Microstructural Studies of Trace Cracking in NASA/DoD Lead-Free Project Test Vehicles

SUMMARY

April 19, 2011

THE ISSUE

A high incidence of cracking of traces close to PDIPs during vibration testing

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BACKGROUND

- NASA/DoD test vehicles exposed to a vibration step stress test had numerous PDIP failures. These failures occurred very early in the test which conflicts with the results of the JCAA/JG-PP Vibration Test which used essentially the same solders, test vehicle, and test conditions.

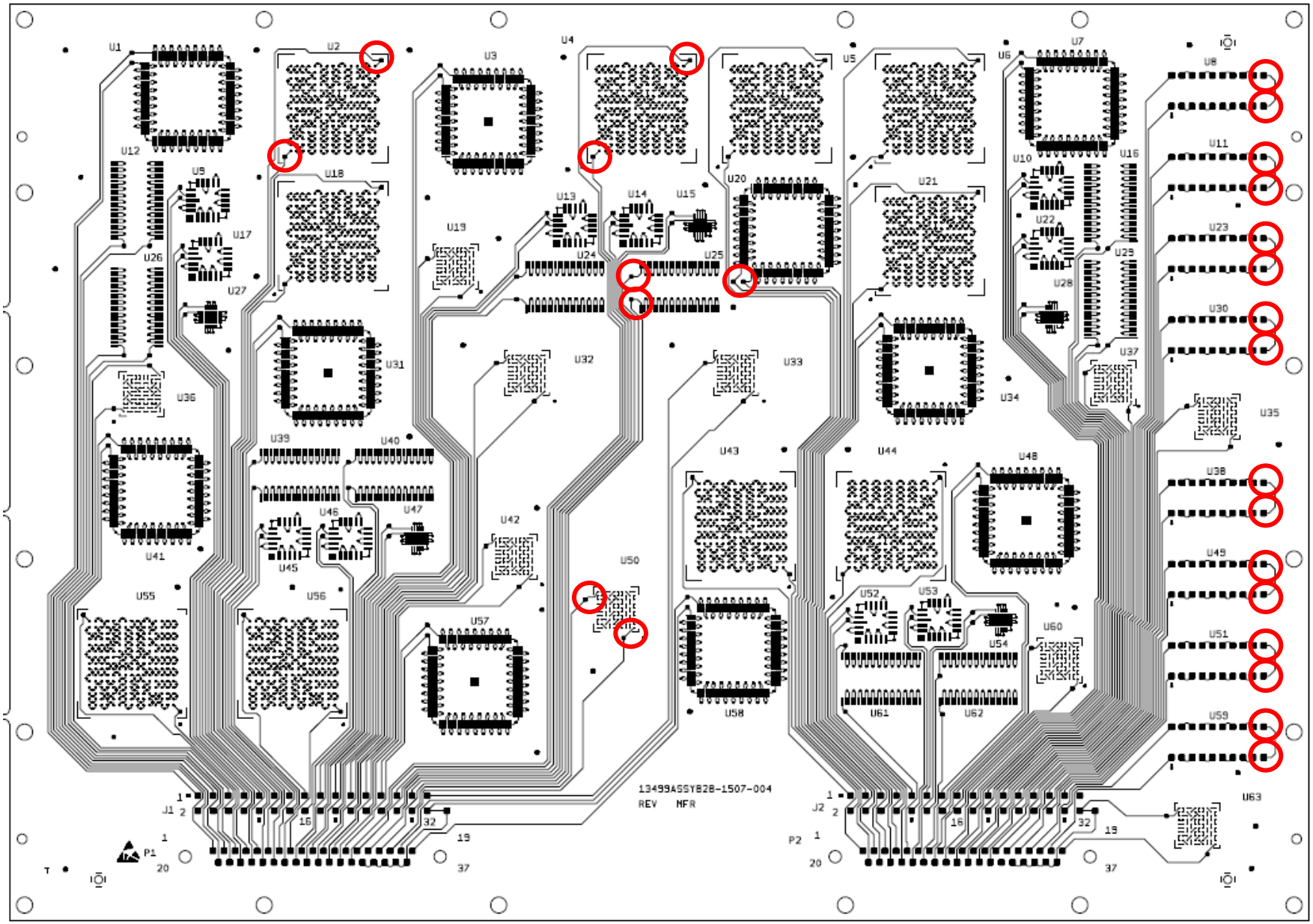
- The PDIPs on both the NASA/DoD and the JCAA/JG-PP test vehicles were located next to a wedgelock. This configuration resulted in high stresses in the region of the PDIPs. These high stresses were due to the high radius of board curvature induced in the vicinity of the wedgelocks by the first bending mode during board flexure and may have played a role in the early PDIP failures.

