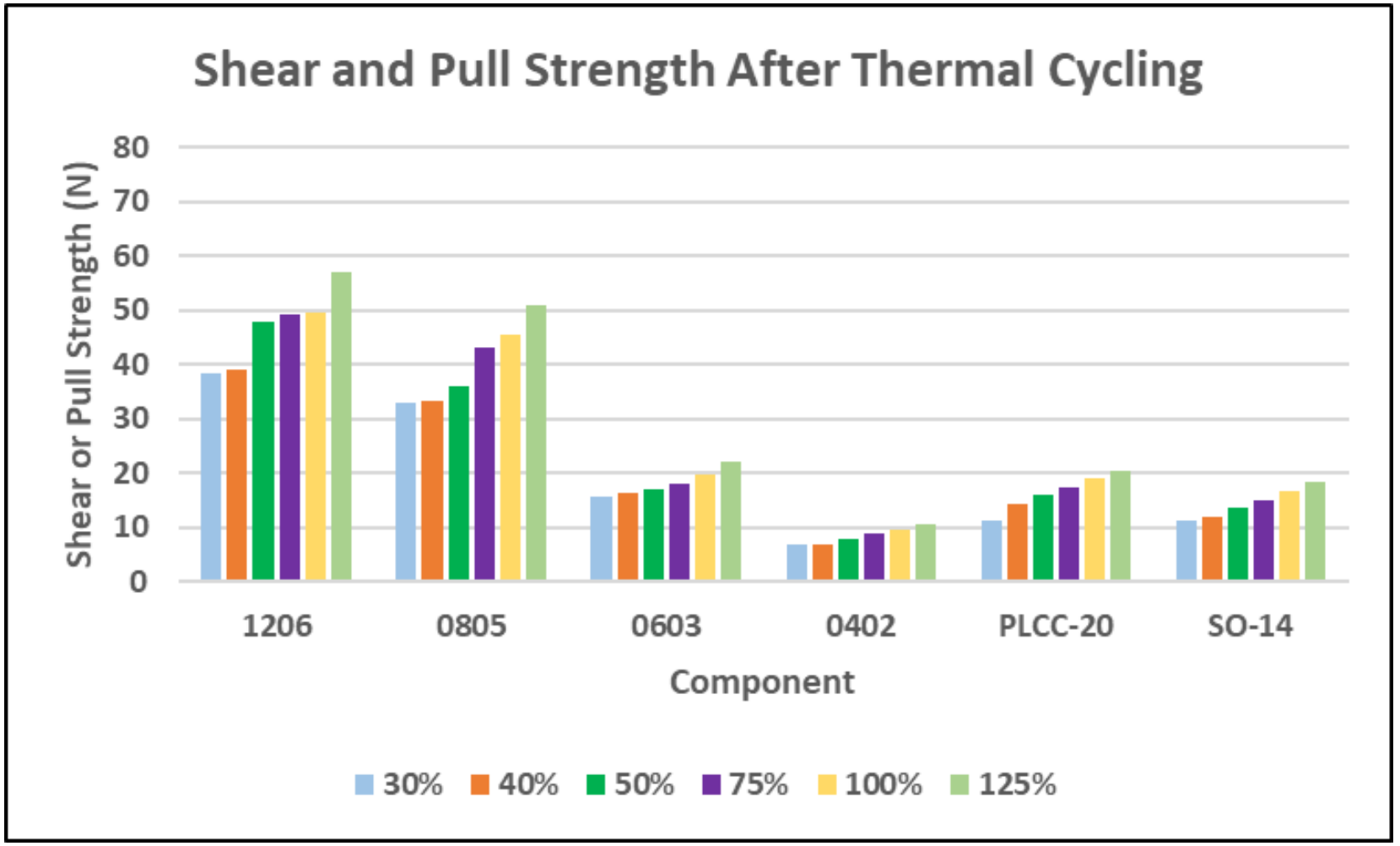


Shear & Pull Strength

Shear and Pull Strength - As Received

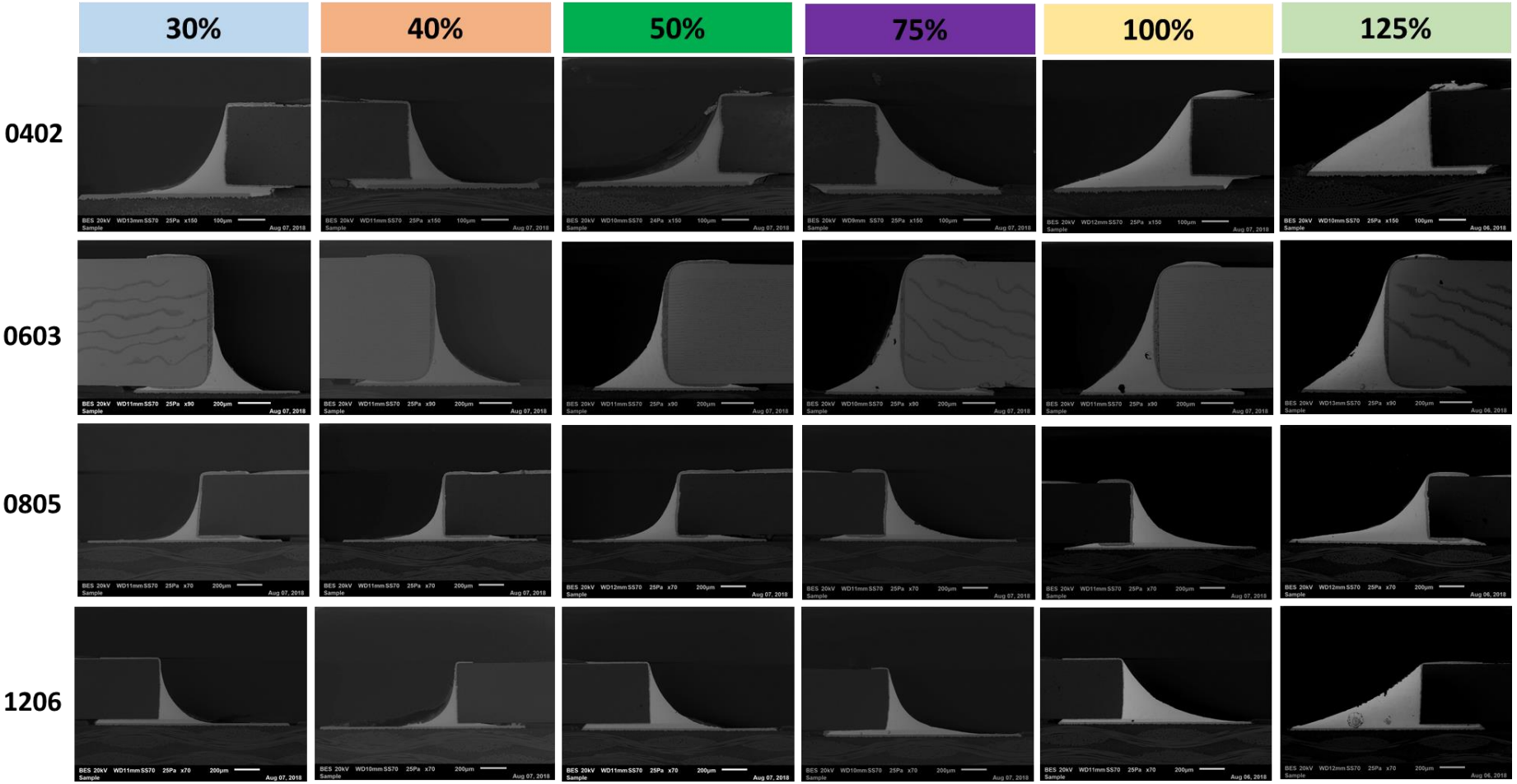


Shear and Pull Strength - After TC

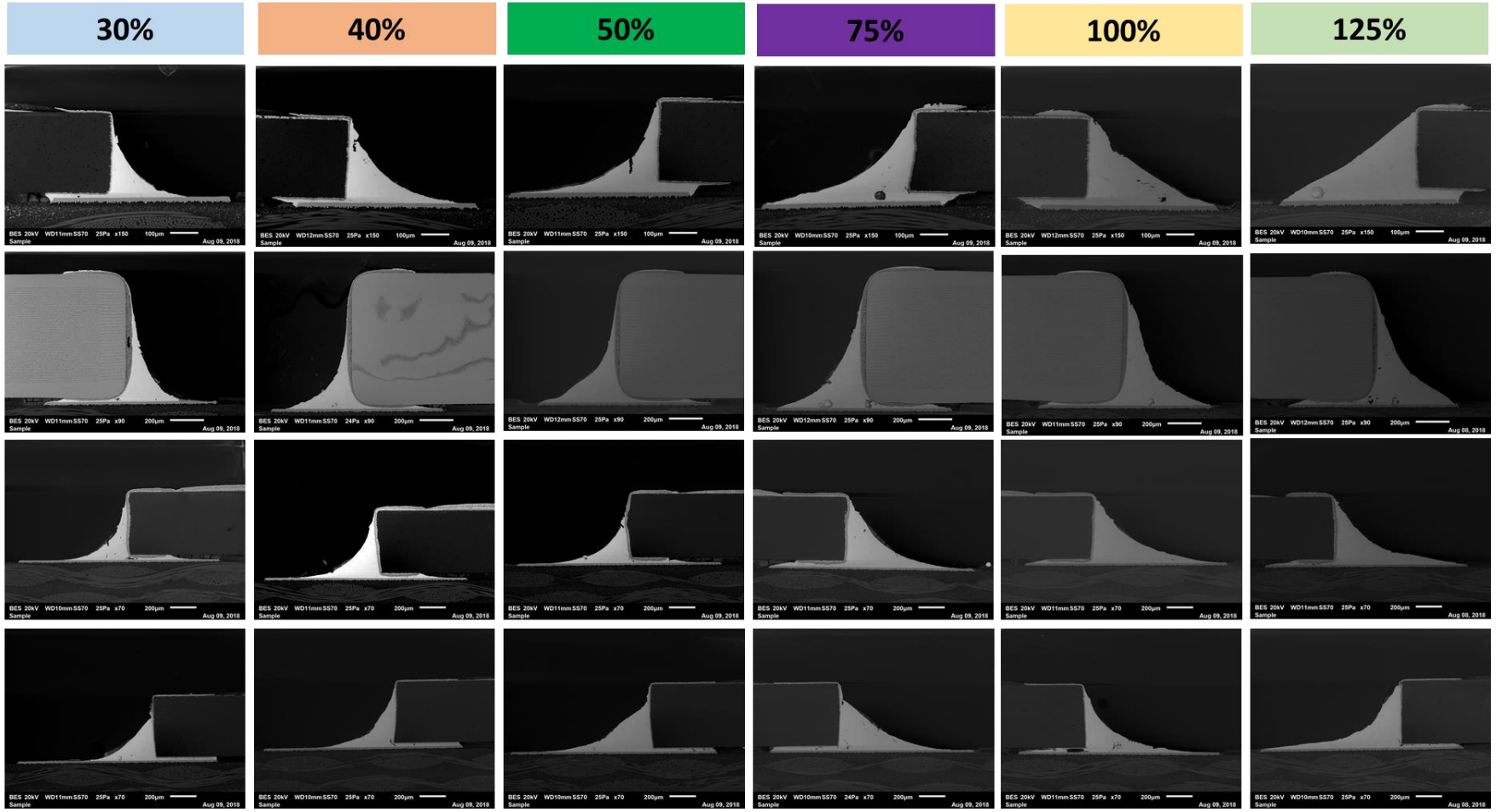


Cross Section of Chip Components

