

Case Study: Metallurgical and Mechanical Analysis of Castellated Via Rigid-Flex

Connection

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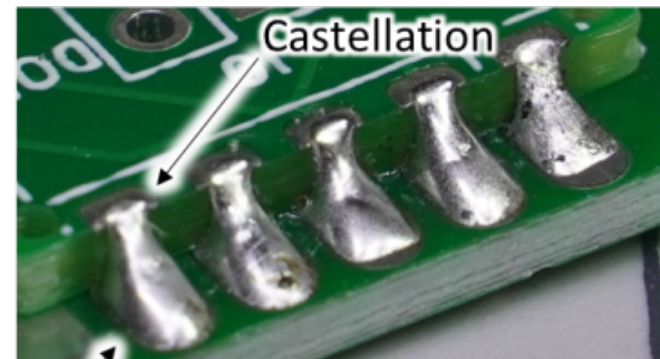
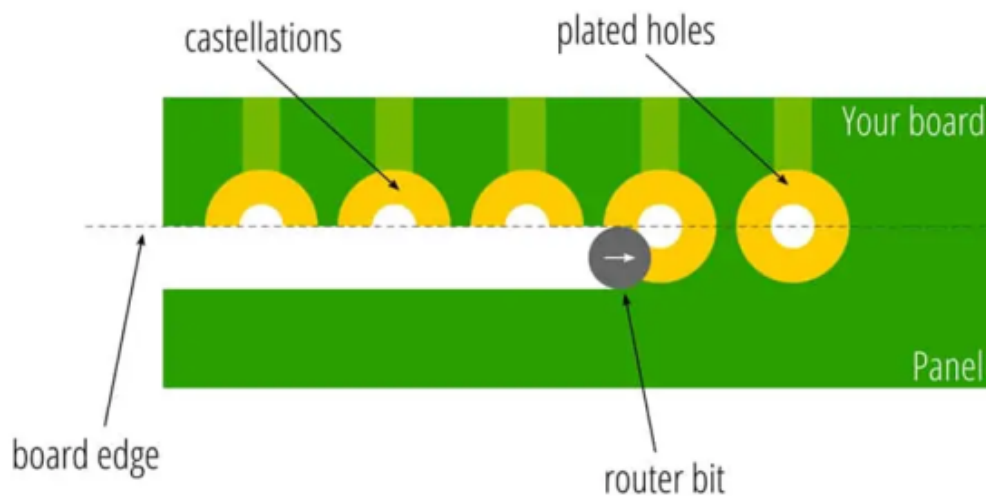
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Outline/Agenda

- Introduction
- Castellated Via
- Reliability Evaluation
 - Mechanical testing and isothermal aging
- Results
- Conclusions
- Acknowledgements (*optional*)
- Q & A

Castellated Via



Top view schematic of a castellated (left), and the final joint geometry (right).

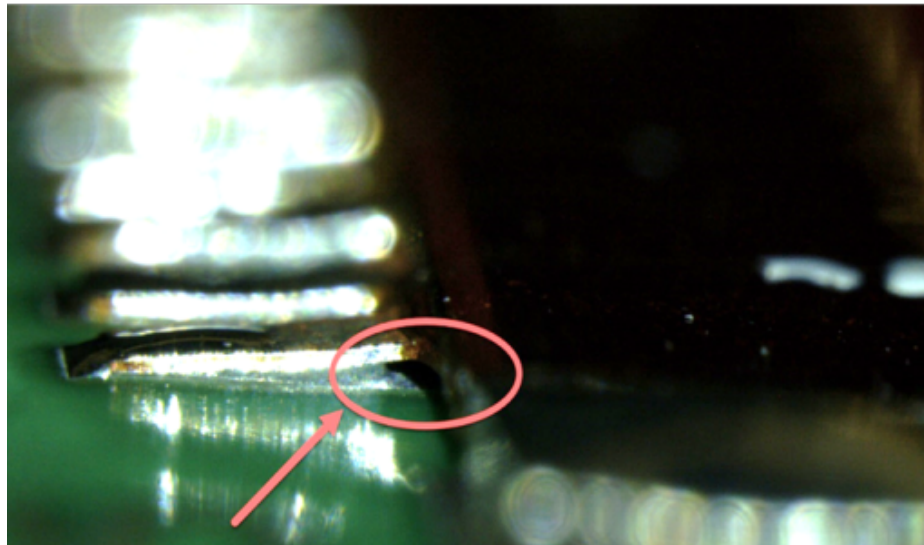
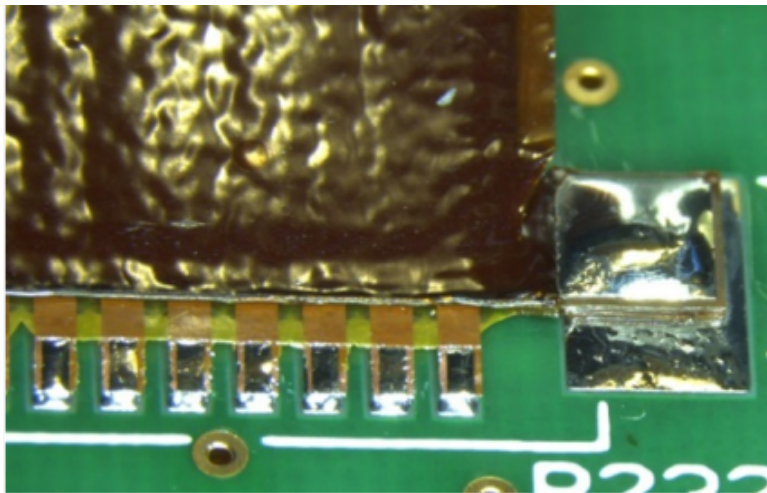
Castellated Via: Limited use in Sandia products



Rigid-flex PWAs



Castellated Via: Limited use in Sandia products



*Top and side views of “finger” solder joints connecting a flex cable to a rigid board.
(Through-holes are another common option)*

