Plated Through Reliability and Material Integrity Results for 24 Materials Processed Through Lead Free Assembly

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Agenda

- Introduction
- Test Vehicle, Test Protocol & Reflow Conditions
- Capacitance Testing Protocol Overview
- Results of Material Robustness in Pb-Free Assembly
- IST Testing Protocol Overview
- Results of IST Testing
- Failure Analysis
- Statistical Analysis
- Material Ranking
- Conclusions
- Acknowledgements
- Q & A

Introduction

- Results of HDPUG Material Reliability Phase 3
- 12 materials constructed with 2 resin contents
  - High Tg FR4 (2) – Halogen Free (6) – High Speed (4)
- Materials Characterization Activities:
  - **Quantify Impact (Damage?) of 6X passes through 260°C SMT reflow oven**
  - **PTH via reliability – Before and After assembly**
  - CAF Resistance
  - Electrical Properties (Dk & Df – 1 to 20 GHz)
  - Thermal Properties (TMA & DMA)
- History - 98 materials tested to date
- Each phase is completed in 2 years
- Phase 4 now underway – 22 New Materials

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High Density Packaging User Group (HDPUG) Phase 3 - Lead-Free Study

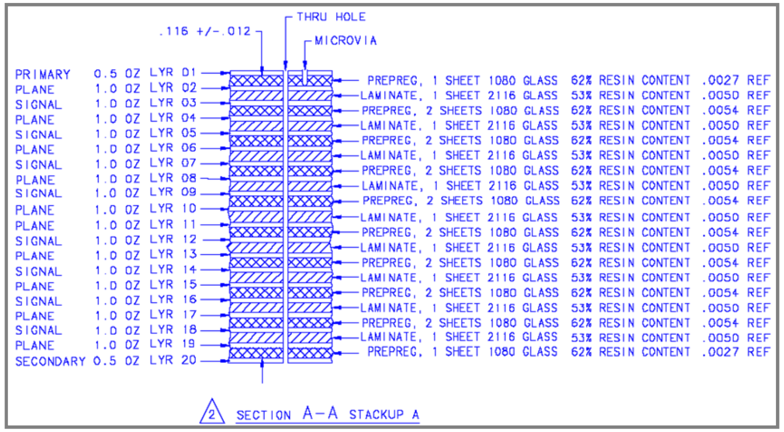
- Purpose – Interconnect Stress Testing (IST) of 24 lead free compatible materials before and after 6X 260°C reflow assembly
- Product Attributes - 20 Layers, 2.9mm thick, 0.25mm drilled PTH, 1mm and 0.8mm grids, IAg finish, 2 resin constructions for 12 materials, built by 1 PWB fabricator (Viasystems China)
- Celestica performed 6X Reflows to 260°C, through 10 zone SMT convection oven
- Correlate measured material change with damage found in micro-sections after reflow
- Correlate IST performance with damage found in micro-sections after reflow

HDPUG Lead-Free Study Responsibilities

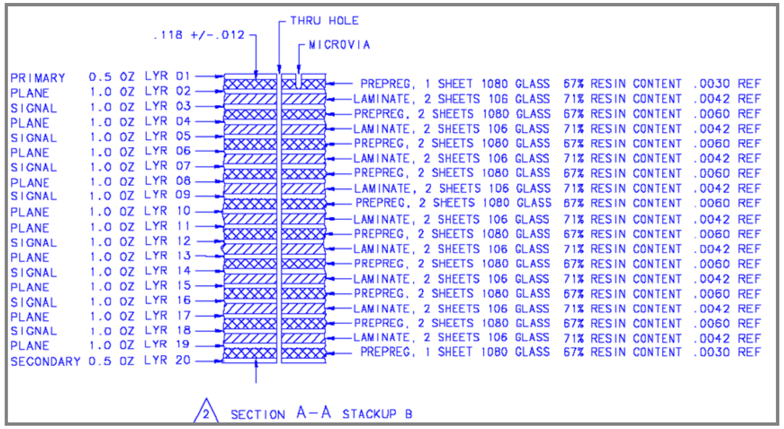
- Material Robustness:
  - Confirm Each Material was Produced With Similar Glass/Resin Constructed Materials
  - Determine Variability Across Each Group of Coupons (1mm and 0.8mm Via Spacing)
  - Identify whether Material Damage (Delamination) was created during and/or after 6X 260°C Reflow Cycles
- Via Reliability:
  - Establish baseline performance for 24 constructions, with 2 grid sizes (non-stressed)
  - Test 2nd set of coupons after exposure to 6X 260°C Reflow Cycles (stressed)
  - Complete failure analysis for both copper plating integrity and material robustness
  - Identify whether material damage impacted location or distribution of PTH barrel cracks
  - Rank performance of materials

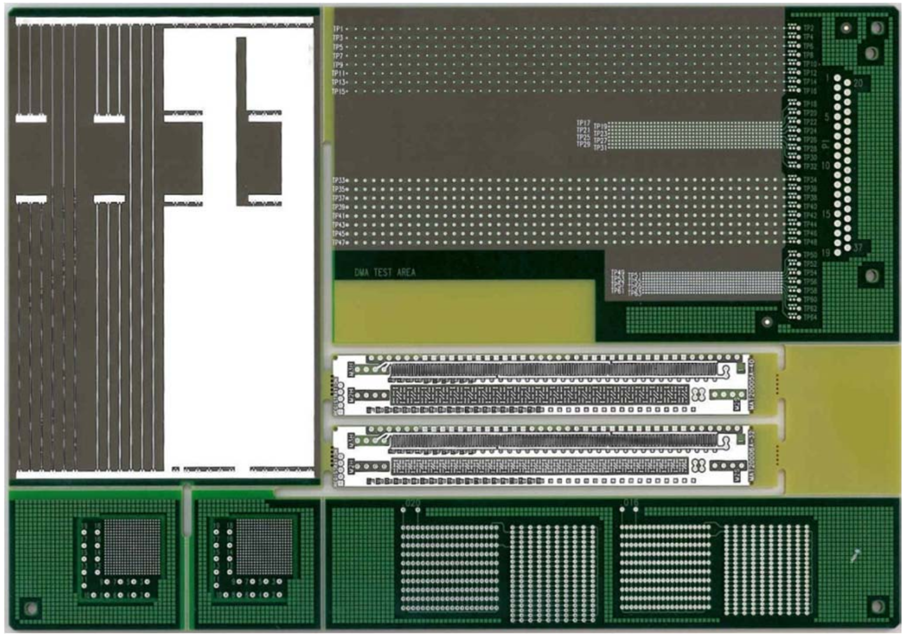
Test Vehicle Construction

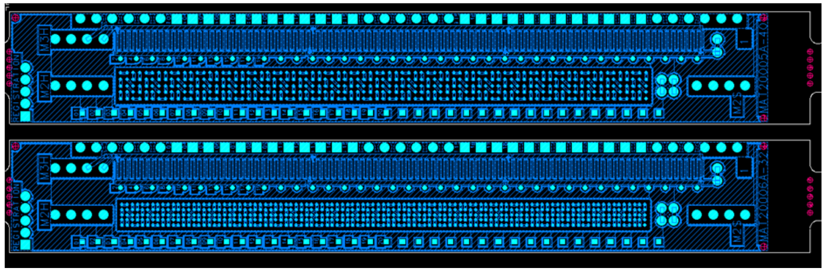
58% Resin Content



69% Resin Content





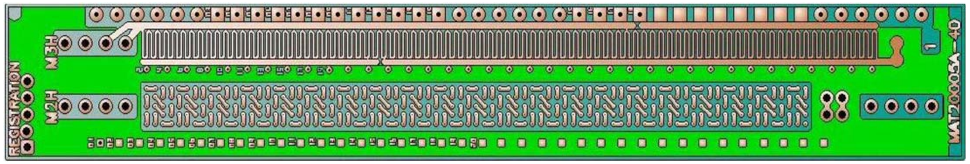


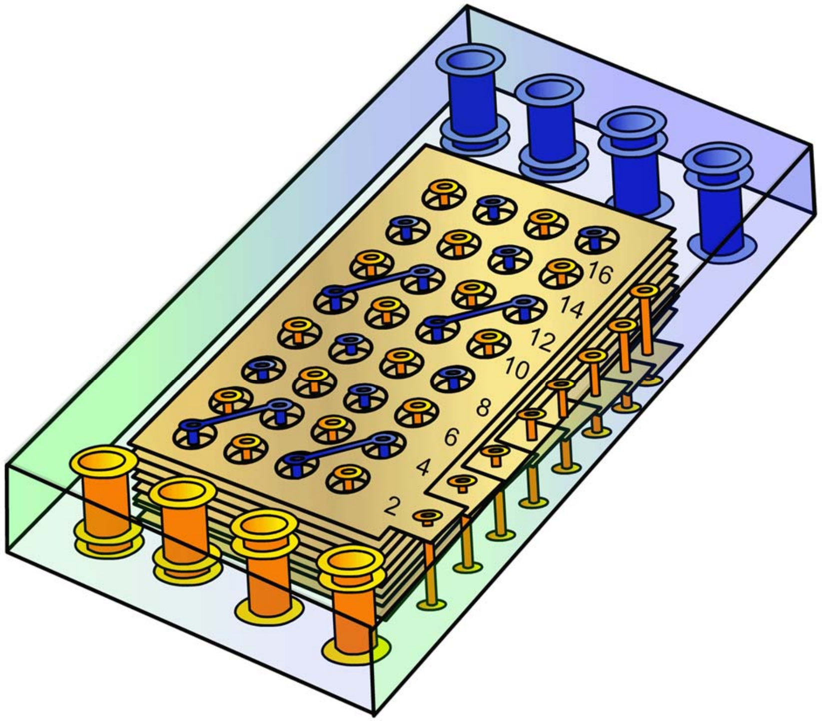
HDPUG Reflow Oven Profile (6X 260°C)