- Two test vehicles were provided to Nihon Superior for failure analysis. These test vehicles were SN18 and SN78. The PDIPs on SN18 were wave soldered using eutectic SnPb and the PDIPs on SN78 were wave soldered with SN100C.

- The traces associated with the PDIPs on these two test vehicles were examined using microsections and SEM/EDX analysis.

- Traces associated with BGAs, CSPs, TQFPs, and TSOPs were similarly examined using microsections. These components were attached with either eutectic SnPb or SAC305. Most of these components were in areas of high strain caused by the first bending mode (down the centerline of the test vehicle).

Traces Examined Using Microsections



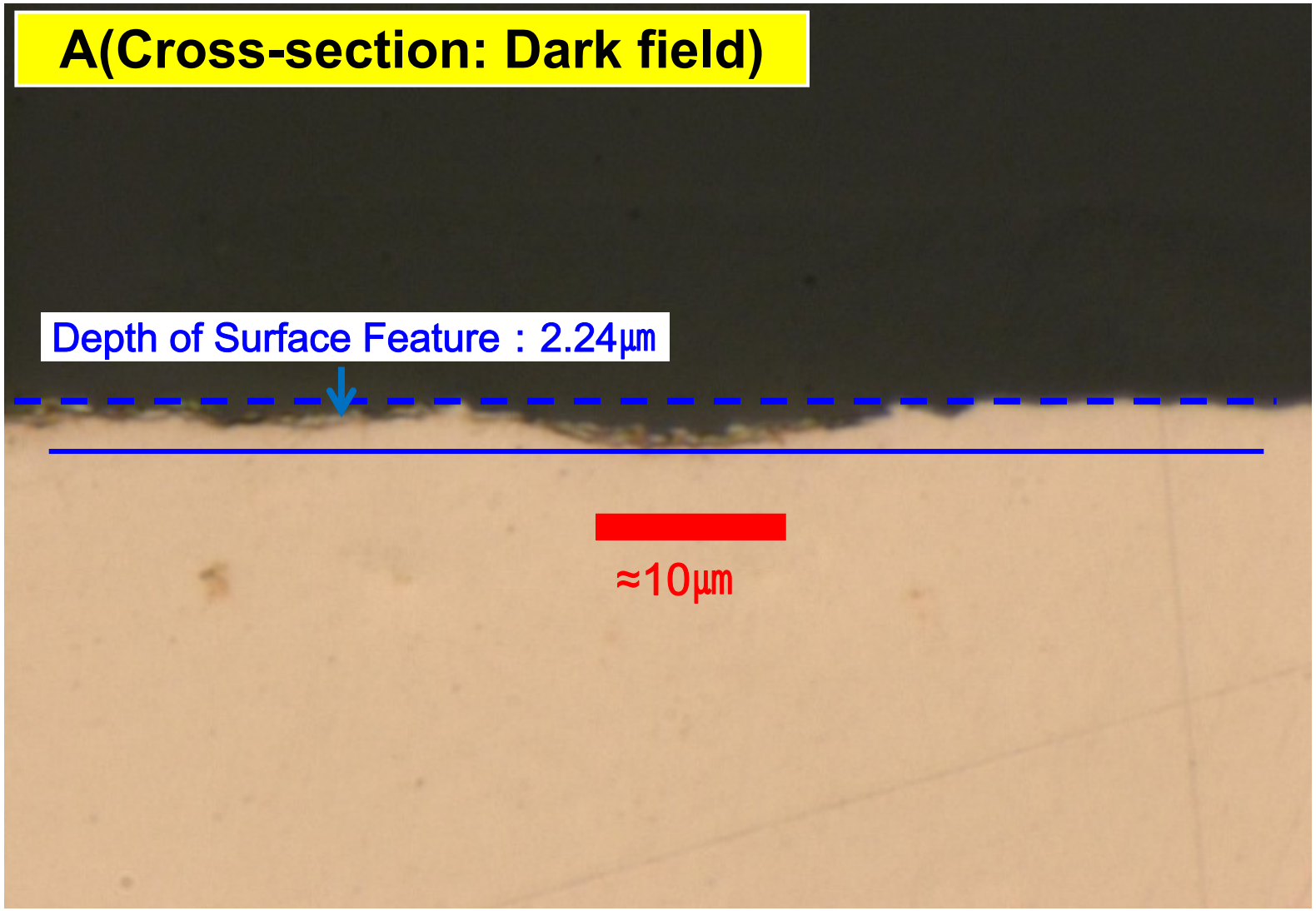
CONCLUSIONS

- There was no significant difference in the incidence of trace cracking in boards soldered with SN100C or SnPb.
- Cracking was associated with surface features on the copper plating.
- These features are typically associated with low copper ductility.
- Under the conditions of high strain to which the PDIP traces were subjected in vibration, the surface features could be expected to behave as stress raisers and the presumed low ductility of the copper would make crack propagation easy. It is believed that the differences in the copper plating used on the NASA/DoD test vehicles and on the JCAA/JG-PP test vehicles were responsible for the differences in the PDIP vibration test results.
- Other component types used on the NASA/DoD test vehicles (BGAs, CSPs, TQFPs, and TSOPs) did not exhibit trace cracking under vibration.

