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Purchase Order Number E40005287

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Test Report

GenerEl PCBA Type 404

Visual Inspection, X-ray Inspection, Dye and Pull Inspection,

And Cross Section of Solder Joints

This report is a work of fiction and was created to demonstrate what a report from Elmet, LLC looks like. This report applies only to the materials tested. Testing was conducted using standard laboratory techniques using reasonable technical judgement; however, Elmet LLC assumes no responsibility for the use of this data. Some or all the testing may be subcontracted at Elmet's direction. Subcontracting shall be pre-approved by the customer and noted in the report. This report shall not be reproduced except in its entirety without written approval from Elmet, LLC. Samples will be discarded 60 days after the report date unless other disposition is arranged.

Sample Information

On July 27, 2022, Johnny Paycheck of Generic Electric supplied Elmet, LLC with one “GenerEl PCBA Type 404” circuit board for visual, whisker and dye-and-pull inspection, x-ray, and cross sectioning. This circuit board has completed 500 hours of high temperature, high humidity exposure. Table 1 shows the identification marked on the board and the name used in this report.

Table 1. Specimen Naming

Customer ID	Elmet ID
4LP1-1AB3T.50UP	Specimen 4LP1

Figure 1 shows the components targeted for cross sectioning, dye-and-pull, and X-ray. The target components are named J4, D2, Vias, T101, IC3, D313, and IC7. IC2 was targeted for dye-and-pull testing. D2 was x-rayed.

All sampling was performed in accordance with the customer supplied sampling plan shown in Figure 1.

Scope of Work and Instructions

Components were X-rayed, dye-and-pulled, and/or cross sectioned in accordance with the document “GenerEl42” emailed to Elmet on June 24, 2022. Figure 1 was taken from that document.

Specifically, the scope of work was as follows:

- Overview photograph of the circuit board to document its incoming condition.
- X-ray D2.
- Dye-and-pull IC2; photograph fractured/pulled solder balls and provide Crack Severity maps and Separation Location maps.
- Mount and polish the cross sectioned components in accordance with IPC-TM-650 2.1.1.
- Inspect all cross sectioned solder joints. Photographs all solder joints of two-terminal devices. Provide high magnification photographs of several representative solder joints of BGAs and header pins.
- Photograph all features of interest, such as cracks, voids, cold solder, delamination, etc.
- Photograph and measure voids that appear to approach or exceed 25% of solder volume. Void fraction is measured as the ratio of void cross sectional area divided by the total solder joint cross sectional area.
- Measure stand-off height of IC7.
- Measure PTH plating thickness.
- Measure the intermetallic layer thickness of J4.

Specifications and Methods

Document “GenerEl42” emailed to Elmet on June 24, 2022.

Inspection and dissection in accordance with GenerEl42.

Whisker inspection in accordance with JEDEC Standard No. 22-A121A.

Dye and Pull in accordance with IPC TM 650 2.3.53 Dye and Pull Test Method

Cross sectioning in accordance with IPC-TM-650 2.1.1.

Plating thickness measurements of vias in accordance with IPC-TM-650 2.2.5.

Results

All inspections and testing were performed between July 27, 2022 and August 4, 2022. Photographs of the circuit boards, target components, cross sections, x-rays, and intermetallic layers are presented in Figures 2 through 44.

Visual Inspection

The boards were visually inspected per GenerEl42.

Degraded Mechanical and Structural Integrity:

No mechanical or structural degradation was observed.

Solder/Part Lead- Fatigue Cracks, Creep, or Pad-Lift:

Specimen 4LP1 has a cracked PTH solder joint. See Figure 4.
No other fatigue cracks, creep, or pad lift was observed.

Damaged Surface Mount Parts:

No damage to surface mount parts was observed.

Degraded Large Part Integrity and Attachment:

No degradation to large part integrity or their attachment was observed.

Material Degradation, Growth, or Residues of Corrosion:

The BNC connector has a corroded mounting lug, shown in Figure 3.
No other material degradation, growth or corrosion residue was observed.

Tin, Zinc, or Silver Whisker Formation:

A tin whisker was observed on a component lead of IC4 and is shown in Figure 6.
No other whisker formation was observed.

Electromigration and Dendritic Growth:

No electromigration or dendritic growth was observed.

Inspection of each component's solder joint condition per IPC-A-610H:

Figure 4 shows a cracked solder joint which does not meet the Class 3 requirements of IPC-A-610H 5.2.10 Soldering Anomalies – Fractured Solder.
The corrosion shown in Figure 3 does not meet the requirements of GenerEl42, and does not meet Class 3 requirements of IPC-A-610H 10.6.4 Cleanliness – Surface Appearance. The solder joints otherwise meet IPC-A-610H Class 3 requirements.

Other Abnormal or Unexpected Conditions:

No abnormal or unexpected condition was observed.

X-Ray Inspection

The X-ray image of D2 is presented in Figure 19. Elmet examined the X-ray image for insufficient solder, displaced components, lead overhang, solder balls, and any other unusual or unexpected feature. No insufficient solder, displaced component, lead overhang, solder balls, or other unusual feature was observed.

Elmet measured the void fraction of the D2 solder joints. The measurements are included in Figure 19 and in Table 2, below.

Table 2 X-ray Void Measurements, percentage.

Specimen	Target	Solder Joint	Void Percentage	Photographs, Figure Num.
Specimen 4LP1	D2	Left	0.3% Void	19
	D2	Right	1.5% Void	19

Solder voiding does not exceed the specification limits.

Dye-and-Pull Inspection

Figures 8 through 11 present the images associated with dye-and-pull testing of Component IC2. The images of the bottom of the ICs have been mirrored across the vertical axis so that the solder ball numbering in those images is the same as the board side images. This allows the IC side and the board side images to be more easily compared.

Table 3 contains a summary of dye-and-pull inspections. Figures depicting cracks and crack maps are referenced in the last two columns. Crack maps summarize the location and type of crack.

Table 3 Dye-and-Pull Inspection Results

Specimen	Target	Solder Cracks	Fractures, 100% Cracks	Maps, Figure Num.	Photographs, Figure Num.
Specimen 4LP1	IC2	None	None	11	8-10

There were no fractured solder balls and no crack was detected.

Cross Sections

Table 4 contains a summary of cross section inspections. The last three columns reference figures depicting cracks, voids, or other features of interest.

Three solder cracks were observed, all three cracks exceed 25% of the length of the solder joint. Two of the solder joints are completely cracked, or fractured. One solder joint contains voids exceeding 25% of its cross-sectional area. A hot tear was observed and is shown as a feature of interest; it is permitted by IPC-A-610H section 5.2.13 Solder Anomalies. No other feature of interest or concern was observed.

Table 4 Cross Section Inspection Results

Specimen	Cross Section	Comments	Cracks	Voids	FOI
Specimen 4LP1	Inspection	-			
	J4	Leg 8: 19.6% Void Leg 4: 12.9% Void		Fig. 14 Fig. 15	
	D2	Hot Tear			Fig. 22
	Vias				
	T101	27.1% Void		Fig. 31 & 32	
	D313	100% Solder Crack 99.4% Solder Crack	Fig. 35 Fig. 36		

Specimen	Cross Section	Comments	Cracks	Voids	FOI
	IC3	22.8% Void 100% Solder Crack	Fig. 40	Fig. 39	
	IC7	Standoff Height: 63 µm Standoff Height: 28 µm			Fig. 43 Fig. 44

Plating Thickness Measurements

Six PTH plating thickness measurements were made on each cross section listed in Table 5. The measurements were averaged to obtain the values presented. The minimum thicknesses were also recorded. Plating thicknesses were measured in accordance with IPC-TM-650 2.2.5. All values are micrometers.

Table 5 Plating Thickness Measurements, micrometers.

Specimen	Cross Section	Average Plating Thickness	Minimum Plating Thickness	Figure Number
Specimen 4LP1	Vias	39.4	35.4	25
Specimen 4LP1	Vias	41.6	34.1	26

The platings have uniform thicknesses. No voids, nodules or cracks were observed. The average plating thicknesses exceed 25 micrometers, and the minimum thicknesses exceed 20 micrometers. Through hole plating meets the requirements of GenerEl42.

Intermetallic Compound Layer Thickness Measurements

The intermetallic compound (IMC) layer thickness of J4 was measured with optical microscope. Using the optical image shown in Figure 16, Elmet measured the area of an 80 micron long segment of the IMC layer. The area was divided by the length of the segment to get the average thickness.

The IMC layer thickness of J4 Leg 6 was measured with a scanning electron microscope (SEM). Using the SEM image shown in Figure 17, Elmet directly measured the IMC layer thickness in six locations and averaged the measurements. Table 6 presents the results of both measurement methods. Although both methods are presented in this report, customers typically request one method or the other.

Table 6 IMC Layer Thickness Measurements of J4, micrometers.

Specimen	Method	Cross Section	Average IMC Thickness	Figure Number
Specimen 4LP1	Optical	Leg 4 component side IMC	2.05	16
Specimen 4LP1	Optical	Leg 4 board side IMC	2.46	16
Specimen 4LP1	SEM	Leg 6 board side IMC	2.84	17

The intermetallic layers are continuous and have reasonably uniform thickness. The Intermetallic layers are thicker than 1 µm and thinner than 6 µm, and meet the specifications set in GenerEl42.

Summary

The corrosion shown in Figure 3 does not meet the requirements of GenerEl42, and does not meet Class 3 requirements of IPC-A-610H 10.6.4 Cleanliness – Surface Appearance.

The cracked solder shown in Figure 4 does not meet the Class 3 requirements of IPC-A-610H 5.2.10 Soldering Anomalies – Fractured Solder.

The circuit board otherwise meets Class 3 visual inspection requirements of IPC-A-610H.

No deficiency was observed in the x-ray of D2. Void measurements by x-ray are less than the 25% limit set by GenerEl42.

IC2's dye and pull inspections revealed no solder cracks or fractures, no missing solder balls, no head-in-pillow defects.