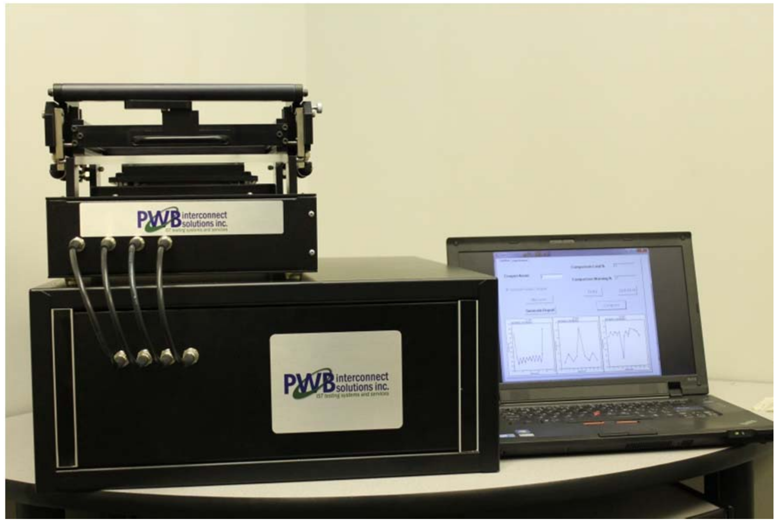
BTU Pyramax150N 10 Zone Forced Convection Oven

Profile Elements	*10 Zone Convection Oven Recommended*
Ramp Rate to 217° C Peak	Linear Ramp desired. Can have a small soak period. Usually 1 to 5° C/sec. No more than 2° C/sec
Pre-heat Temperature	Usually measured from 150° C to 200° C. Times within this temperature range are usually 60 to 120 seconds
TAL (Time above 217° C Liquidus)	Target 60 to 90 seconds
Time Within 5° C of Max Peak Temp.	10 to 20 seconds ok. Usually will be lower time.
Target Peak Temperature	**260° C Minimum +5° C / -0° C**
Ramp Down Rate	Target from 1.5° C/sec to 2.5° C/sec with normal oven cooling configuration
Reflow Atmosphere	Run all samples in air. (Worst case scenario)
Total Time in Oven	Usually 4 to 6 minutes
Thermocouples Attachment	Require minimum of 3 T/C's to properly profile raw card. (Leading Edge + Centre of Card +Trailing edge) are recommended locations.

Capacitance Testing (DELAM)







Capacitance Testing Protocol

- 10 coupons per construction tested non-stressed for 0.8mm & 1mm grids
- 5 coupons from 0.8mm measured after 2nd, 3rd, 4th reflow cycle
- All coupons measured after 6th reflow cycle
- 10 coupons x 2 grids x 24 constructions x 43 readings = 72,000+ data points
- -4% change in bulk capacitance confirms material damage (delamination)

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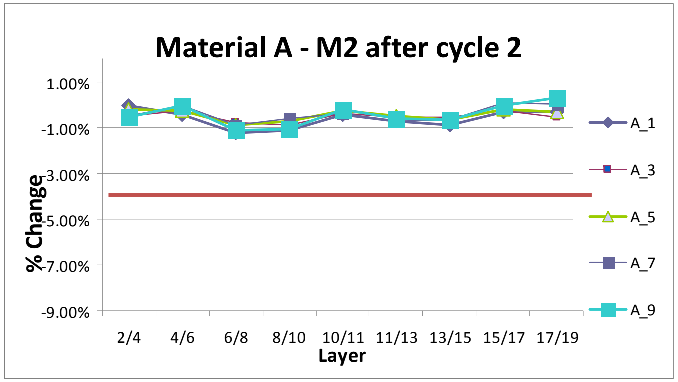
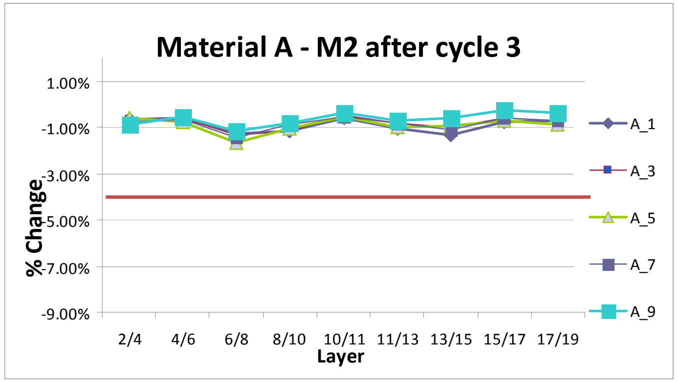
Robust Material Through 6X 260°C

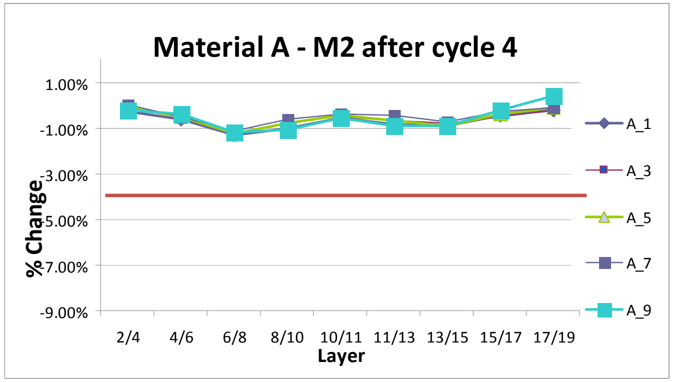
Reflow #2



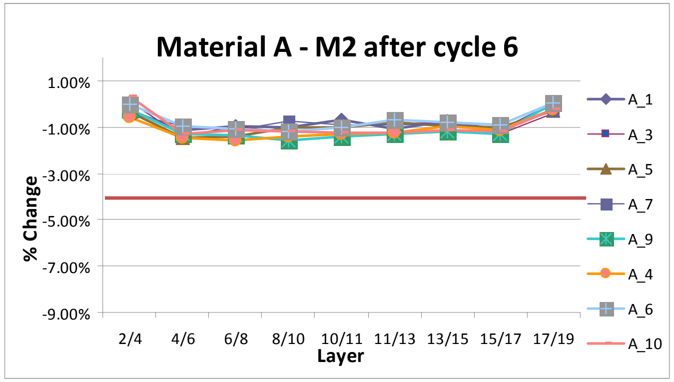
Reflow #3



Reflow #4

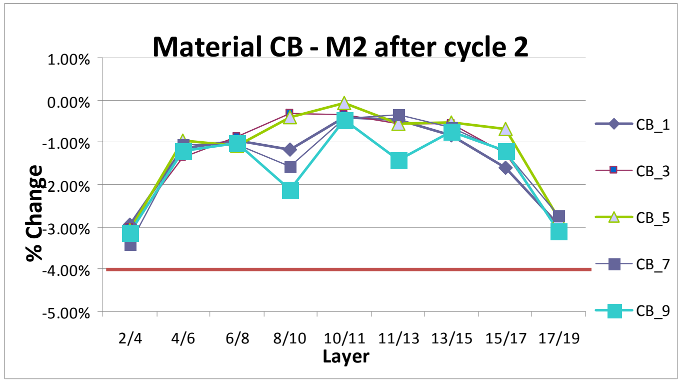


Reflow #6

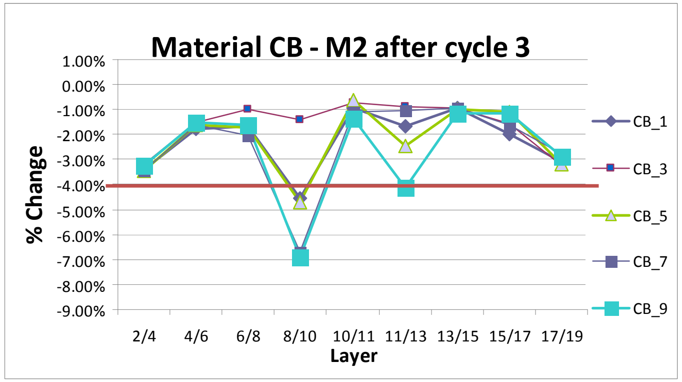


Non-Robust Material Through 6X 260°C

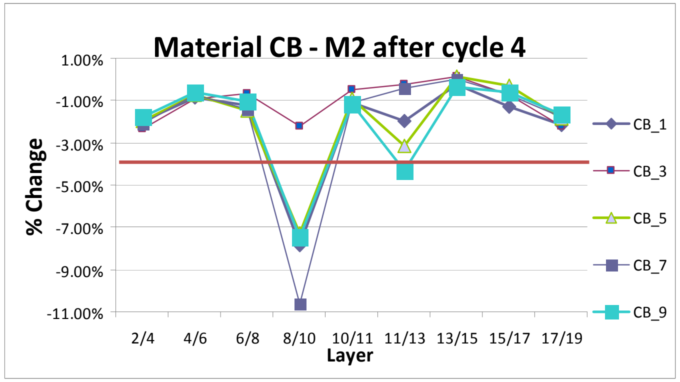
Reflow #2



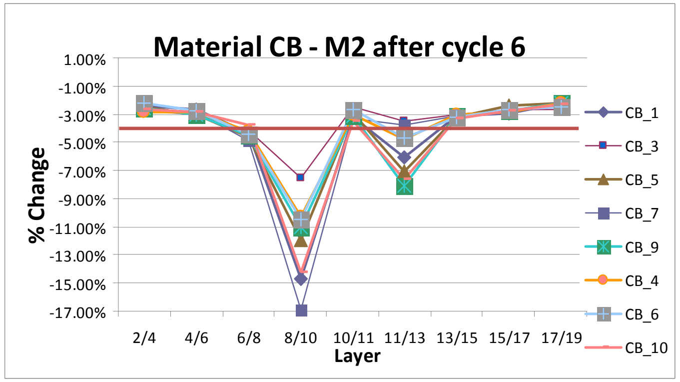
Reflow #3



Reflow #4



Reflow #6



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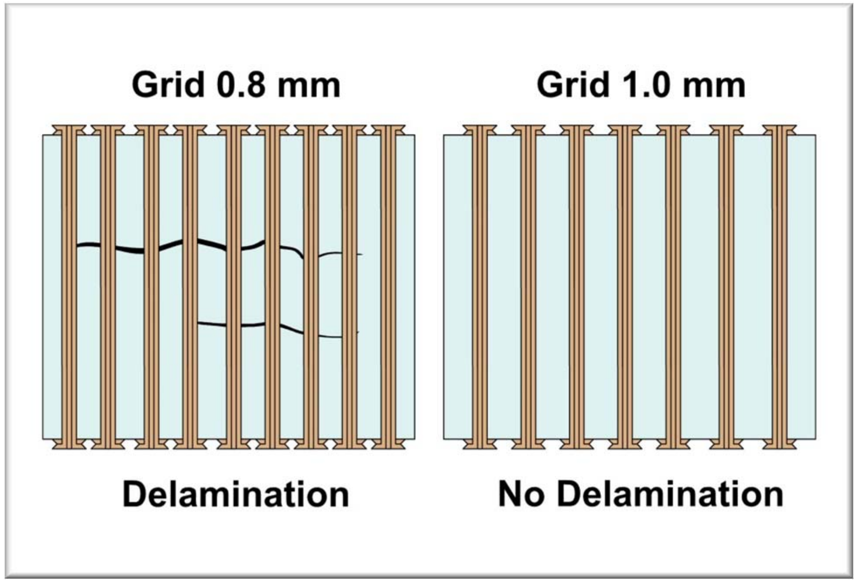
Reflow Cycles versus Damage Measured