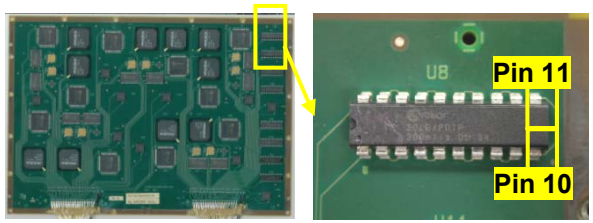
FURTHER INVESTIGATION

Prepare cross-sections for examination of the grain structure to confirm that it is consistent with that expected in copper plated under sub-optimal conditions. This will require chemical etching of the copper, possibly after further polishing. Viewing under polarized light might help to reveal the grain structure.

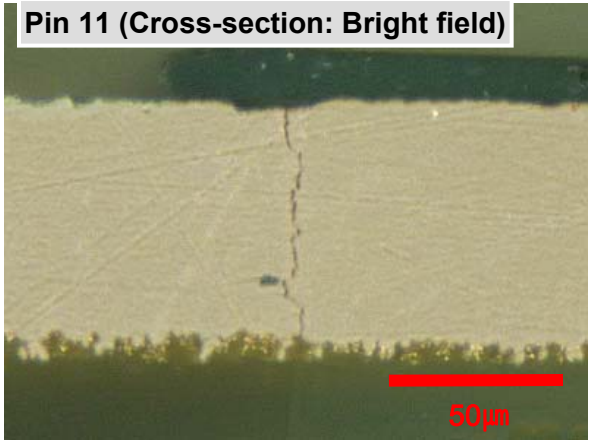
Surface Feature Observed on Surface of Copper Trace on NASA/DoD Test Vehicle