Cross sectioning revealed three solder cracks. All three solder cracks exceed 25% of the length of the solder joint. Two of the solder joints are completely cracked, or fractured. See Figures 35 and 40.

One solder joint contains voids exceeding 25% of its cross-sectional area. See Figures 31 and 32. This does not comply with the requirements of GenerEl42.

A hot tear was observed in a D2 solder joint. This is permitted by IPC-A-610H section 5.2.13 Solder Anomalies and is reported as a feature of interest.

The PTH plating thicknesses and conditions meet the requirements of customer specification GenerEl42.

The IMC thicknesses meet the requirements of customer specification GenerEl42.

No other feature of interest or concern was observed.

Any statement of compliance is based upon simple acceptance.

Contact me if you have questions or suggestions for improvement, and Thank You for using Elmet, LLC!

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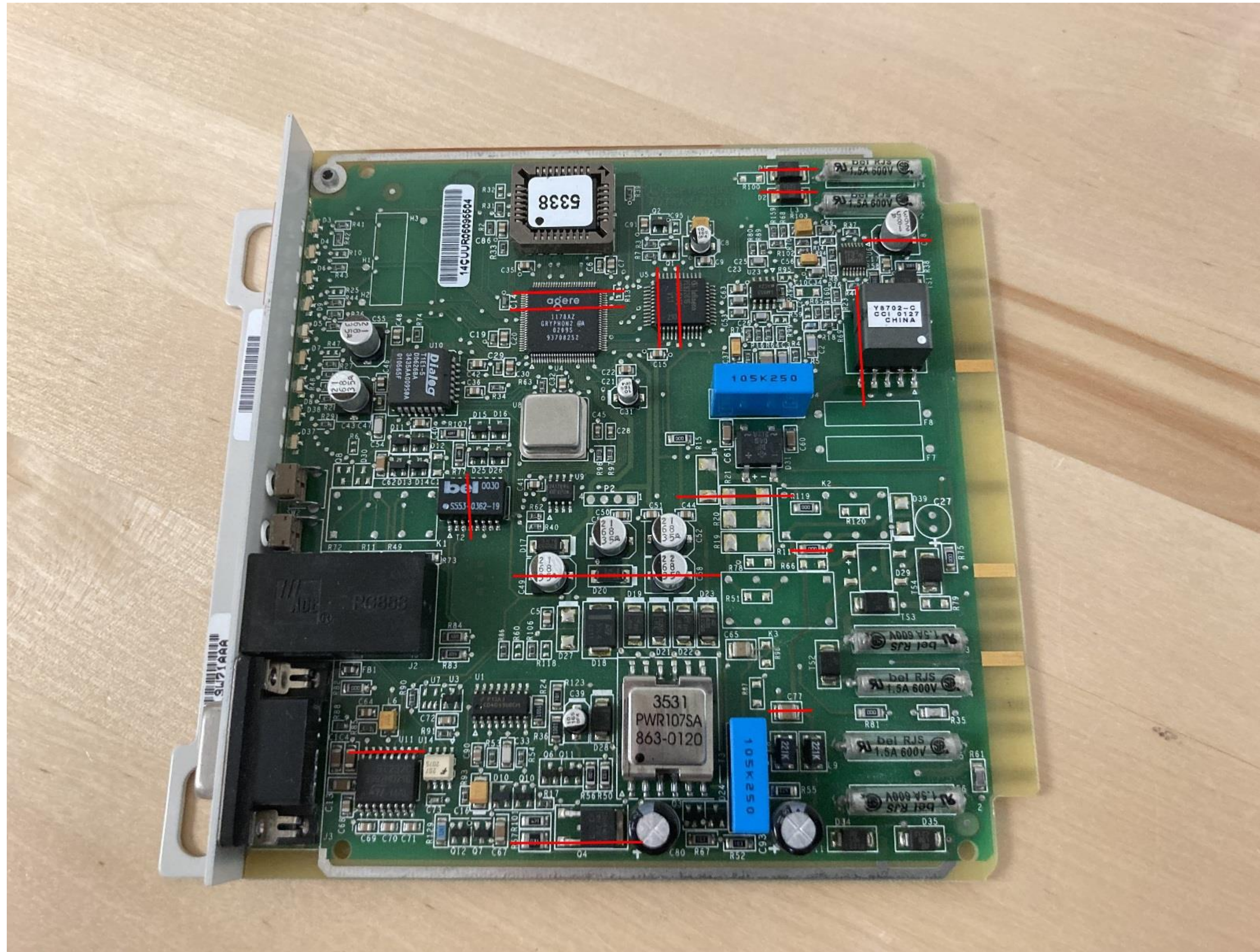

Figure 1. Customer provided sampling plan, top side. The red lines indicate the cross section planes. This is an example sampling plan and not a depiction of the example images in this report beyond Figure 2.

Figure 2. Specimen 4LP1 Board overview, top side.

Figure 3. Specimen 4LP1 Visual inspection. Corroded magnesium BNC connector mounting stud.

Figure 4. Specimen 4LP1 Visual inspection. Cracked solder visible beneath the component housing.

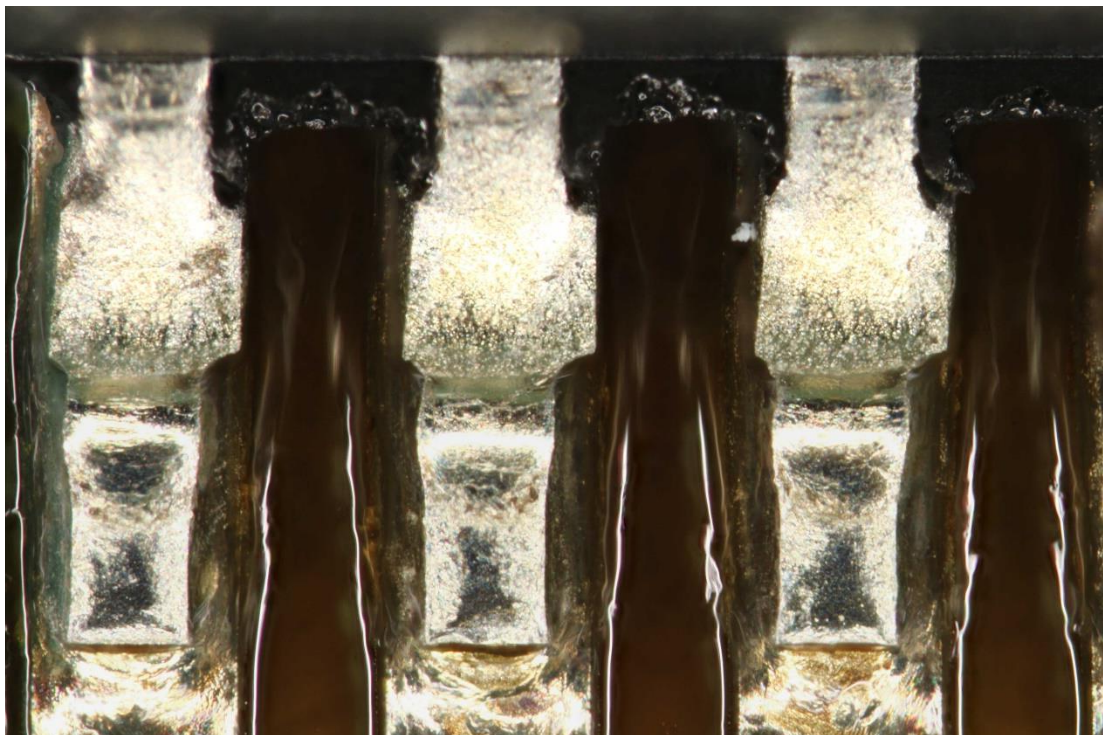

Figure 5. Specimen 4LP1 IC4 Visual whisker inspection. The visual inspection located the whisker that is shown in the next image.

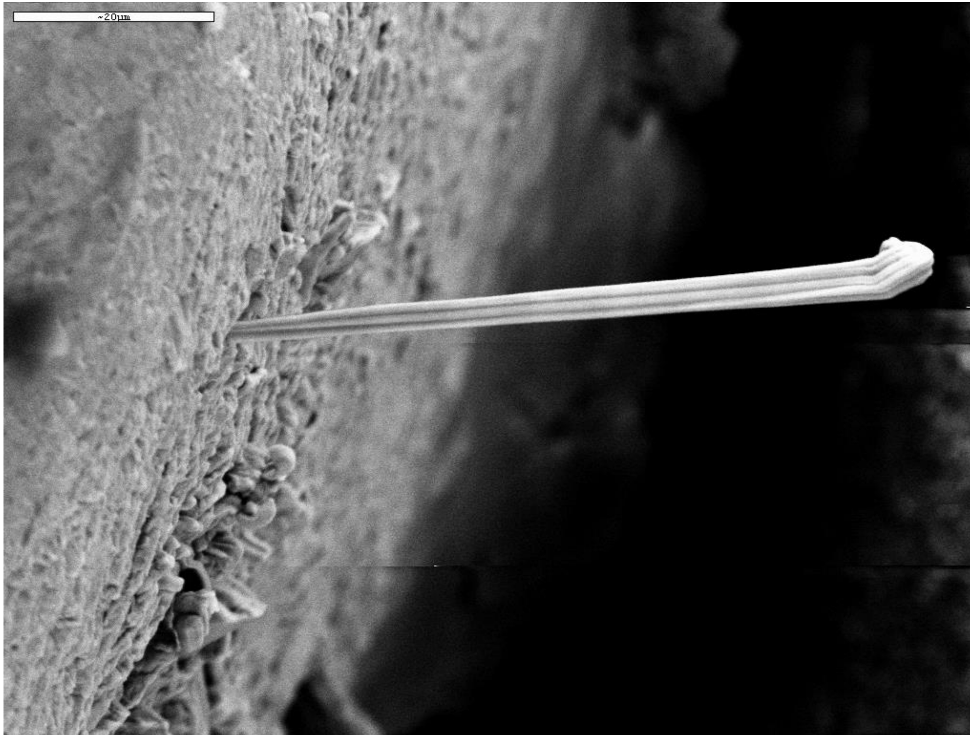

Figure 6. Specimen 4LP1 IC4 SEM whisker inspection. This whisker was observed on the leads of IC4.

