Materials Analysis Report
Center for Advanced Vehicle and Extreme Environment Electronics (CAVE3)
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Whisker Search on Mechanical and Thermal Shock Components

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Kennedy Space Center, FL

Scanning Electron Microscopy Inspection for Whiskers on Mechanical and Thermal Shock Components

Techniques: Scanning Electron Microscopy (SEM) and Energy-Dispersive X-ray Spectroscopy (EDX)

Sample Identification: Five boards were supplied.

Three Mechanical Shock Tested Boards

- S/N 28, Manufactured Control Board
- S/N 98, Manufactured SAC Board
- S/N 136, Manufactured SACB Board

Two Thermal Shock Tested Boards

- S/N 82, Manufactured SAC Board
- S/N 158, Reworked SAC Board

We focused on parts TSOP and TQFP per each board and examined finishes Sn, SnCu, NiPdAu, and SnPb, per instructions from NASA.

Methodology: The boards were removed (by surgical gloves) from the shipping packages and the specific TSOP, TQFP parts were cut out of the boards with a band saw. Subsequently, each part was Au coated for analysis in scanning electron microscopy. No additional pretreatment or special handling was performed. The specimens were attached to the SEM sample mount under screw pressure.

Within the SEM, most parts were inspected in secondary electron mode (SED) using three magnifications:

- Defining view (~ 25 X)
- Close-up (~ 50X)
- Close examination (~ 200-300 X)

Representative SEM photos were taken at each of these magnifications. Subsequently, close examination magnification was used to search for whiskers. All connector pins per each package type were examined for whiskers, both in plan view and in tilt, which allowed for examination of the sides of the connector pins. When whiskers were observed, several higher magnification views were recorded to characterize the type of whiskers. The Appendix shows SEM photos of the connector pins for each finish class examined.

Conclusions:

Whisker Observation Summary
Whisker Characteristics vs Finish Type

Component Finish	Whisker Observations	Typical Whisker Diameter (μm)	Typical Whisker Length (μm)
NiPdAu	No Whiskering	-----	----
Sn	Intermediate Whiskering	9	7 - 25
SnCu	Sporadic Whiskering	5	10 – 30
SnPb	Significant Whiskering	7	5 - 25

Whisker Observation Summary
Shock Method vs Board and Component Type

	Board Finish Type			
Board ID	**Sn**	**SnPb**	**SnCu**	**NiPdAu**
Mechanical Shock S/N 28	No	Yes (TSOP)	No	No
Mechanical Shock S/N 98	No	No	No	No
Mechanical Shock S/N 136	No	No	No	No
Thermal Shock S/N 82	Yes (TQFP)	No	Yes (TSOP)	No
Thermal Shock S/N 158	Yes (TQFP)	Yes (TSOP)	No	No

Representative Whiskers on Sn Finish Parts

Figs. 1-3 show several representative tin whiskers on Sn finish parts. Whiskers were found on the upper knee and along the sides of the leads with densities varying from a few isolated whiskers to large whisker plantations.

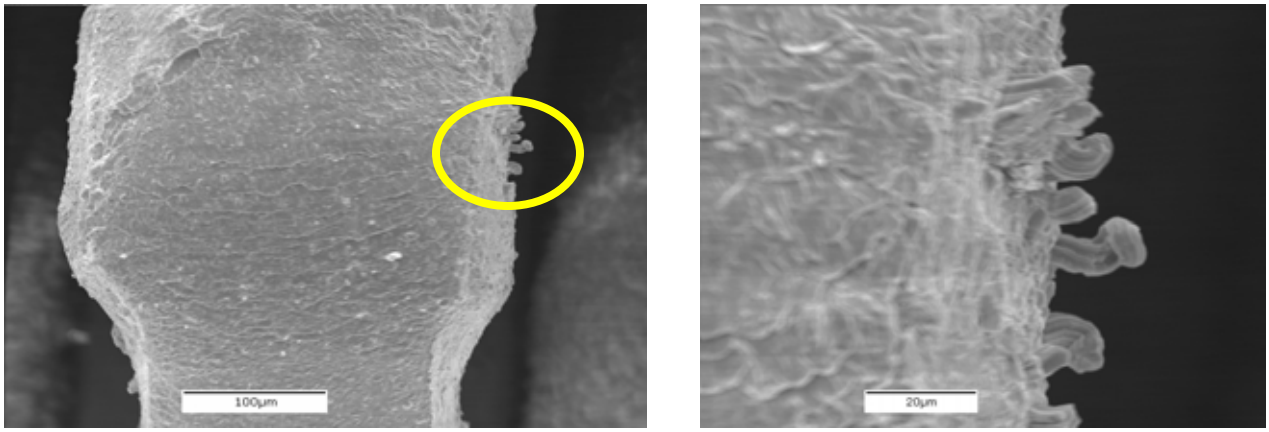


Figure 1. SEM image of TQFP component with Sn finish showing whiskers on the upper knee of the connector.

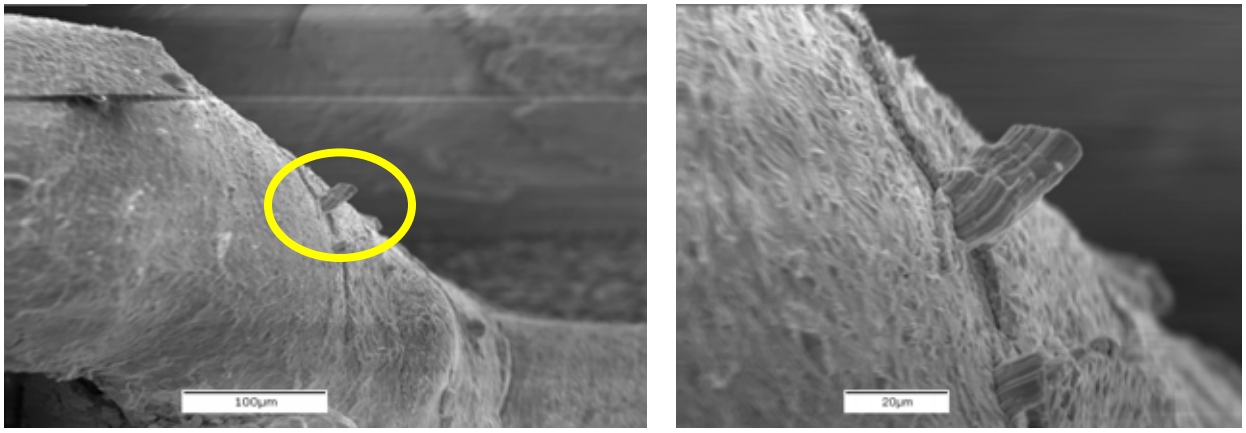


Figure 2. SEM image of TQFP component with Sn finish showing whiskers on the middle knee of the connector.

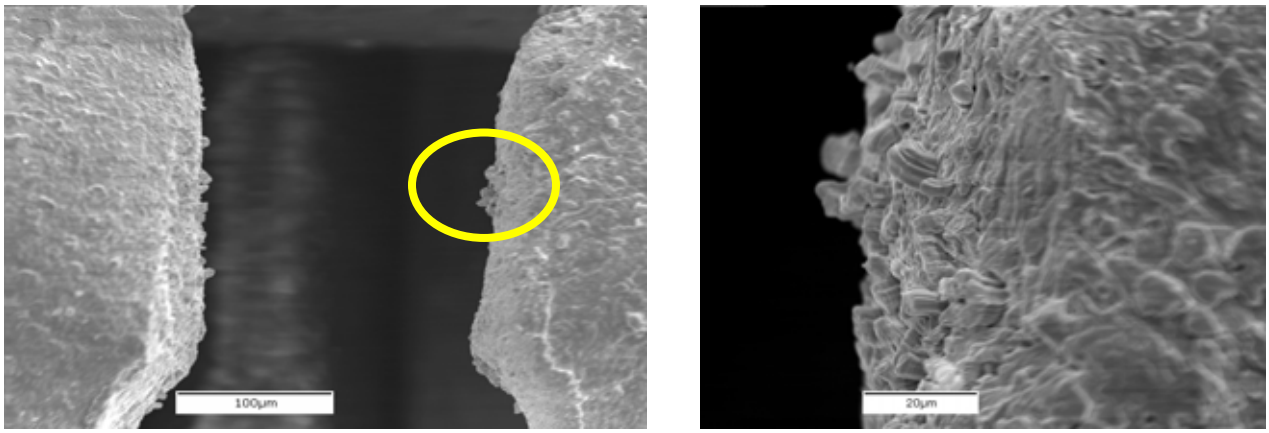
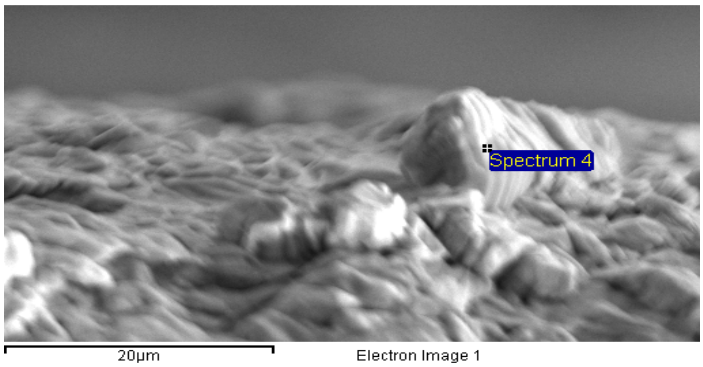
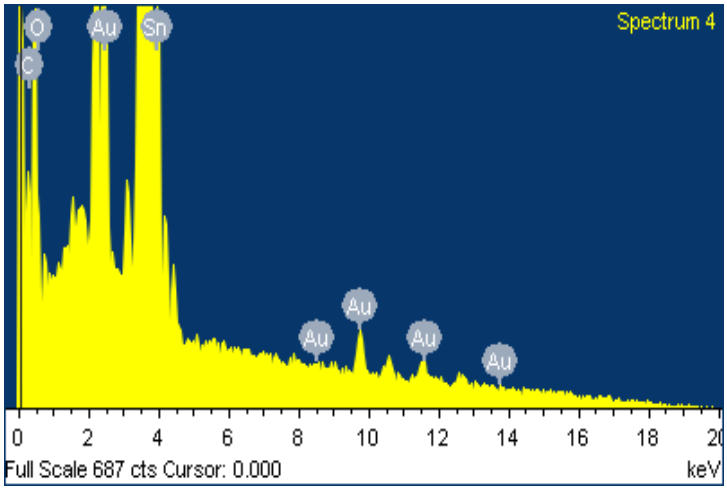


Figure 3. SEM image of TQFP component with Sn finish showing whiskers on sides of leads.

Figure 4 shows the EDX spectrum for a single whisker on a TQFP component (Sn finish). The major peaks are Sn and Au. The Au originates from the Au coating used to render the specimens conductive for observation in the SEM.





EDX Elemental Composition

Element	Weight Percentage	Atomic Percentage
C (K)	1.39	9.33
O (K)	6.16	31.10
Sn (L)	79.98	54.46
Au (M)	12.48	5.12

Figure 4. EDX scan of a whisker on a TQFP component with tin surface finish.

Representative Whiskers on SnCu Finish Parts

Figs. 5-6 show representative tin whiskers and accompanying EDX spectrum produced on thermally shocked TSOP components with a SnCu finish. The majority of these whiskers lived on the sides of the leads near the bend and on the face.

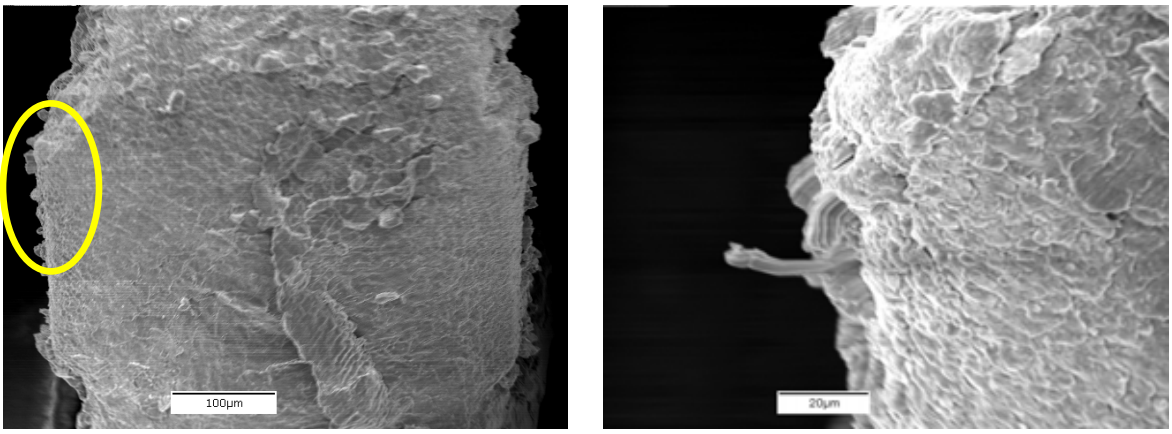


Figure 5(a). SEM image of TSOP component with SnCu finish showing whisker growth on the connector sides.

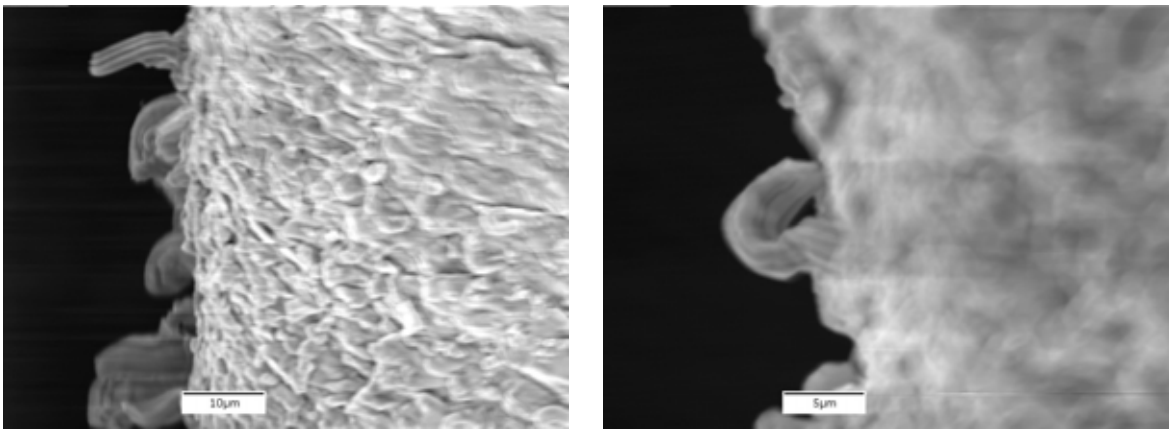
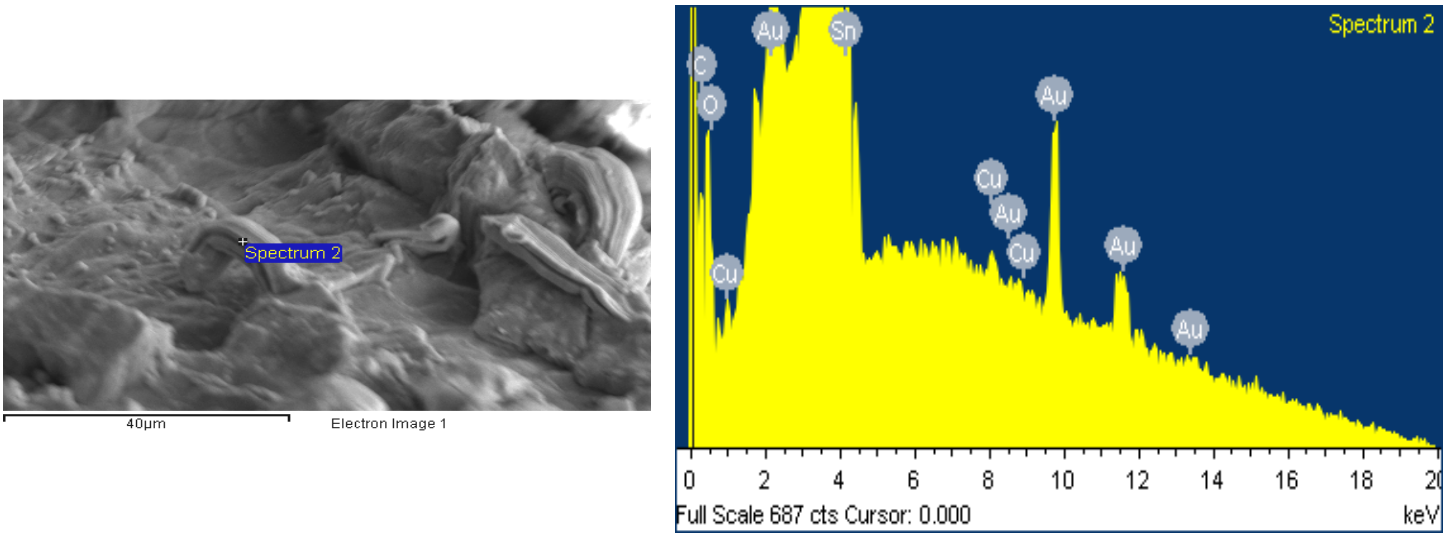


Figure 5(b). SEM image of TSOP component with SnCu finish showing whisker growth on the connector sides.