IST Coupons Exhibiting Material Degradation (Delamination) Between/After 6X 260°C Reflow Cycles					
Assembly Level	2X Reflow Cycle (Out of 5)	3X Reflow Cycle (Out of 5)	4X Reflow Cycle (Out of 5)	6X Reflow Cycle (Out of 8)	6X Reflow Cycle Only
	Minimum	Standard	One Rework	BGA Rework	BGA Rework
Material Code	.032" / 0.8mm Coupons				.040" / 1mm
FR4:					
A	0	0	0	0	No
AB	0	0	0	0	No
B	0	0	0	0	No
BB	0	0	0	0	No
Halogen Free FR4:					
C	0	40%	80%	88%	No
CB	0	80%	80%	100%	No
D	0	20%	40%	100%	No
DB	0	0	60%	100%	Yes
E	0	0	0	0	No
EB	0	0	20%	100%	Yes
F	100%	100%	100%	100%	Yes
FB	100%	100%	100%	100%	Yes
G	0	40%	40%	50%	No
GB	0	20%	80%	100%	Yes
H	0	0	0	0	No
HB	0	0	0	0	No
High Speed Materials:					
I	0	0	0	100%	No
IB	0	20%	100%	100%	Yes
J	0	60%	100%	100%	No
JB	100%	100%	100%	100%	Yes
K	0	0	0	65%	No
KB	0	0	0	88%	No
L	0	0	0	0	No
LB	0	0	0	0	No
Defective Materials	3	10	12	15	8

Material Damage After 6X 260°C

Presence of Material Damage		
Material Type	.032" Grid	.040" Grid
FR4:		
A	None	None
AB	None	None
B	None	None
BB	None	None
Halogen Free FR4:		
C	Present	None
CB	Present	None
D	Present	None
DB	Present	Present
E	None	None
EB	Present	Present
F	Present	Present
FB	Present	Present
G	Present	None
GB	Present	Present
H	None	None
HB	None	None
High Speed Materials:		
I	Present	None
IB	Present	Present
J	Present	None
JB	Present	Present
K	Present	None
KB	Present	None
L	None	None
LB	None	None
Damaged Material	**15/24**	**8/24**



Correlation Between DELAM and X-section

DELAM Achieved 98% Correlation to X-Section

ECWC13 Code	DELAM 1mm	X section 1mm	Match	DELAM 0.8mm	X section 0.8mm	Match
FR4:						
A	No	No		No	No	
AB	No	No		No	No	
B	No	No		No	No	
BB	No	No		No	No	
Halogen Free FR4:						
C	No	Minor		Yes	Yes	
CB	No	Minor		Yes	Yes	
D	No	Yes	No Yes	Yes	Yes	
DB	Yes	Yes		Yes	Yes	
E	No	No		No	No	
EB	Yes	Yes		Yes	Yes	
F	Yes	Yes		Yes	Yes	
FB	Yes	Yes		Yes	Yes	
G	No	No		Yes	Yes	
GB	Yes	Yes		Yes	Yes	
H	No	No		No	No	
HB	No	No		No	No	
High Speed Materials:						
I	No	Minor		Yes	Yes	
IB	Yes	Yes		Yes	Yes	
J	No	No		Yes	Yes	
JB	Yes	Yes		Yes	Yes	
K	No	No		Yes	Yes	
KB	No	Minor		Yes	Yes	
L	No	No		No	No	
LB	No	No		No	No	
Results	**23 Match 1 No Match**			**24 Match 0 No Match**		

Correlation Between Reflow Oven versus 6X 288°C Solder Float

6X 288° C Solder Float Achieved 58% Correlation to Reflow Oven

ECWC13 Code	6X 260C SMT REFLOW OR 6X 288C SOLDER FLOAT	0.8mm/.032"				1mm/.040"			
		Hole Qty Examined	Delam(15)	Delam Cracks	Match	Hole Qty Examined	Delam(8)	Delam Cracks	Match
A	6X Reflow	13	no	0		11	no	0	
	6X Solder Float	23	no	0		17	no	0	
AB	6X Reflow	16	no	0	No	12	no	0	
	6X Solder Float	24	Yes	1		19	no	0	
B	6X Reflow	15	no	0		12	no	0	
	6X Solder Float	24	no	0		19	no	0	
BB	6X Reflow	16	no	0	No	13	no	0	
	6X Solder Float	23	Yes	1		19	no	0	
C	6X Reflow	17	Yes	9	No	11	no	0	
	6X Solder Float	24	no	0		20	no	0	
CB	6X Reflow	16	Yes	14		14	no	0	
	6X Solder Float	24	Yes	2		19	no	0	
D	6X Reflow	14	Yes	17		12	Yes	10	No
	6X Solder Float	24	Yes	3		20	no	0	
DB	6X Reflow	15	Yes	13	No	12	Yes	7	No
	6X Solder Float	23	no	0		19	no	0	
E	6X Reflow	14	no	0		13	no	0	
	6X Solder Float	24	no	0		20	no	0	
EB	6X Reflow	15	Yes	15	No	12	no	0	
	6X Solder Float	24	no	0		19	no	0	
F	6X Reflow	14	Yes	18		13	Yes	12	
	6X Solder Float	23	Yes	21		18	Yes	28	
FB	6X Reflow	15	Yes	23		12	Yes	13	
	6X Solder Float	25	Yes	22		19	Yes	6	
G	6X Reflow	15	Yes	13		13	no	0	No
	6X Solder Float	23	Yes	21		18	Yes	2	
GB	6X Reflow	15	Yes	15		12	Yes	2	No
	6X Solder Float	23	Yes	1		19	no	0	
H	6X Reflow	15	no	0		12	no	0	
	6X Solder Float	24	no	0		19	no	0	
HB	6X Reflow	15	no	0		13	no	0	
	6X Solder Float	20	no	0		18	no	0	
I	6X Reflow	15	Yes	15	No	12	no	0	
	6X Solder Float	20	no	no		20	no	0	
IB	6X Reflow	15	Yes	15	No	13	Yes	6	No
	6X Solder Float	24	no	0		18	no	0	
J	6X Reflow	15	Yes	16	No	14	no	0	
	6X Solder Float	23	no	0		18	no	0	
JB	6X Reflow	16	Yes	18	No	13	Yes	13	No
	6X Solder Float	24	no	0		19	no	0	
K	6X Reflow	16	no	0	No	13	no	0	
	6X Solder Float	23	Yes	2		19	no	0	
KB	6X Reflow	16	no	0		12	no	0	
	6X Solder Float	23	no	0		19	no	0	
L	6X Reflow	15	no	0		13	no	0	
	6X Solder Float	24	no	0		20	no	0	
LB	6X Reflow	16	no	0		12	no	0	
	6X Solder Float	23	no	0		19	no	0	
Results		14 Match 10 No Match				18 Match 6 No Match			

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0.8mm Material Damage Crack Count