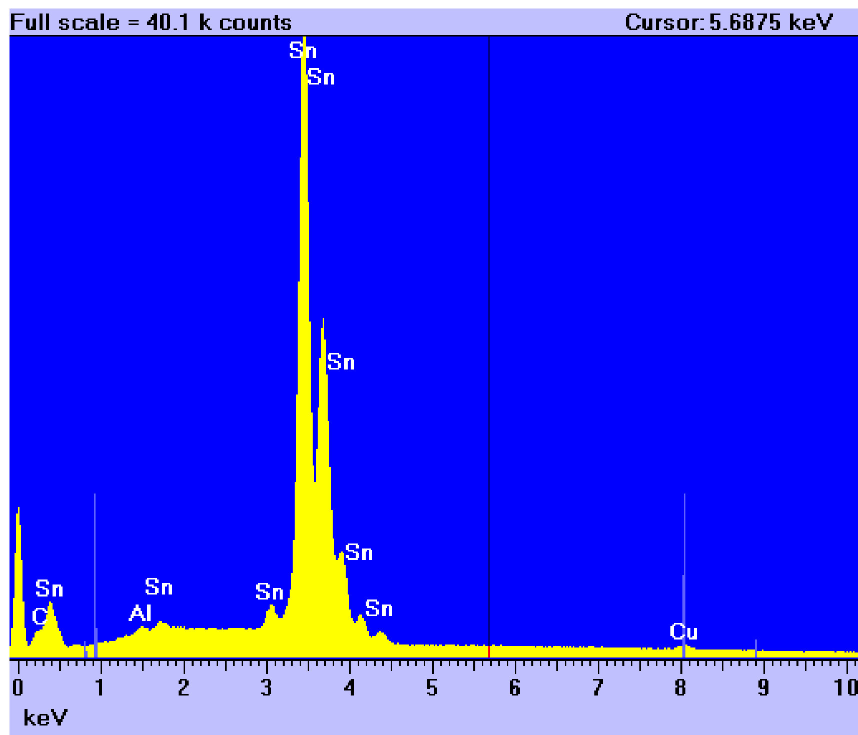

Figure 7. Specimen 4LP1 Spectrum of the tin whisker that is shown in Figure 6. This spectrum confirms the whisker is pure tin.

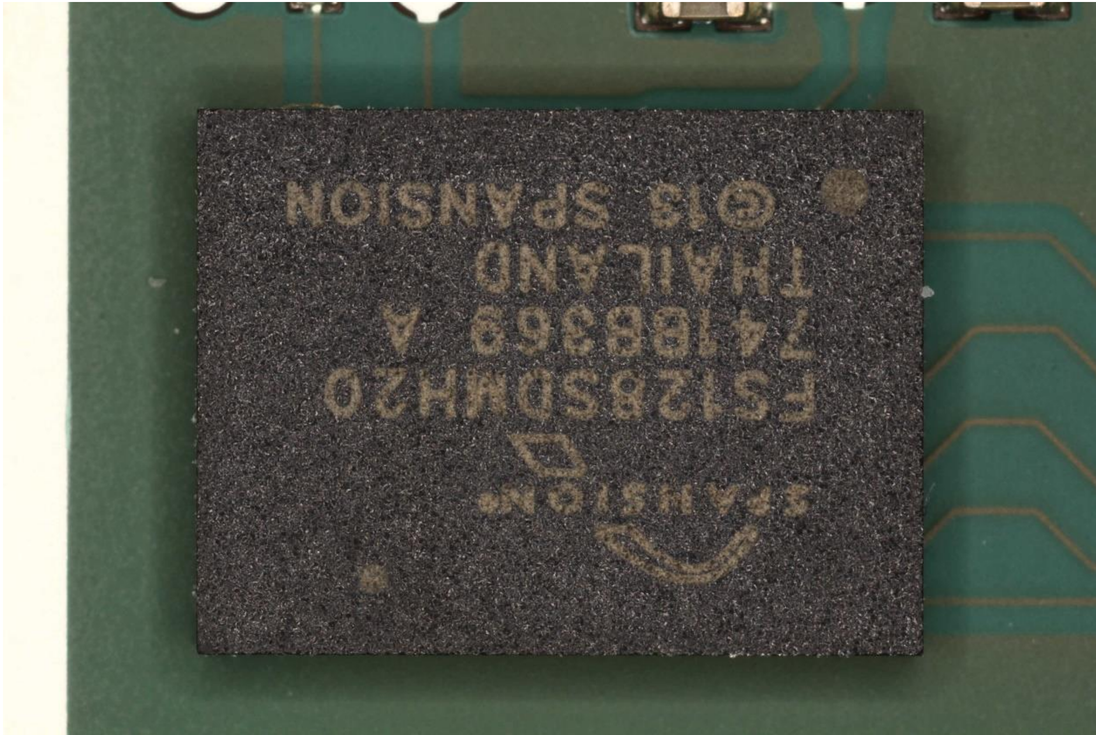

Figure 8. Dye & Pull Sequence. Specimen 4LP1 IC2 Target component overview.

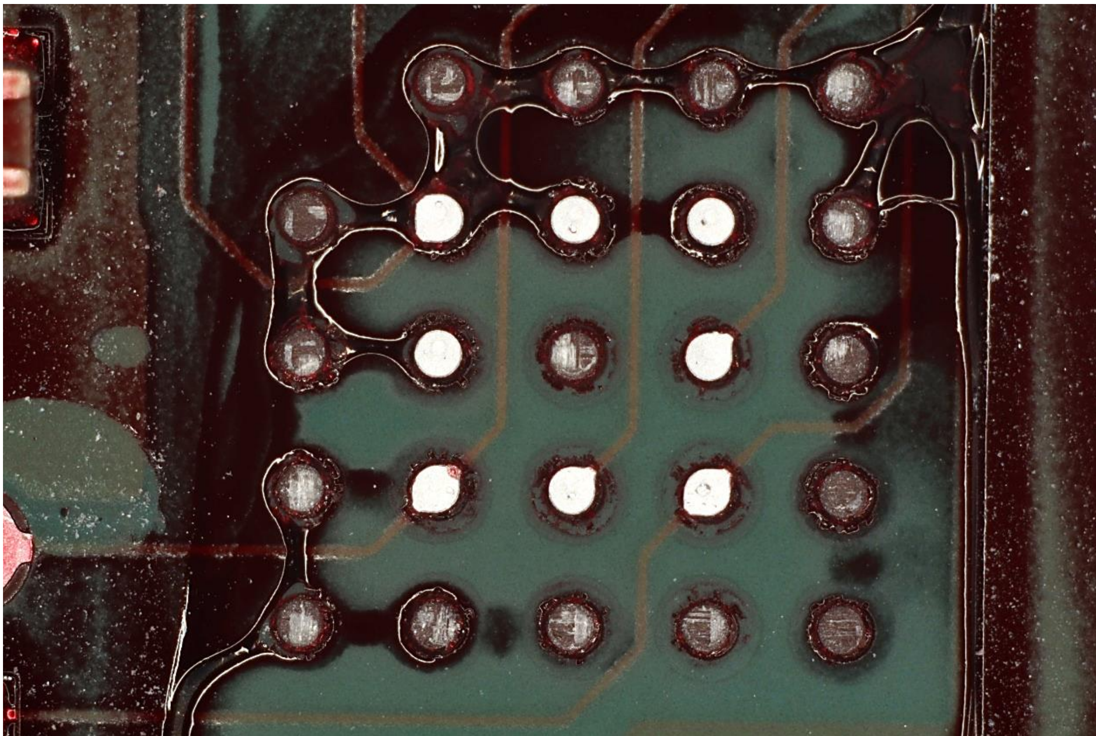

Figure 9. Specimen 4LP1 IC2 Board side solder balls.

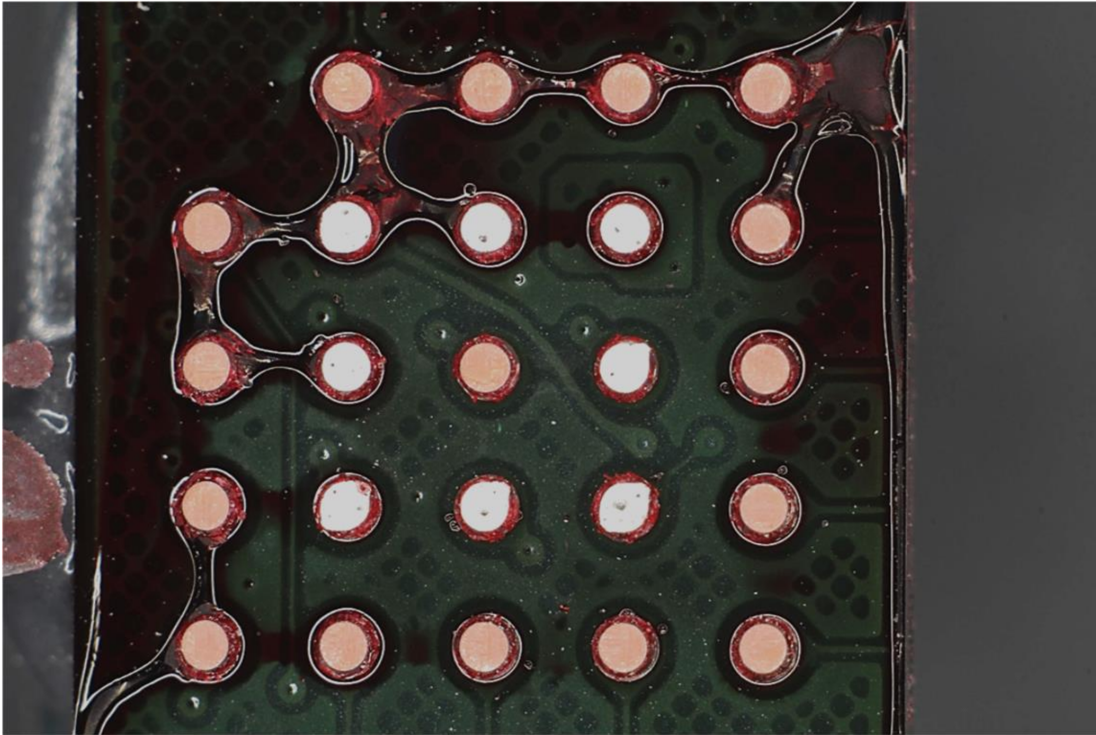

Figure 10. Specimen 4LP1 IC2 Chip side solder balls.