EDX Elemental Composition

Element	Weight Percentage	Atomic Percentage
C (K)	0.76	6.40
O (K)	2.18	13.84
Sn (L)	86.12	73.70
Au (M)	10.56	5.45
Cu (K)	0.38	0.61

Figure 6 EDX spectrum of a single whisker on a TSOP-50 component with a SnCu finish.

Representative Whiskers on SnPb Finish Parts

Figs. 7-10 shows tin whisker growth on thermally shocked TSOP-50 components with a SnPb finish. Seas of whiskers were observed all around the head of the leads (bend, top, face, sides).

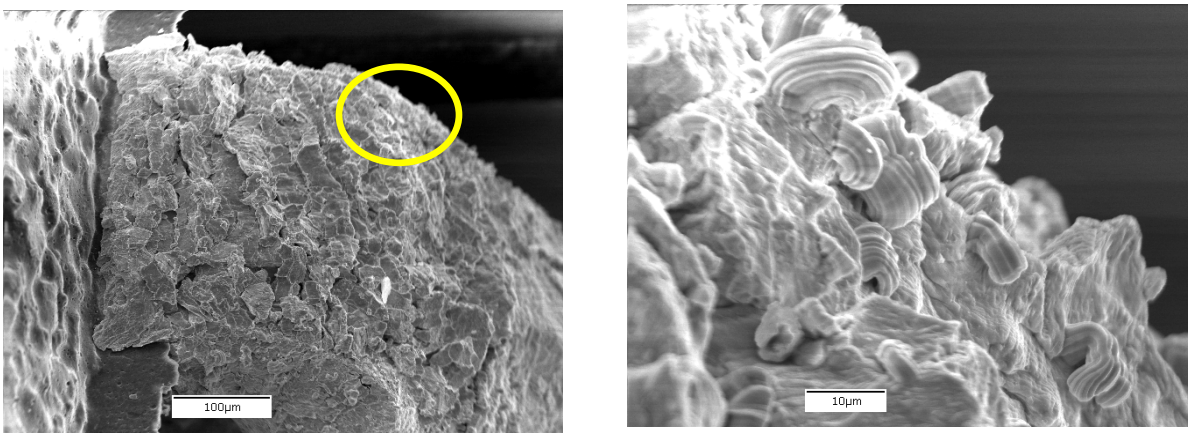


Figure 7 SEM image of TSOP component with SnPb surface finish showing whiskers on the side of lead.

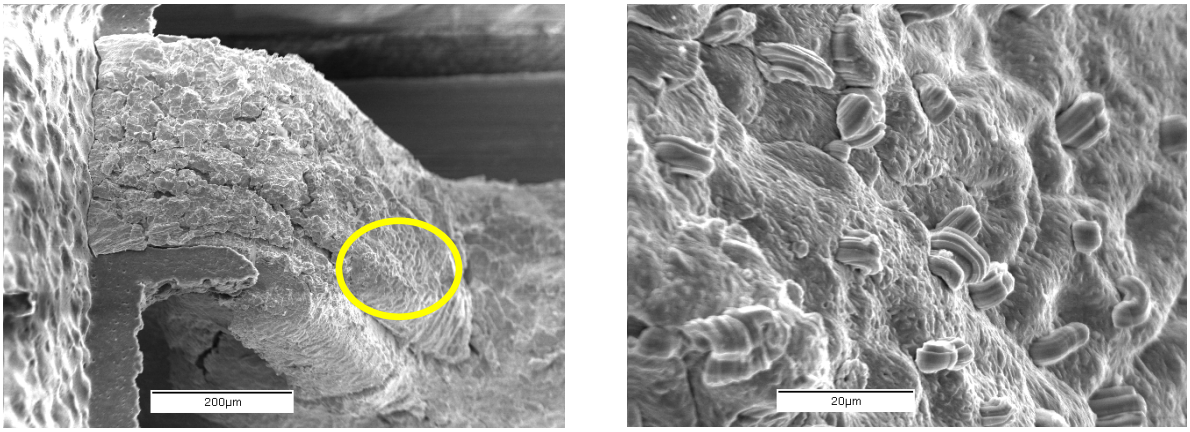


Figure 8. SEM image of TSOP component with SnPb surface finish showing whiskers on the middle neck of the lead.

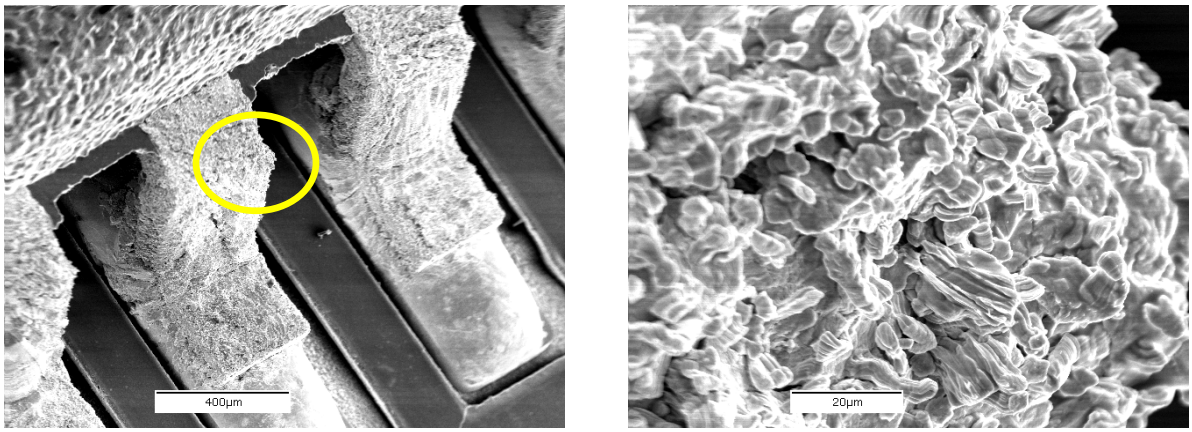
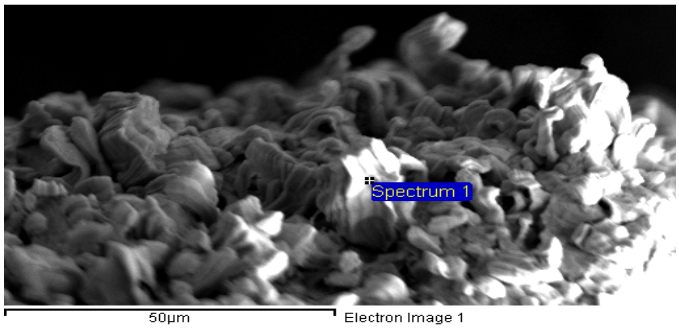
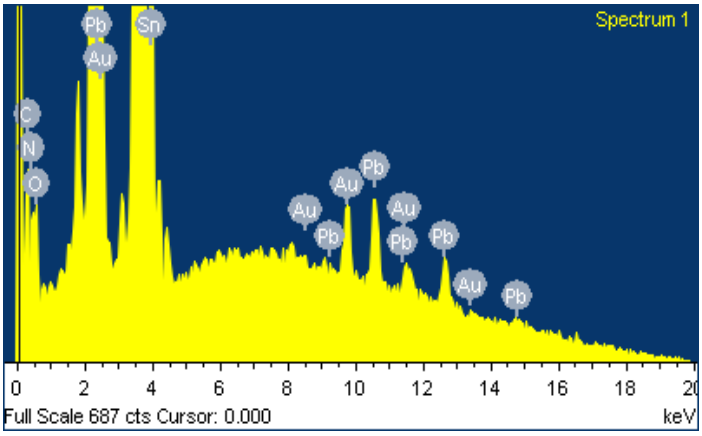


Figure 9. SEM image of TSOP component with SnPb surface finish showing whiskers on the knee of the lead.





EDX Elemental Composition*

Element	Weight Percentage	Atomic Percentage
C (K)	3.31	20.01
O (K)	6.26	28.44
Sn (L)	63.84	39.08
Au (M)	10.21	3.77
Pb (M)	15.76	5.53
N (K)	0.61	3.18

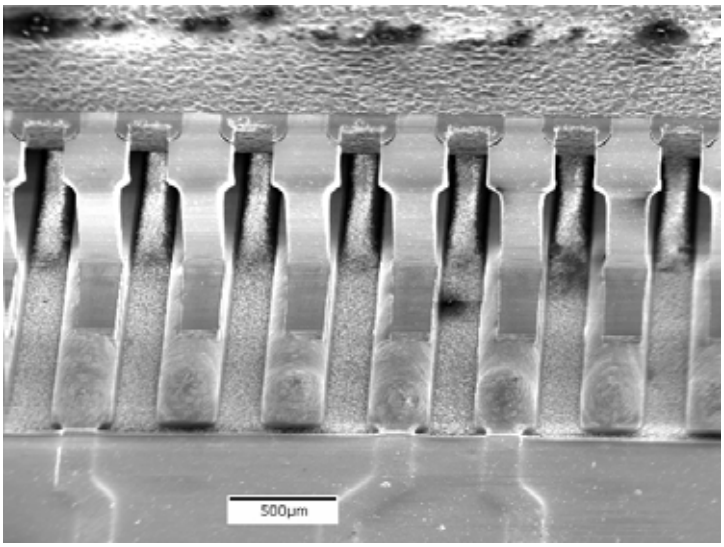
* Nearly all studies of Sn whiskers show that the whisker composition is 100% Sn. The small % of Pb we find in the whisker here may be due to electron scattering (from the Sn-37Pb) finish and/or depth of penetration effects in EDX (EDX samples material on the order of 3-4 µm beneath the surface at 20 kV accelerating voltage).

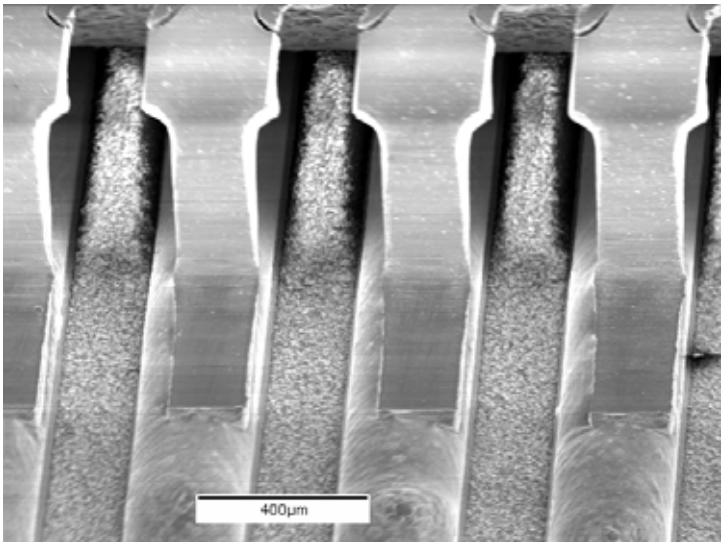
Figure 10. EDX of a Sn whisker on a lead of a TSOP component with SnPb finish.

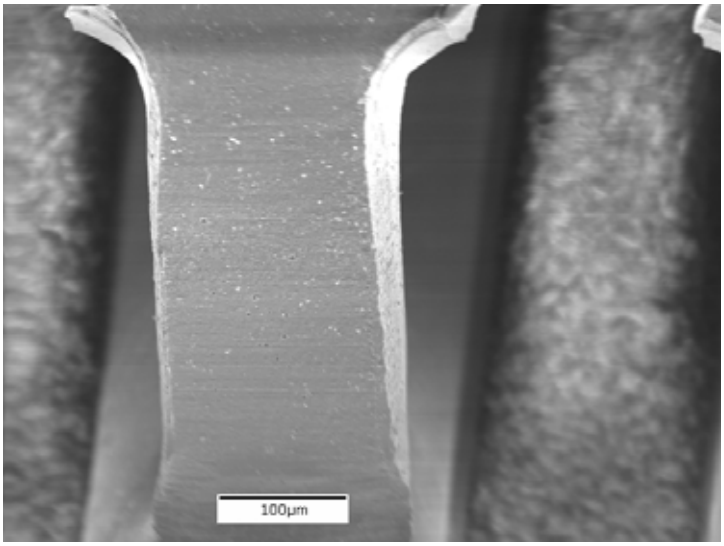
Appendix

Repository of SEM Photographs

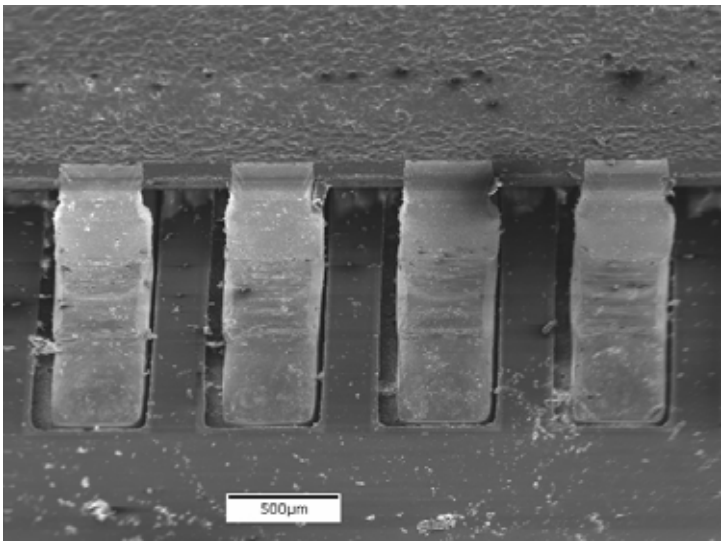
Mechanical Shock Test Board
S/N 28, Manufactured Control Board
U3/TQFP-208/NiPdAu