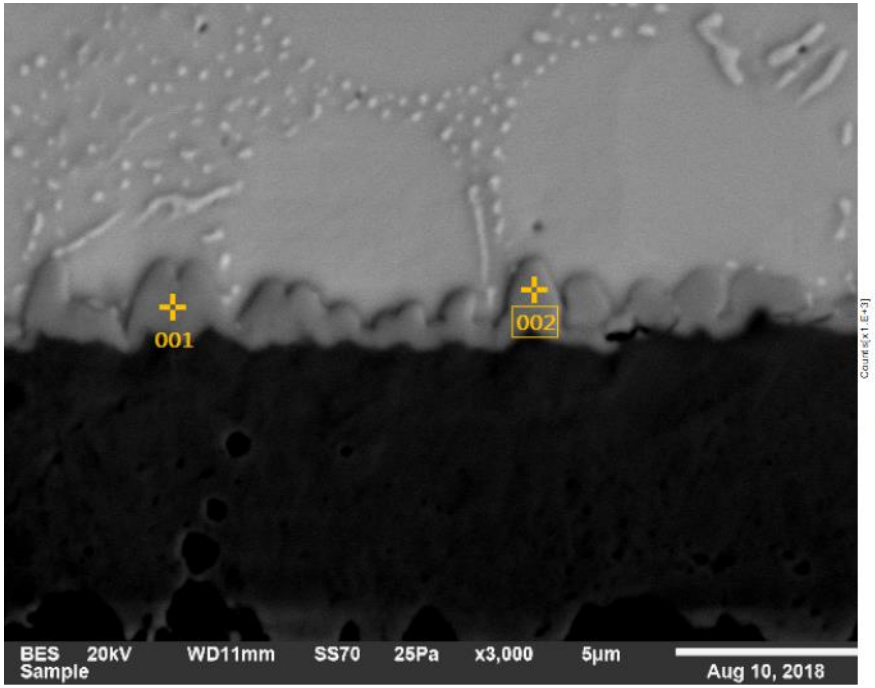
Cross Sections of Passive Chips - As Received

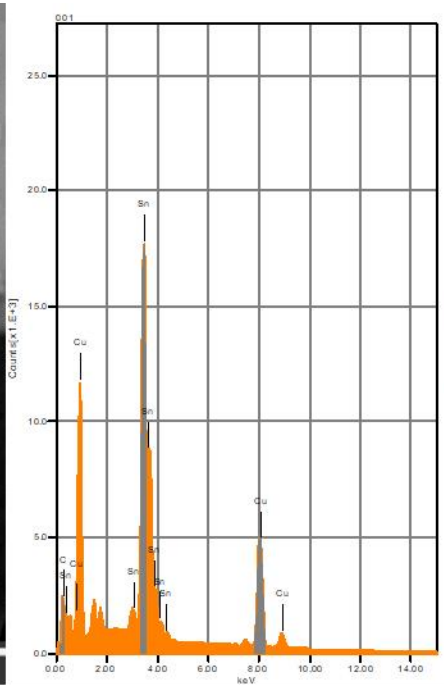


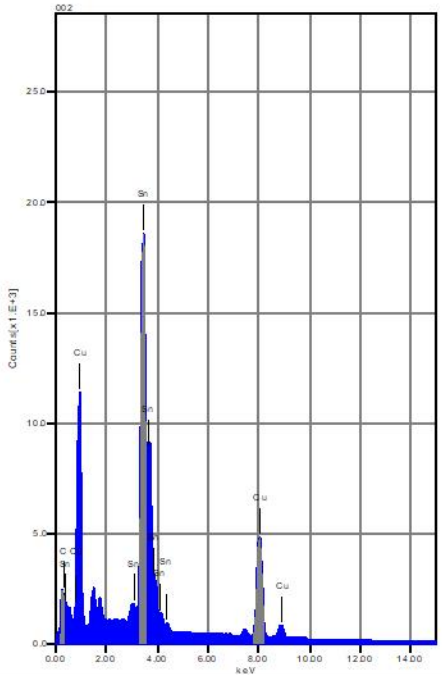
Cross Sections of Passive Chips - After Thermal Cycling