Reliability Evaluation

■ Mechanical Testing

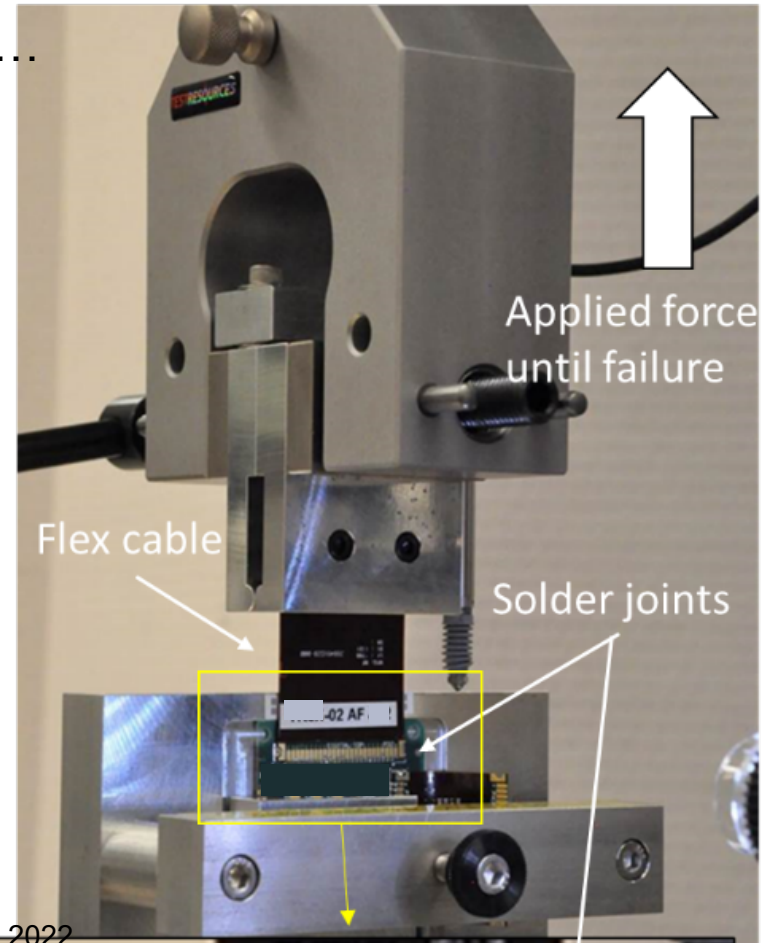
- ☐ Mechanical Integrity/performance metric
- ☐ Shear AND Peel Evaluations
- ☐ As-received, cycled between 300 and 1000x (IPC-____ - 55 to 125C, 10 min dwells)

■ Isothermal Aging

- ☐ Metallurgical phenomena (especially along interfaces)
- ☐ 70 or 100C for 0, 25, 50, 100 days

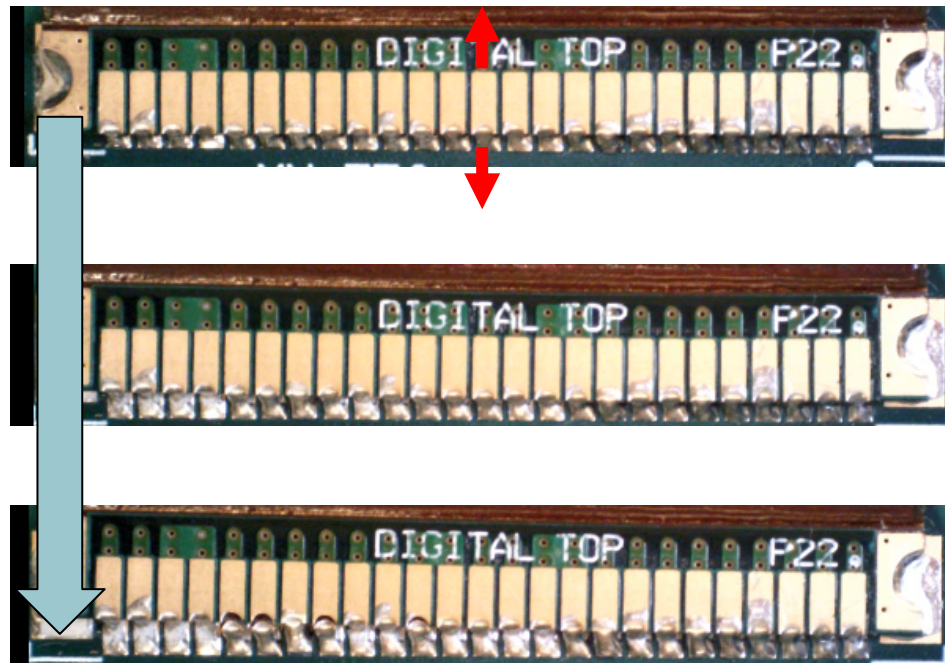
Shear Test

Black some stuff out...



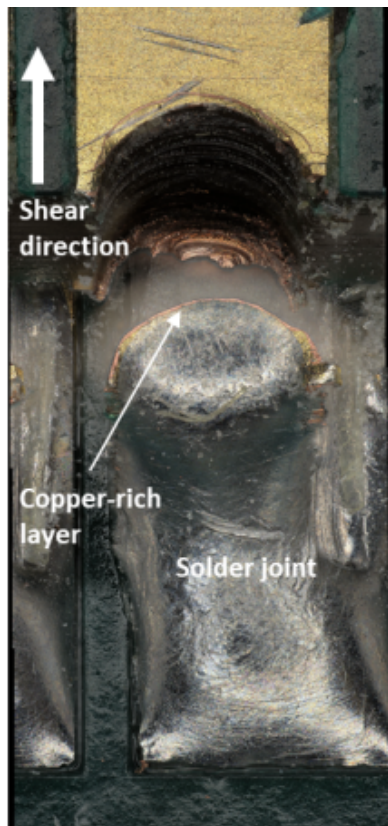
Shear Test

START



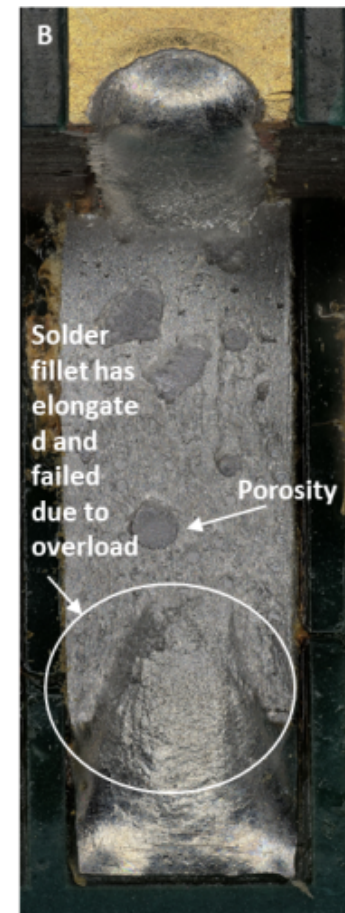
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Shear Test: Failure Modes