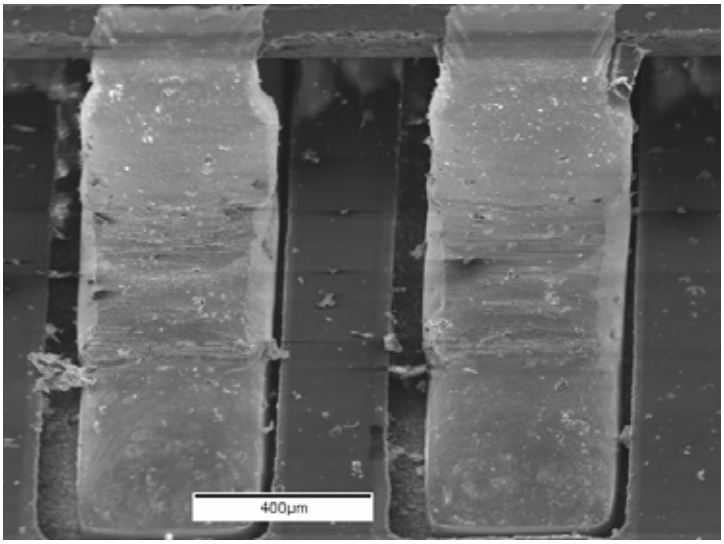


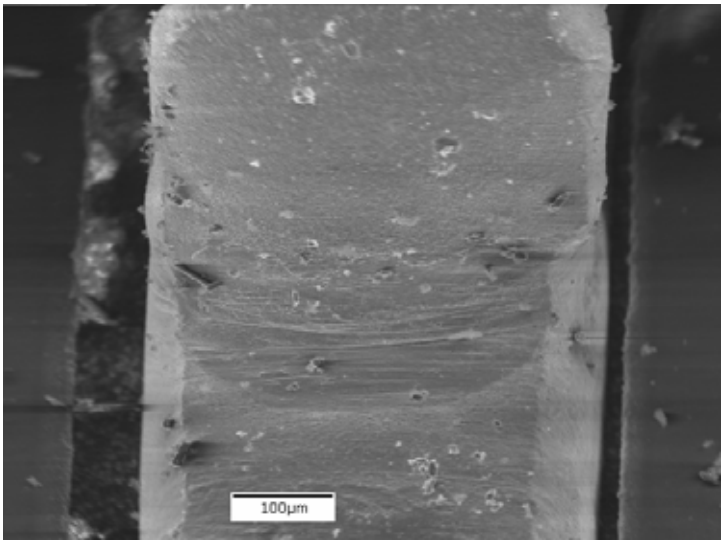




Mechanical Shock Test Board
S/N 28, Manufactured Control Board
U12/TSOP-50/SnCu







Mechanical Shock Test Board
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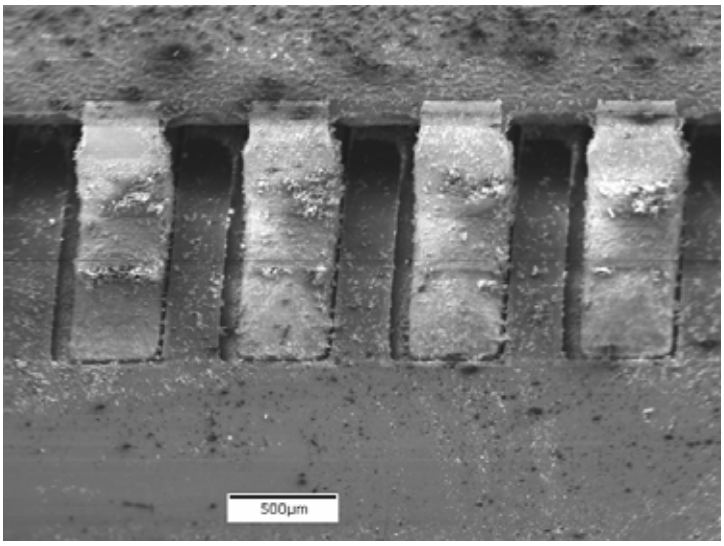
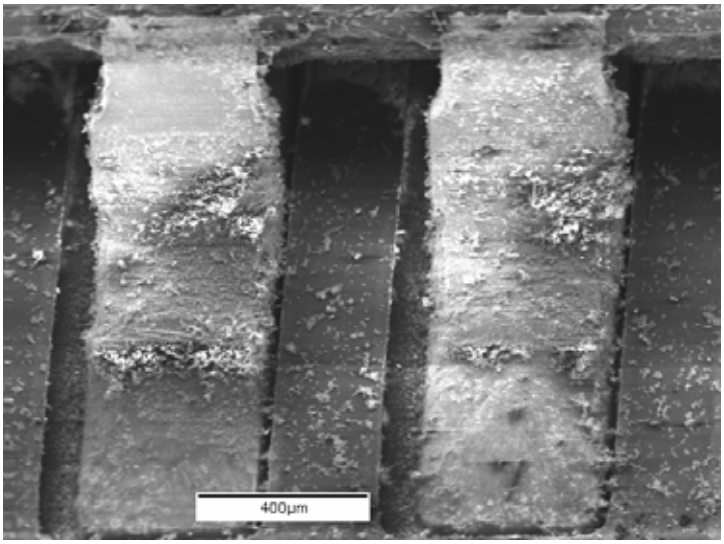
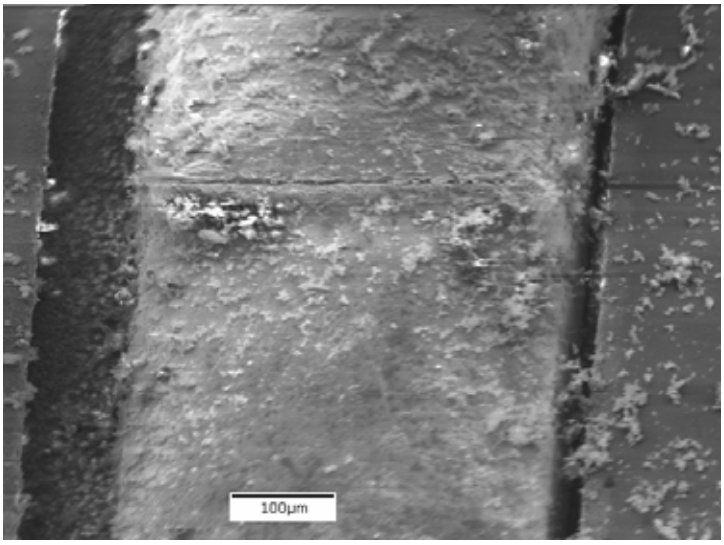
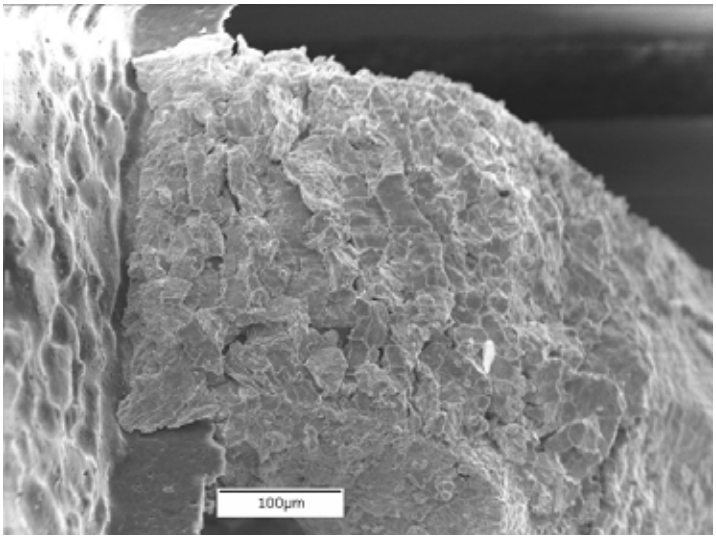
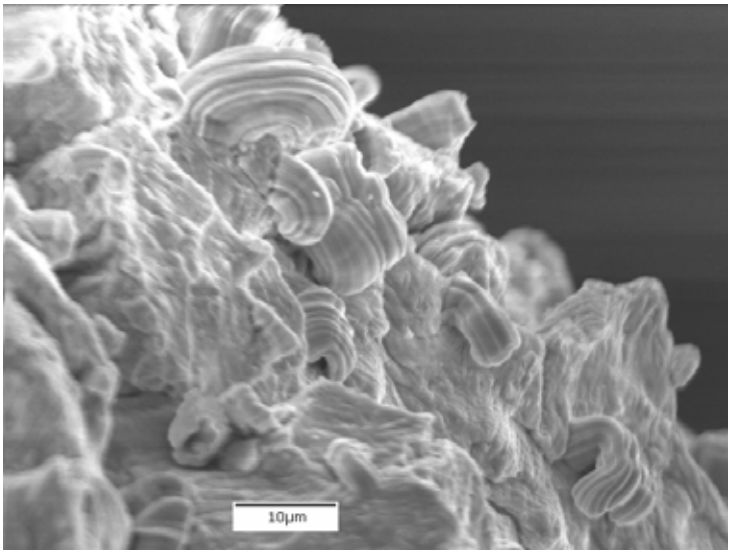
U26/TSOP-50/SnPb

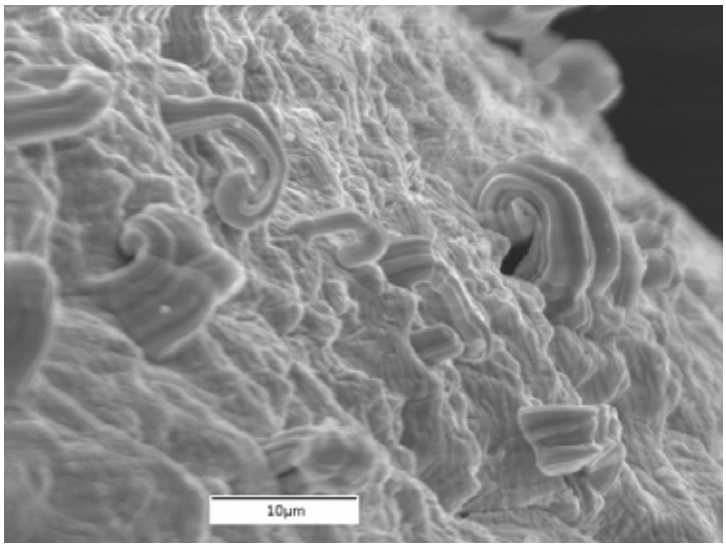




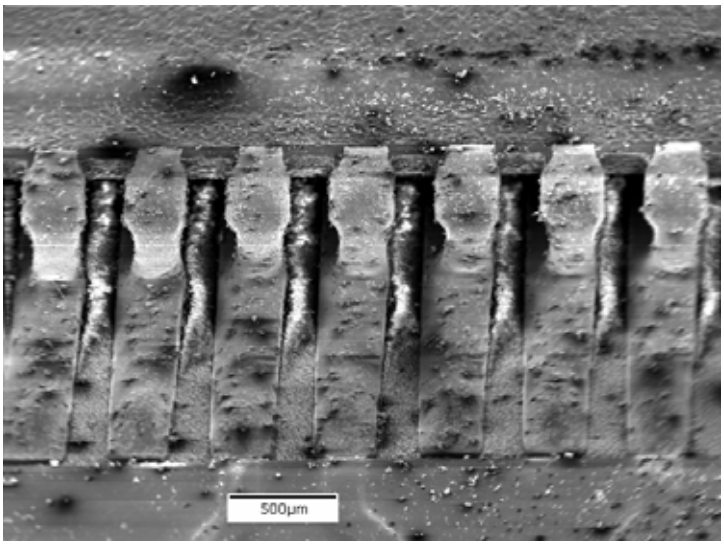


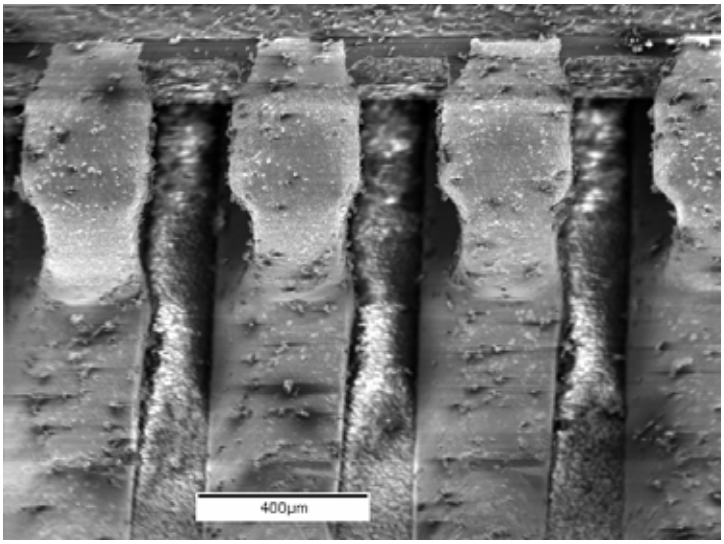

100µm

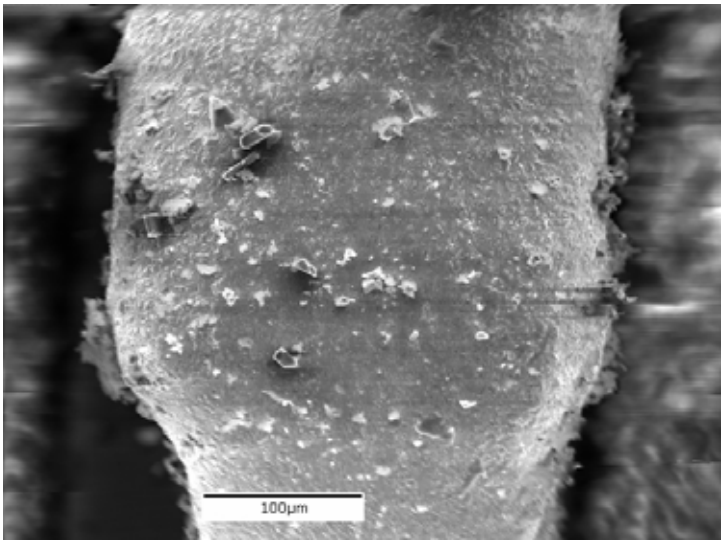

10µm


10µm

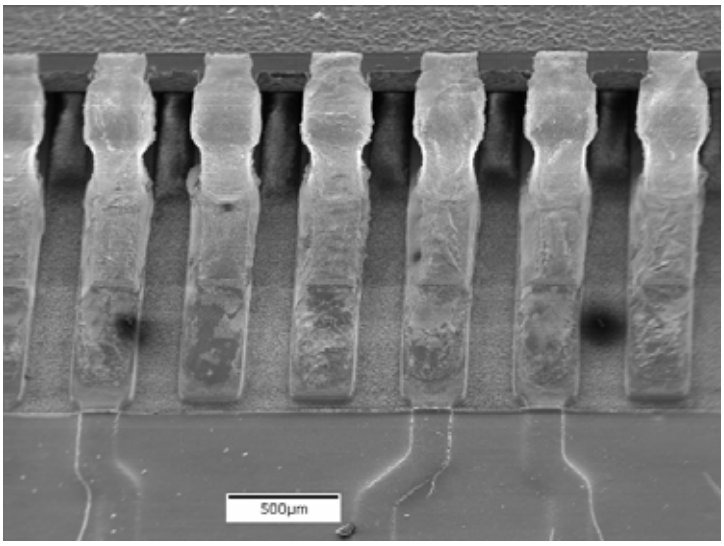
Mechanical Shock Test Board
S/N 28, Manufactured Control Board
U41/TQFP-1440/Sn