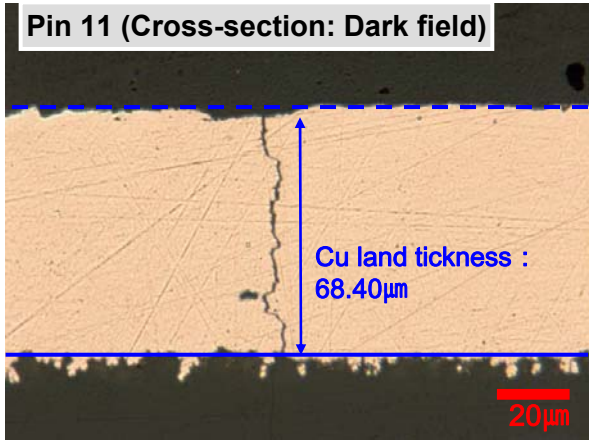


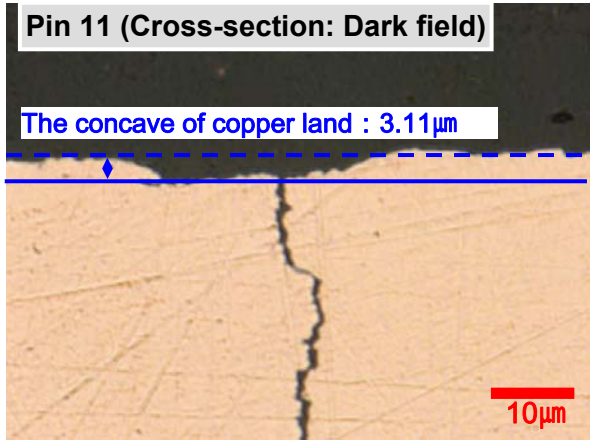
SnPb U2 Trace Crack Outside

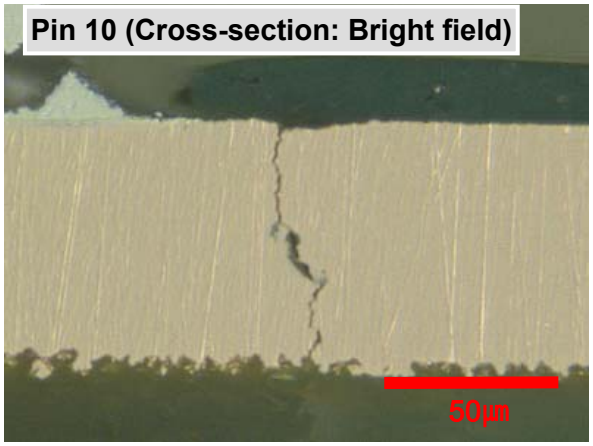


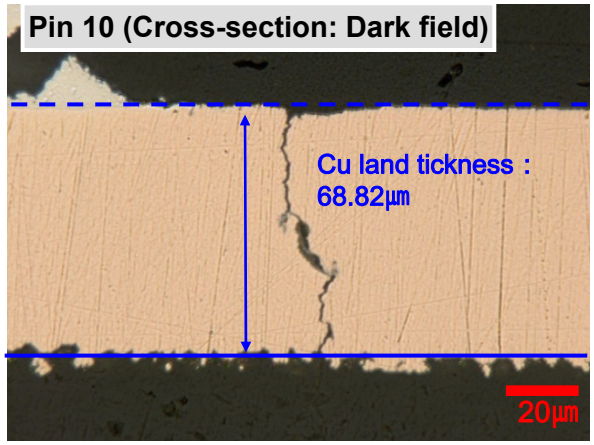
Surface Observations & Cross-sectional Observations: SN100C U8 Trace Crack