Crack Count vs. Electrical Data on .032"/0.8mm Grid Coupons

Layer	2/4				4/6				6/8				8/10				10/11				11/13				13/15				15/17				17/19			
R32 Coupons	S	M	L		S	M	L		S	M	L		S	M	L		S	M	L		S	M	L		S	M	L		S	M	L		S	M	L	
A	0	0	0		0	0	0		0	0	0		0	0	0		0	0	0		0	0	0		0	0	0		0	0	0		0	0	0	
AB	0	0	0		0	0	0		0	0	0		0	0	0		0	0	0		0	0	0		0	0	0		0	0	0		0	0	0	
B	0	0	0		0	0	0		0	0	0		0	0	0		0	0	0		0	0	0		0	0	0		0	0	0		0	0	0	
BB	0	0	0		0	0	0		0	0	0		0	0	0		0	0	0		0	0	0		0	0	0		0	0	0		0	0	0	
C	0	0	0		0	0	0		0	0	0		0	0	8	✓	1	0	0	✓	0	0	23	✓	0	8	0	✓	0	0	0		0	0	0	
CB	0	0	0		0	0	0		2	0	2	✓	0	1	28	✓	0	0	0		2	0	1	✓	0	0	1	✓	0	0	0		0	0	0	
D	0	0	0		0	0	0		6	1	0	✓	0	2	10	✓	0	0	10	✓	1	0	3	✓	0	0	0		0	0	0		0	0	0	
DB	0	0	0		0	0	0		0	1	0	✓	0	2	14	✓	0	2	3	✓	0	5	16	✓	0	5	1	✓	0	0	0		0	0	0	
E	0	0	0		0	0	0		0	0	0		0	0	0		0	0	0		0	0	0		0	0	0		0	0	0		0	0	0	
EB	0	0	0		0	0	0		0	4	4	✓	0	0	18	✓	0	0	0		2	0	19	✓	5	0	9	✓	0	0	0		0	0	0	
F	0	0	0		10	0	0	X	0	6	7	✓	0	3	12	✓	0	0	0		0	0	32	✓	12	0	0	✓	0	0	0		0	0	0	
FB	13	0	0	X	22	2	0	X	13	0	3	✓	0	2	14	✓	0	0	0		0	3	20	✓	4	0	0	✓	0	0	0		0	0	0	
G	0	0	0		0	0	0		0	0	0		0	5	9	✓	0	3	4	✓	0	0	7	✓	2	1	2	✓	0	0	0		0	0	0	
GB	0	0	0		0	0	0		12	4	1	✓	0	2	25	✓	0	1	3	✓	0	12	7	✓	7	0	0	✓	0	0	0		0	0	0	
H	0	0	0		0	0	0		0	0	0		0	0	0		0	0	0	0	0	0	0		0	0	0		0	0	0		0	0	0	
HB	0	0	0		0	0	0		0	0	0		0	0	0		0	0	0	0	0	0	0		0	0	0		0	0	0		0	0	0	
I	0	0	0		0	0	0		1		1	✓	0	0	5	✓	0	0	0	0	0	3	10	✓		0	5	✓	0	0	0		0	0	0	
IB	0	0	0		0	0	0		0	4	5	✓	0	6	18	✓	7	0	1	✓	0	0	28	✓	2	0	0	✓	0	0	0		0	0	0	
J	0	0	0		0	0	0		0	0	6	✓	27	0	0	✓	19	0	0	✓	0	0	31	✓	7	0	0	✓	0	0	0		0	0	0	
JB	0	0	0		0	0	0		8	1		✓	32	0	0	✓	23	0	0	✓	1	0	27	✓	0	0	7	✓	0	0	0		0	0	0	
K	0	0	0		0	0	0		0	0	0		6	0	7	✓	1	0	0	✓	0	0	12	✓	0	0	12	✓	0	0	0		0	0	0	
KB	0	0	0		0	0	0		1	0	0	✓	15	0	2	✓	0	0	0		0	0	31	✓	2	0	0	✓	0	0	0		0	0	0	
L	0	0	0		0	0	0		0	0	0		0	0	0		0	0	0		0	0	0		0	0	0		0	0	0		0	0	0	
LB	0	0	0		0	0	0		0	0	0		0	0	0		0	0	0		0	0	0		0	0	0		0	0	0		0	0	0	
Note:	A check mark ✓ indicates the demage in the microsection and the electrical damage agree. An X indicates a disagreement.																																			

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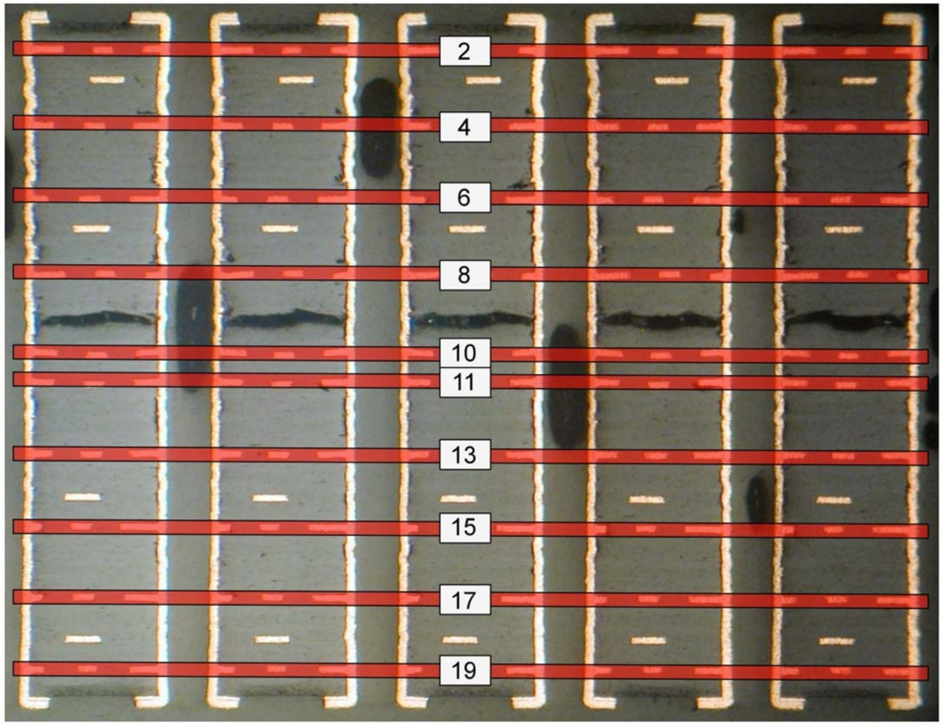
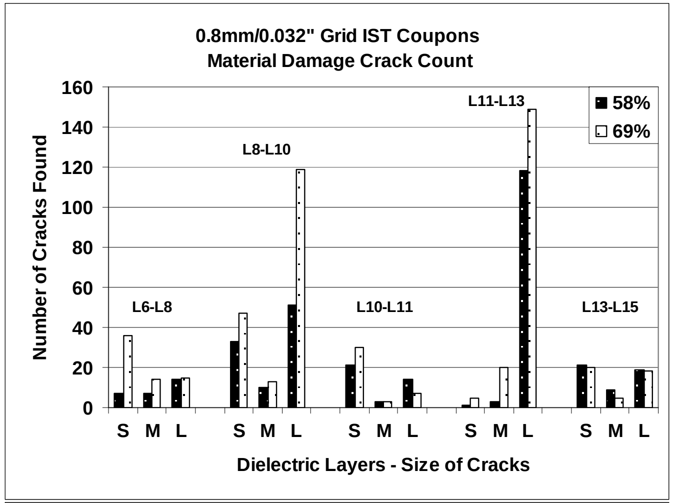
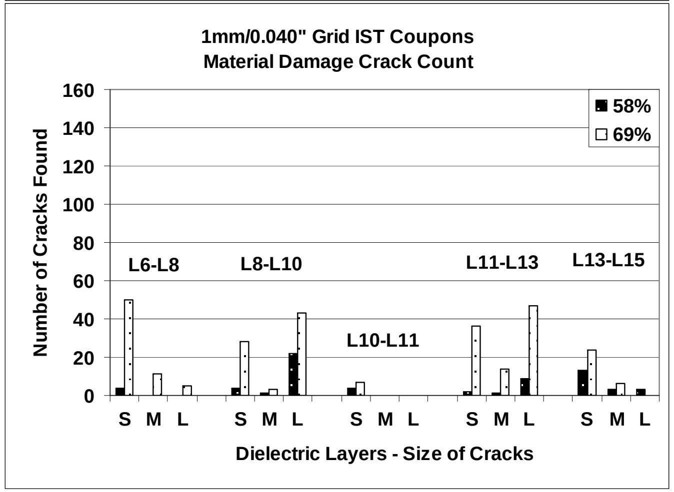
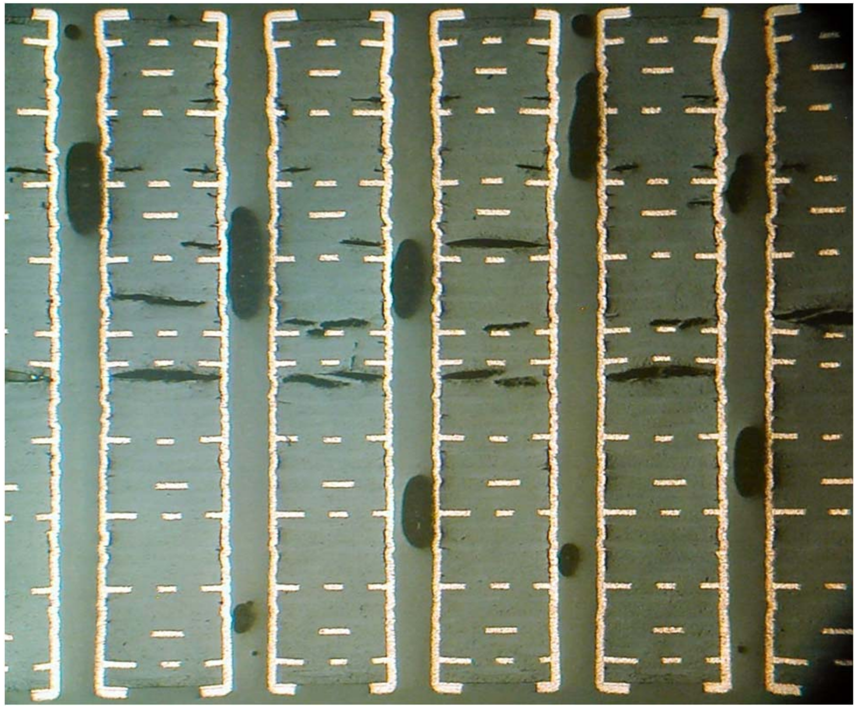
Material Damage Crack Count







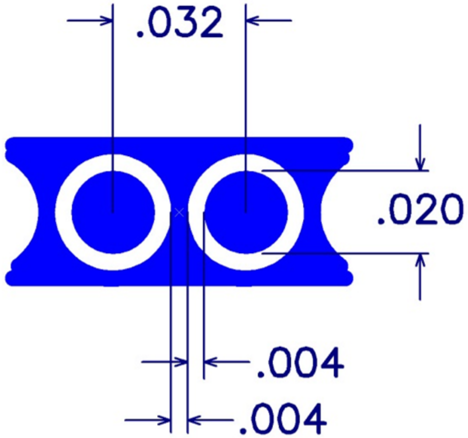
Cohesive Damage by Glass Style/Type



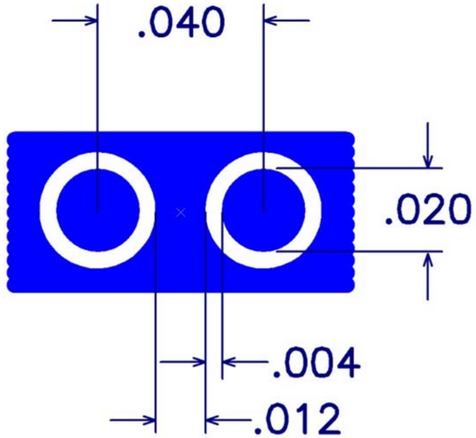
Material Type	58%		69%	
	C=1X 2116	B= 2X 1080	C= 2X 106	B= 2X 1080
C		x		
CB				x
D	x			
DB			x	x
EB			x	
F		x		
FB				x
G	x	x		
GB			x	x
I	x	x		
IB			x	x
J		x		
JB				x
K		x		
KB				x

Impact of 0.8mm Vs 1mm Grid Size

15 Constructions Delaminated



8 Constructions Delaminated



Note: The severity of damage found on 0.8mm was 2X the level found on 1mm

Why is 0.8mm grid more susceptible to material damage?