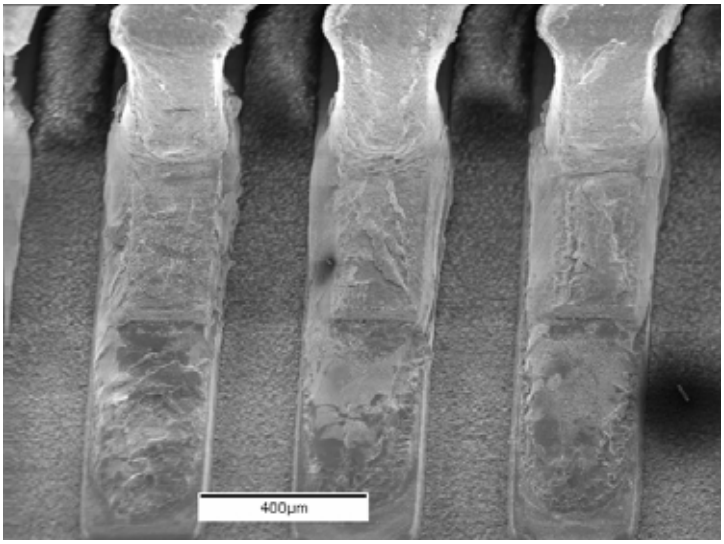


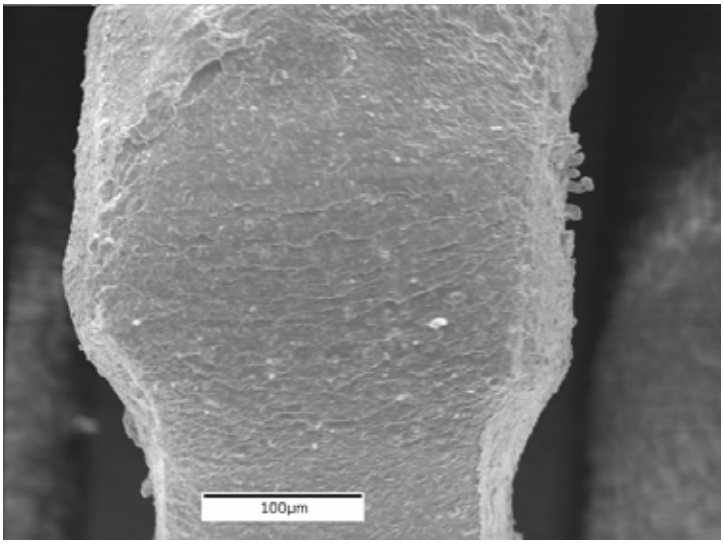


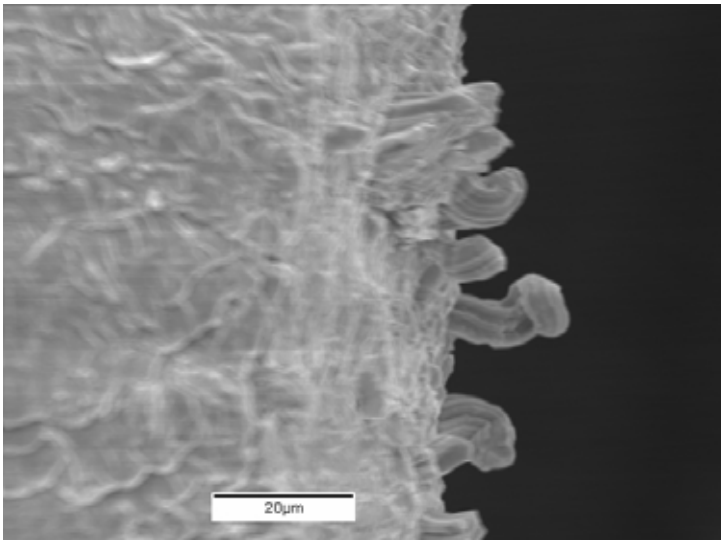


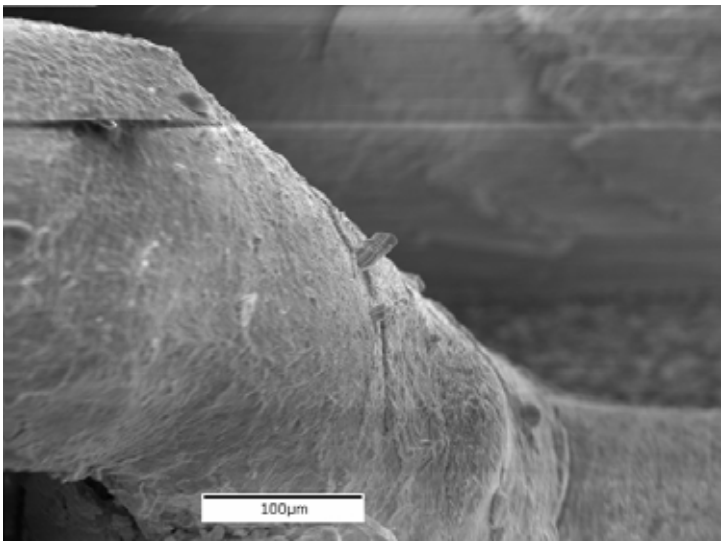
Thermal Shock Test Board
S/N 82, Manufactured SAC Board
U1/TQFP-144/Sn

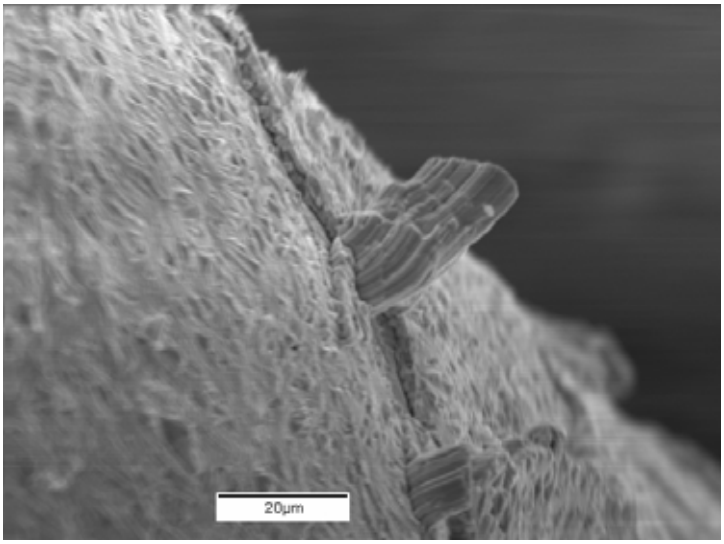


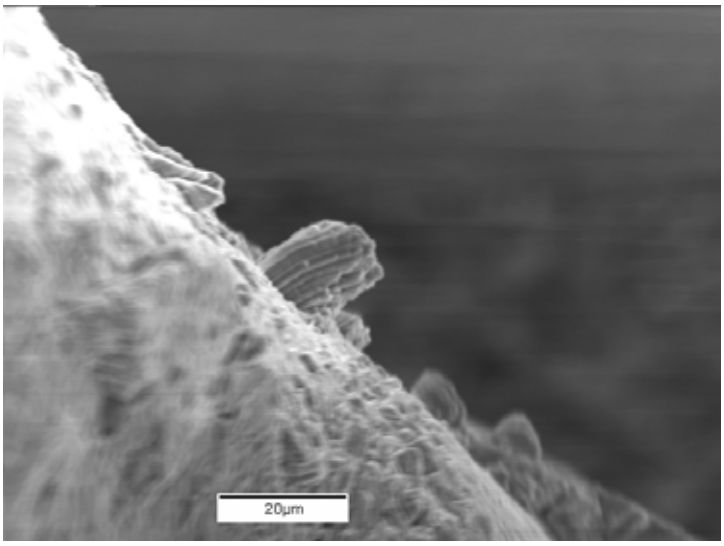




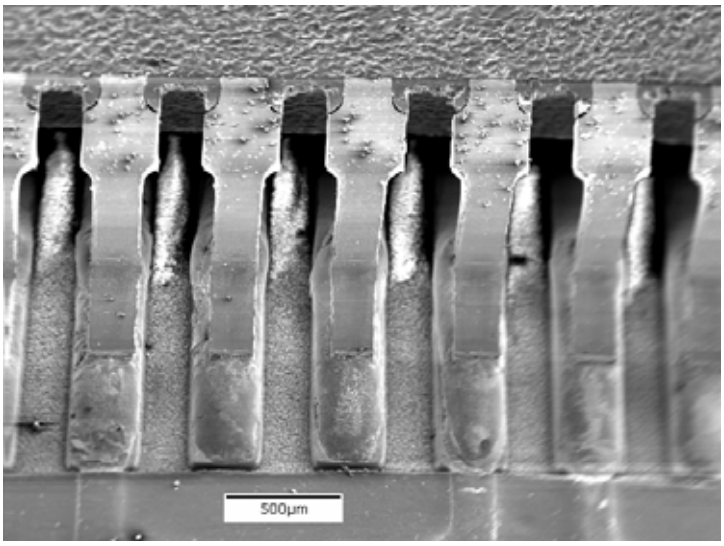


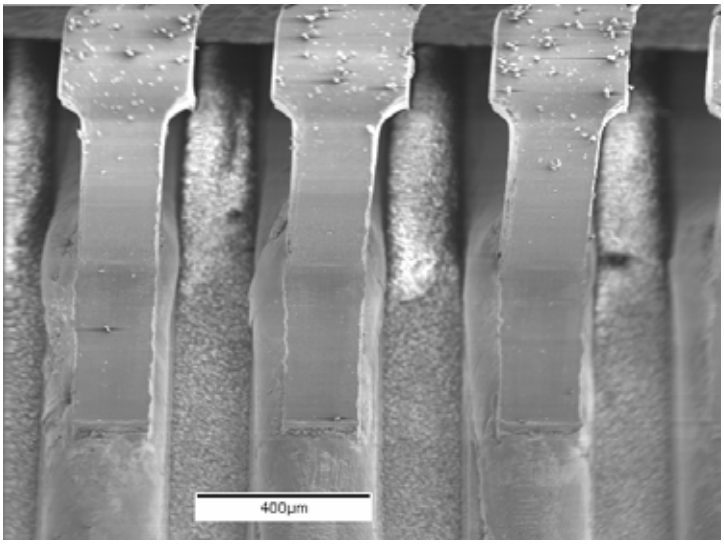

100µm

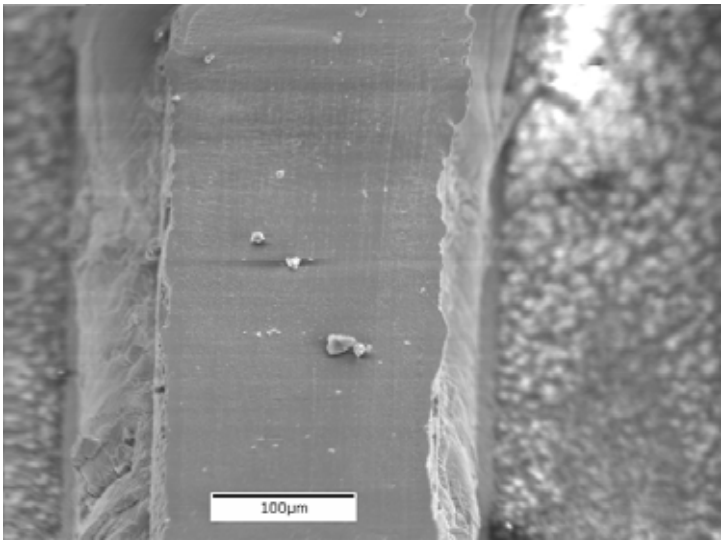

20µm


20µm

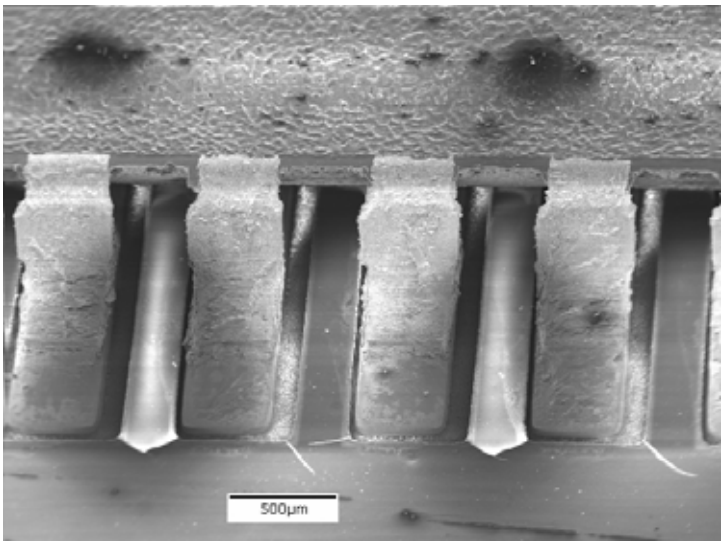
Thermal Shock Test Board
S/N 82, Manufactured SAC Board
U3/TQFP-208/NiPdAu