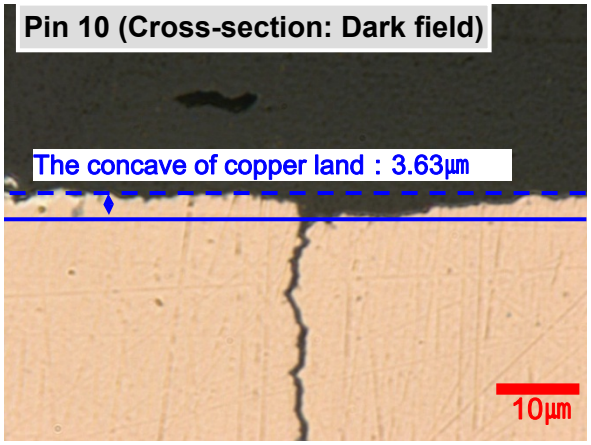






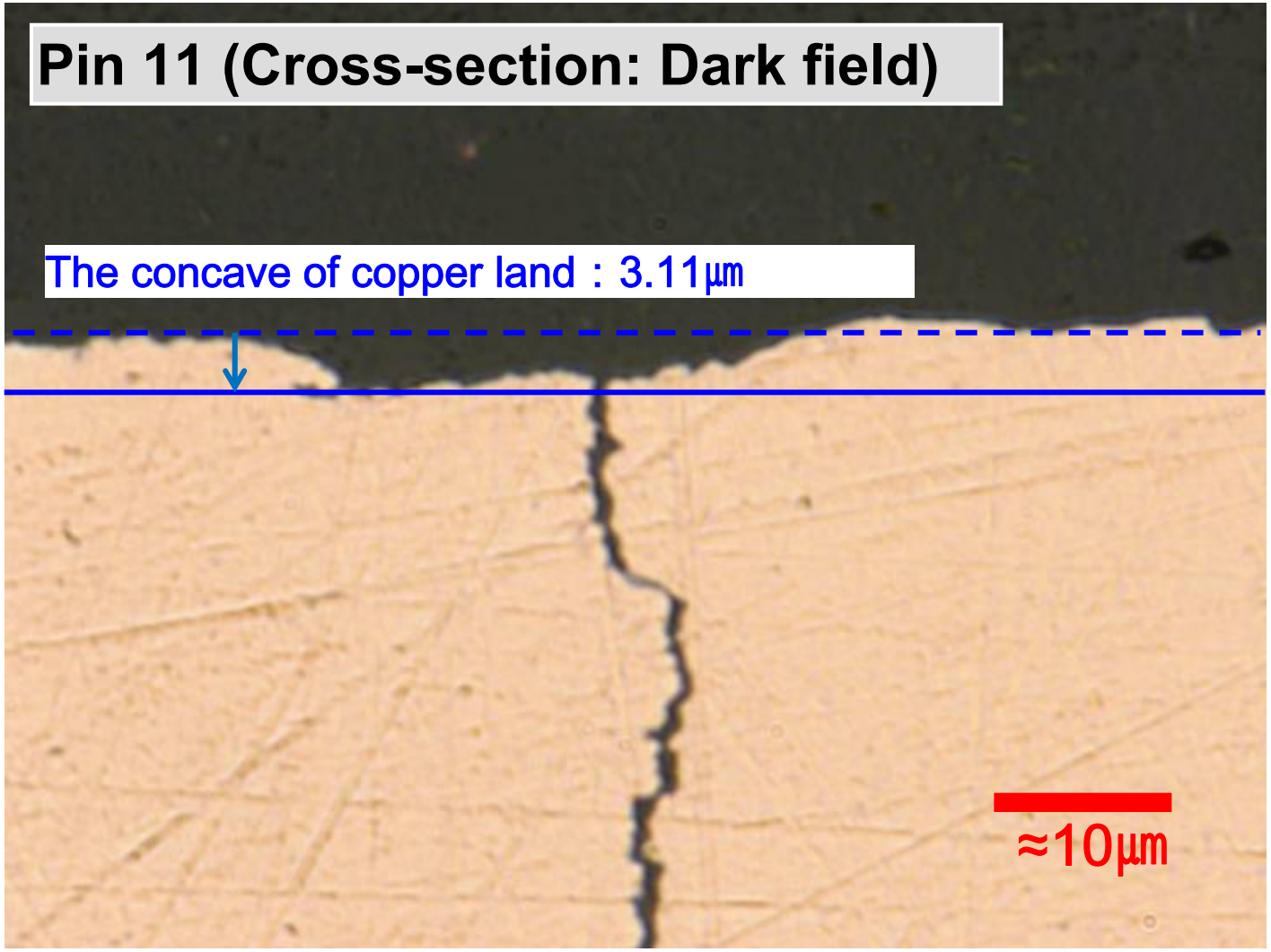






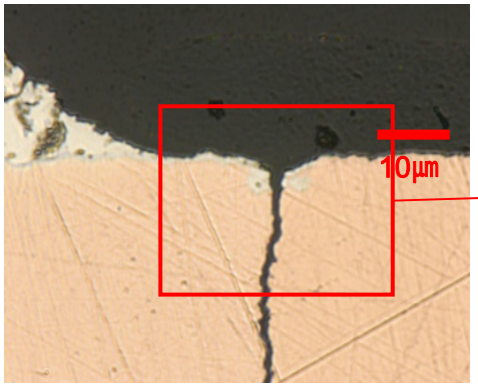
Cracks were associated with surface features on the copper.

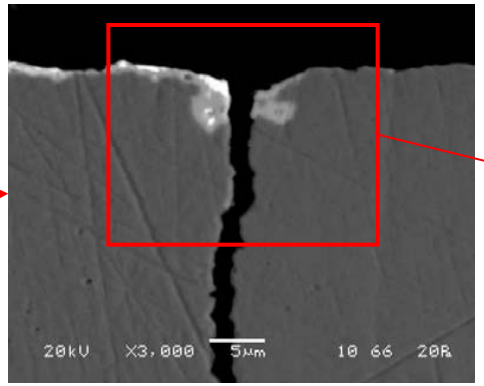
Cracks in traces close to the PDIPs were invariably associated with surface features of the copper. These surface features reflect microstructural features in the underlying copper.



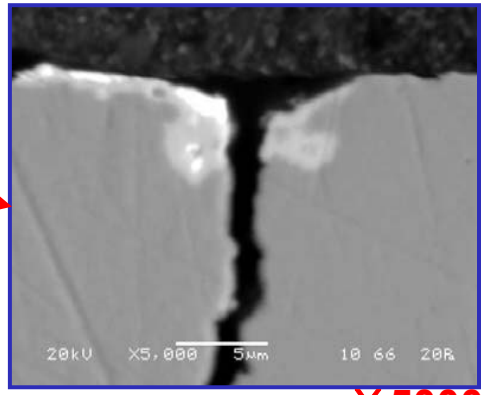
Test Vehicle SN18 SnPb U49 TraceCrack

There is clear evidence that solder had penetrated the surface feature from which the crack originates. That suggests that this feature was present before the board was subjected to vibration testing