When the structure of the composite materials reaches a specific temperature an internal shear stress is generated by the mis-match of CTE. The CTE mismatch is caused by the combination of the strength of the glass restricting the x axis expansion, versus the non-restricted expansion of the resin in the y axis. The focal point of this CTE mismatch is located at the "knuckle" between the woven glass fabrics, this is premised on the examination of microsections that consistently exhibit material cracks at the cross-over point between the warp and the weft glass directions.

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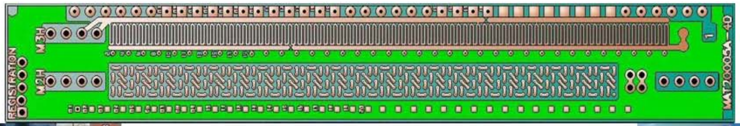
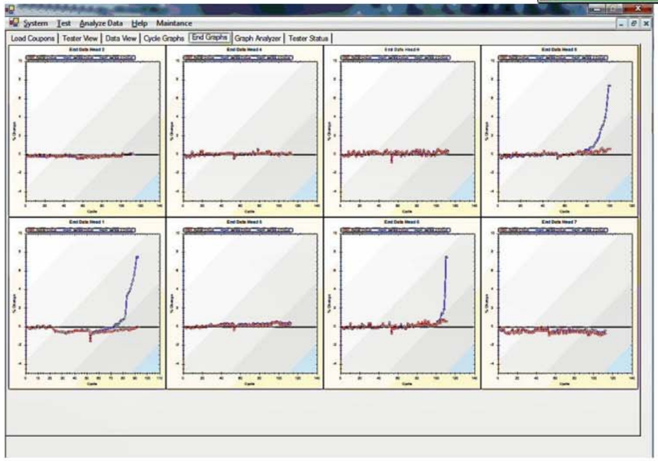
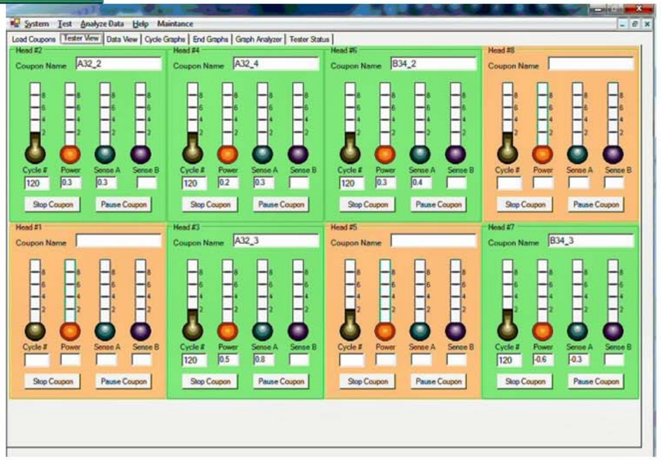
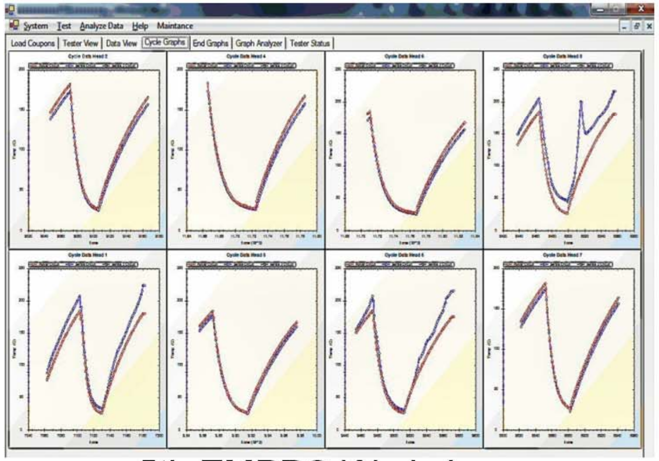
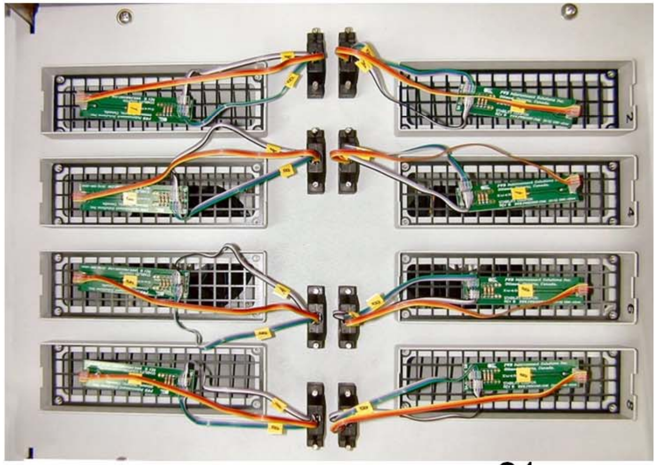
I.S.T. Accelerated Reliability Testing





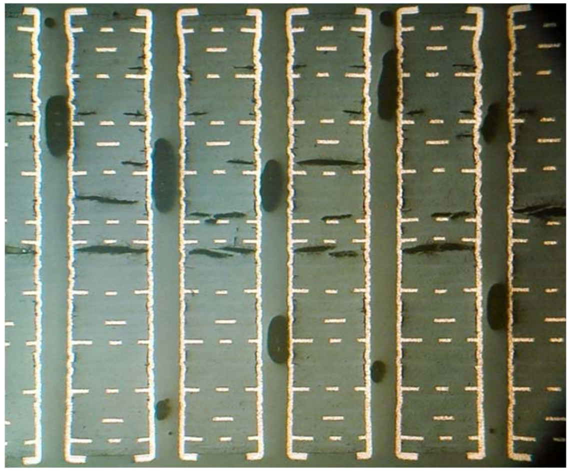


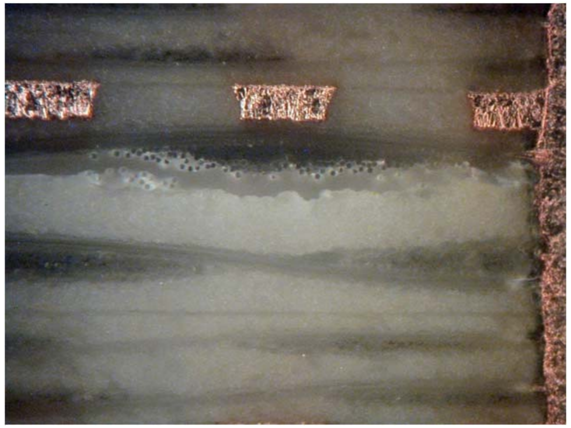




6X 260°C Reflow Cycles Caused Damage!

	Capacitance Testing Indicates Material Damage After 6X 260C Reflow		Microsection Indicates Material Damage After 6X 260C Reflow	
SMTAI CODE	**DELAM 1mm**	**DELAM 0.8mm**	**X section 1mm**	**X section 0.8mm**
High Tg FR4				
A	No	No	No	No
AB	No	No	No	No
B	No	No	No	No
BB	No	No	No	No
Halogen Free				
C	No	Yes	Minor	Yes
CB	No	Yes	Minor	Yes
D	No	Yes	Yes	Yes
DB	Yes	Yes	Yes	Yes
E	No	No	No	No
EB	Yes	Yes	Yes	Yes
F	Yes	Yes	Yes	Yes
FB	Yes	Yes	Yes	Yes
G	No	Yes	No	Yes
GB	Yes	Yes	Yes	Yes
H	No	No	No	No
HB	No	No	No	No
High Speed FR4				
I	No	Yes	Minor	Yes
IB	Yes	Yes	Yes	Yes
J	No	Yes	No	Yes
JB	Yes	Yes	Yes	Yes
K	No	Yes	No	Yes
KB	No	Yes	Minor	Yes
L	No	No	No	No
LB	No	No	No	No
	Minor	= Not Rejectable Damage		





Presence of Material Damage		
Material Type	**.032" Grid**	**.040" Grid**
FR4:		
A	None	None
AB	None	None
B	None	None
BB	None	None
Halogen Free FR4:		
C	Present	None
CB	Present	None
D	Present	None
DB	Present	Present
E	None	None
EB	Present	Present
F	Present	Present
FB	Present	Present
G	Present	None
GB	Present	Present
H	None	None
HB	None	None
High Speed Materials:		
I	Present	None
IB	Present	Present
J	Present	None
JB	Present	Present
K	Present	None
KB	Present	None
L	None	None
LB	None	None
Damaged Material	**15/24**	**8/24**