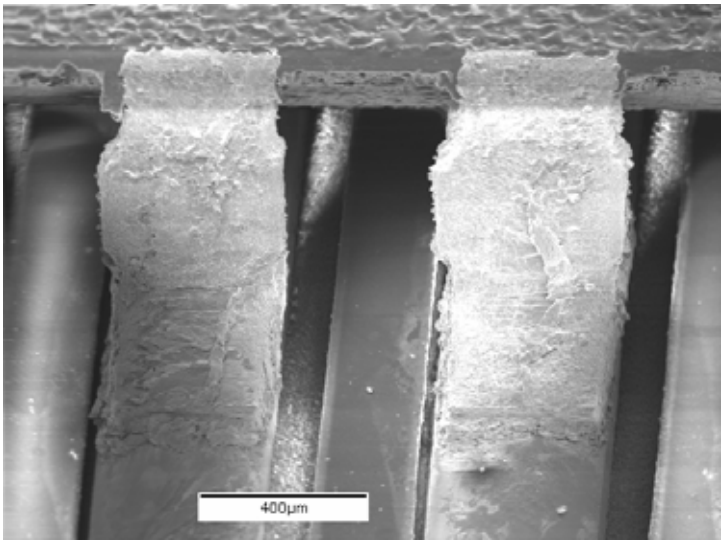


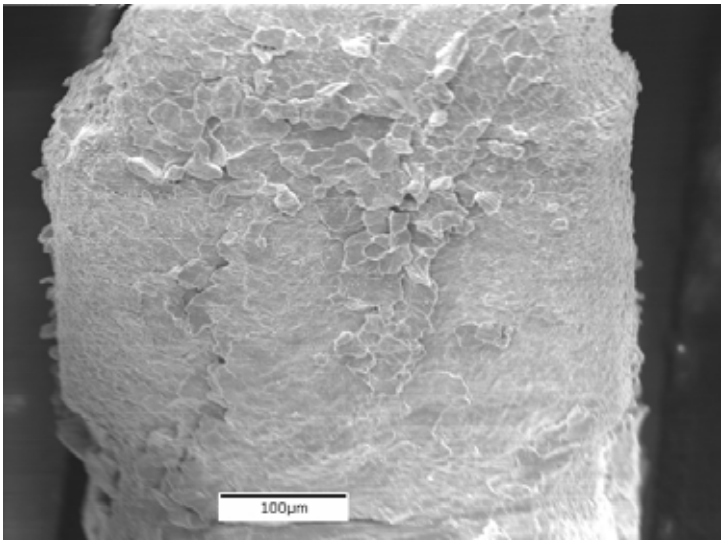


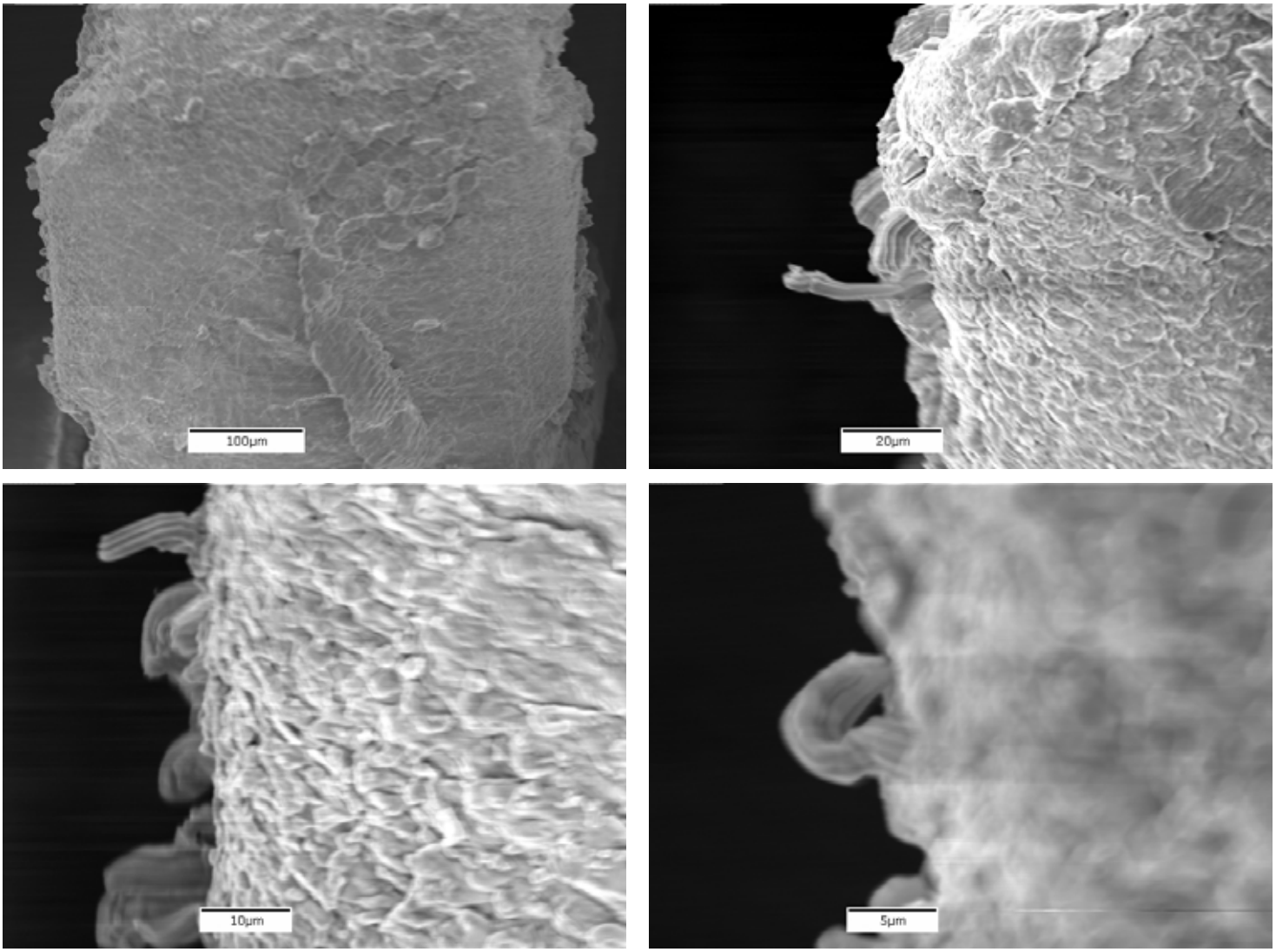


Thermal Shock Test Board
S/N 82, Manufactured SAC Board
U12/TSOP-504/SnCu

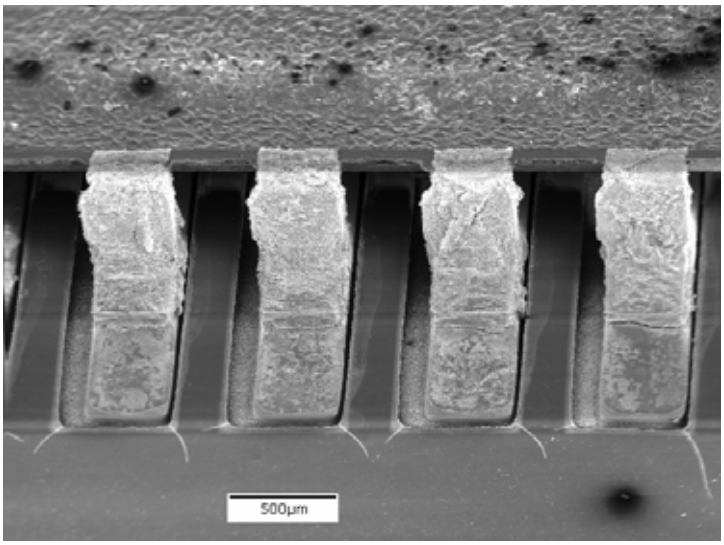


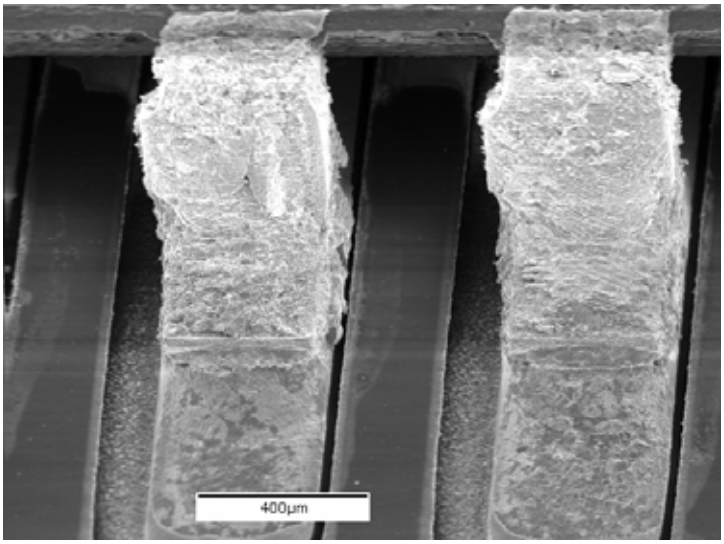


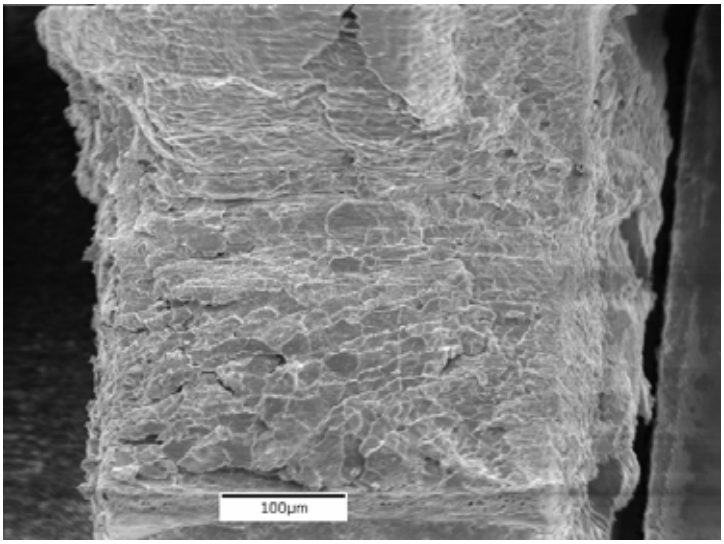



100µm
20µm
10µm
5µm

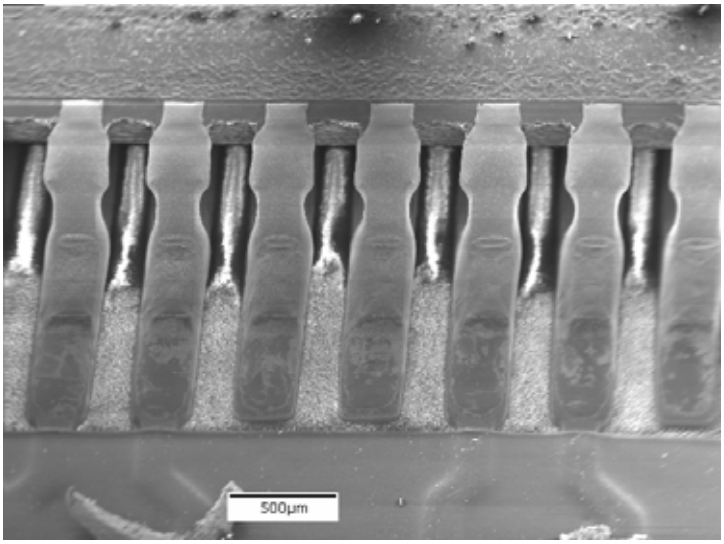
Thermal Shock Test Board
S/N 82, Manufactured SAC Board
U26/TSOP-50/SnPb

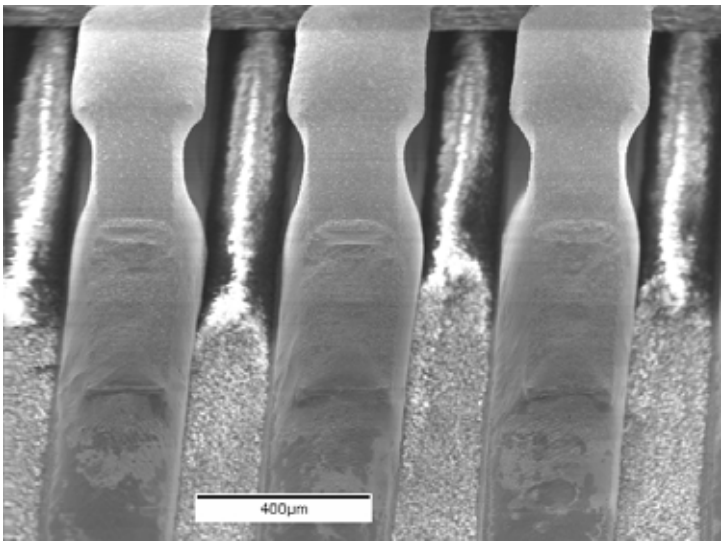


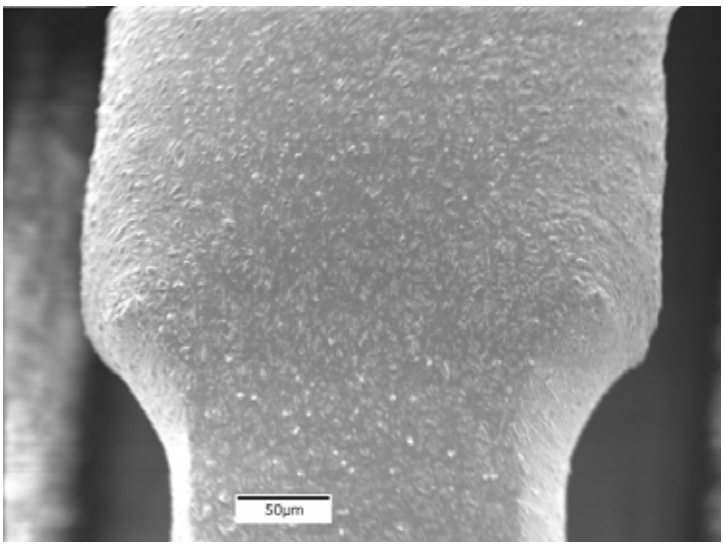




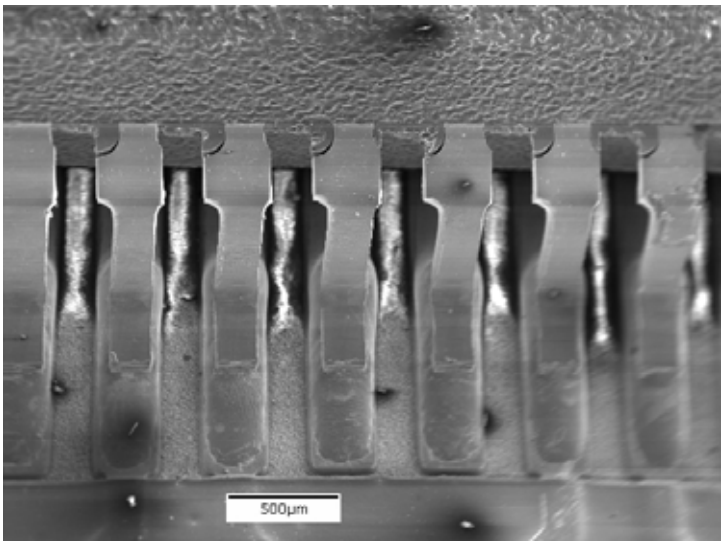
Mechanical Shock Test Board
S/N 98, Manufactured SAC Board
U1/TQFP-144/Sn