EDX Analysis - Board Pad Intermetallic

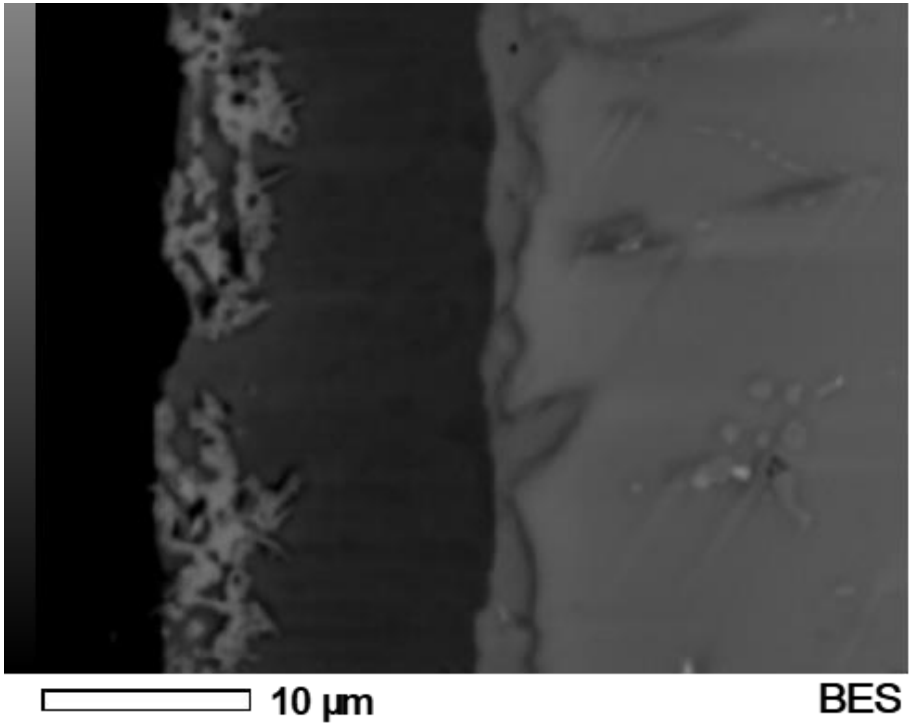


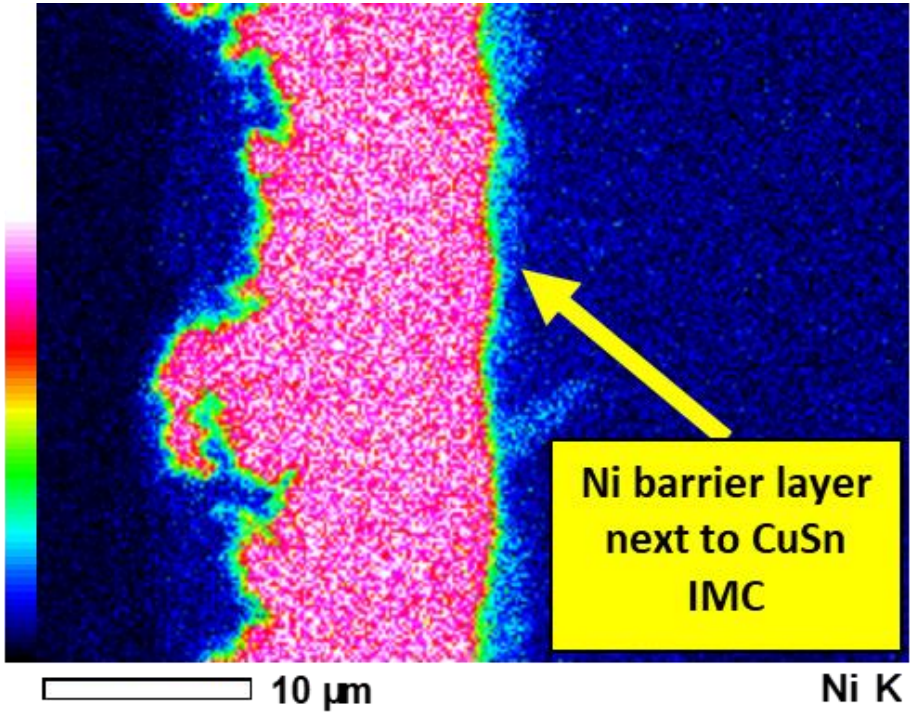




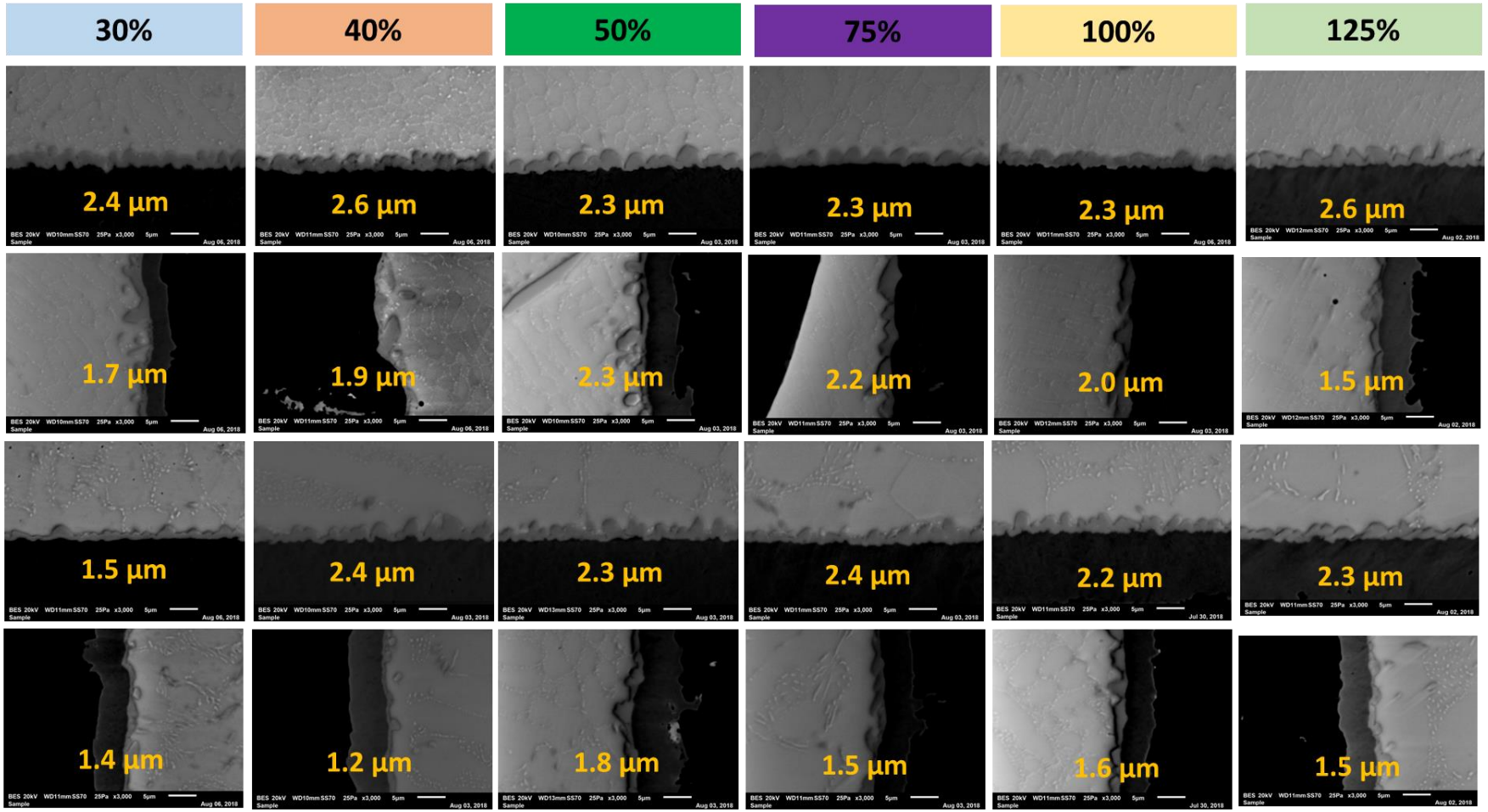
	C	Cu	Sn
001	9.62	33.18	57.20
002	9.29	31.16	59.55
Average	9.46	32.17	58.37
Standard deviation	0.12	0.71	0.83