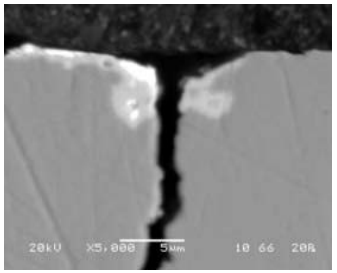


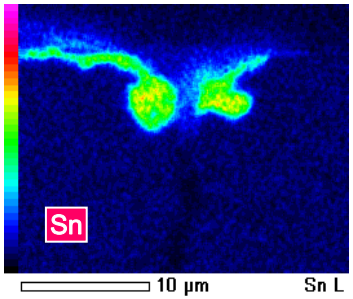
X 3000

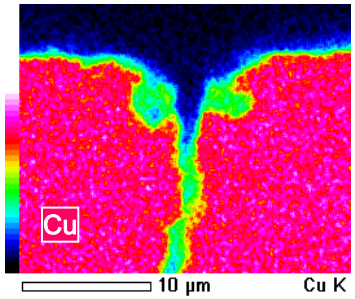


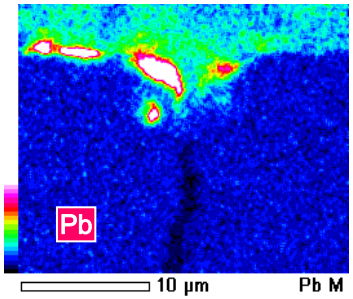
X 5000

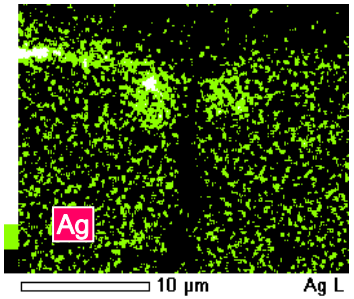
Element Mapping

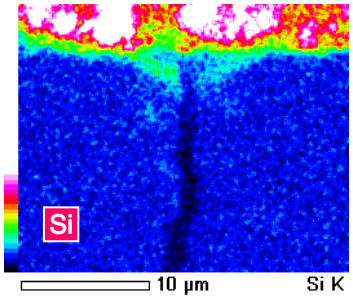


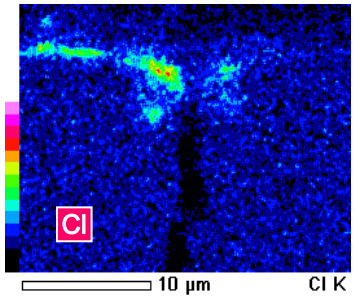






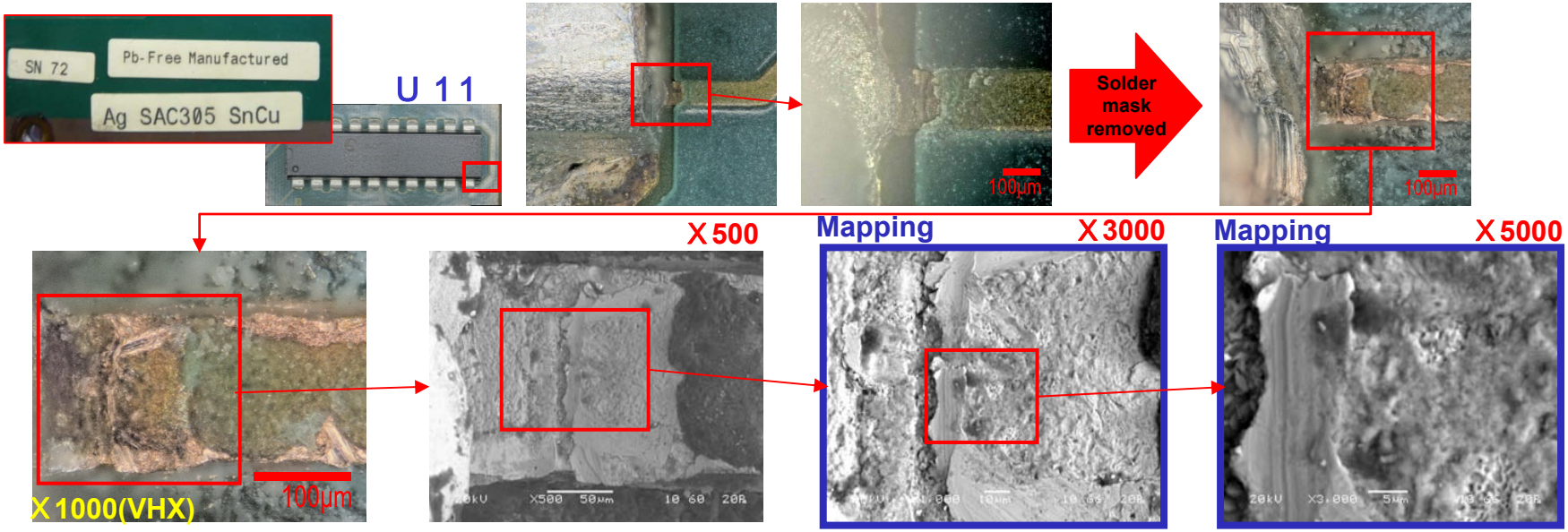






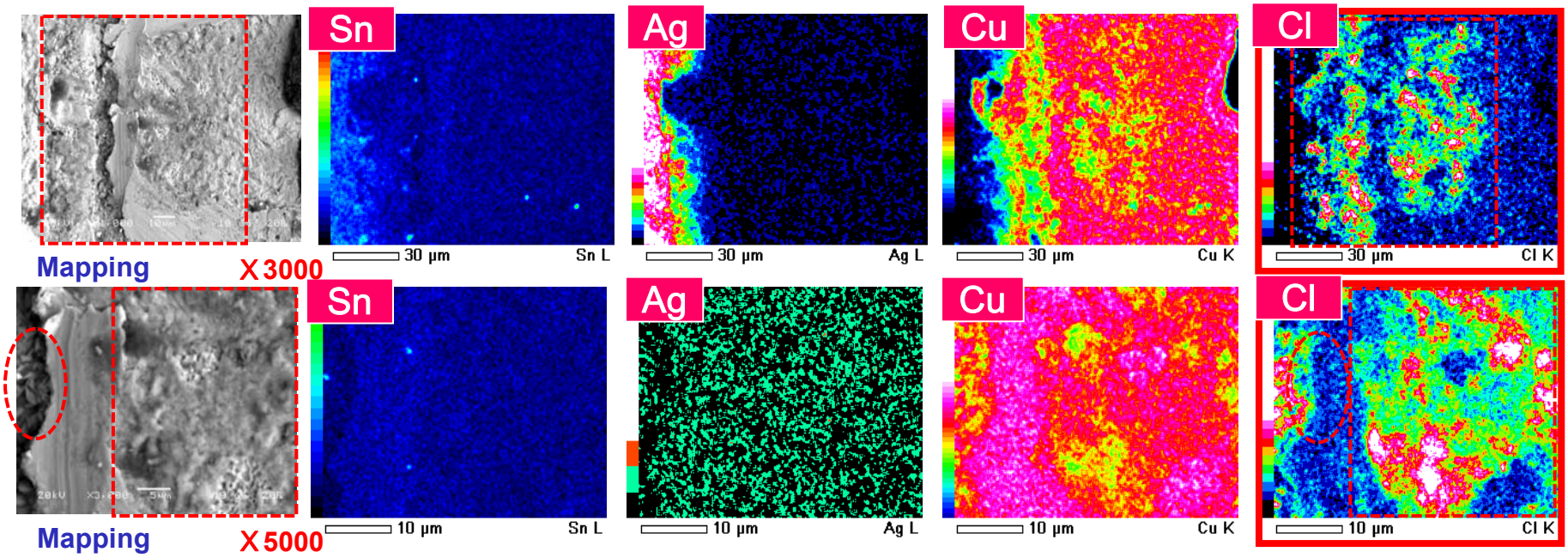
SnPb U49 PIN 10 Trace Crack

Test Vehicle SN78 SN100C U11 TraceCrack

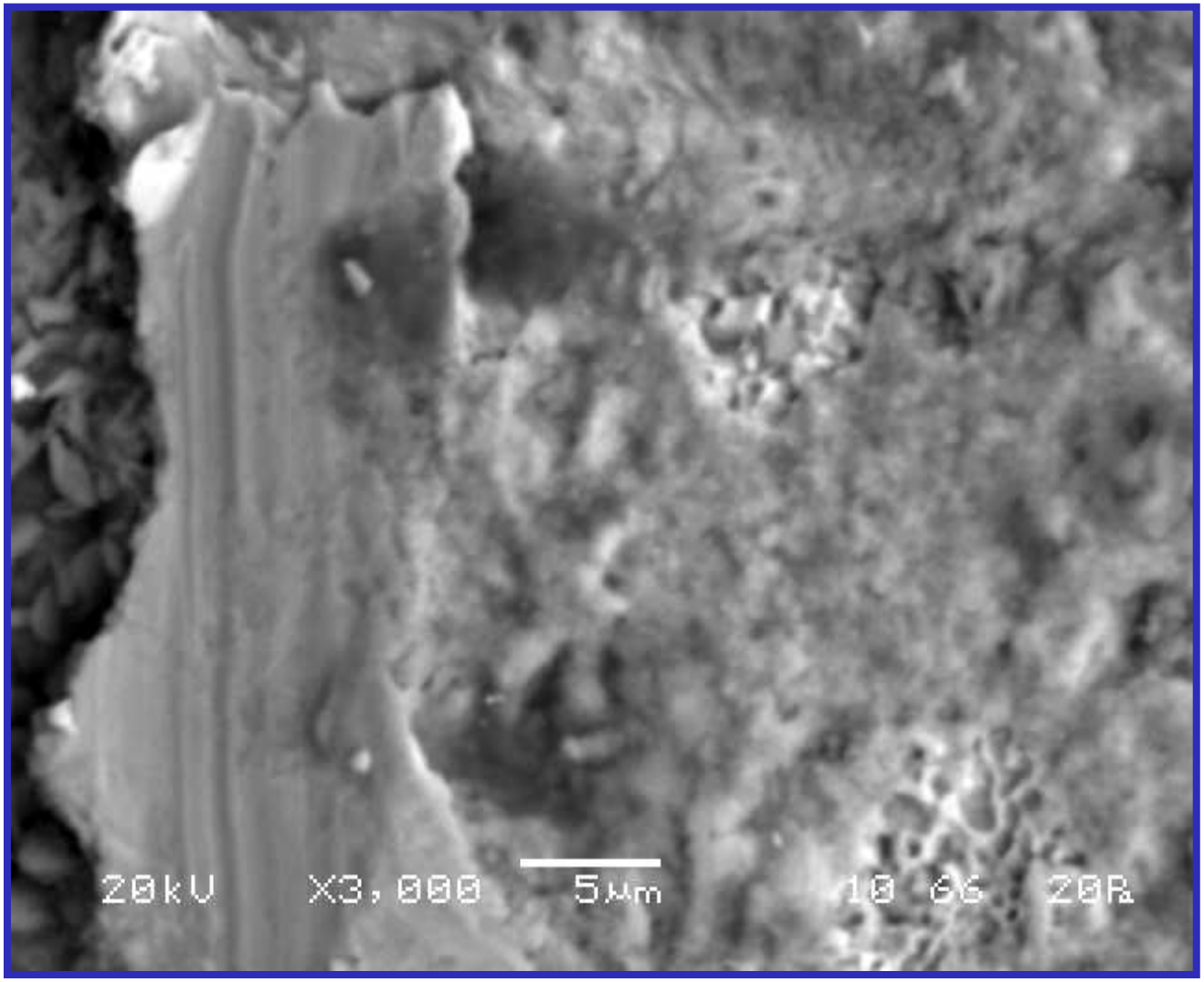


Test Vehicle SN78 SN100C U11 Trace Crack

- There are chlorine residues from the PCB manufacturing process associated with surface features on the copper from which cracks originate. This suggests that they were trapped in these surface features from which they could not be easily removed when the panel was rinsed.
- These residues might also have contributed to further opening up of the crack during storage or testing.