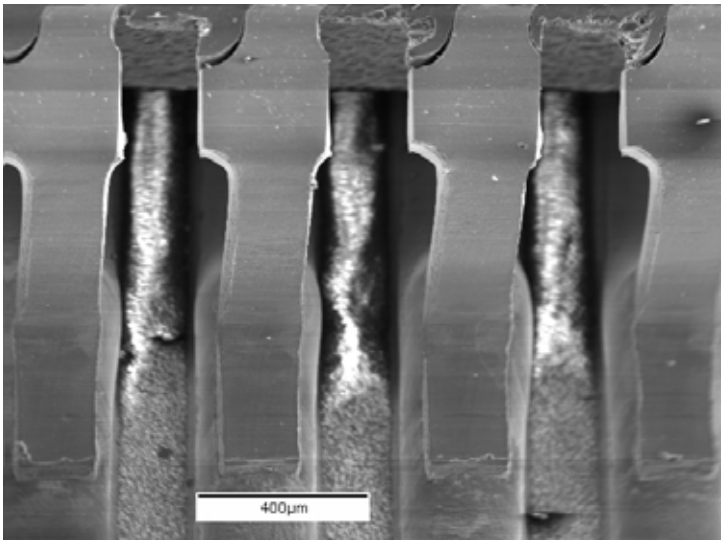


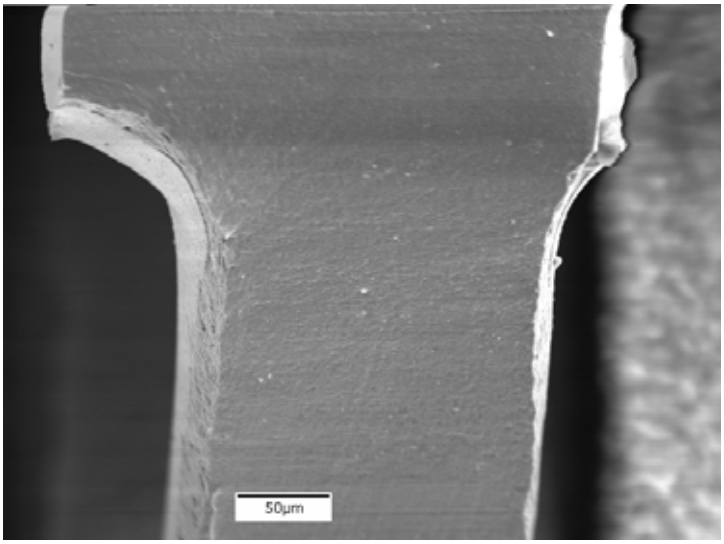




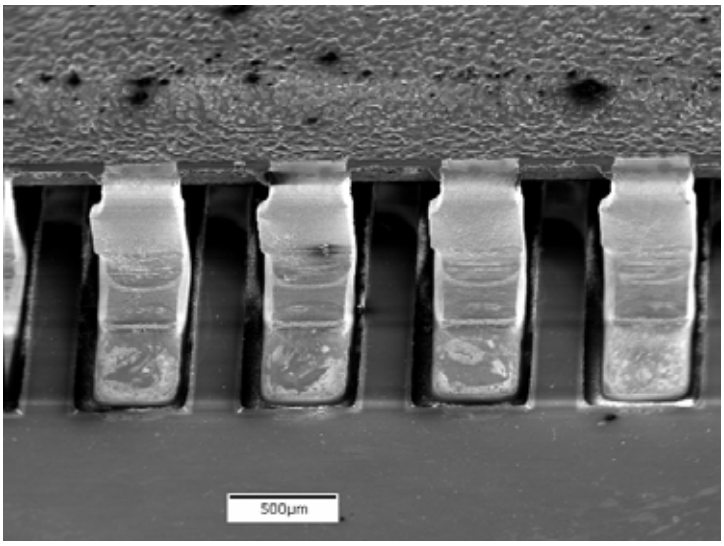
Mechanical Shock Test Board
S/N 98, Manufactured SAC Board
U3/TQFP-208/NiPdAu

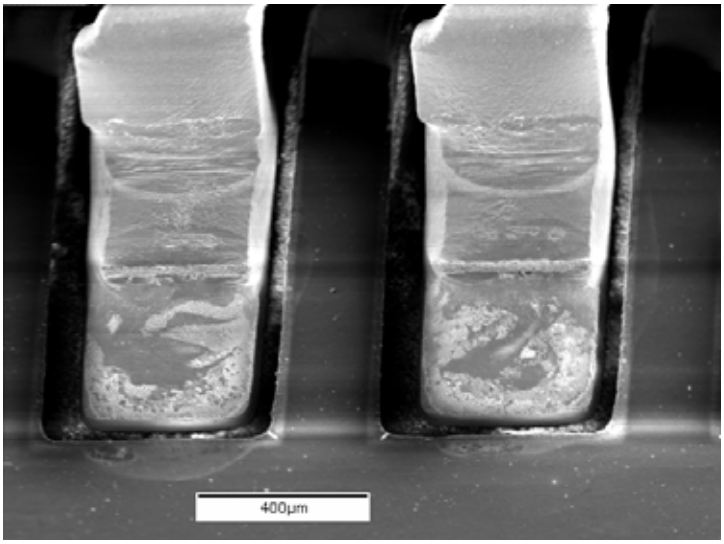


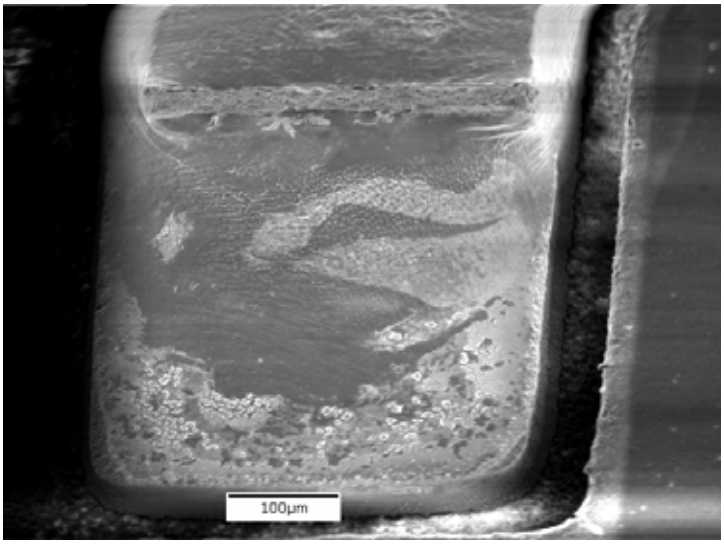




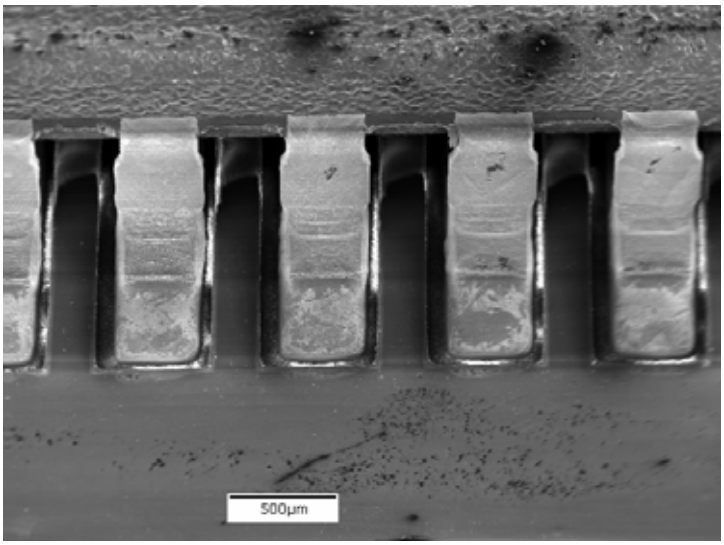
Mechanical Shock Test Board
S/N 98, Manufactured SAC Board
U12/TSOP-50/SnCu

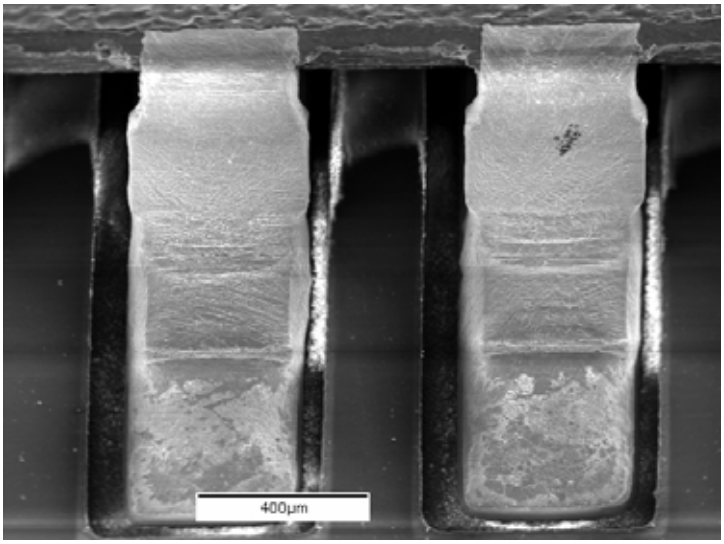


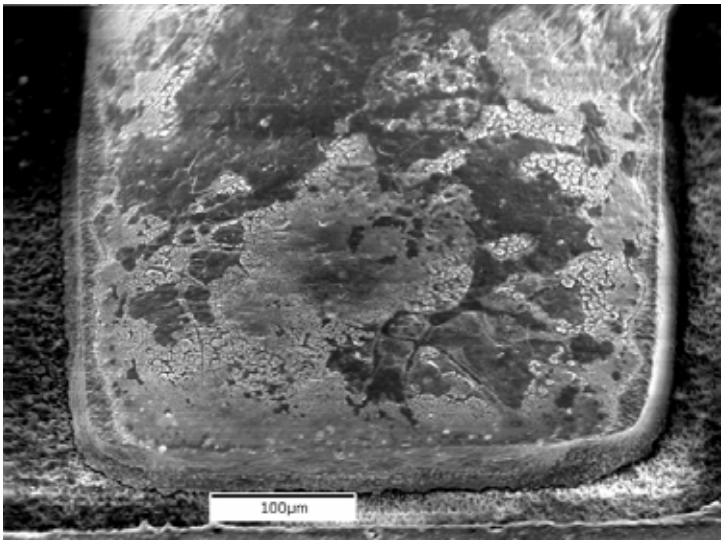




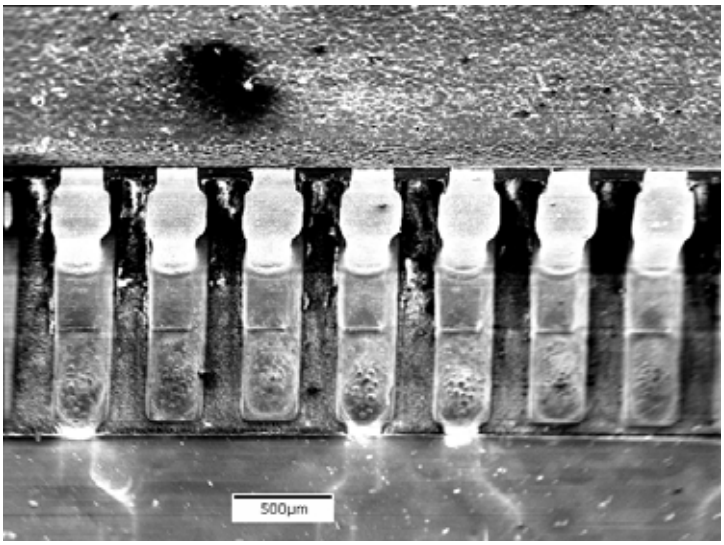
Mechanical Shock Test Board
S/N 98, Manufactured SAC Board
U26/TSOP-50/SnPb

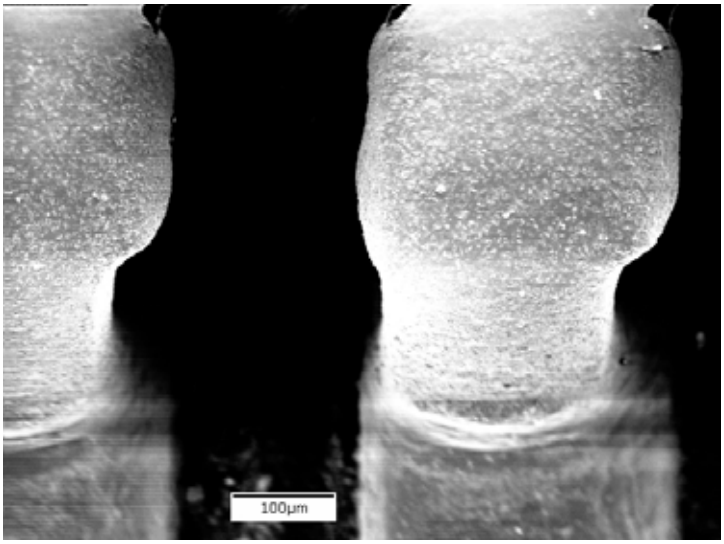




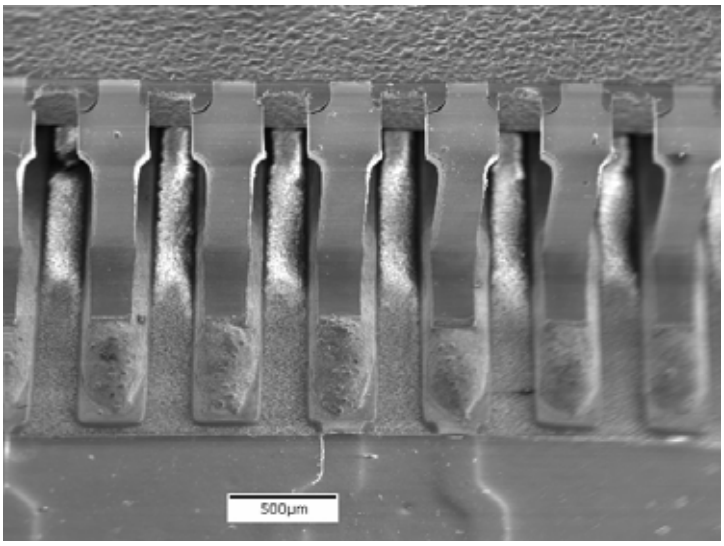


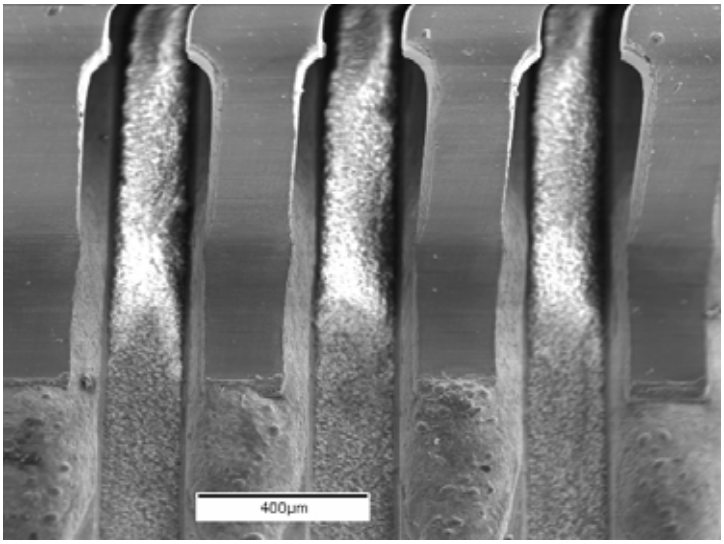
Mechanical Shock Test Board
S/N 136, Manufactured SACB Board
U1/TQFP-144/Sn