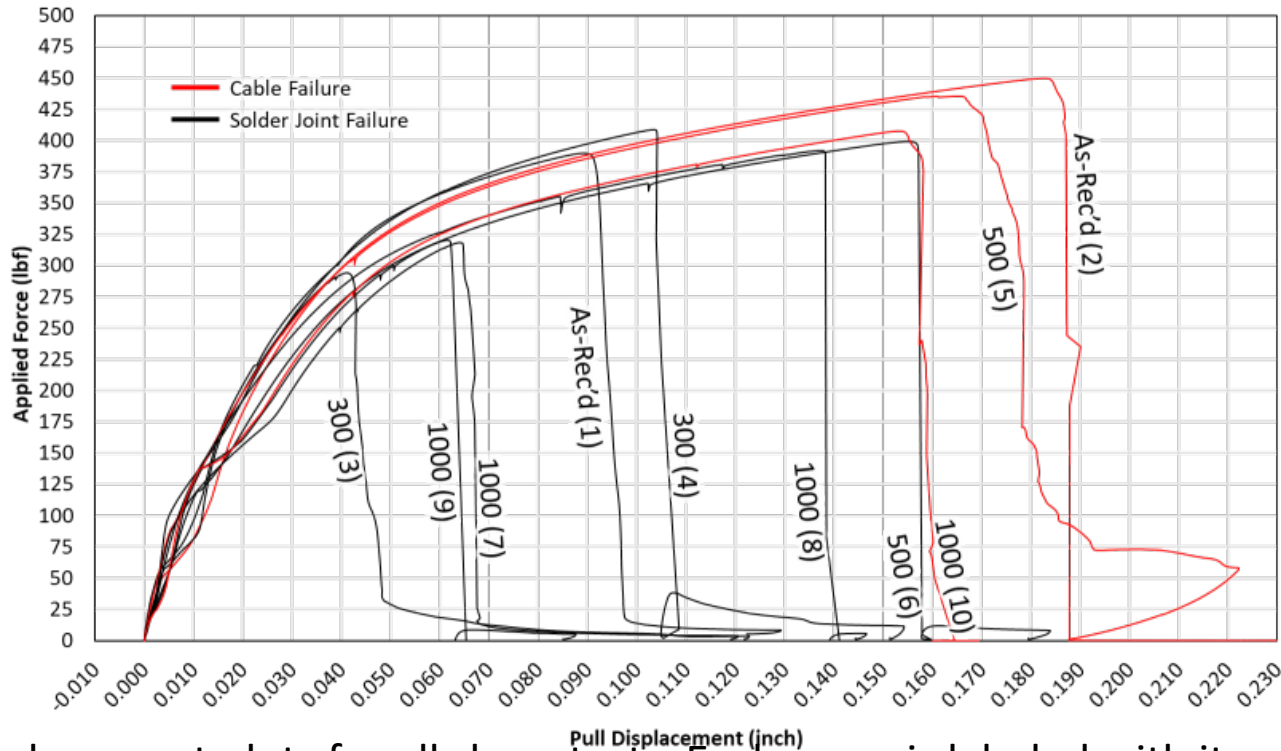
Higher magnification optical images highlighting pad peel-off (A) and ductile shear (B) failure modes.

Higher magnification optical image of a potential interfacial failure at the castellation-solder interface.



Shear Test: Results

Compiled Shear Tests (Force vs. Displacement)



Force vs. displacement plots for all shear tests. Each curve is labeled with its aging condition in number of cycles and its sample ID in parenthesis. Black curves indicate solder joint failures and red curves indicate flex cable failures.

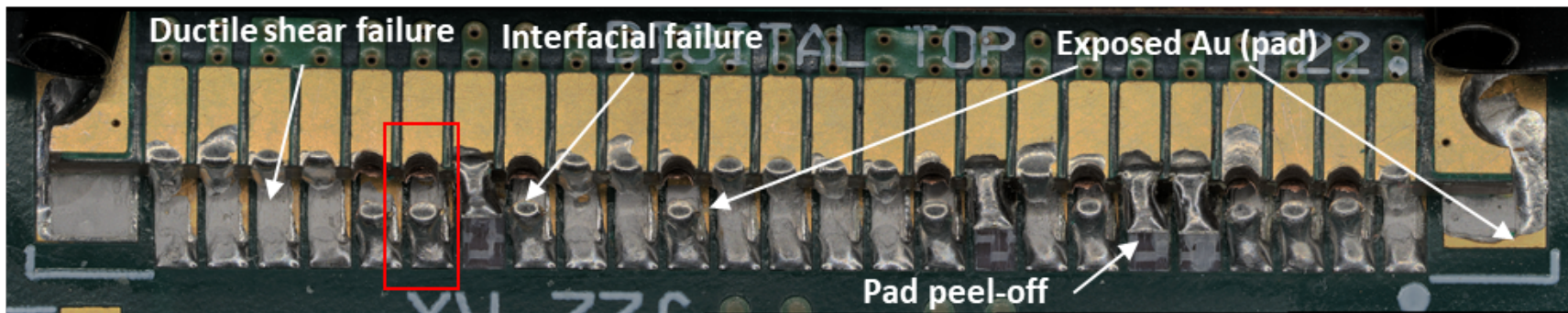
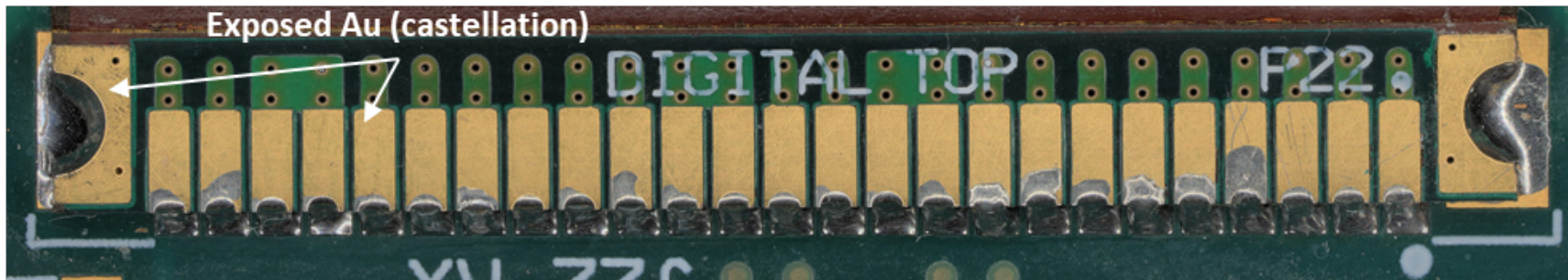
Shear Test: Results

Sample ID	Cycles	Failure Description	Peak Force (lbf)	Castellation-Pad Alignment	Solder Coverage	Castellation Failures	PWB Pad Failures
1	0	Mixed mode (ductile shear, interfacial, pad)	392	Misaligned	Poor C Poor P	Ductile (12) Interfacial (9)	Peel-Off (4)
2	0	Flex cable tearing at grip	450	Misaligned	Poor C Moderate P	None	None
3	300	Majority ductile shear	294	Aligned	Poor C Poor P	Ductile (24) Interfacial (1)	Peel-Off (4)
4	300	Majority ductile shear	409	Aligned	Poor C Poor P	Ductile (23) Interfacial (4)	Peel-Off (4)
5	500	Flex Cable Tearing at Grip and PWB ends	435	Aligned	Excellent C Moderate P	None	None
6	500	Mixed mode (ductile shear, interfacial, pad)	399	Aligned	Poor C Moderate P	Ductile (9) Interfacial (16)	Peel-Off (9)
7	1000	Mixed mode (ductile shear, interfacial, pad)	318	Misaligned	Poor C Moderate P	Ductile (4) Interfacial (17)	Peel-Off (8)
8	1000	Mixed mode (ductile shear, interfacial, pad)	392	Aligned	Poor C Poor P	Cohesive (6) Interfacial (18)	Peel-Off (6)
9	1000	Mixed mode (ductile shear, interfacial, pad)	320	Aligned	Poor C Poor P	Ductile (19) Interfacial (6)	Peel-Off (19)
10	1000	Flex cable tearing at grip	408	Aligned	Poor P Poor C	None	None