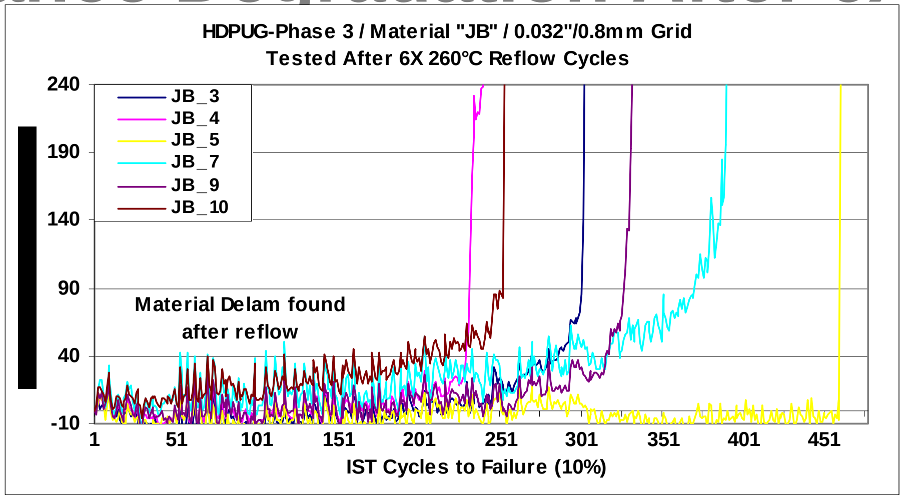
Problem Statement

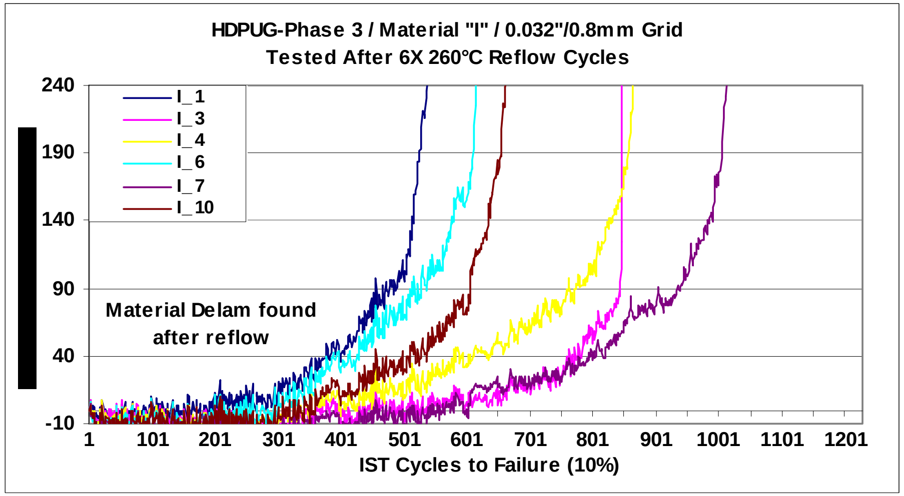
- The basis of a successful PTH via reliability study is built upon the premise that material integrity is not compromised, and an assurance that fatigue in the central zone of the PTH barrel is the only failure mode.

IST Testing Protocol

- Cycle between ambient and 150°C in 3 min's, cool to ambient in 2 min's, reject at 10% (IPC) increase in resistance
- IST test 6 coupons, superheat designed with the 0.8mm and 1mm grids, for 24 constructions tested in the non-stressed condition
- All materials received 6X 260°C reflow cycles
- IST test 2nd set of 6 coupons of each grid/ construction tested in the stressed condition
- Failure analysis completed on 1 coupon from each grid size, test condition and construction
- IST results statistically compared (24 builds x 2 grid sizes x 2 test conditions x 6 coupons = 576 test coupons

Resistance Degradation After 6X 260°C





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Mean IST Cycles to Failure Results

ECWC13 Coding	1mm/0.040" Grid: IST 1mm As Built	1mm/0.040" Grid: IST 1mm after 6X 260C	1mm/0.040" Grid: Damage - 1mm	1mm/0.040" Grid: 1mm 6X Compare better than AB?	0.8mm/0.032" Grid: IST 0.8mm As Built	0.8mm/0.032" Grid: IST 0.8mm after 6X 260C	0.8mm/0.032" Grid: Damage - 0.8mm	0.8mm/0.032" Grid: 0.8mm 6X Compare better than AB?
High Tg FR4								
A	677	513	No	No	699	521	No	No
AB	447	358	No	No	420	362	No	No
B	372	256	No	No	332	228	No	No
BB	380	173	No	No	386	201	No	No
Halogen Free								
C	993	568	No	No	932	628	Yes	No
CB	768	393	No	No	805	598	Yes	No
D	516	332	Yes	No	566	289	Yes	No
DB	490	378	Yes	No	499	642	Yes	Yes
E	**173**	**43**	No	No	**169**	**16**	No	No
EB	**115**	**42**	Yes	No	**109**	**53**	Yes	No
F	280	527	Yes	Yes	259	558	Yes	Yes
FB	235	381	Yes	Yes	223	260	Yes	Yes
G	>2000	1269	No	No	>2000	1753	Yes	No
GB	>2000	1217	Yes	No	1860	2000	Yes	Yes
H	>2000	>2000	No	No	>2000	1860	No	No
HB	1906	1157	No	No	1955	1032	No	No
High Speed FR4								
I	1040	576	No	No	962	760	Yes	No
IB	819	374	Yes	No	757	756	Yes	No
J	434	191	No	No	404	333	Yes	No
JB	302	224	Yes	No	280	331	Yes	Yes
K	821	335	No	No	768	392	Yes	No
KB	602	382	No	No	623	385	Yes	No
L	>2000	1703	No	No	>2000	1859	No	No
LB	>2000	1567	No	No	>2000	1730	No	No

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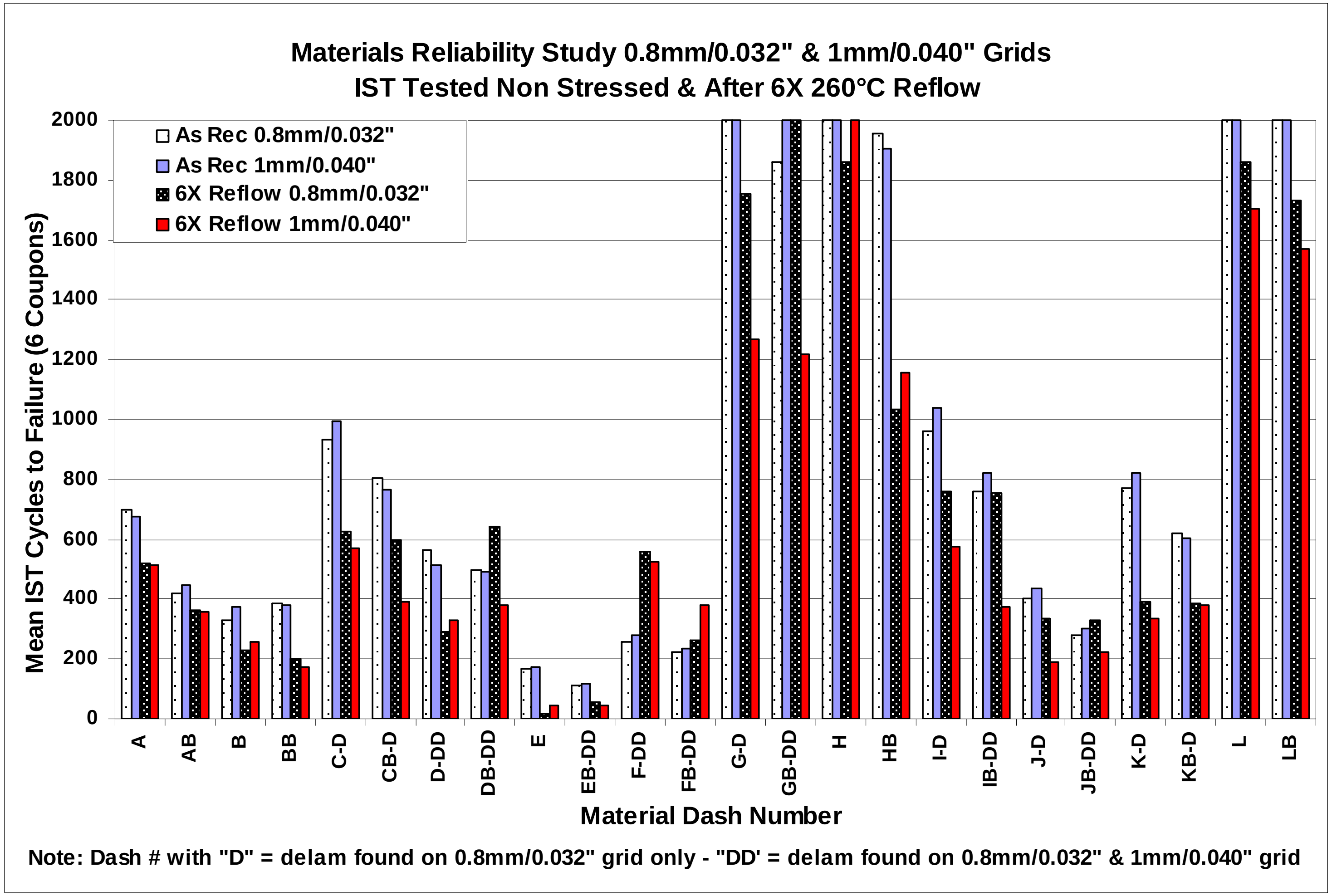
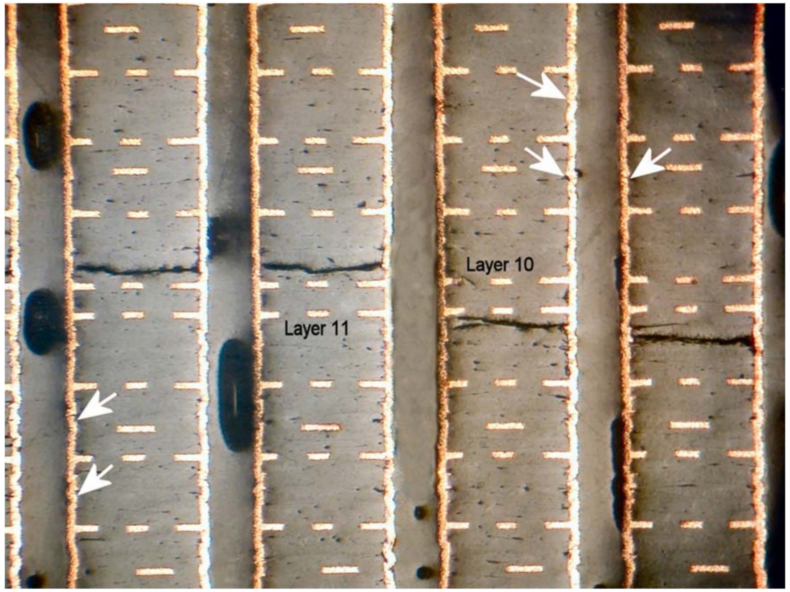
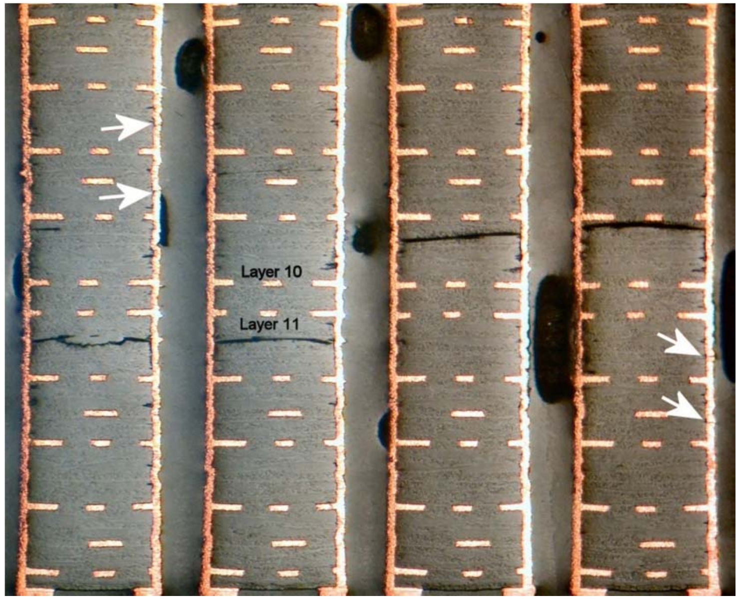
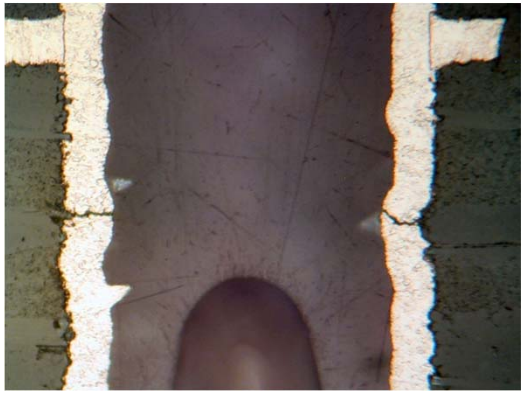
Relative Performance of 24 Constructions