EDX Analysis - Component Intermetallic



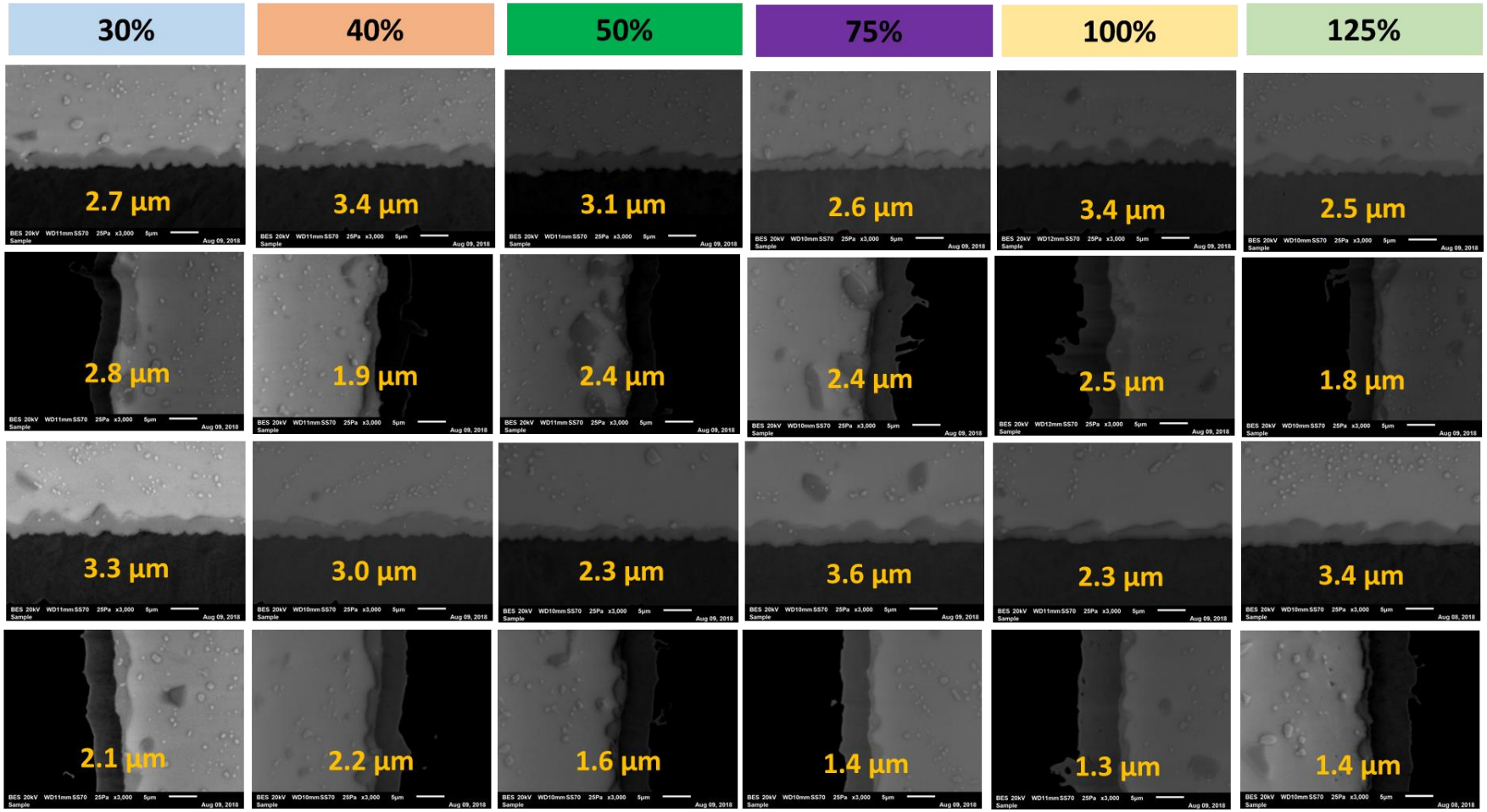


Intermetallic Thickness - As Received



B = Board Pad Interface
C = Component Lead Interface

Intermetallic Thickness - After TC