Shear Test: Results

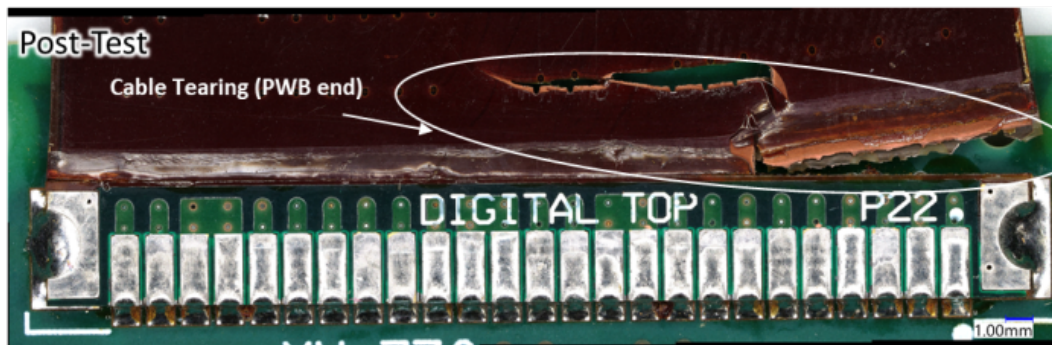
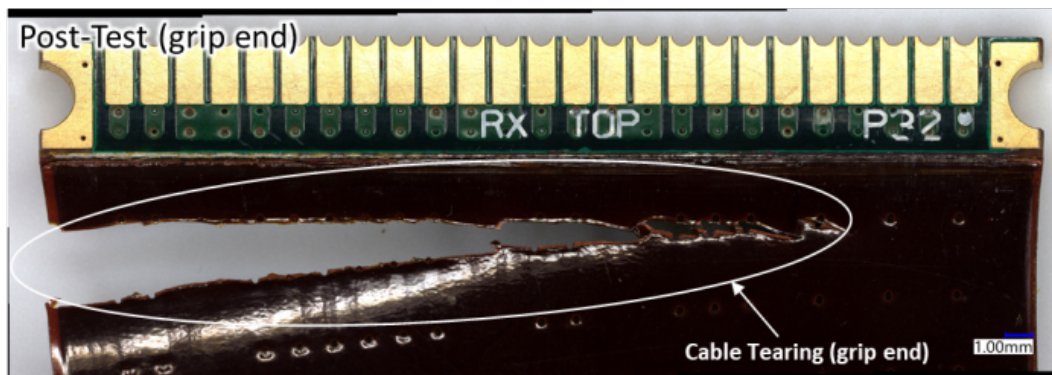
Pre-Test

As-Received (1)



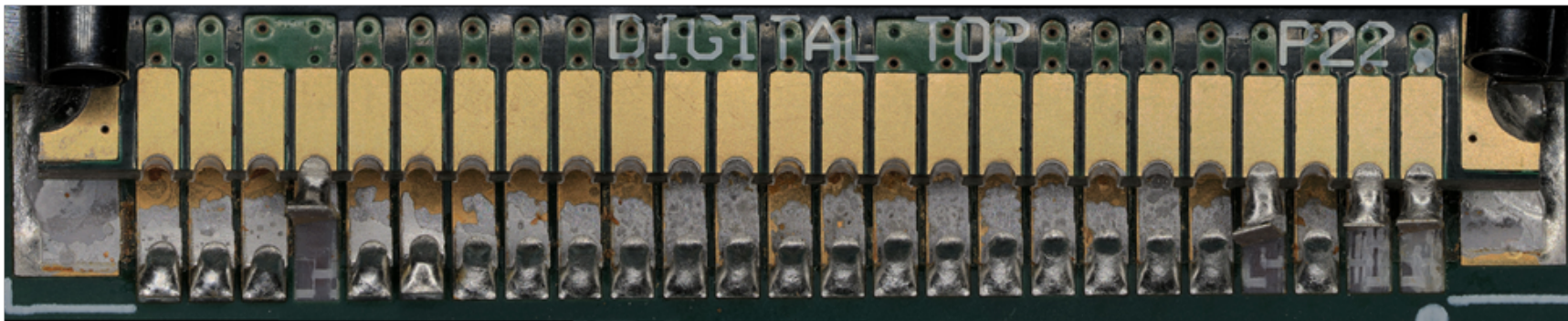
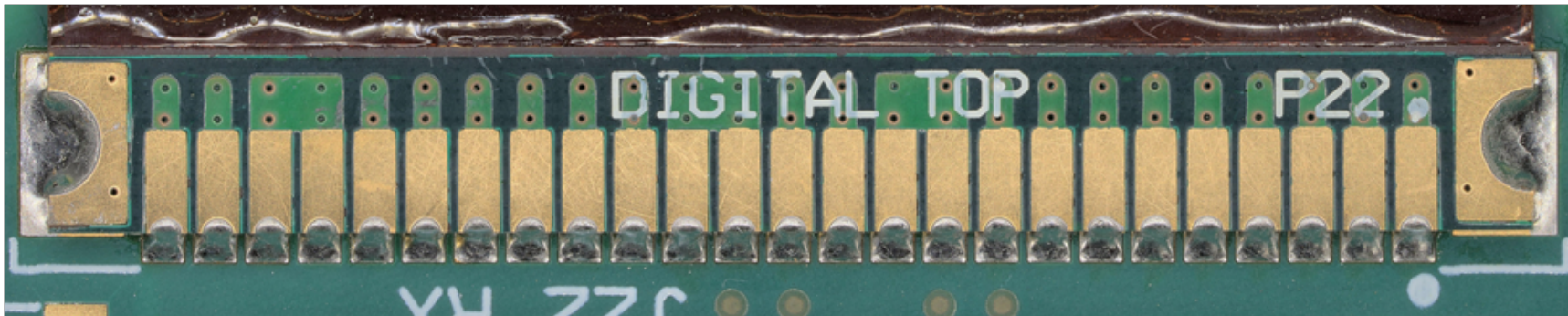
Post-Test