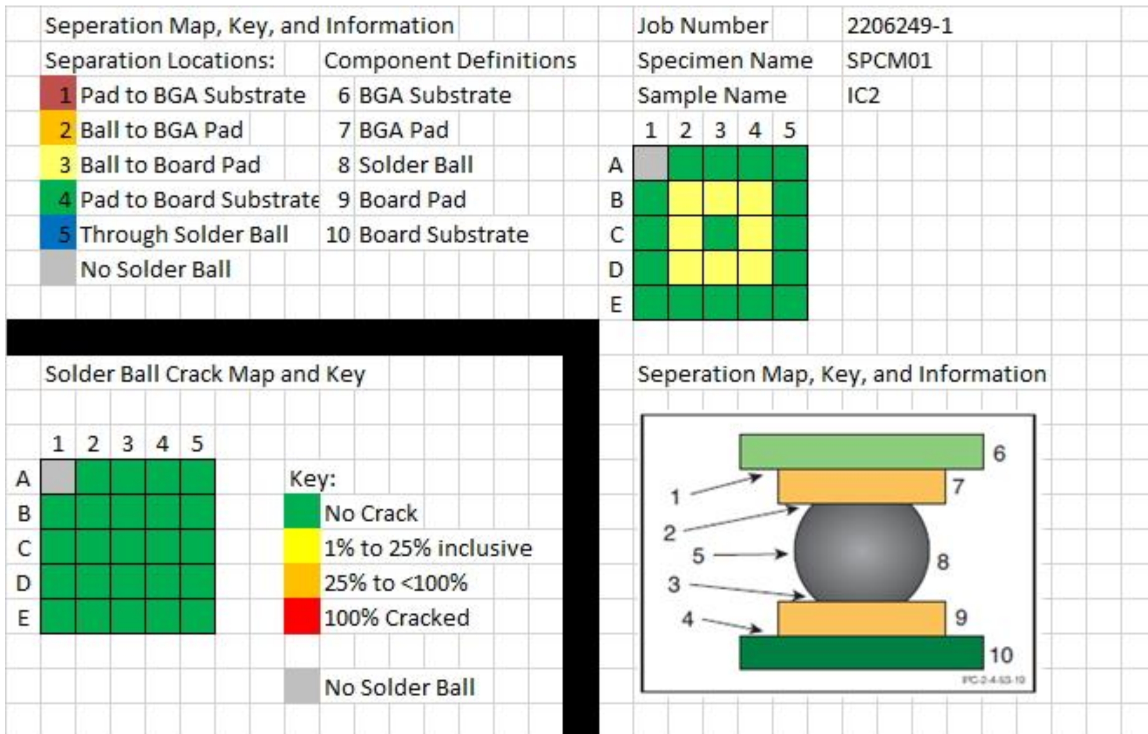

Figure 11. Specimen 4LP1 IC2 Crack and separation Map.

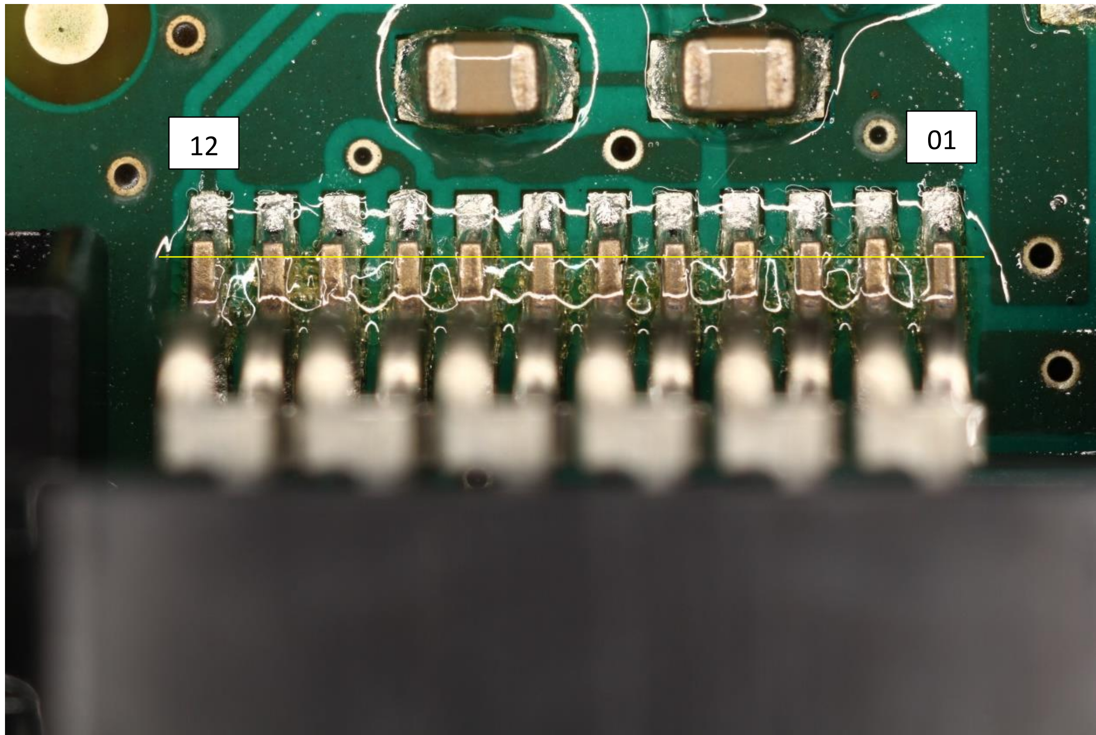

Figure 12. Cross Section and IMC/SEM Sequence. Specimen 4LP1 J4 Component overview. The yellow line indicates the cross section plane.

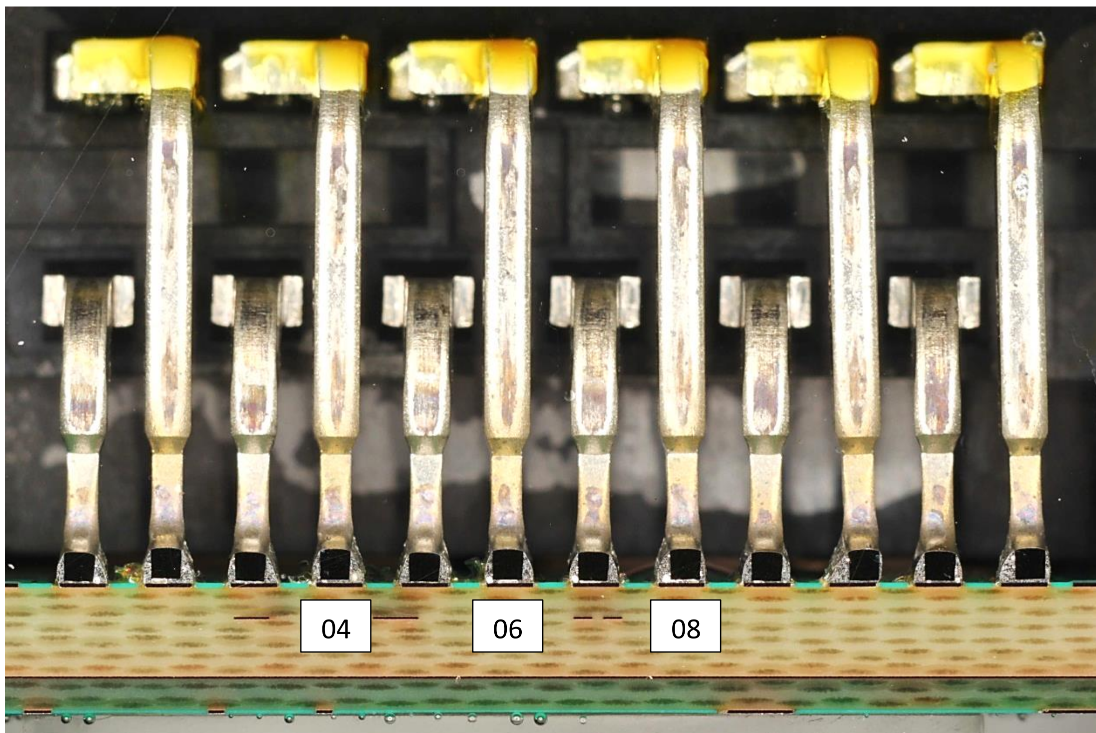

Figure 13. Specimen 4LP1 J4 Cross section overview.