B = Board Pad Interface
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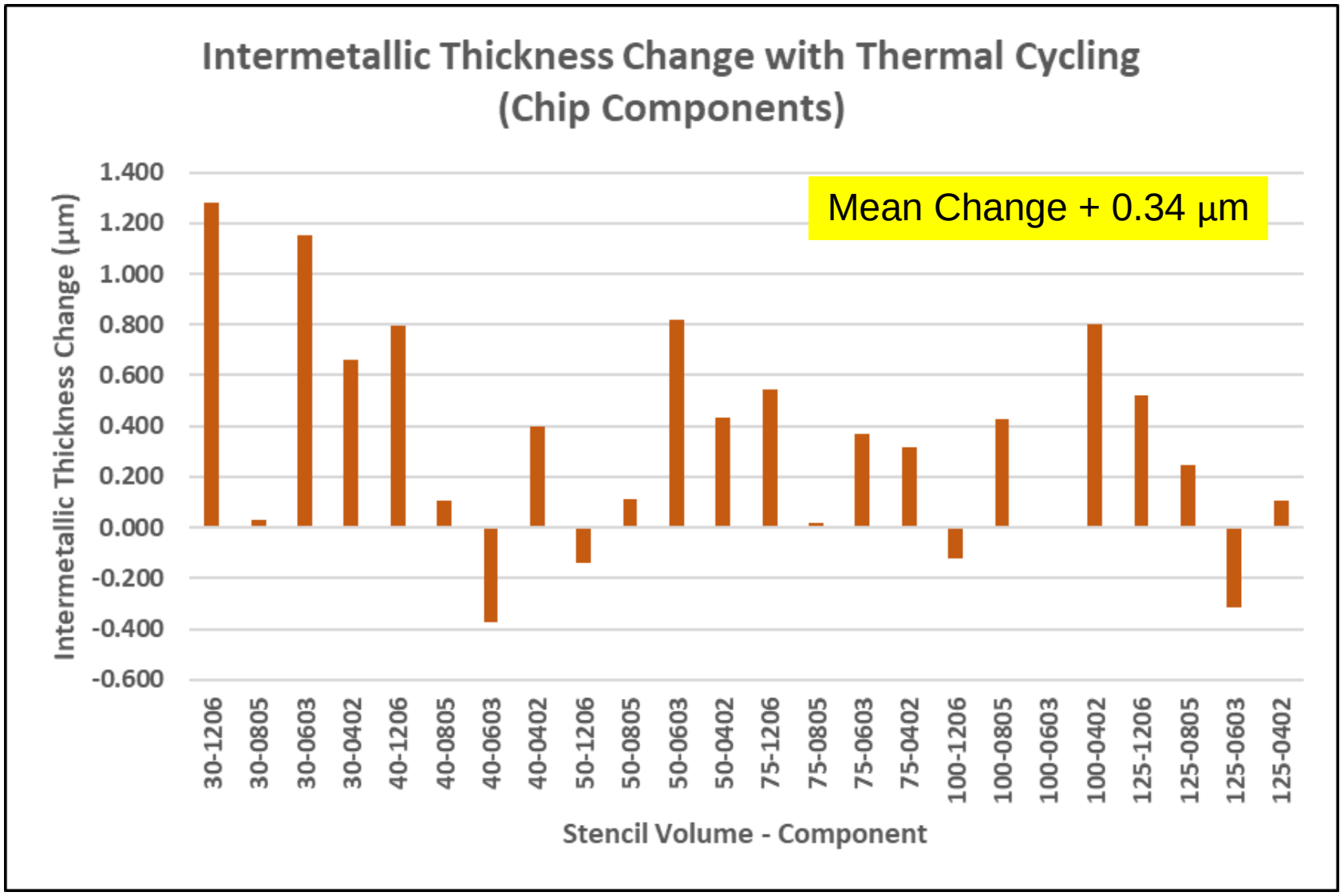
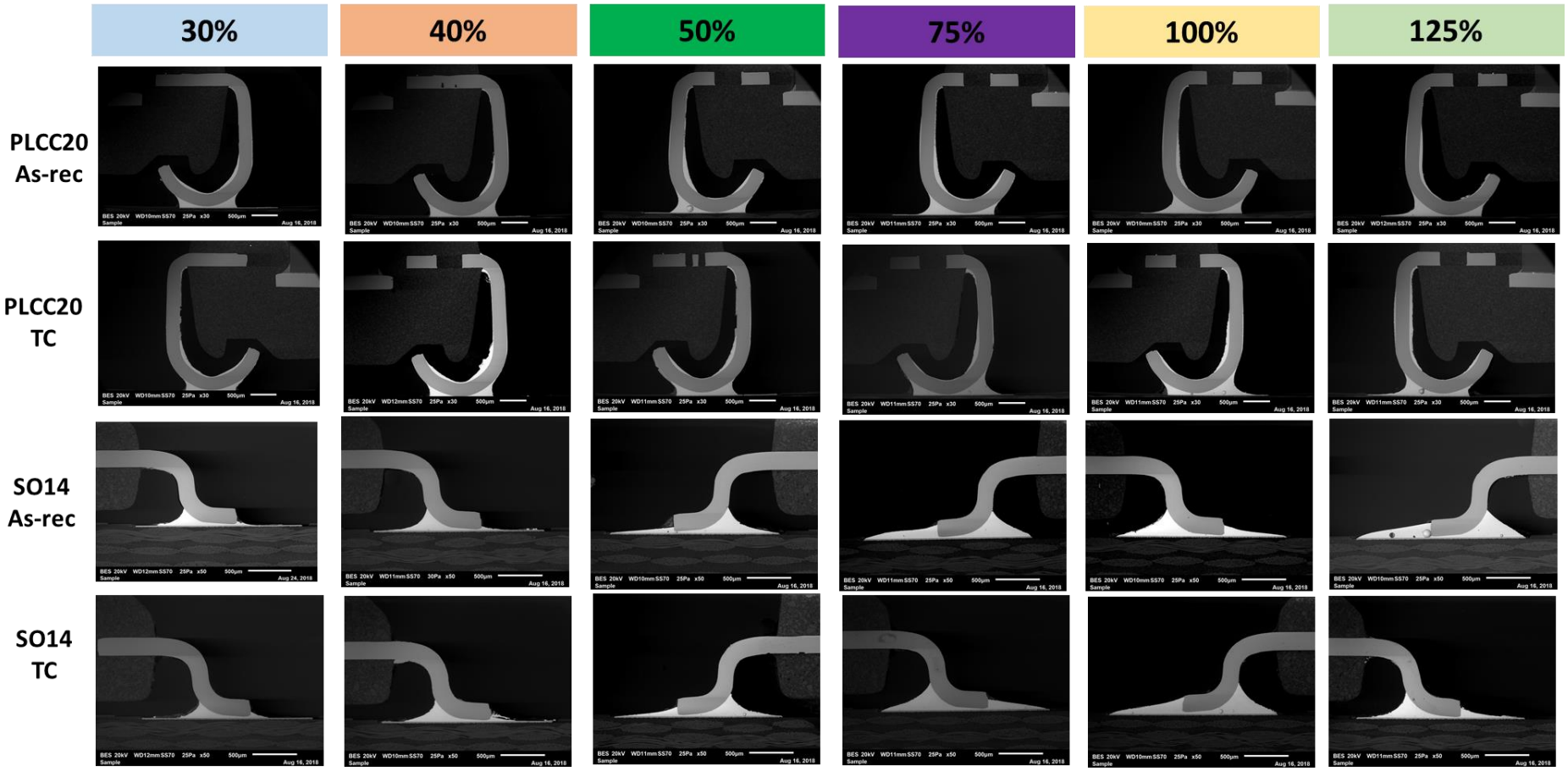
Intermetallic Thickness Change