500 Cycles (5)



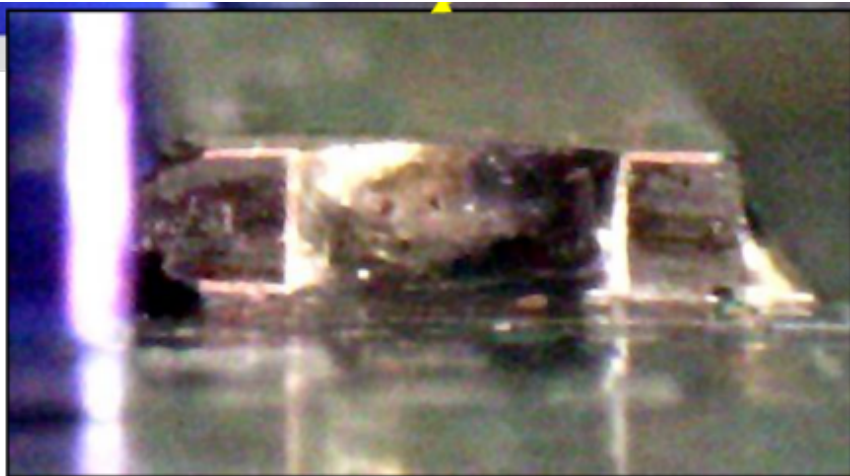
Pre-Test

1000 Cycles (7)

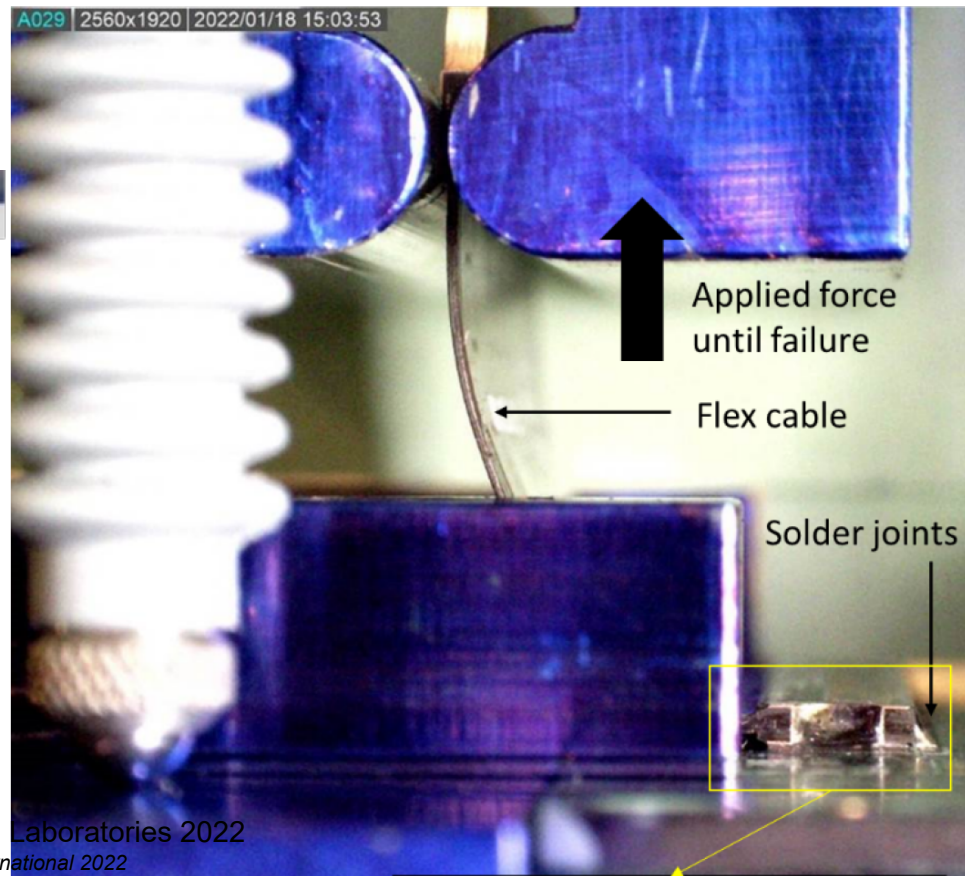


Post-Test

Peel Test



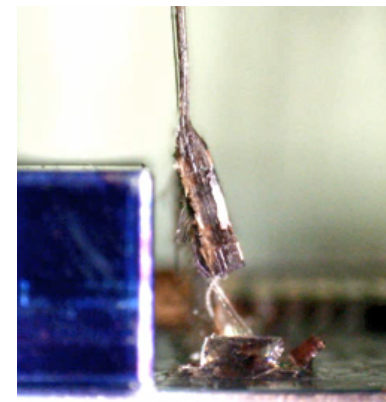
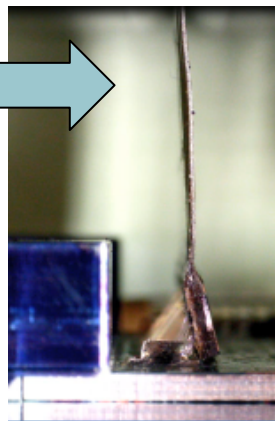
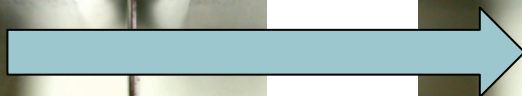
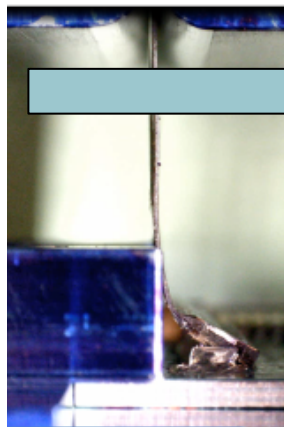
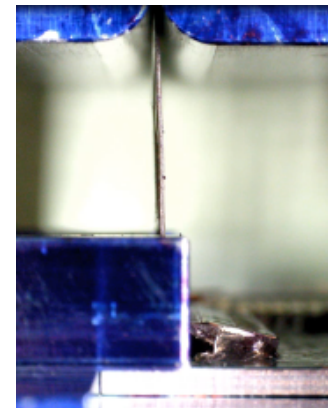
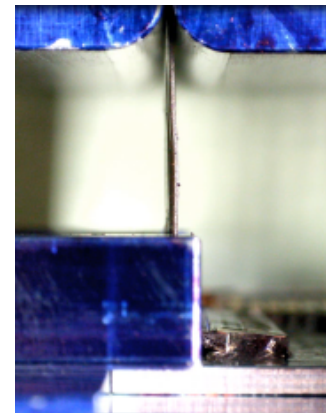
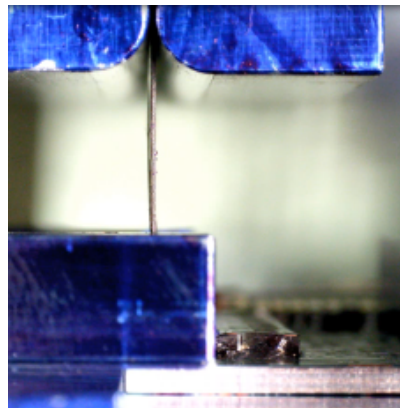
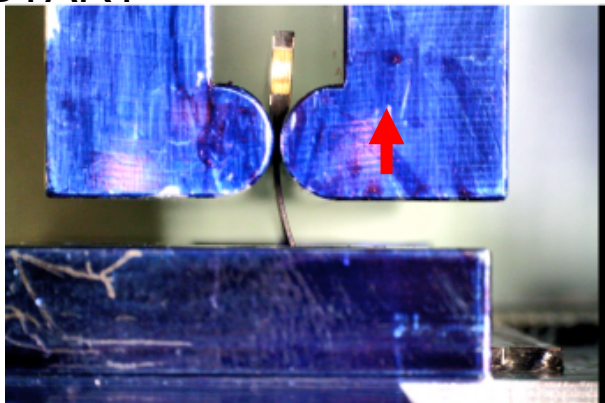
Peel Test