Surface Features on Copper Trace



There was a clear association between copper surface features and cracking in traces in the vicinity of the PDIPs

Trace		U8	U11	U23	U30	U38	U49	U51	U59	Average
SN100C	Cu land thickness of PIN 11 (μm)	68.4	66.5	67.8	66.4	63.3	63.0	64.0	65.6	66.4
	Cu land thickness of PIN 10 (μm)	68.8	67.2	67.1	68.8	65.1	65.8	66.5	67.6	
	The depression of copper land of PIN 11 (μm)	3.6	0	0	0	4.7	3.8	8.0	5.9	4.0
	The depression of copper land of PIN 10 (μm)	3.1	3.5	4.7	3.4	5.7	6.5	6.2	4.9	
Sn-Pb	Cu land thickness of PIN 11 (μm)	59.5	62.3	61.1	62.6	64.3	65.8	65.9	66.5	63.4
	Cu land thickness of PIN 10 (μm)	57.3	59.5	61.2	64.1	64.7	66.1	65.8	68.3	
	The depression of copper land of PIN 11 (μm)	2.6	3.1	2.3	3.4	4.2	3.8	4.6	5.2	4.2
	The depression of copper land of PIN 10 (μm)	3.4	5.1	4.1	6.8	3.8	4.4	3.9	7.1	

Crack

Crack(Open)