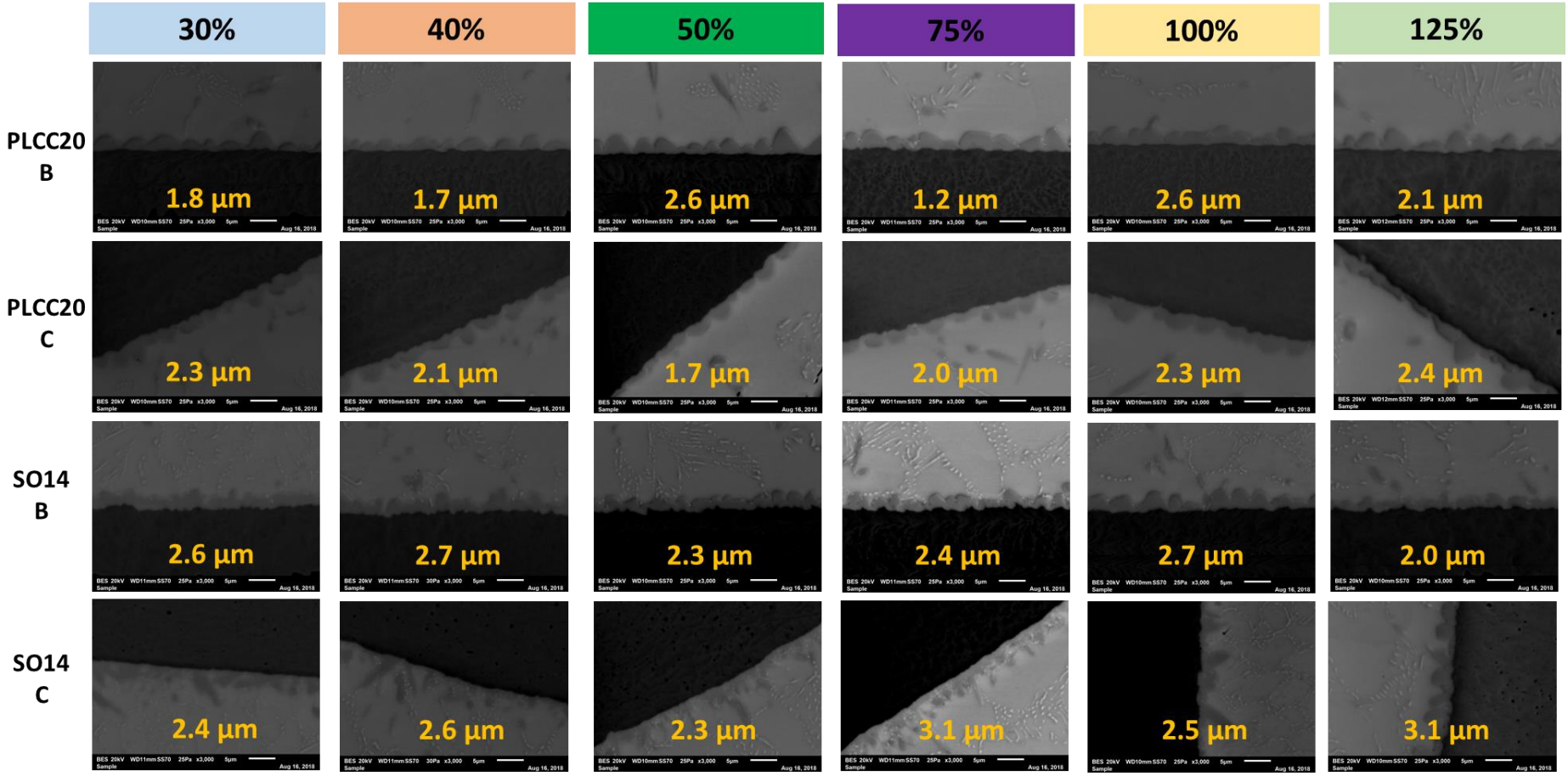


Cross Section of Lead-Frame Components

Cross Sections of Lead-Frame Components



Intermetallic Thickness of the Lead-Frame Components - As Received



B = Board Pad Interface
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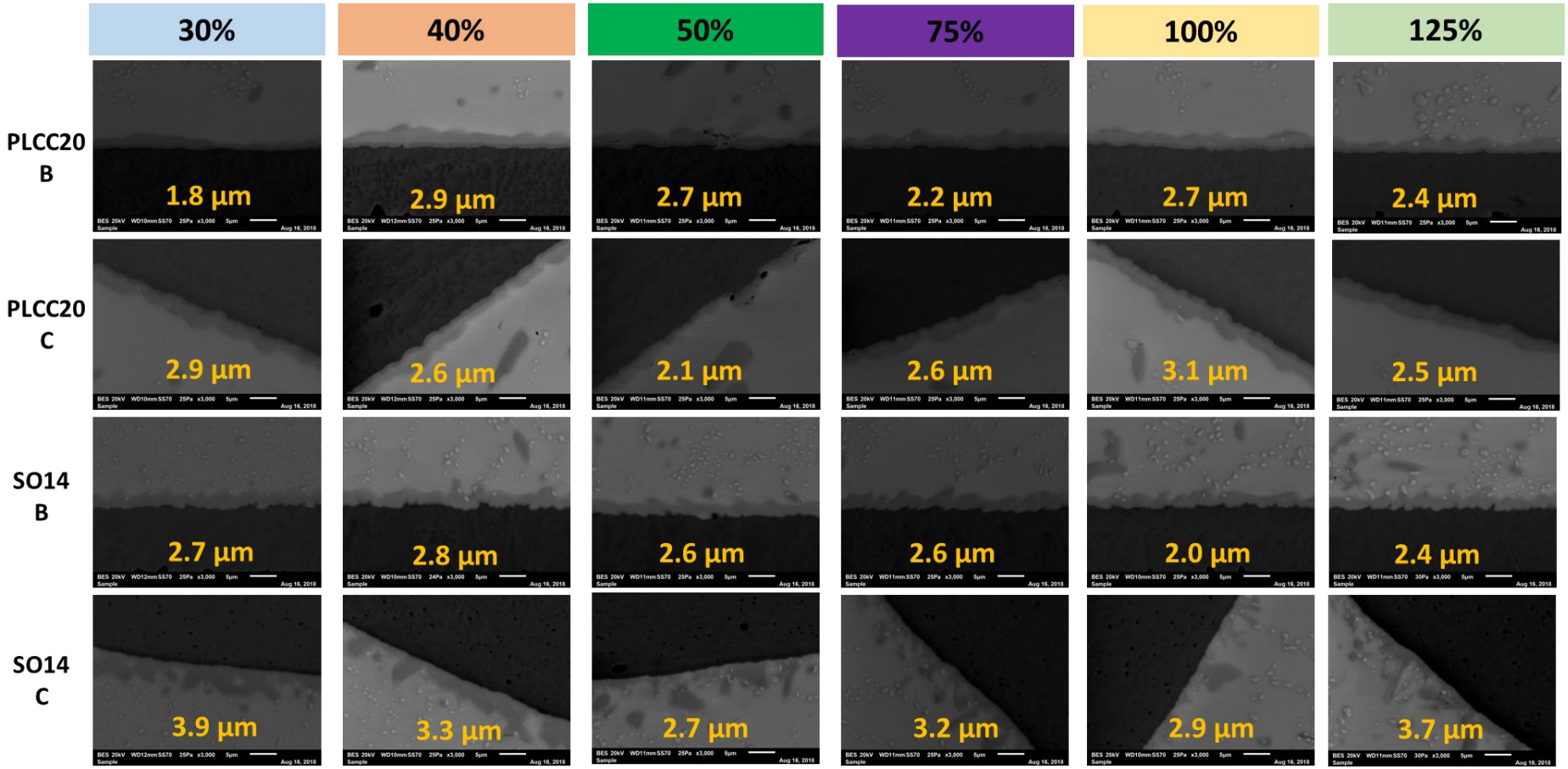
Intermetallic Thickness of the Lead-Frame Components - After TC