Peel Test

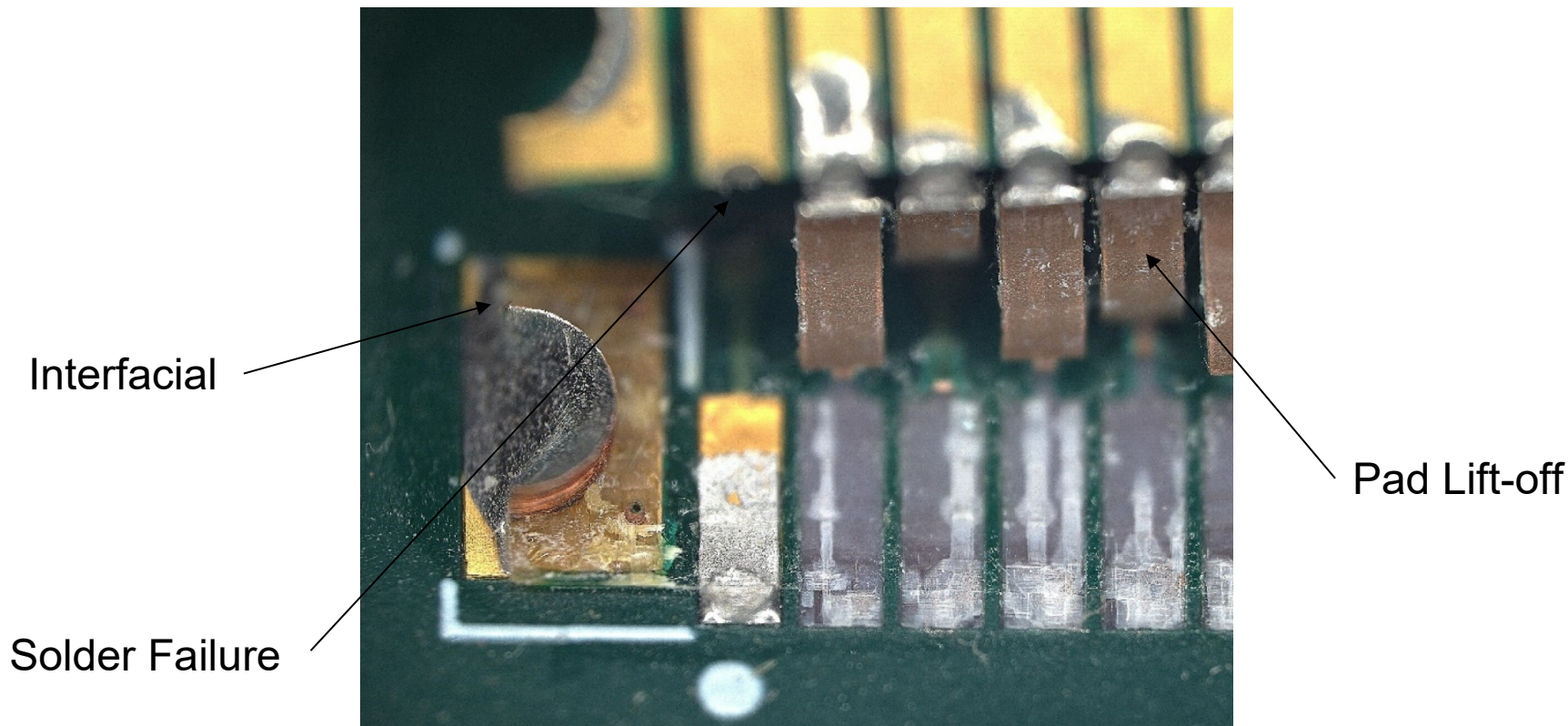


START



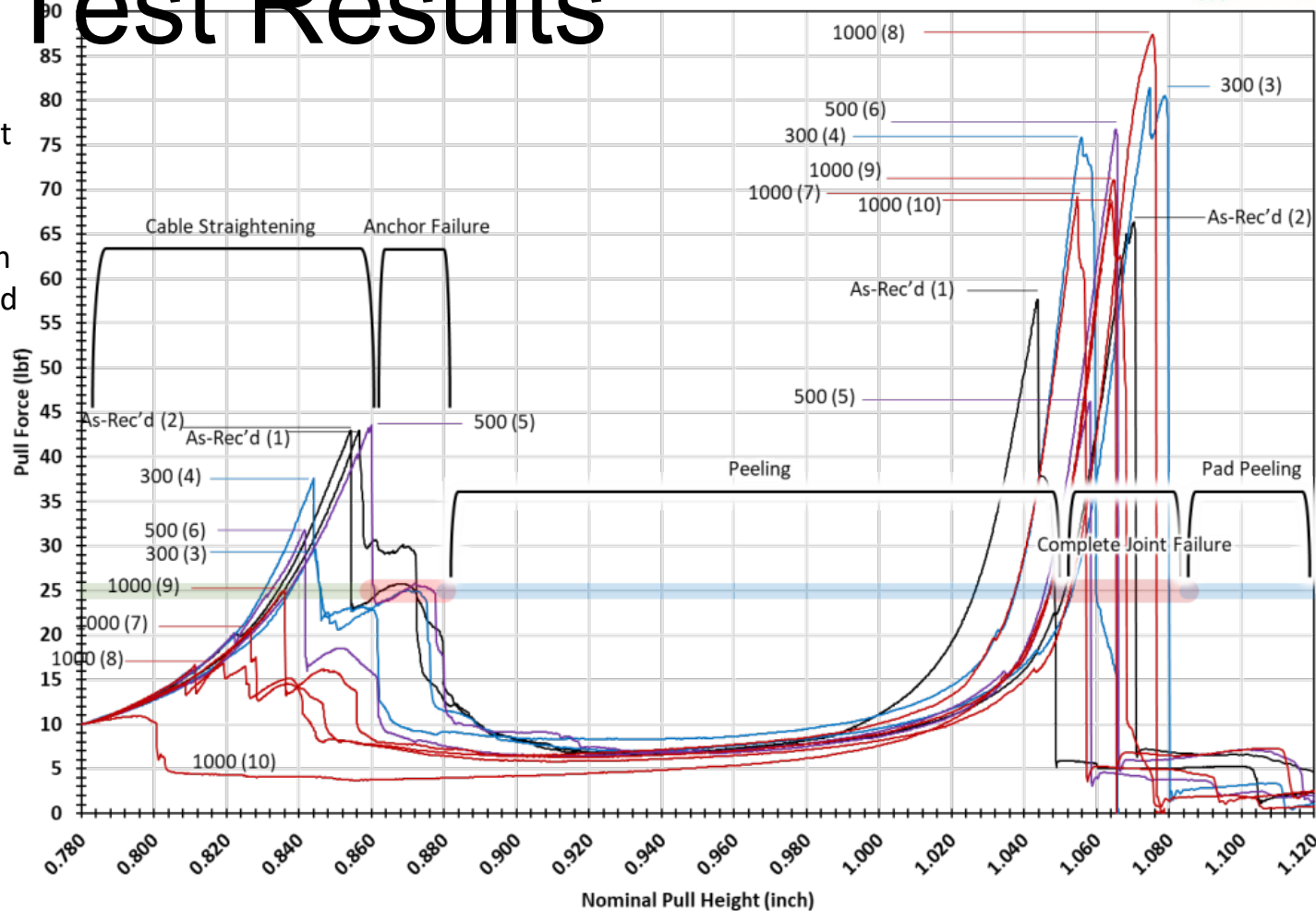
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Peel Test: Failure Modes