Copper surface features in the vicinity of the BGAs, CSPs, TQFPs, and TSOPs were not associated with trace cracking

Trace		BGA U2-outside	BGA U2-inside	BGA U4-outside	BGA U4-inside	TQFP U20	TSOP U25	CSP U50-inside	CSP U50-outside right side only	Average
SAC	Cu land thickness of A (μm)	68.1	65.9	72.2	74.1	68.1	68.8	73.8		70.2
	Cu land thickness of B (μm)	64.5	65.9	71.9	70.7		68.6	73.3	76.6	
	The depression of copper land of A (μm)	1.3	1.0	1.8	1.5	1.7	1.4	7.6		2.4
	The depression of copper land of B (μm)	2.8	1.2	1.9	1.1		2.6	2.9	4.2	
Sn-Pb	Cu land thickness of A (μm)	65.7	66.2	66.9	67.2	71.7	68.5	85.2		71.5
	Cu land thickness of B (μm)	65.5	64.6	65.3	64.3		72.5	88.3	89.4	
	The depression of copper land of A (μm)	2.2	1.4	2.6	1.2	2.3	1.7	3.0		2.0
	The depression of copper land of B (μm)	1.9	1.6	1.0	1.8		2.4	1.9	3.2	

	U2-outside	U2-inside	U4-outside	U4-inside	U20	U25	U50-inside	U50-outside right side only
SAC	○	○	○	○	○	○	○	○
Sn-Pb	○	○	○	○	○	○	○	○