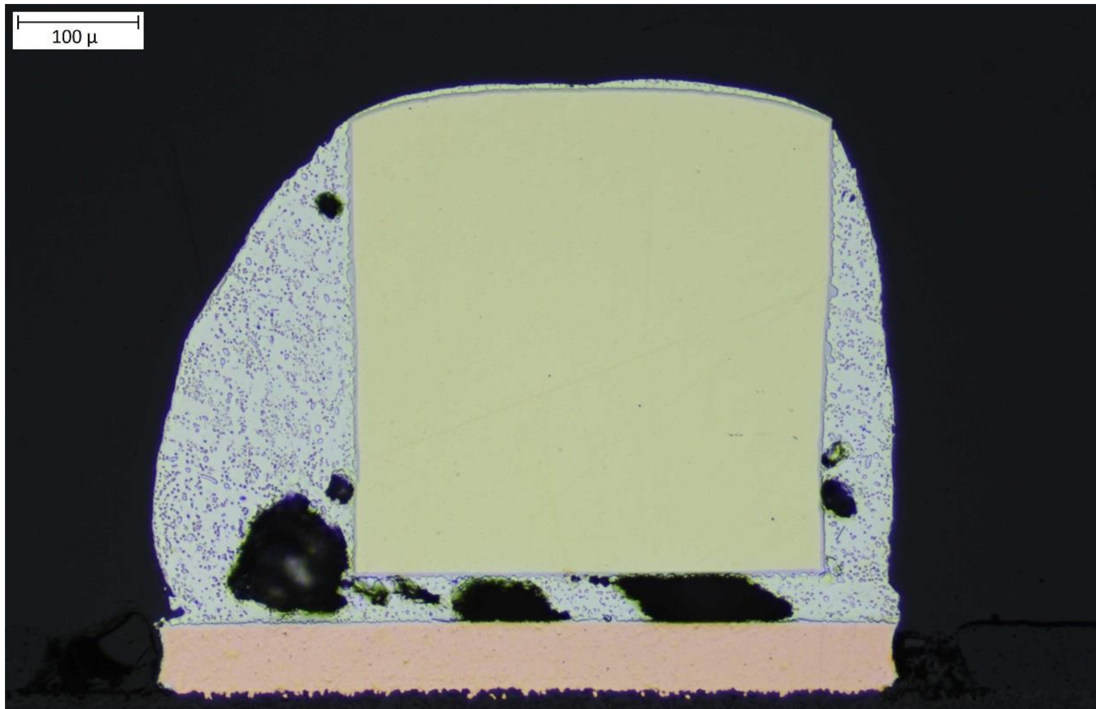

Figure 14. Specimen 4LP1 J4 leg 08. This solder joint's cross-sectional area is 19.6% void.

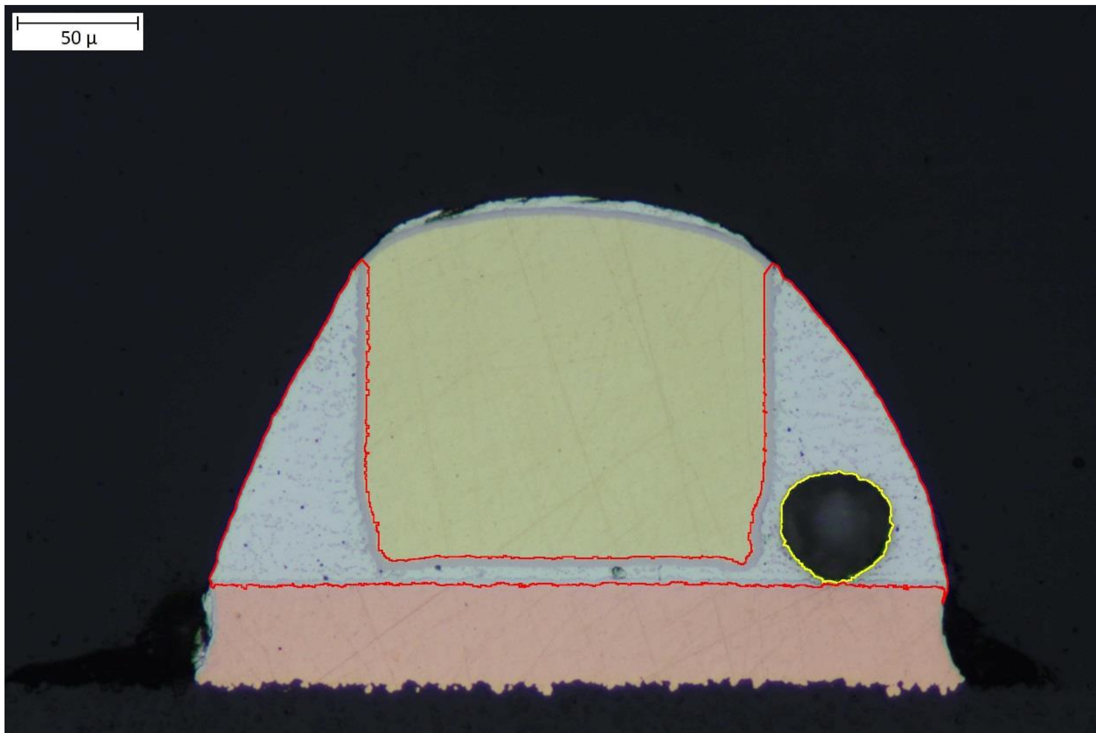

Figure 15. Specimen 4LP1 J4 Leg 04. This solder joint's cross-sectional area is 12.9% void. The solder joint is outlined in red and the solder voids are outlined in yellow to demonstrate Elmet's void measurement procedure. Outlines are not typically included in reports. See Figures 14 and 31 for typical examples.

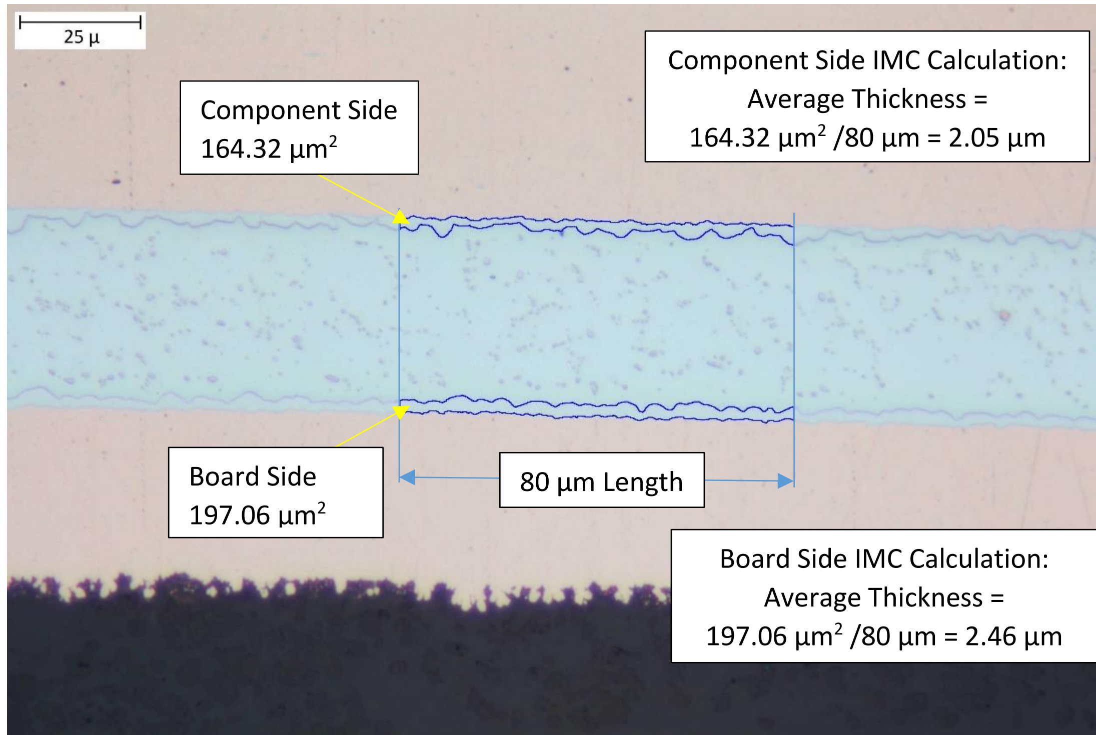

Figure 16. Specimen 4LP1 J4 Leg 04. Optical IMC measurement. The outlines are 80 microns in length.

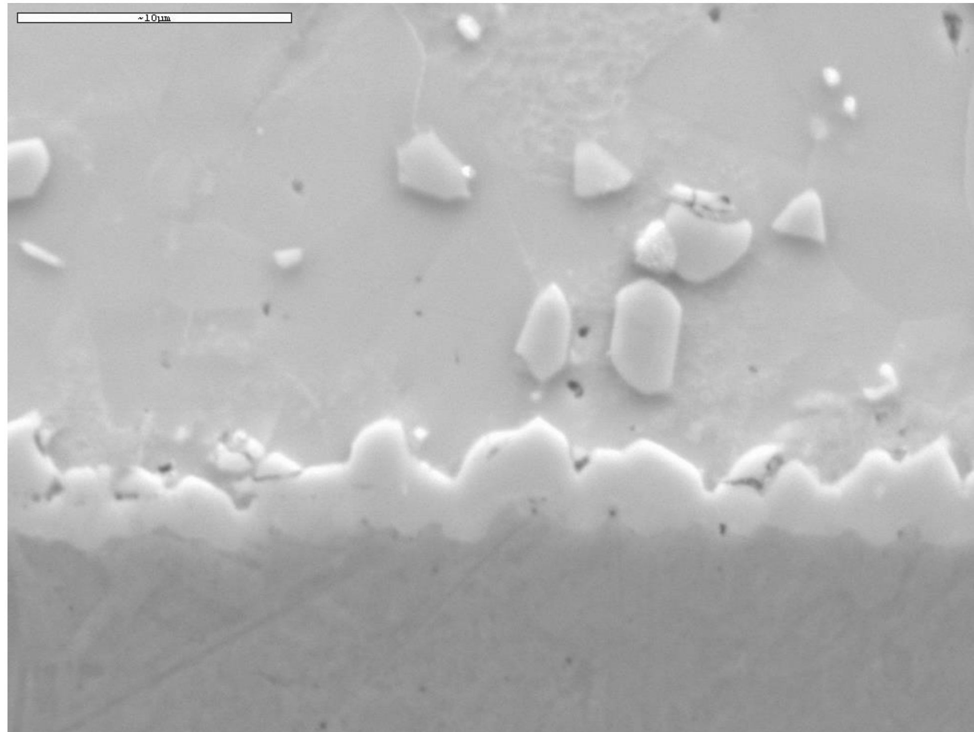

Figure 17. Specimen 4LP1 J4 Leg 06. SEM IMC measurement, solder to board. Elmet averages the IMC layer thickness in 6 locations to obtain an IMC thickness value. This IMC layer thickness averages 2.84 microns.