Peel Test Results

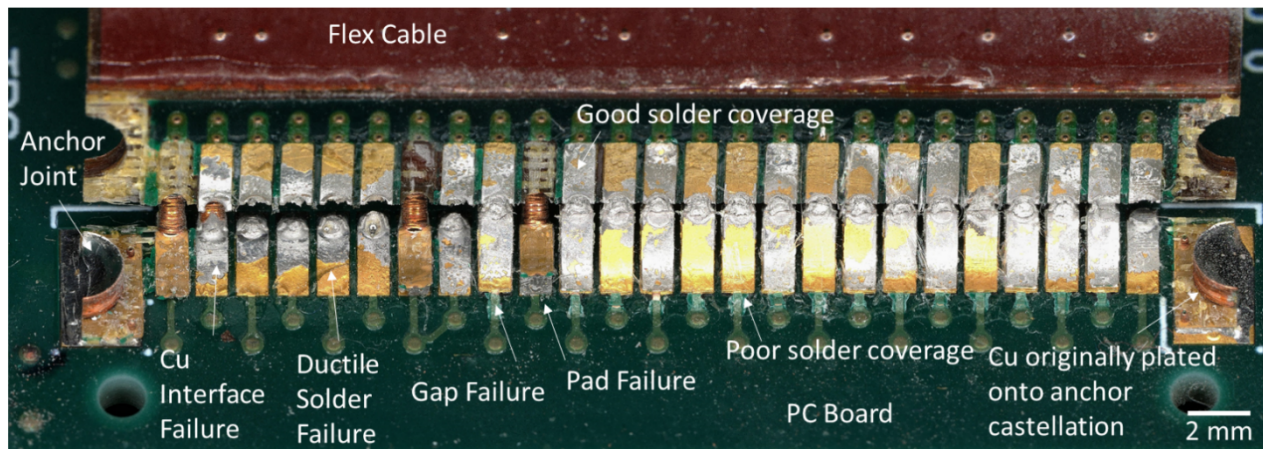
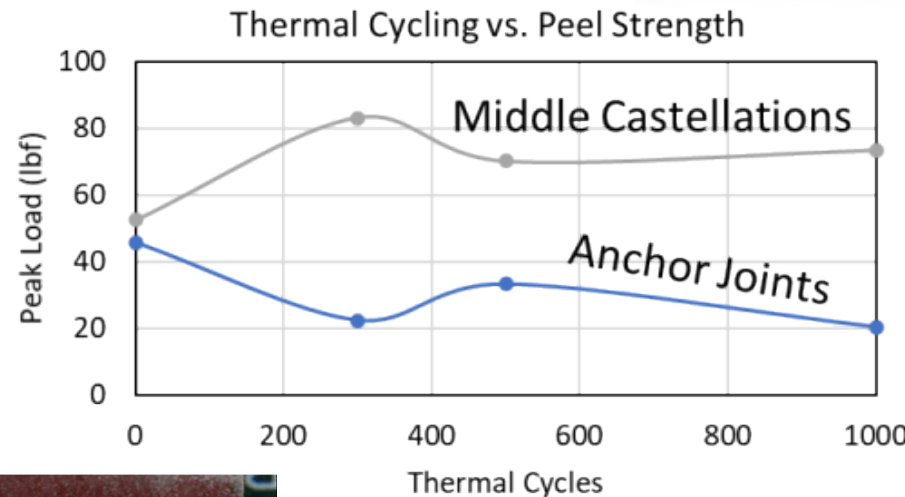
Force vs. displacement plots for all peel tests. Each curve is labeled with its aging condition in number of cycles and its sample ID in parenthesis. Black, blue, purple, and red curves denote as-received, 300 cycle, 500 cycle, and 1000 cycle conditions, respectively. The curves are broken into 5 regions, denoting observed behavior during testing.



Peel Test Results

Sample ID	Connector ID	Cycles	Anchor Failure Load (lbf)	Anchor Failure Mode	Castellation Failure Load (lbf)	Castellation Failure Mode
1	J23	0	33.3	Cu Interface	57.9	Cu Interface (4) Ductile Solder (10) Gap (11)
	J24		43	Cu Interface	57.7	Cu Interface (4) Ductile Solder (6) Gap (15)
2	J23	0	63.7	Cu Interface	28	Cu Interface (9) Ductile Solder (8) Gap (2) Board Pad (6)
	J24		43	Cu Interface	66.4	Cu Interface (4) Ductile Solder (3) Gap (18)
3	J23	300	18.3	Cu Interface	92.6	Cu Interface (10) Ductile Solder (6) Gap (9)
	J24		10	Cu Interface	81.5	Cu Interface (3) Ductile Solder (10) Gap (12)
4	J23	300	23.2	Cu Interface	82.3	Cu Interface (1) Ductile Solder (18) Gap (6)
	J24		37.6	Cu Interface	76	Cu Interface (10) Ductile Solder (10) Gap (5)
5	J23	500	36.5	Cu Interface	71.5	Cu Interface (7) Ductile Solder (10) Gap (7) Board Pad (1)
	J24		43.6	Cu Interface	46.3	Cu Interface (0) Ductile Solder (7) Gap (15) Board Pad (3)
6	J23	500	20.6	Cu Interface	85.6	Cu Interface (0) Ductile Solder (11) Gap (14)
	J24		31.9	Solder Interface, Cu Interface	77	Cu Interface (0) Ductile Solder (7) Gap (18)
7	J23	1000	20	Solder Interface, Cu interface	62	Cu Interface (5) Ductile Solder (12) Gap (8)
	J24		20.9	Solder interface	69.3	Cu Interface (0) Ductile Solder (12) Gap (13)
8	J23	1000	15.1	Cu interface, board pad	90.3	Cu Interface (9) Ductile Solder (15) Gap (1)
	J24		16.9	solder interface	87.4	Cu Interface (1) Ductile Solder (18) Gap (6)
9	J23	1000	29.8	solder interface	55.1	Cu Interface (0) Ductile Solder (12) Gap (13)
	J24		25.2	Cu interface, solder interface	71.3	Cu Interface (1) Ductile Solder (3) Gap (21)
10	J23	1000	23.1	Cu interface, board pad	82.5	Cu Interface (10) Ductile Solder (11) Gap (4)
	J24		11	Cu Interface, solder interface	68.8	Cu Interface (6) Ductile Solder (16) Gap (3)