Cu Fatigue Cracks Moved Away From Damage!

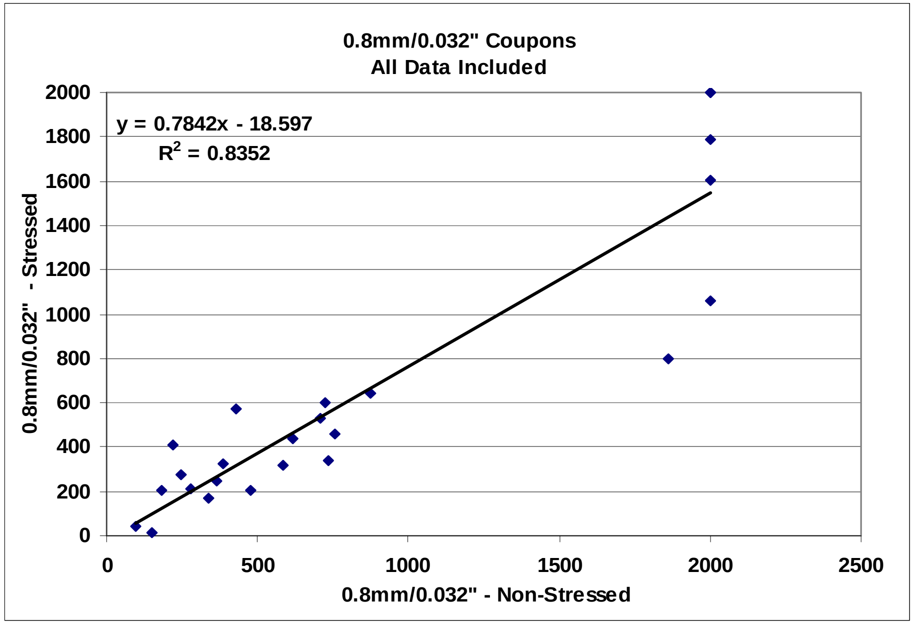




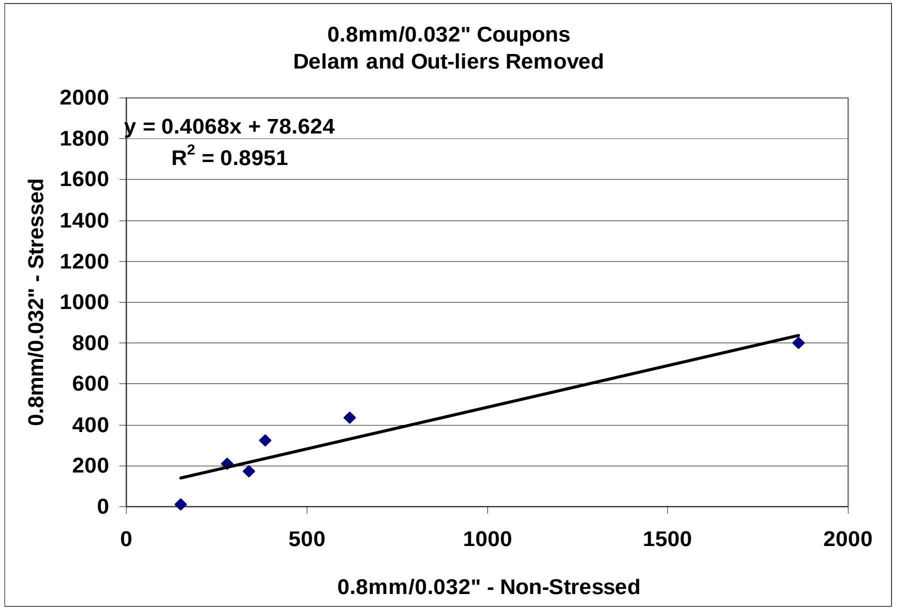


0.8mm Non Stressed Vs Stressed

Material Damage Included

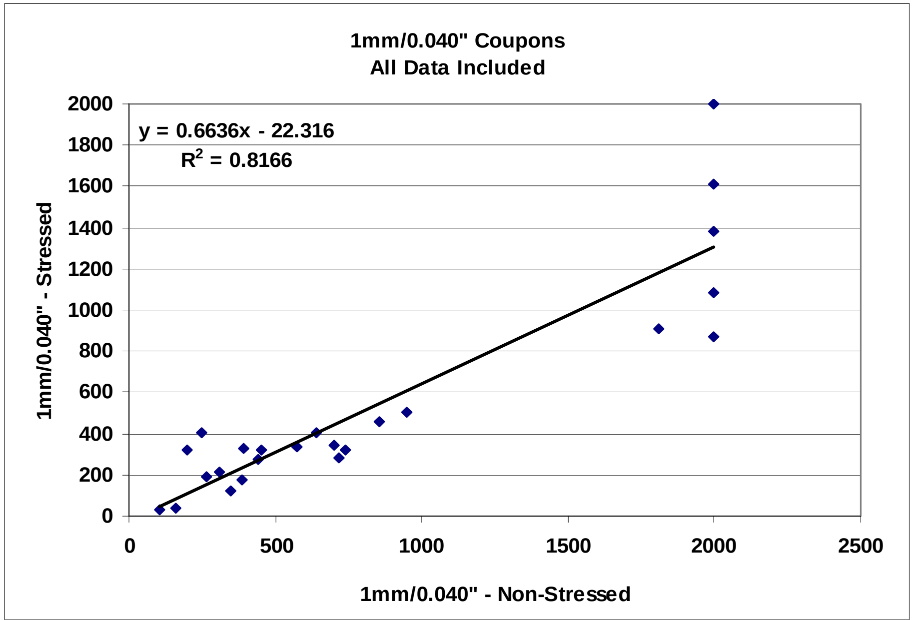


Material Damage Removed

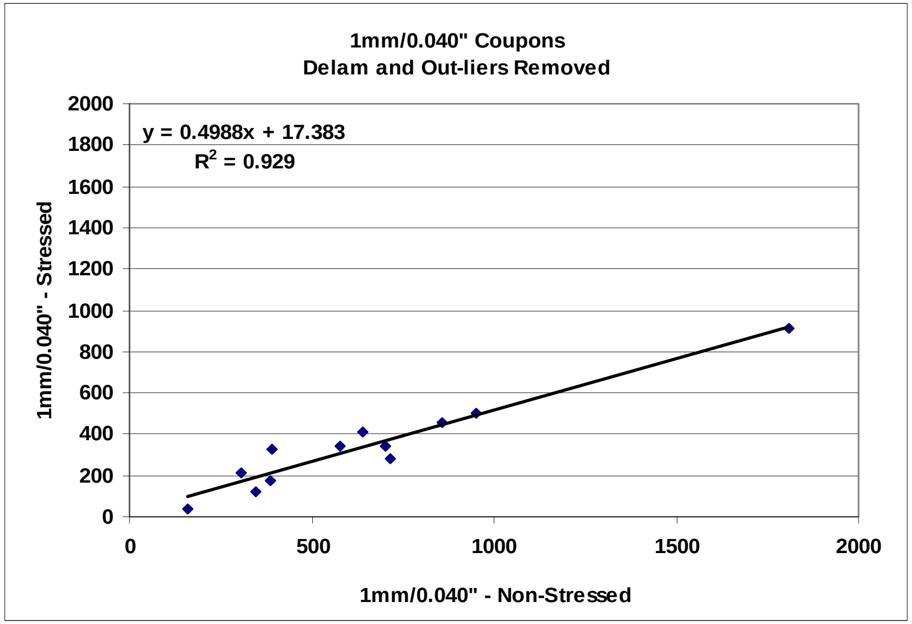


1mm Non Stressed Vs Stressed

Material Damage Included

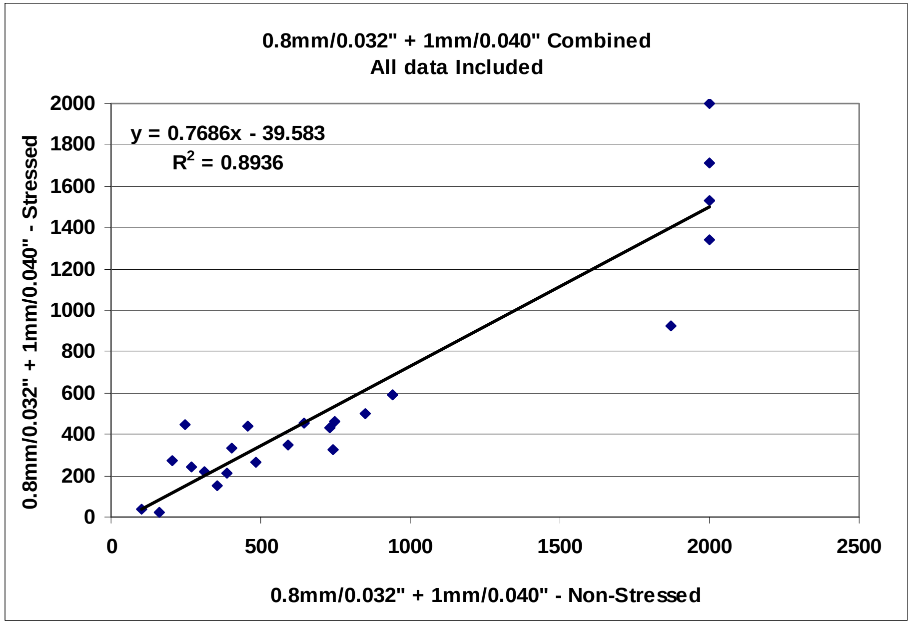


Material Damage Removed

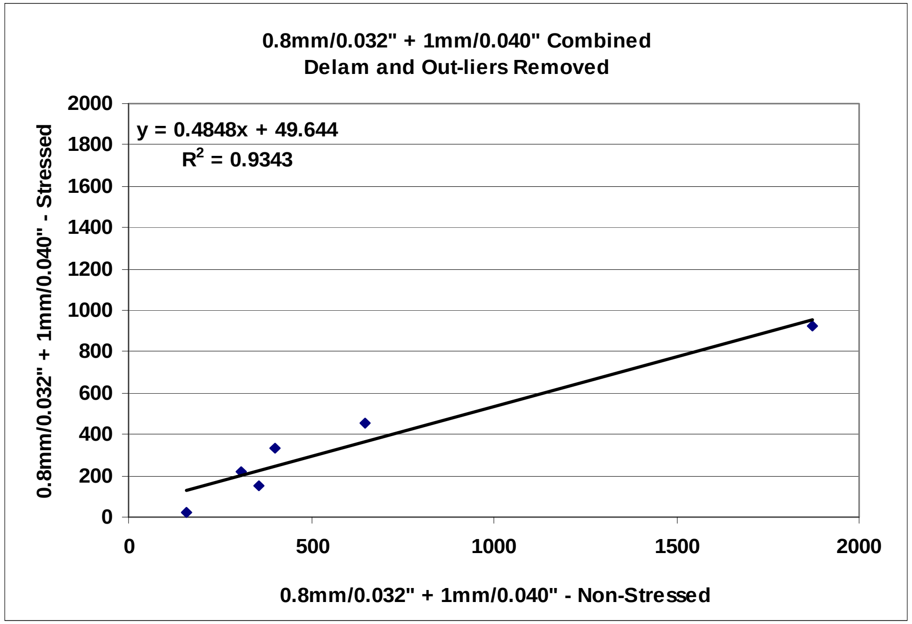


0.8mm + 1mm Non Stressed Vs Stressed

Material Damage Included



Material Damage Removed



Ranking FR4 Performance

High Tg FR4					
Ranking of **Non-stressed** Coupons With Both Grids			Ranking of **Stressed** Coupons With Both Grids		
Coupon	Log N	Delam	Coupon	Log N	Delam
A	**646**	No	A	**453**	No
AB	**402**	No	AB	**337**	No
BB	**355**	No	B	**219**	No
B	**310**	No	BB	**155**	No

Ranking Halogen Free Performance

Halogen Free											
Ranking of **Non-stressed** Coupons With Both Grids			Ranking of **Stressed** Coupons With Both Grids			Ranking of **Stressed** 1mm/0.040" Coupons Only			Ranking of **Stressed** Coupons With Both Grids		
Coupon	Log N	Delam	Coupon	Log N	Delam	Coupon	Log N	Delam	Coupon	Log N	Delam
G	**2000**	No	H	**2000**	No	H	**2000**	No	H	**2000**	No
GB	**2000**	No	G	**1533**	Yes	HB	910	No	HB	**925**	No
H	**2000**	No	GB	**1340**	Yes	G	**869**	No	E	**25**	No
HB	**1873**	No	HB	**925**	No	C	**458**	No			
C	**852**	No	C	**498**	Yes	CB	**341**	No			
CB	**730**	No	F	**448**	Yes	E	**40**	No			
D	**482**	No	DB	**436**	Yes						
DB	**457**	No	CB	**433**	Yes						
F	**245**	No	FB	**271**	Yes						
FB	**203**	No	D	**265**	Yes						
E	**160**	No	EB	**39**	Yes						
EB	**104**	No	E	**25**	No						

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Ranking High Speed FR4 Performance

High Speed FR4

Ranking of **Non-stressed** Coupons With Both Grids		
Coupon	Log N	Delam
L	**2000**	No
LB	**2000**	No
I	**940**	No
IB	**745**	No
K	**744**	No
KB	**591**	No
J	**389**	No
JB	**268**	No

Ranking of **Stressed** Coupons With Both Grids		
Coupon	Log N	Delam
L	**1713**	No
LB	**1532**	No
I	**594**	Yes
IB	**460**	Yes
KB	**345**	Yes
K	**327**	Yes
JB	**240**	Yes
J	**215**	Yes

Ranking of **Stressed** 1mm/0.040" Coupons Only		
Coupon	Log N	Delam
L	**1607**	No
LB	**1383**	No
I	**505**	No
KB	**339**	No
K	**285**	No
J	**173**	No

Ranking of **Stressed** Coupons With Both Grids		
Coupon	Log N	Delam
L	**1713**	No
LB	**1532**	No

Material Robustness Conclusions

- Fifteen of the 24 materials proved unsuitable after 6X 260°C Pb free assembly, specifically on the 0.8mm/.032” grid size. Eight materials proved unsuitable on the 1mm/.040” grid size.
- Three “Pb free compatible” materials demonstrated delamination in the 2nd cycle of assembly, 10 materials delaminated in the 3rd cycle. 12 materials delaminated in the 4th cycle Each preconditioning cycle produced increasing levels of material damage.
- Material damage through Pb free assembly was dominated by cohesive failure, primarily across the central zone of the construction.
- The nature of the cohesive damage is compromising the critical glass/resin interface. Laminate manufacturers must investigate this situation to understand root cause and introduce improvements.

Material Robustness Conclusions Con't