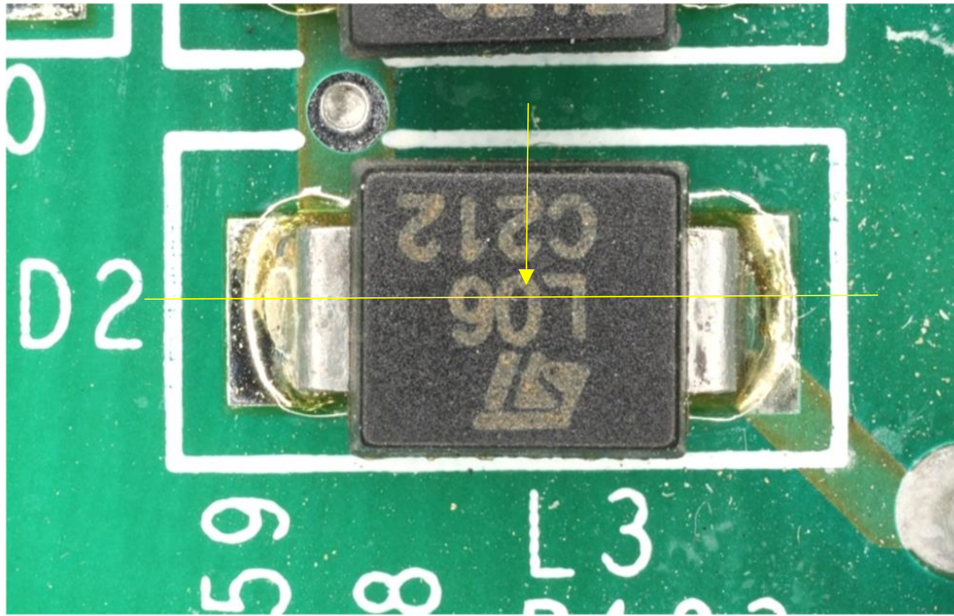

Figure 18. Specimen 4LP1 D2 Component overview. The yellow line indicates the cross section plane. The yellow arrow indicates the grind and viewing direction.

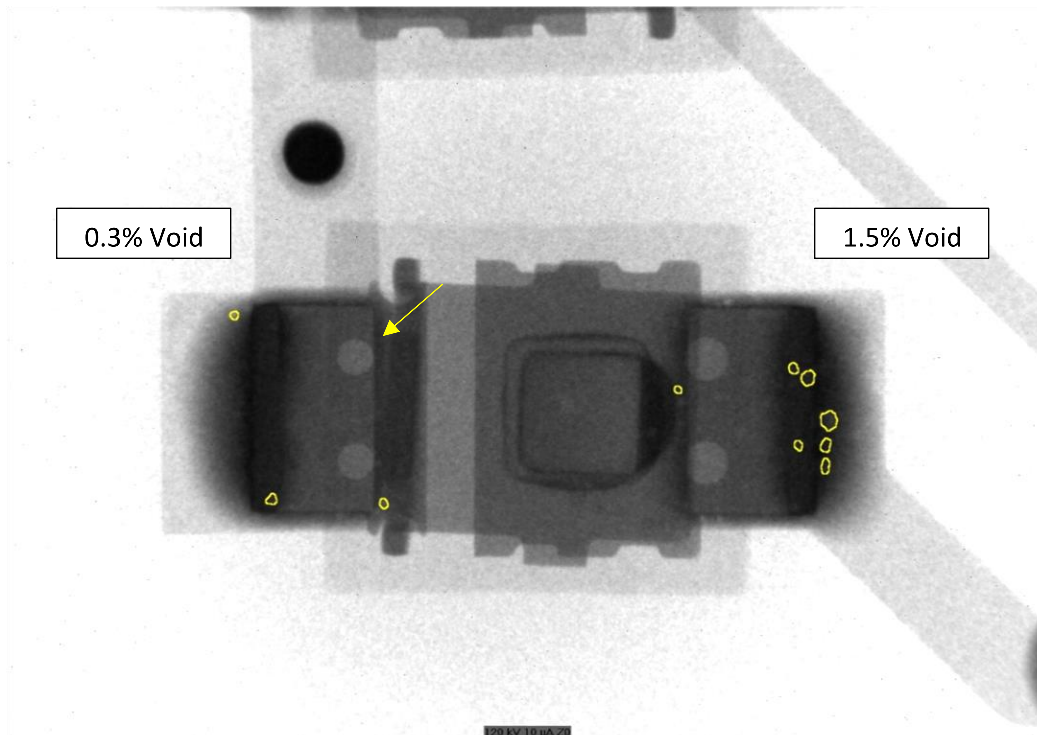

Figure 19. Specimen 4LP1 D2 X-ray. The yellow circles are voids. The four circles that are not outlined, such as the one indicated by the yellow arrow, and internal features of D2 and not voids.

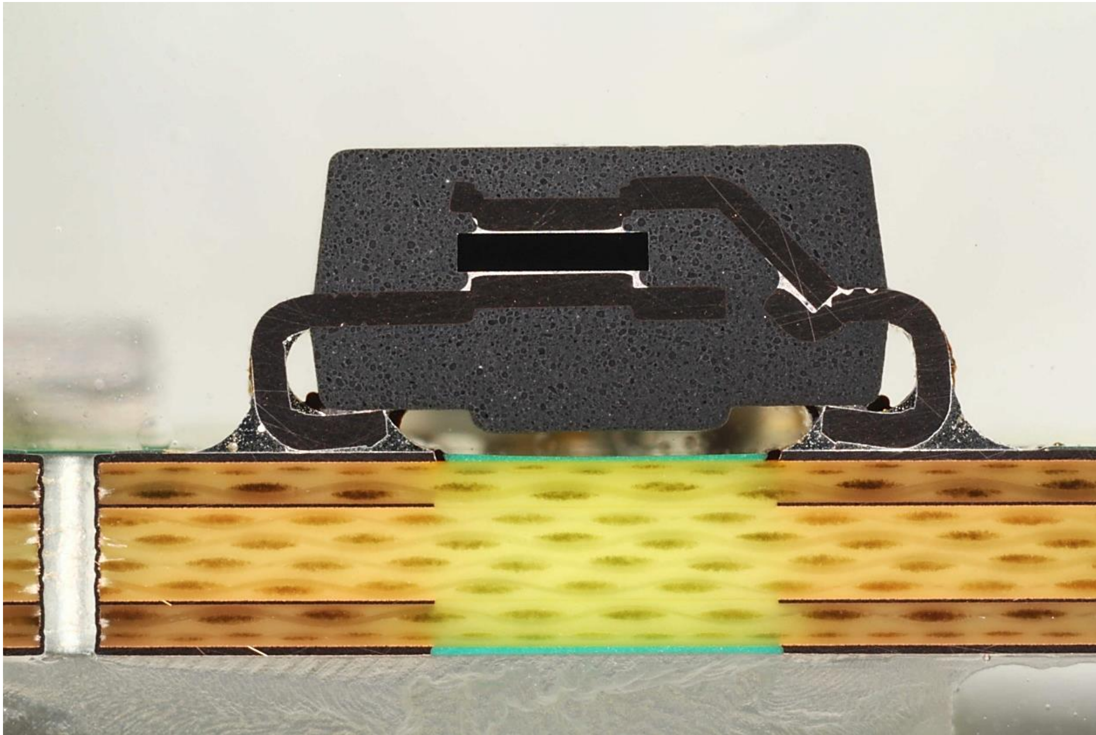

Figure 20. Specimen 4LP1 D2 Cross section overview.

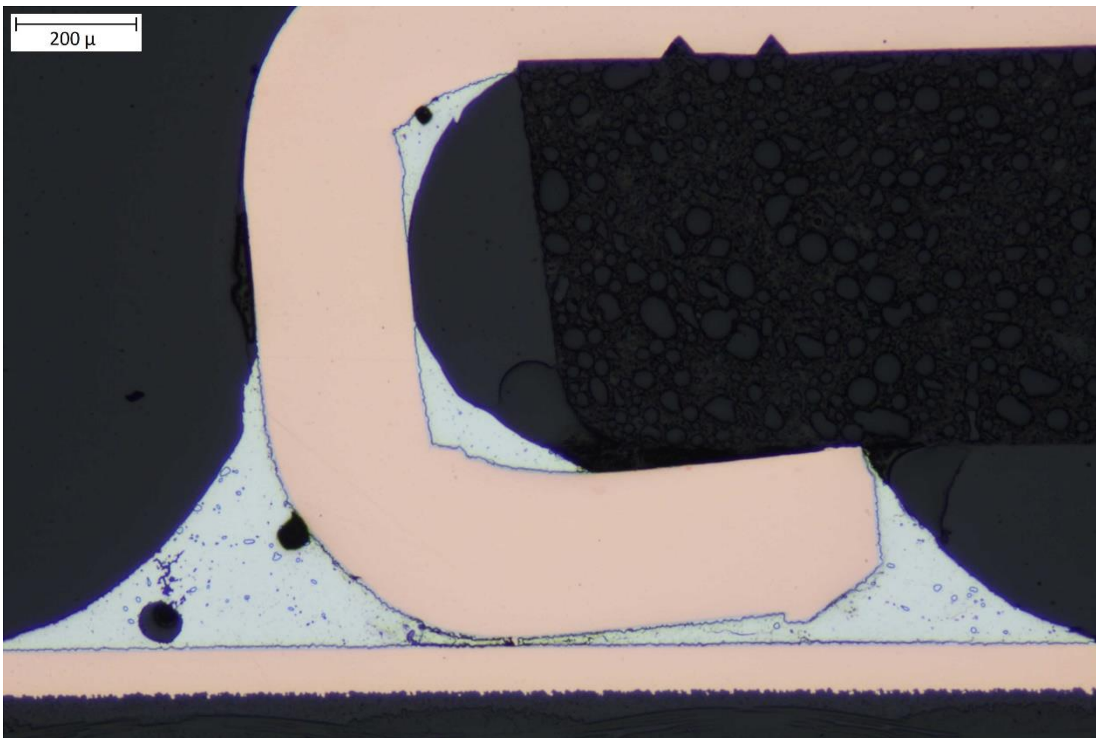

Figure 21. Specimen 4LP1 D2.