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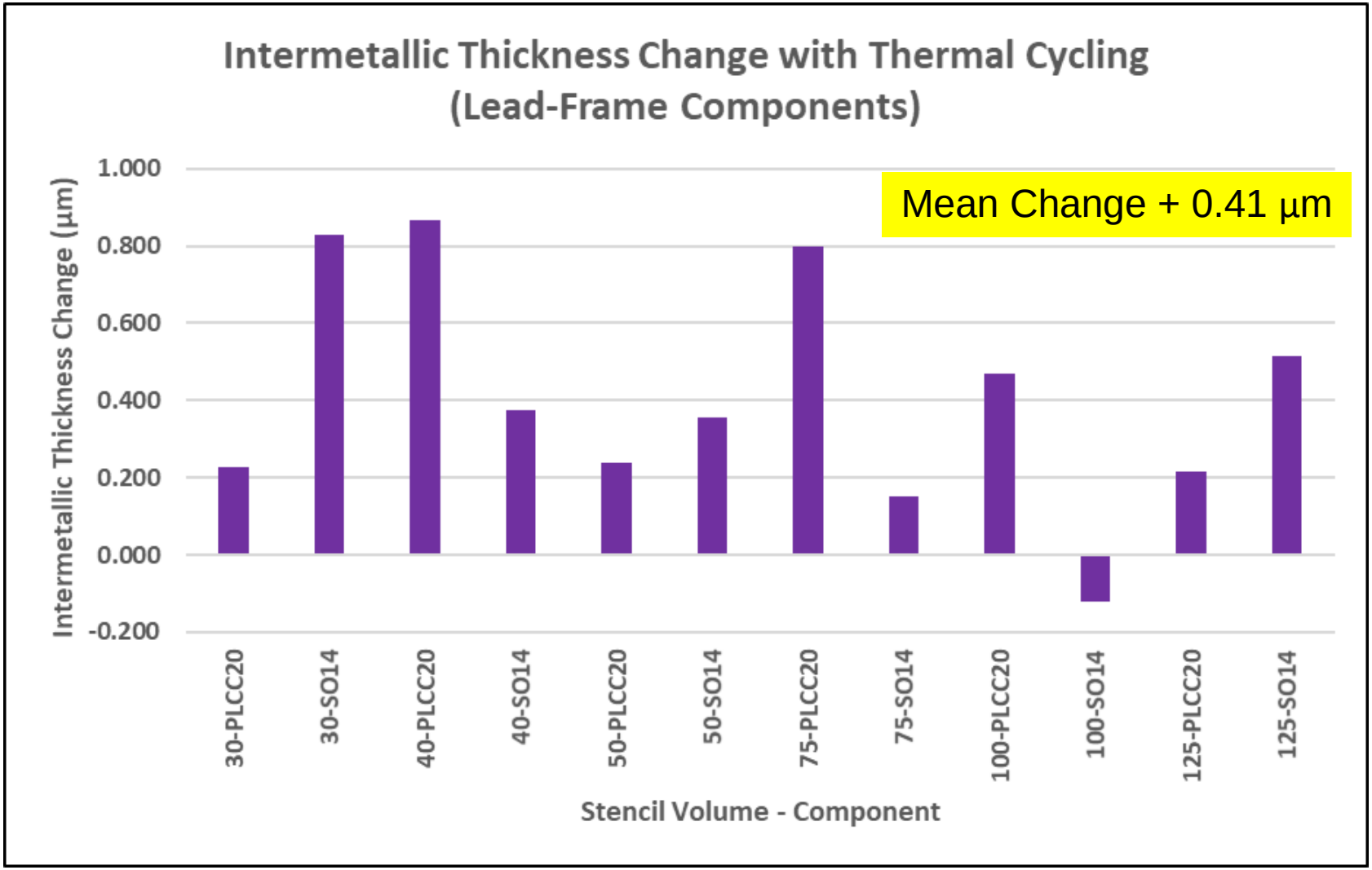
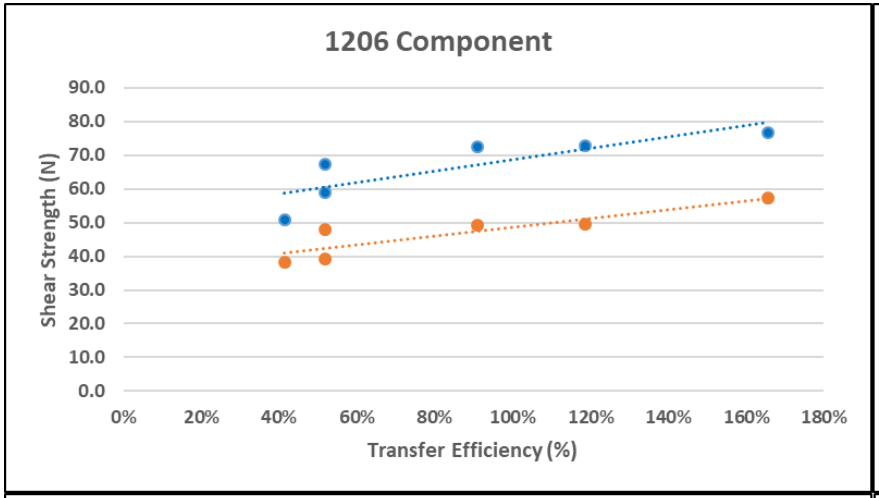
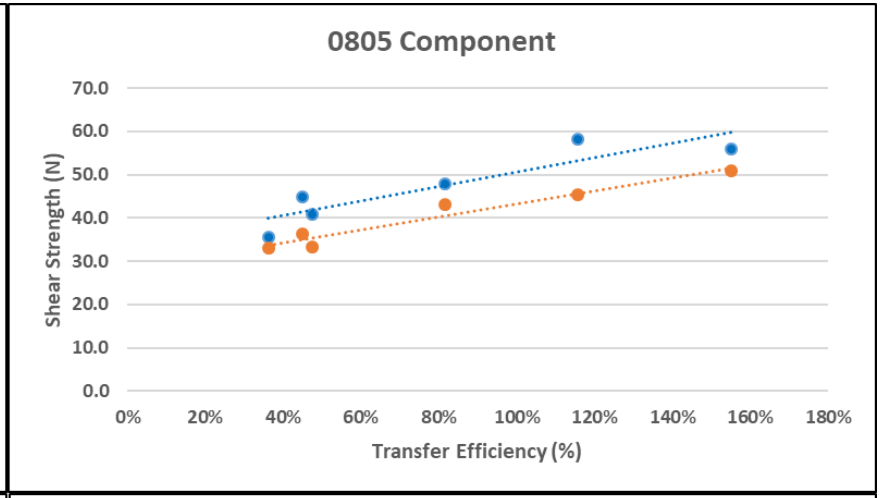
Intermetallic Thickness Change

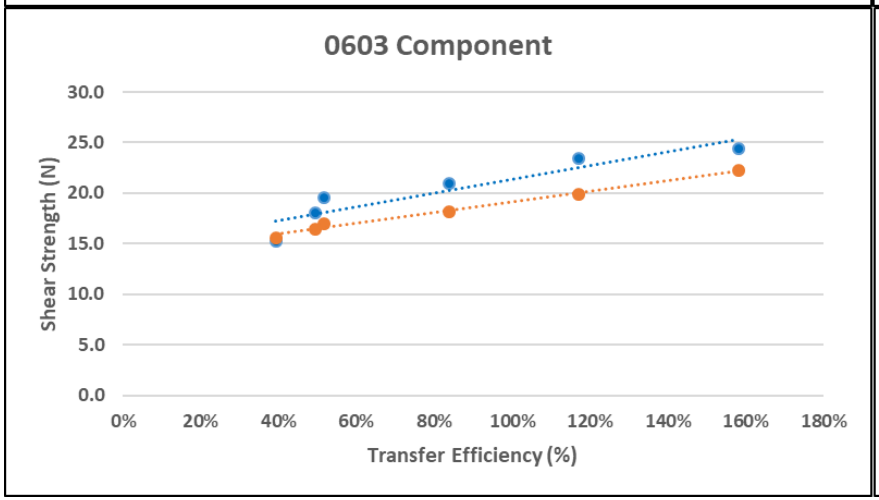


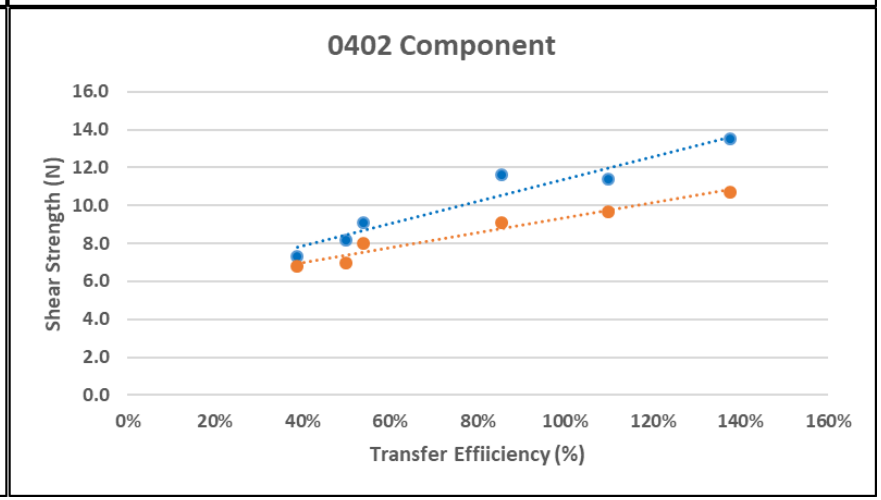
Solder Joint Strength Correlation to TE%