- The MRT-5 IST test coupon design and DELAM testing protocol proved very effective at characterizing the presence, location and magnitude of material damage during and after Pb free assembly, achieving a 98% confidence when compared with microsection analysis.
- The electrical specification based on a minimum of 4% decrease in bulk capacitance demonstrated the ability to identify and confirm material damage.
- The results of conventional 6X solder float testing to 288°C did not achieve statistical correlation (58%) with coupons that received 6X 260°C Pb free reflow assembly.
- The majority of damage caused during assembly was focused toward the centre of the construction. The material damage was not visible on the surface layers, although major delamination was present throughout the construction.

IST Accelerated Reliability Conclusions

- IST results ranged from immediate failures to no failures found at 2000 cycles. This is based on identical electrolytic copper plating conditions for all constructions
- Cohesive material damage was demonstrated to be stress relieving, the areas of copper cracks, effectively redistributing the strain into different locations within the construction.
- There were 7 instances (out of 24) where PTH via reliability performances were increased following exposure to 6X 260°C reflow cycles, compared to non-stressed results. The combined effects of stress redistribution and stress relieving across the central zone of the copper plated barrel are considered to be the primary explanation.

Overall Study Conclusions

- Any future PWB PTH thermal cycling reliability studies that combines a grid size of 1mm/0.040 or smaller, and will apply multiple exposures to Pb-free reflow assembly must anticipate the requirement to quantify the presence of material damage in their testing protocols.
- Material suitability for Pb-free assembly reflow cannot be determined by visual inspection alone. Applying methodologies like DELAM testing is a complementary strategy to identifying material damage in test vehicles.
- The majority of cohesive damage was found in the same location of the construction, where copper fatigue cracks were found to initiate and propagate.

Overall Study Conclusions (Cont'd)

- Grid sizes of 0.8mm/0.032" are 2X more susceptible to cohesive material damage during multiple Pb-free reflow cycles compared to 1mm/0.040". Fifteen out of 24 materials exhibited multiple levels of cohesive delamination in 0.8mm/0.032" coupons compared to "only" 8 materials in 1mm/0.040" coupons.
- Quantifying the overall PTH via reliability performance proved difficult when attempting to make a material ranking, due to the confounded effects of cohesive material damage.
- In the ranking system demonstrated in this study equal importance was applied to both the performance of via reliability and material integrity.

Acknowledgements

- **Viasystems – China**
  - Construction of 24 materials
  - Failure Analysis
  - TMA/DSC Thermal Analysis
- **Celestica – Canada**
  - Profiling and Processing Through Reflow Oven
- **PWB Interconnect Solutions Inc. – Canada**
  - IST and DELAM Testing
  - Statistical Analysis
  - Failure Analysis
  - DMA Thermal Analysis
  - Report Writing
- **HDPUG – USA/UK**
  - Project Coordination

Thank you for your attention!

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