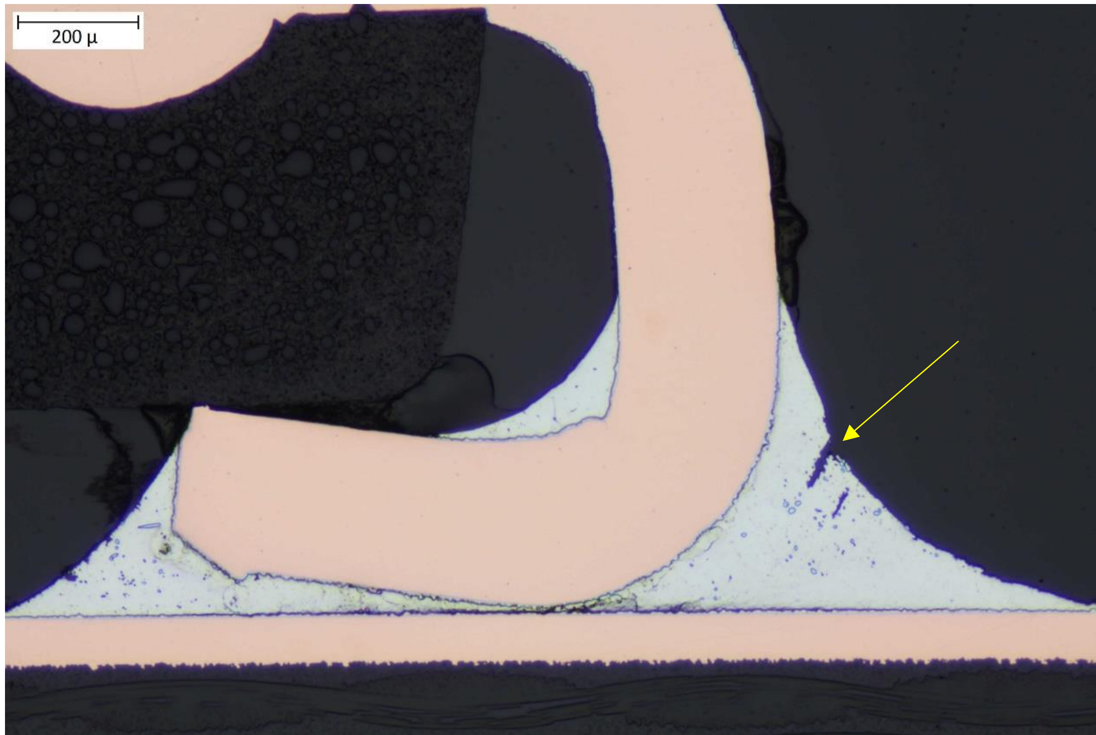

Figure 22. Specimen 4LP1 D2. The yellow arrow points to a hot tear. Hot tears are not cracks.

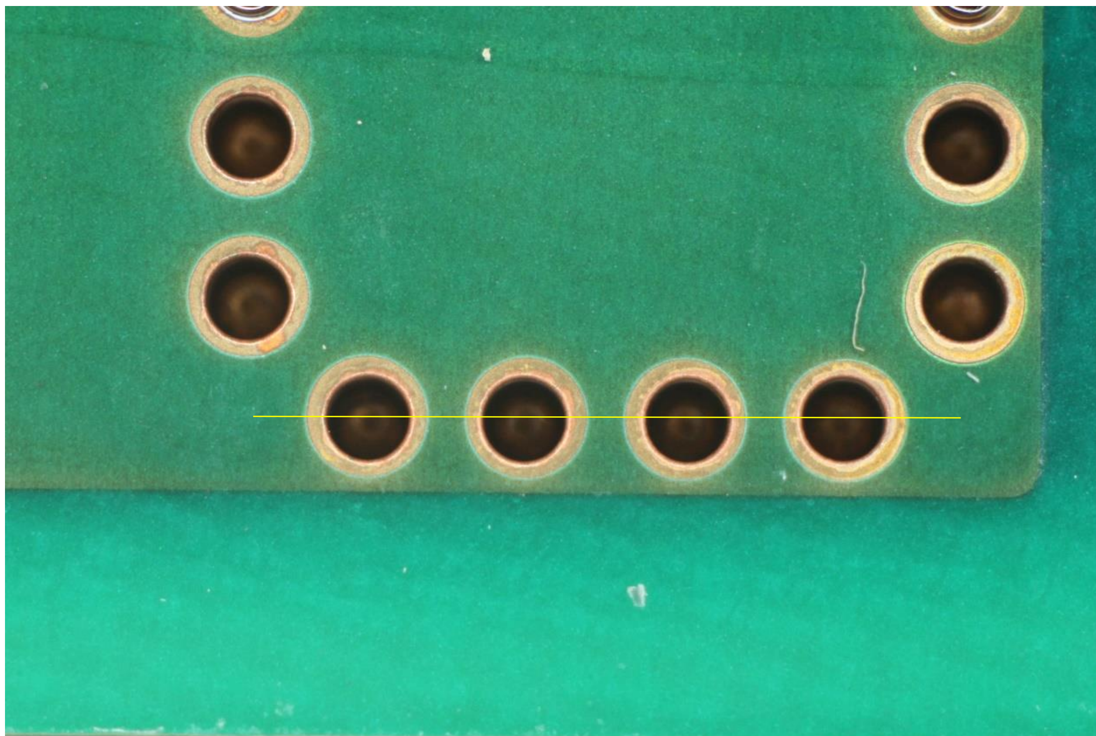

Figure 23. Via Sequence. Specimen 4LP1 Vias Component overview. The yellow line indicates the cross section plane.

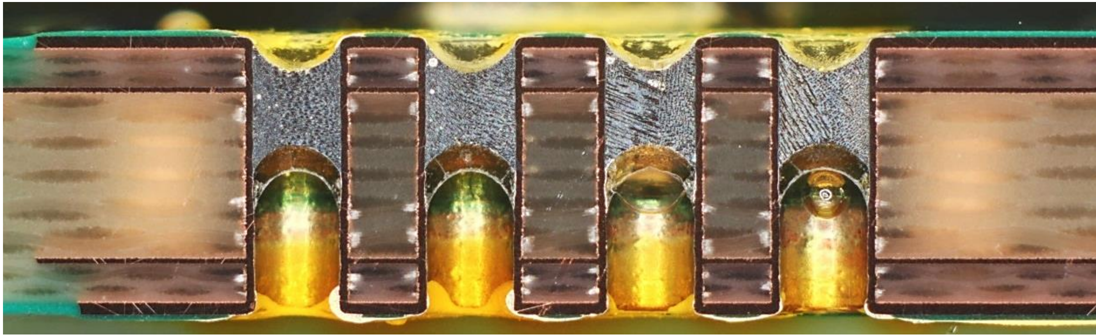

Figure 24. Specimen 4LP1 Vias Cross section overview.

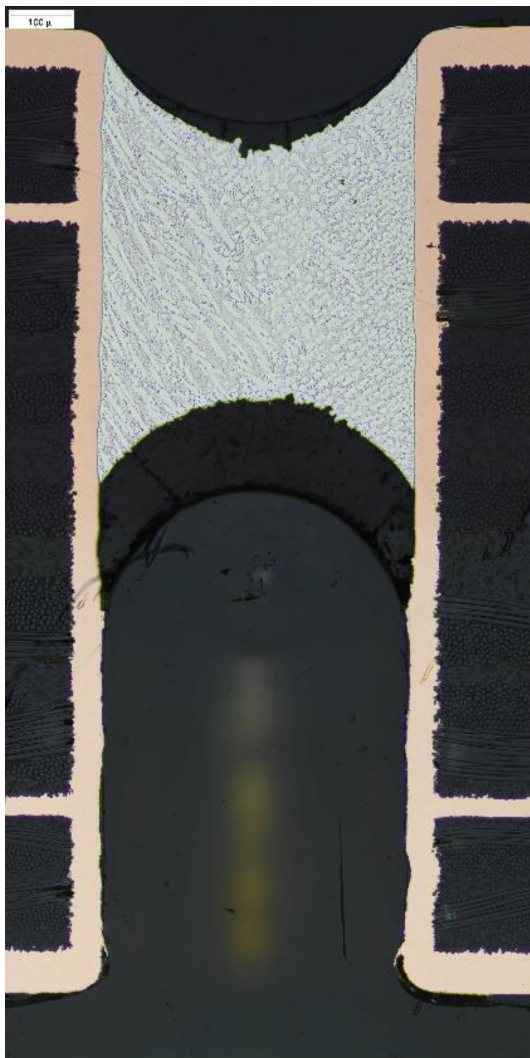

Figure 25. Specimen 4LP1 Vias. No plating cracks, no voids, no nodules, no intrusions. Reasonably uniform plating thickness.

Figure 26. 103 Specimen 4LP1 Vias. No plating cracks, no voids, no nodules, no intrusions. Reasonably uniform plating thickness.