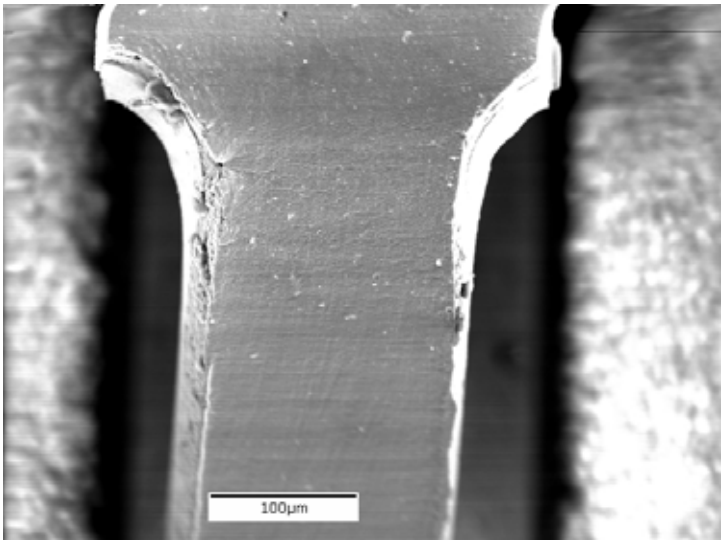




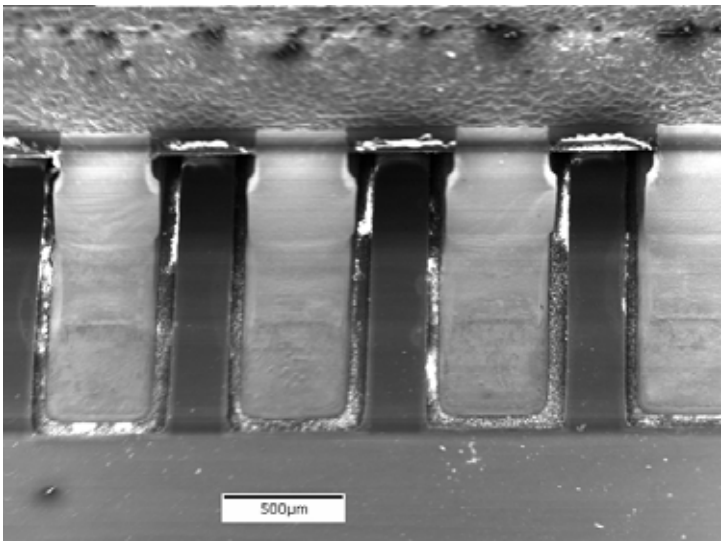
Mechanical Shock Test Board
S/N 136, Manufactured SACB Board
U3/TQFP-208/NiPdAu

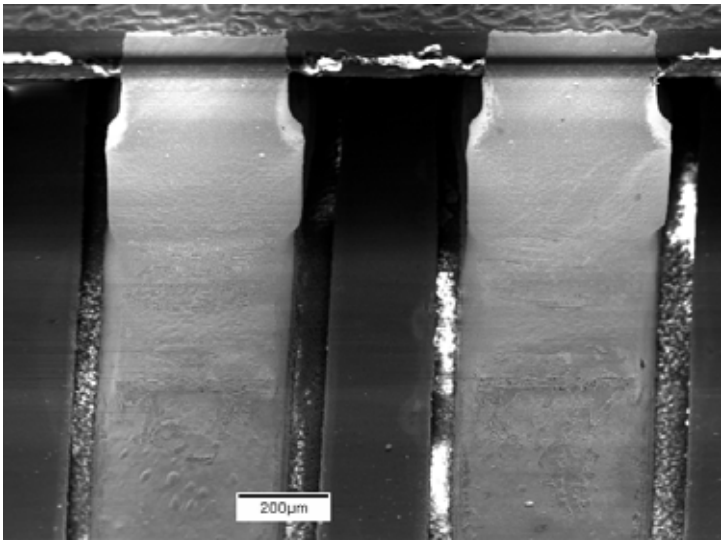


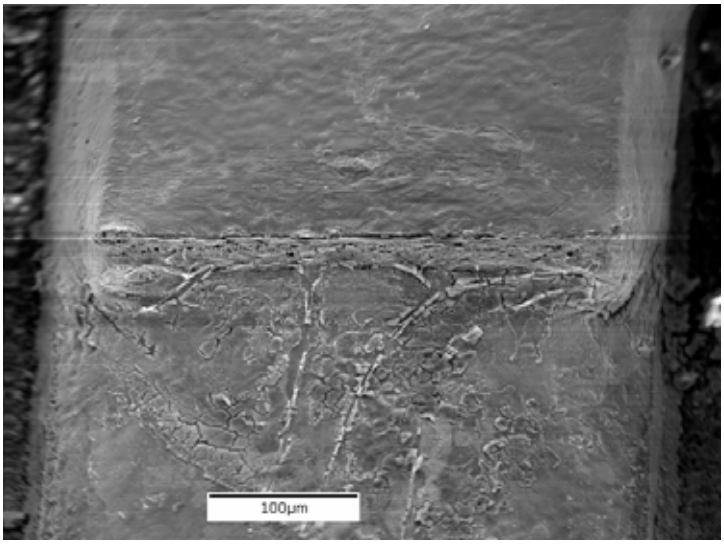




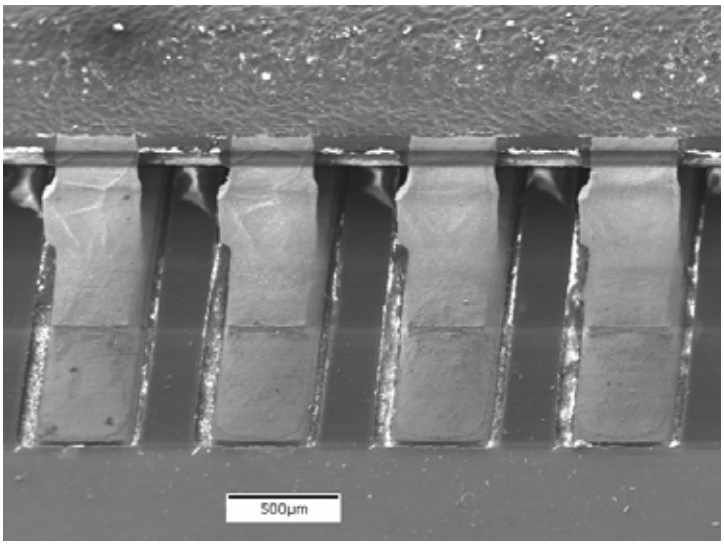
Mechanical Shock Test Board
S/N 136, Manufactured SACB Board
U12/TSOP-50/SnCu

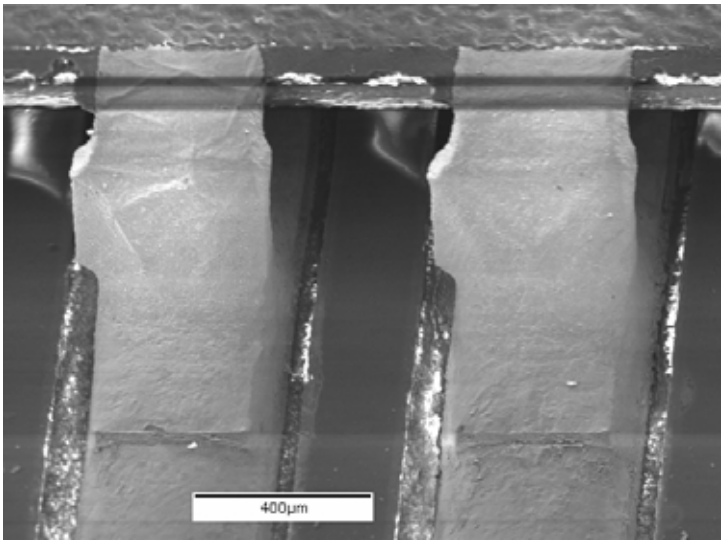


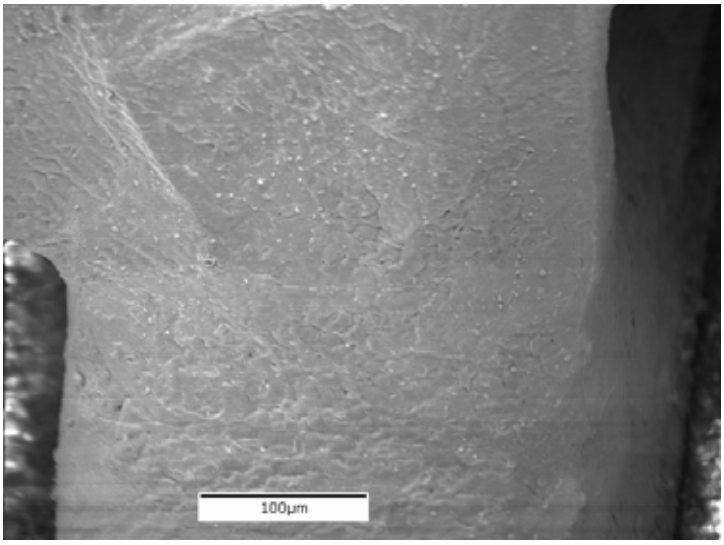




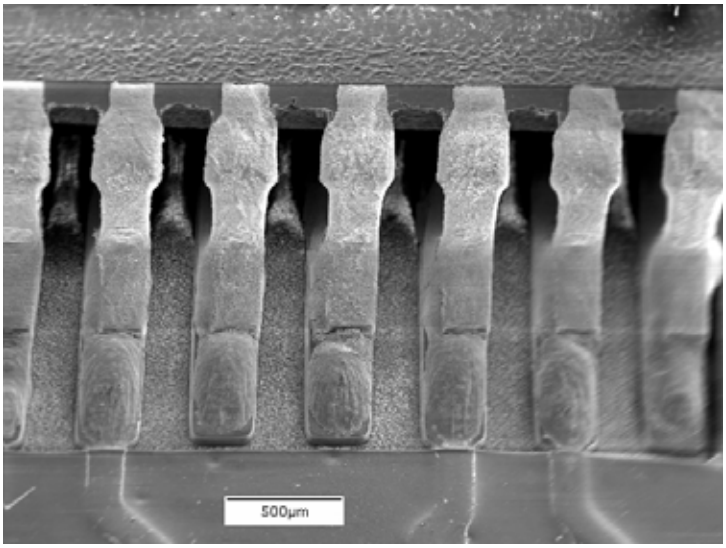
Mechanical Shock Test Board
S/N 136, Manufactured SACB Board
U26/TSOP-50/SnPb

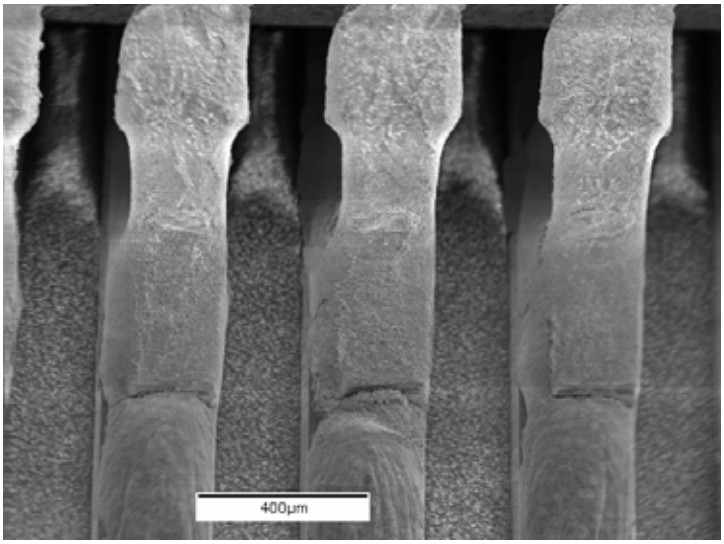


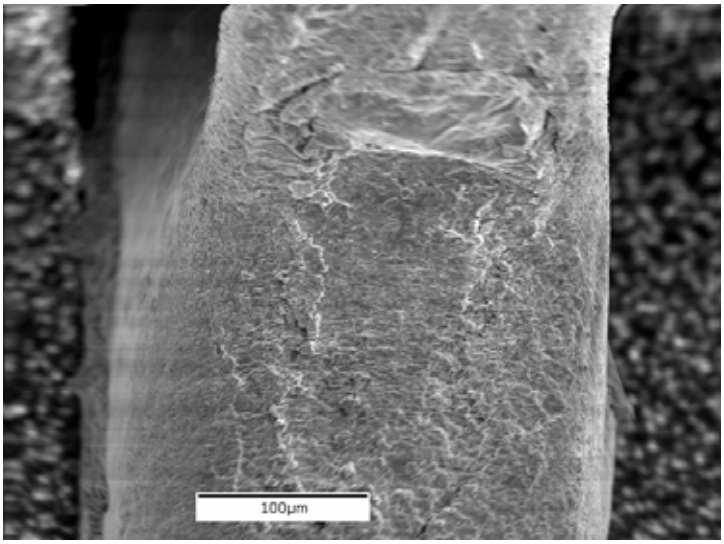


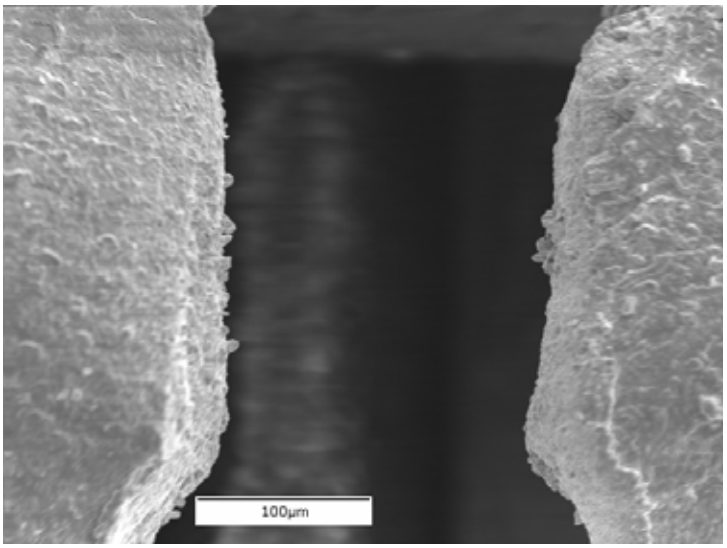


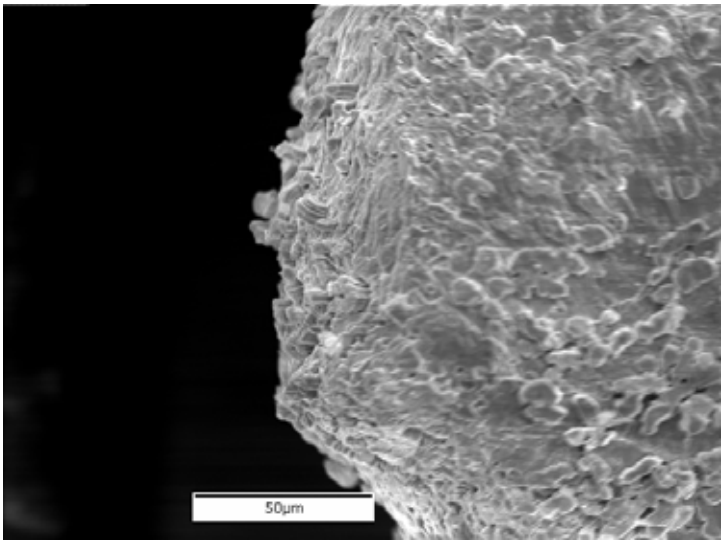
Thermal Shock Test Board
S/N 158, Reworked SAC Board
U1/TQFP-144/Sn