Shear Strength of Passive Chip Components with TE%





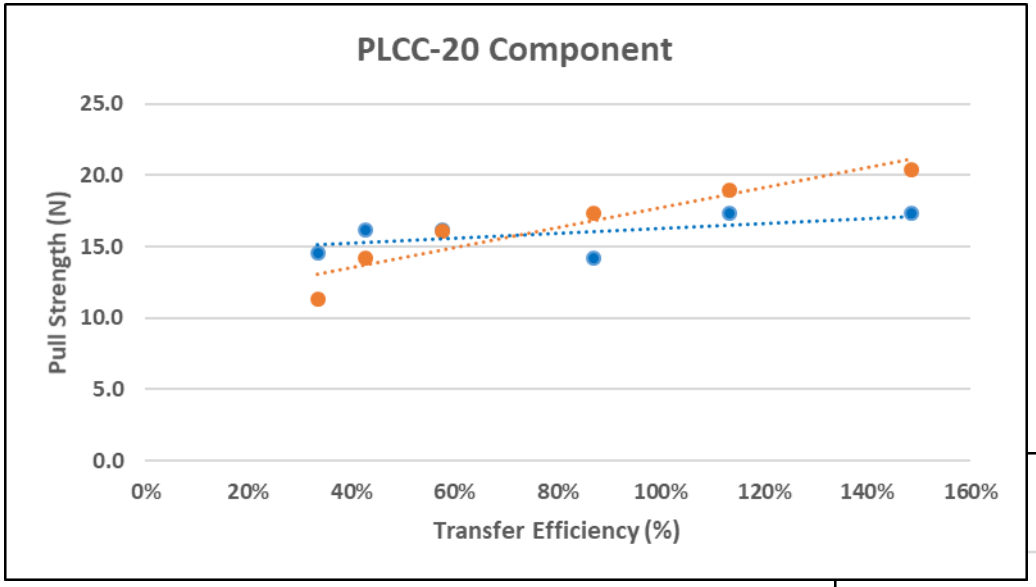


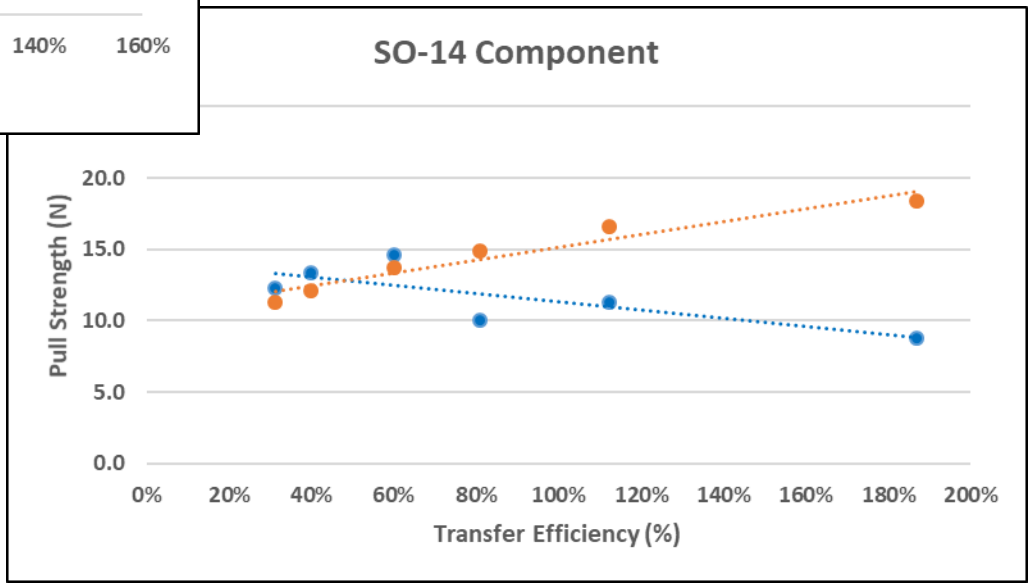


Blue = As-received

Orange = Thermally Cycled

Pull Strength of Lead-Frame Components with TE%





Blue = As-received

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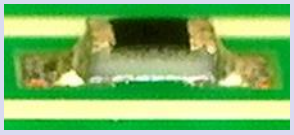
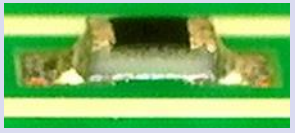
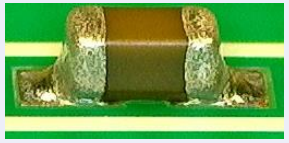
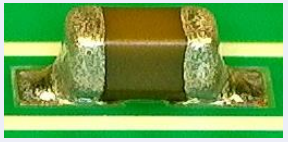
Summary

Summary of Results

Stencil Volume	Solder Joint Visual	Solder Defects	Cross Section	Joint Strength
25%	✗	N/A	N/A	N/A
30%	✓	Missing & Skew	NOK Leaded Components	✗
40%	✓	Missing & Skew	✓	✗
50%	✓	Missing & Mid Chip Bead	✓	✓
75%	✓	Mid Chip Bead	✓	✓
100%	✓	Mid Chip Bead	✓	✓
125%	✓	Mid Chip Bead	✓	✓

Conclusions & Recommendations

Conclusions & Recommendations

Component	TE% for Acceptable Solder Joints	TE% for Reliable Solder Joints
0402 Imperial (1005 metric)	50 	50 
0603 Imperial (1608 metric)	50 	50 
0805 Imperial (2012 metric)	30 	50 
1206 Imperial (3216 metric)	30 	50 
PLCC20	40 	40* 
SO14	40 	40* 
SOT23	75 	More data needed

*Comparable Data Not Available for These Components

Conclusions & Recommendations

- Wide range of solder paste volumes gives acceptable joints.
- If the solder volume is too low then reliability may be an issue.
- 50% solder paste volume provides acceptable joints for passive chip, and 40% PLCC20 and SO14 components. (SOT 23 needs more study)
- It is advisable for PCB assemblers to create their own standards for solder paste volume based on requirements and the components used.

Acknowledgements

- ✓ Mr. Tetsuro Nishimura, Mr. Yuji Kozutsumi and Mr. Keith Howell of Nihon Superior
  - Thermal cycling
  - Solder joint strength testing
  - Cross sectioning
  - Data analysis
- ✓ Mr. Greg Smith of BlueRing Stencils
  - Stencil design
  - PCB assembly and inspection

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