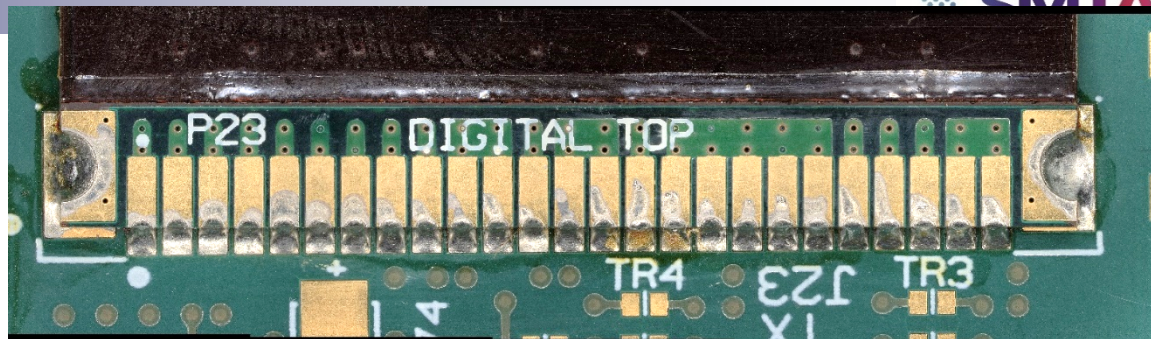
Peel Test Results



Peel Test Results

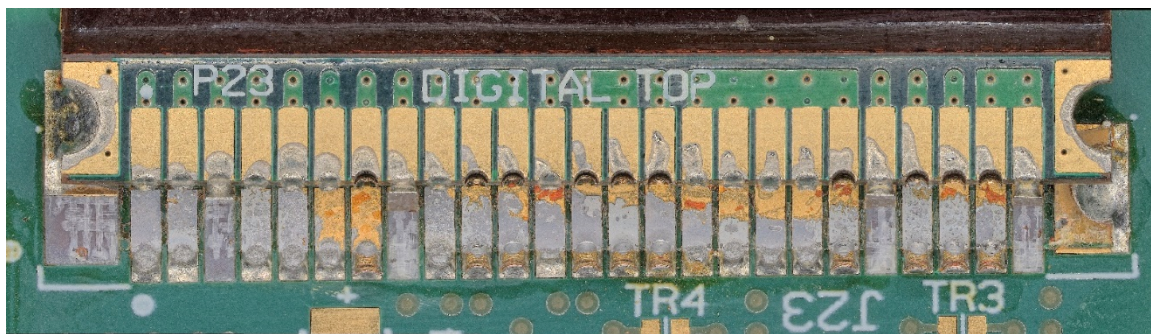
PRETEST
1000 cycles

Slight Misalignment in Anchor to PWB Pads



Left Anchor Pad Pull-Off PWB;
Right Anchor Pad Pull-Off Cable Board;
Interfacial Castellated Failures

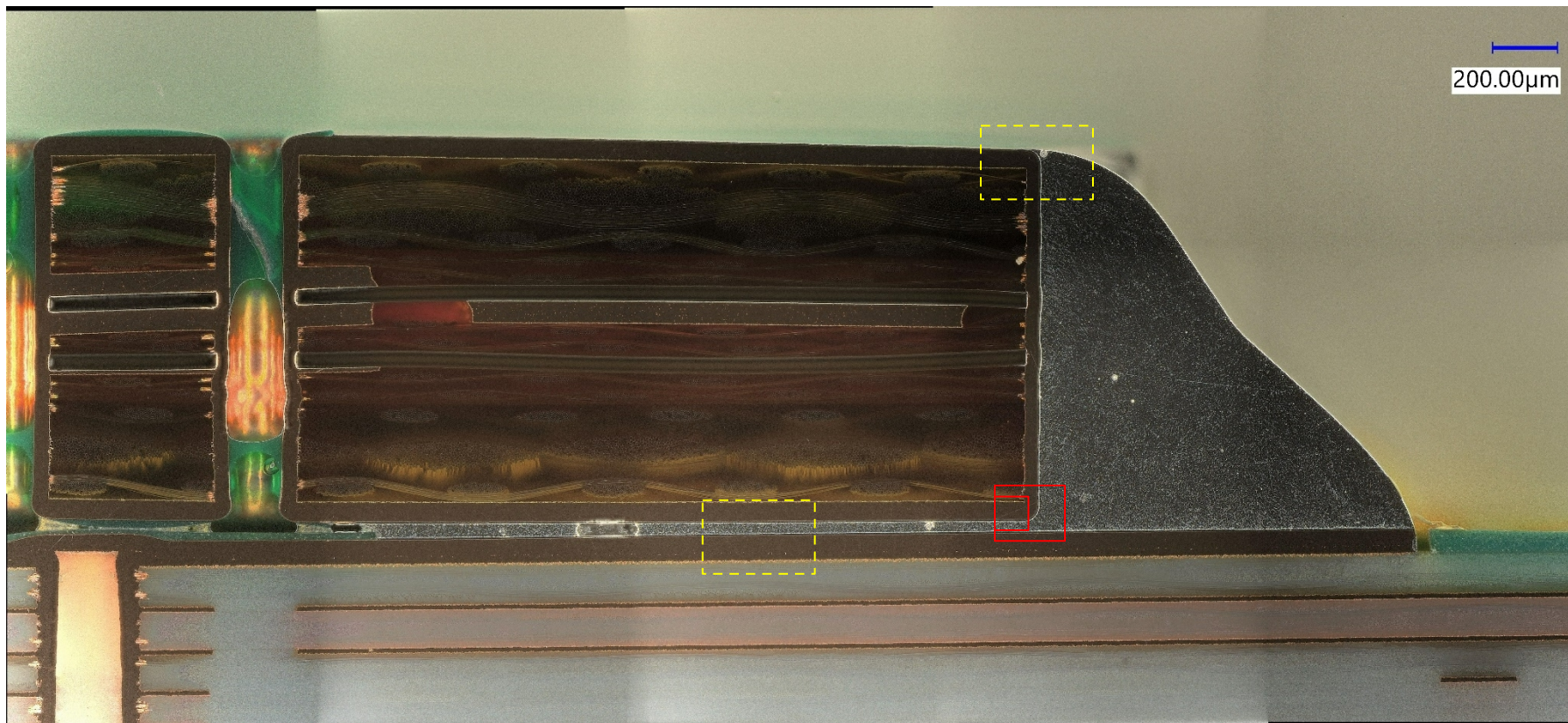
POST TEST – TOP

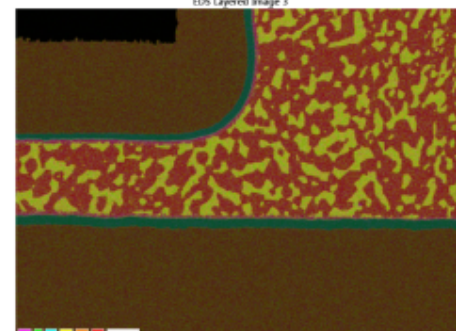
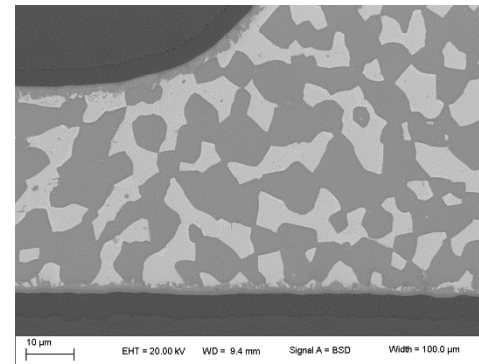
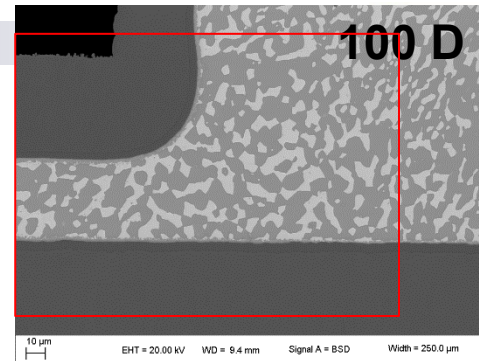


POST TEST – BOTTOM



Isothermal Aging





Discussion & Conclusions

1. Hand-solder is not consistent, could lead to anomalous failures
2. Exposed Au best practice
3. For reason 1 and 2, maybe consider reflow procedure (printing on paste first) or changing inspection criteria
4. Cleaning needs to be addressed
5. Mixed mode failures do not exhibit trends as cycling increases; solder failures are not a limiting failure mode
6. Au embrittlement is not observed (Likely due to the thin ENEPIG finish)
7. Inspection criteria needs to be addressed (IPC 8.3.4...doesn't account for solder pads on the top of the castellation...you don't want huge lumps of solder but you don't want exposed Au either)
8. **Castellated via solder joints appear to be an adequate joining method in the case of FLAT rigid-flex connections**

Thank You!

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