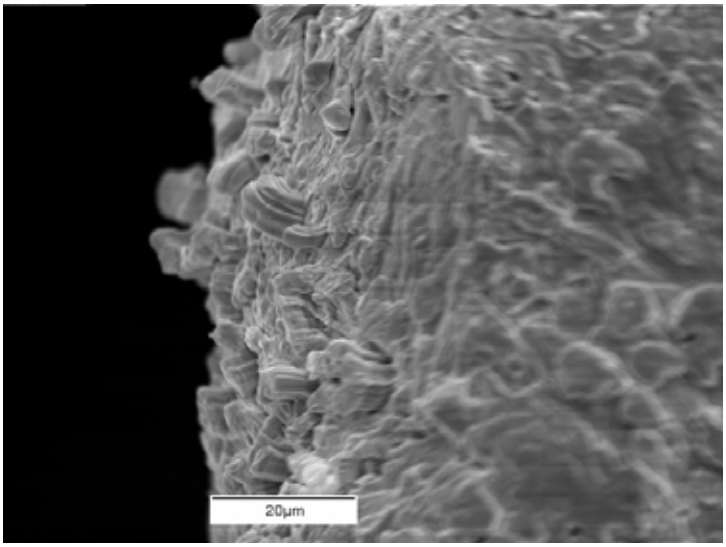




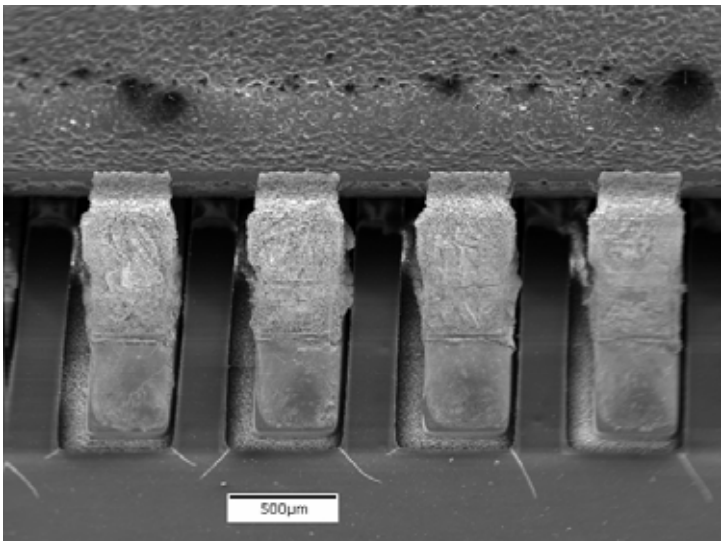


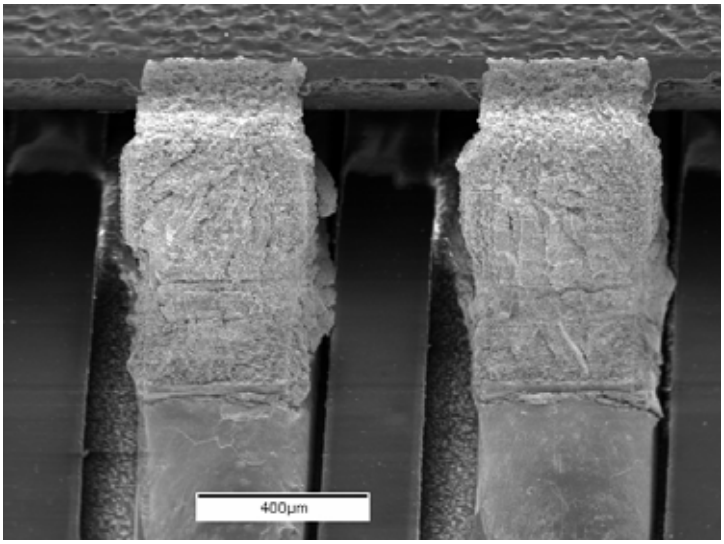

100µm

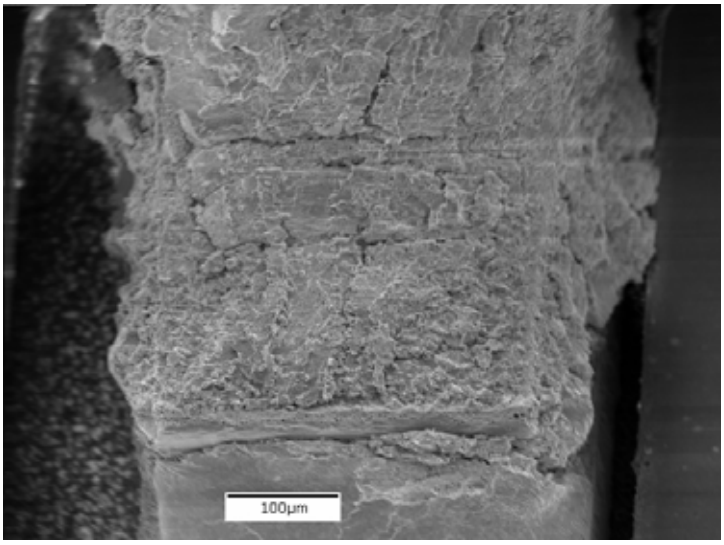

50µm

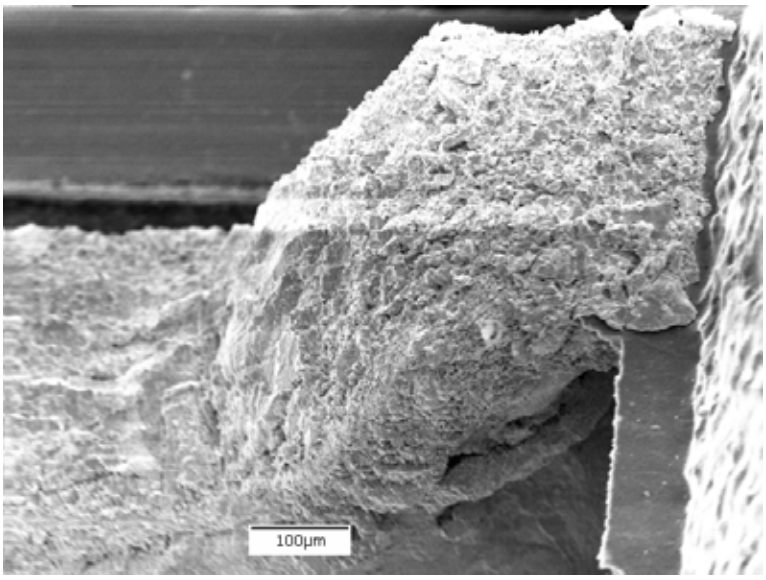

20µm

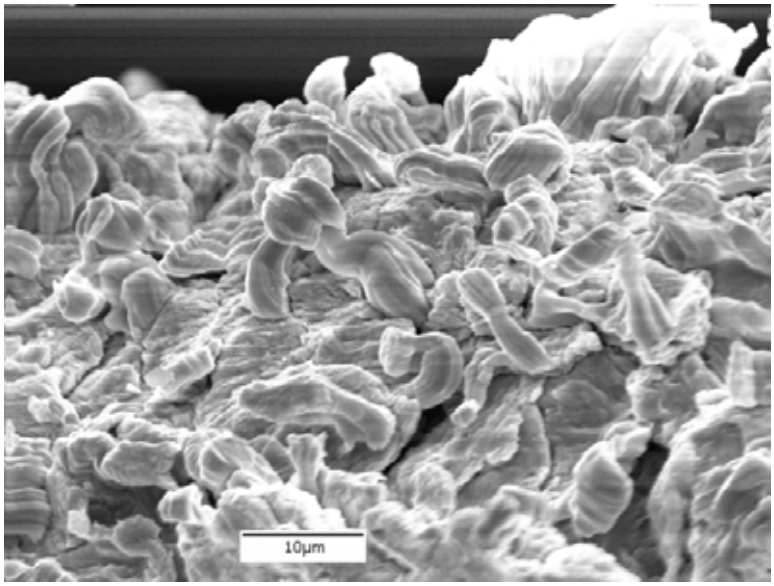
Thermal Shock Test Board
S/N 158, Reworked SAC Board
U26/TSOP-50/SnPb

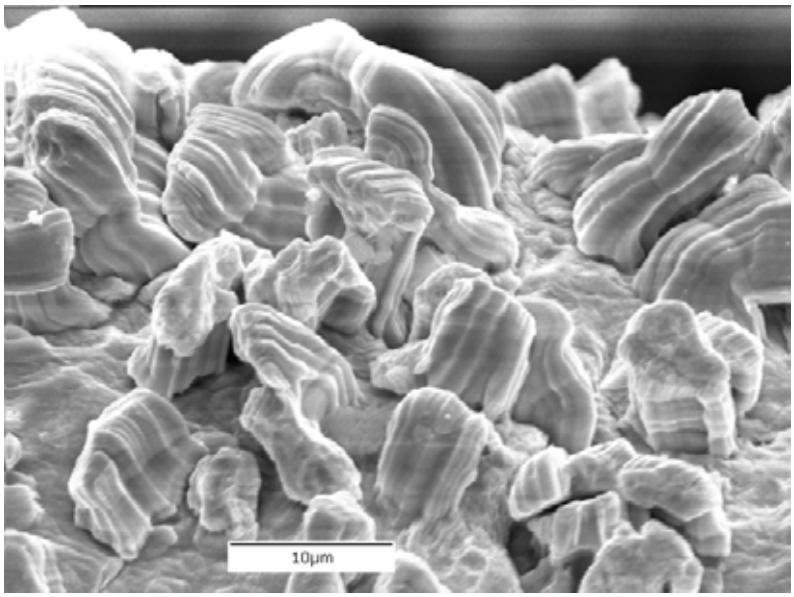




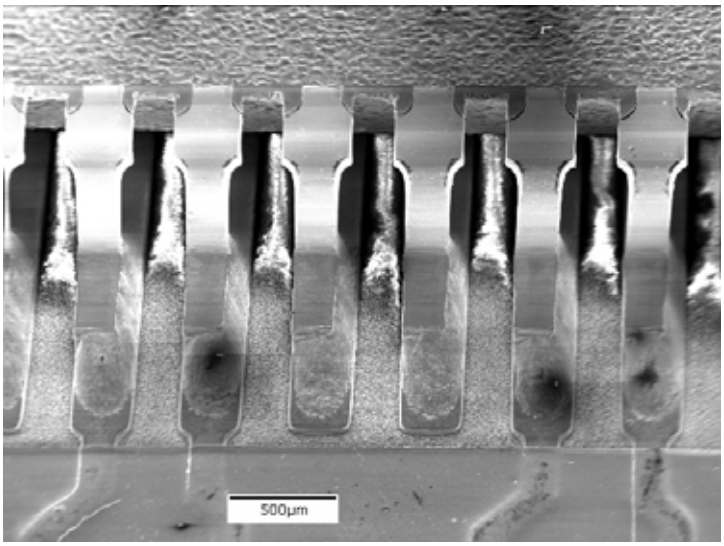


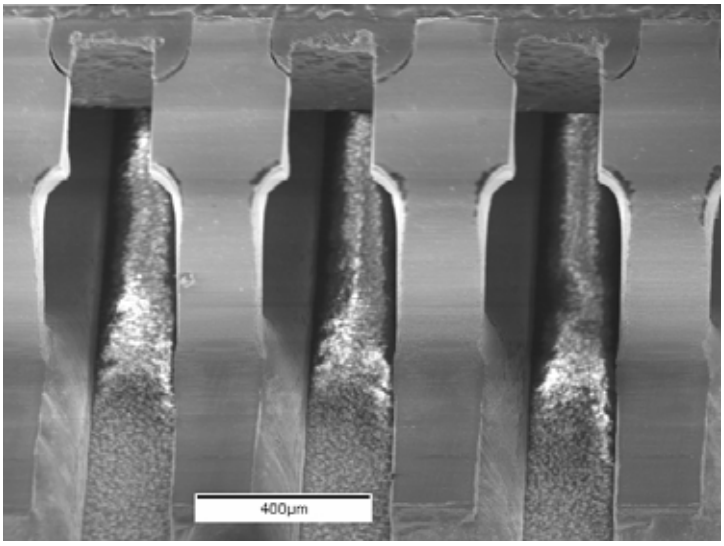

100µm

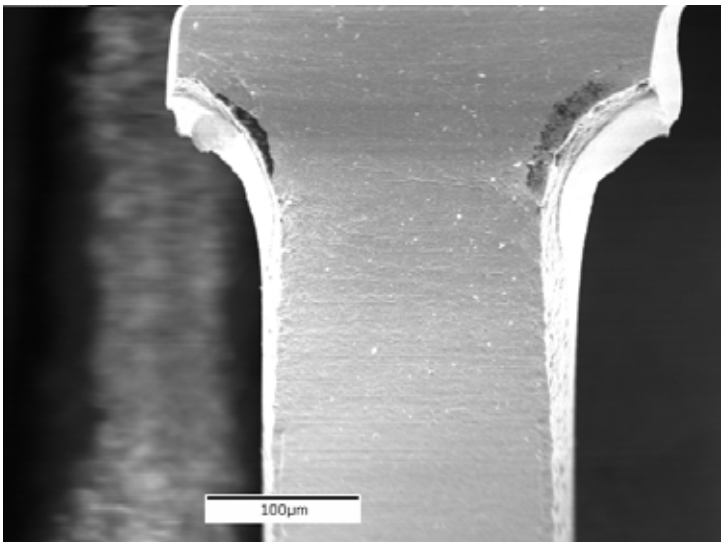
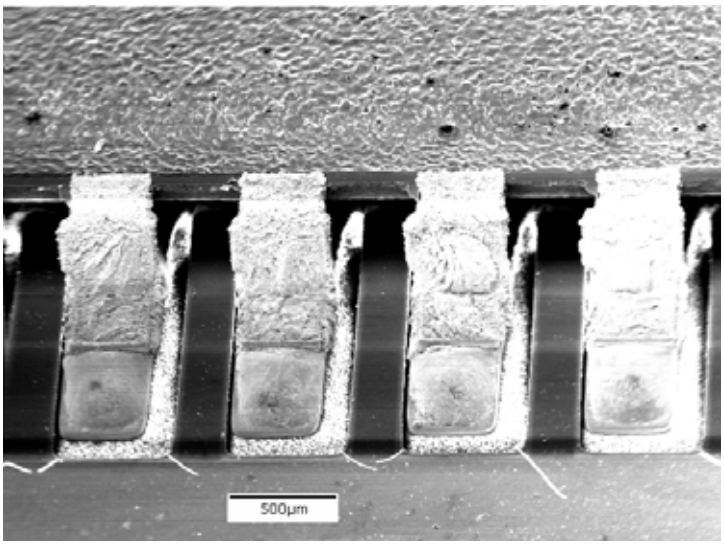
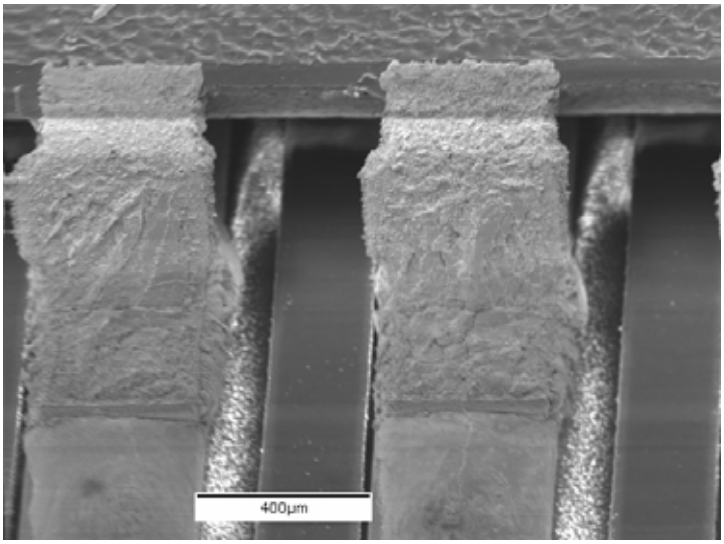

10µm


10µm

Thermal Shock Test Board
S/N 158, Reworked SAC Board
U48/TQFP-208/NiPdAu







Thermal Shock Test Board
S/N 158, Reworked SAC Board
U61/TSOP-50/SnCu