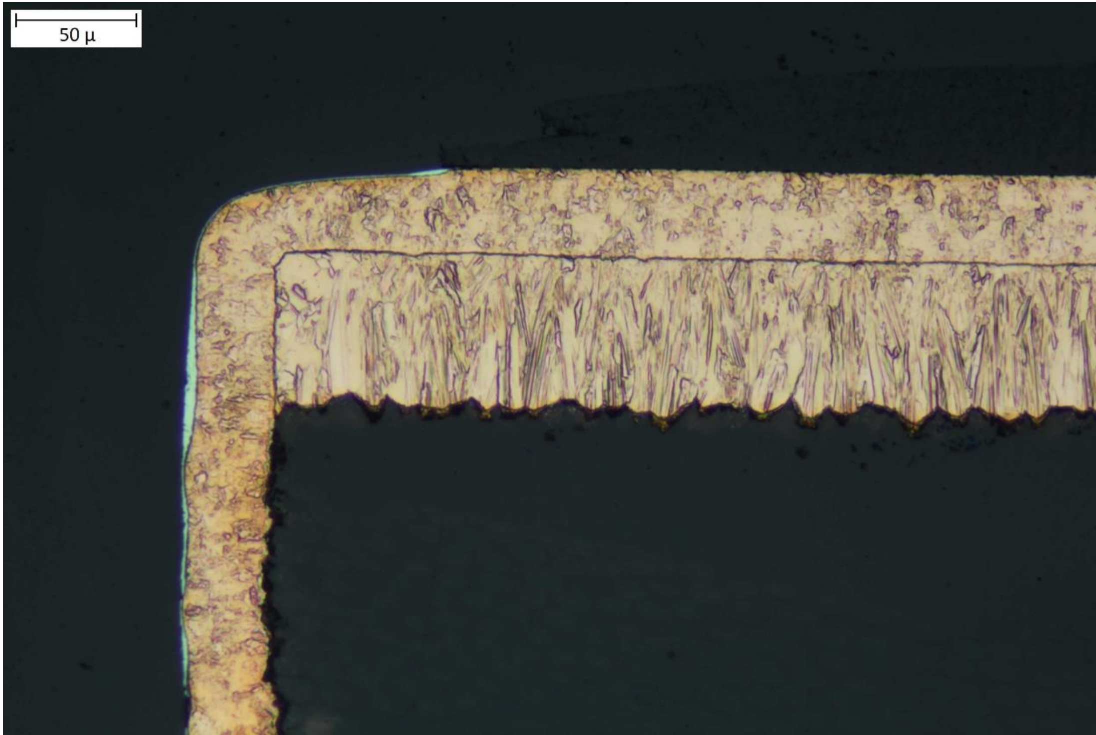

Figure 27. Specimen 4LP1 Vias. Etched to show the multiple copper layers that comprise the via.

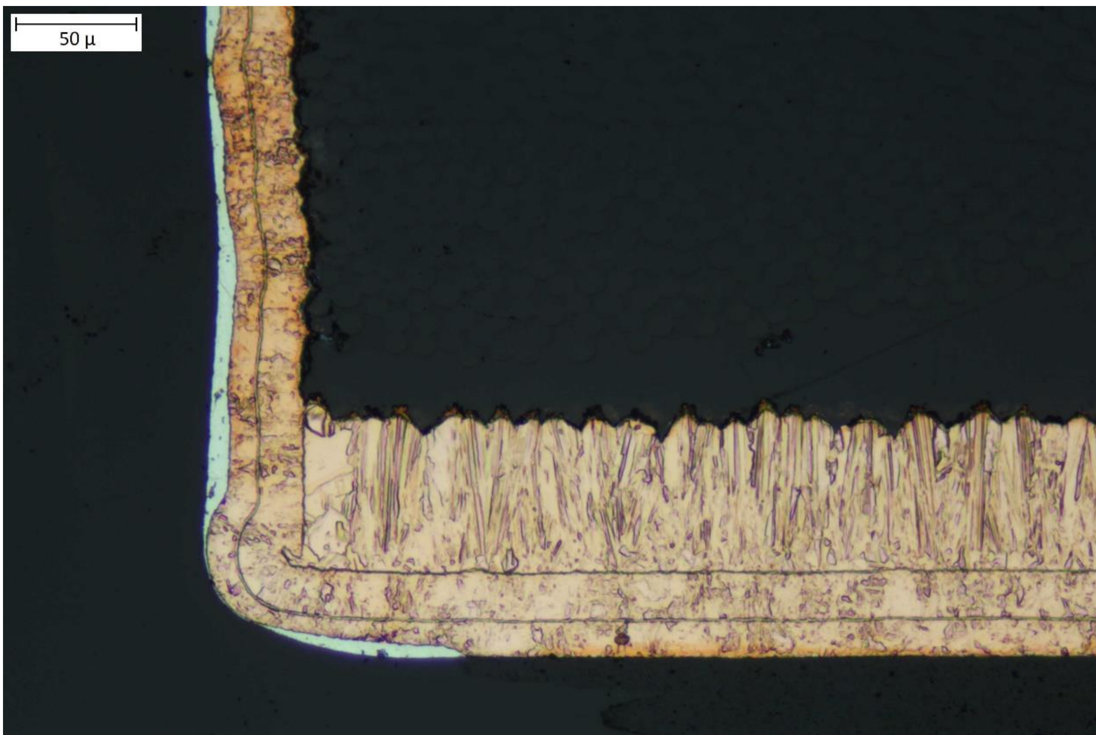

Figure 28. Specimen 4LP1 Vias. Etched to show the multiple copper layers that comprise the via.

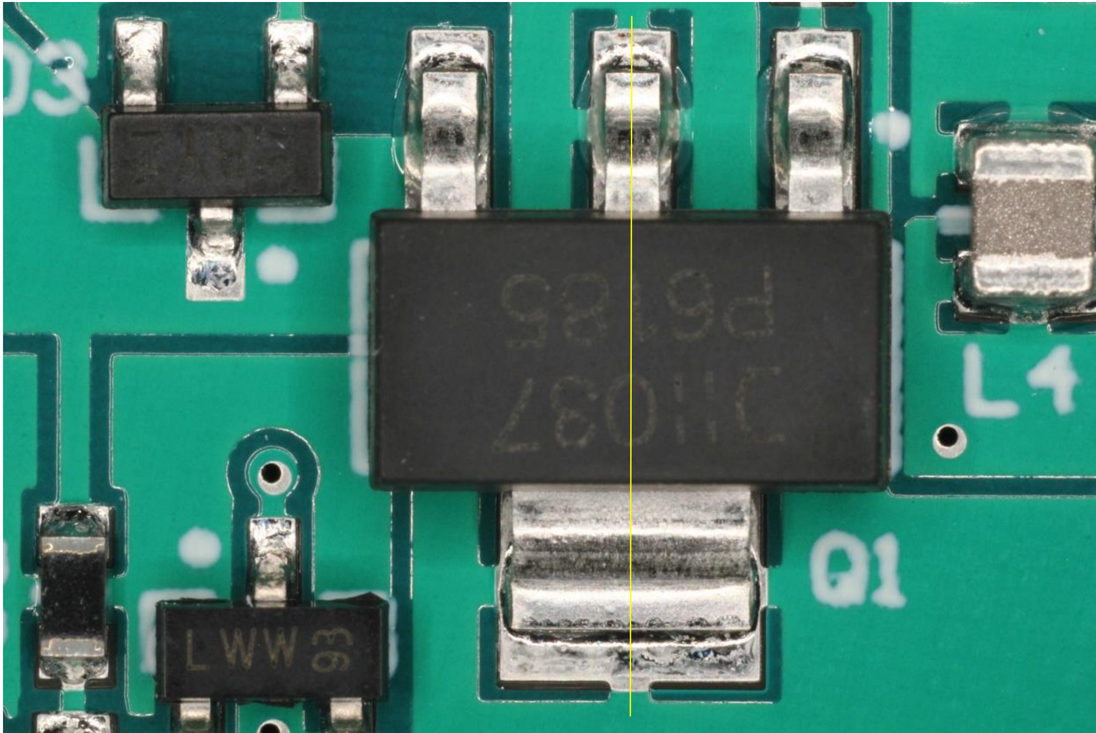

Figure 29. Brightfield/Darkfield Sequence. Specimen 4LP1 T101 Component overview. The yellow line indicates the cross section plane.

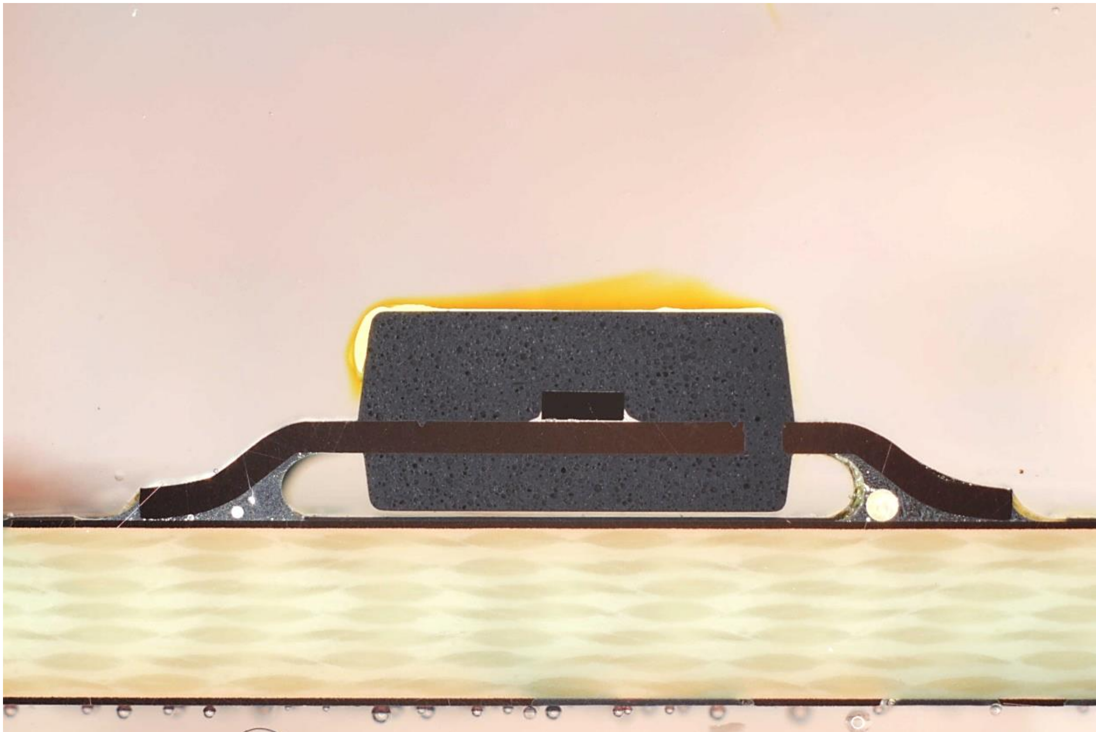

Figure 30. Specimen 4LP1 T101 Cross section overview.

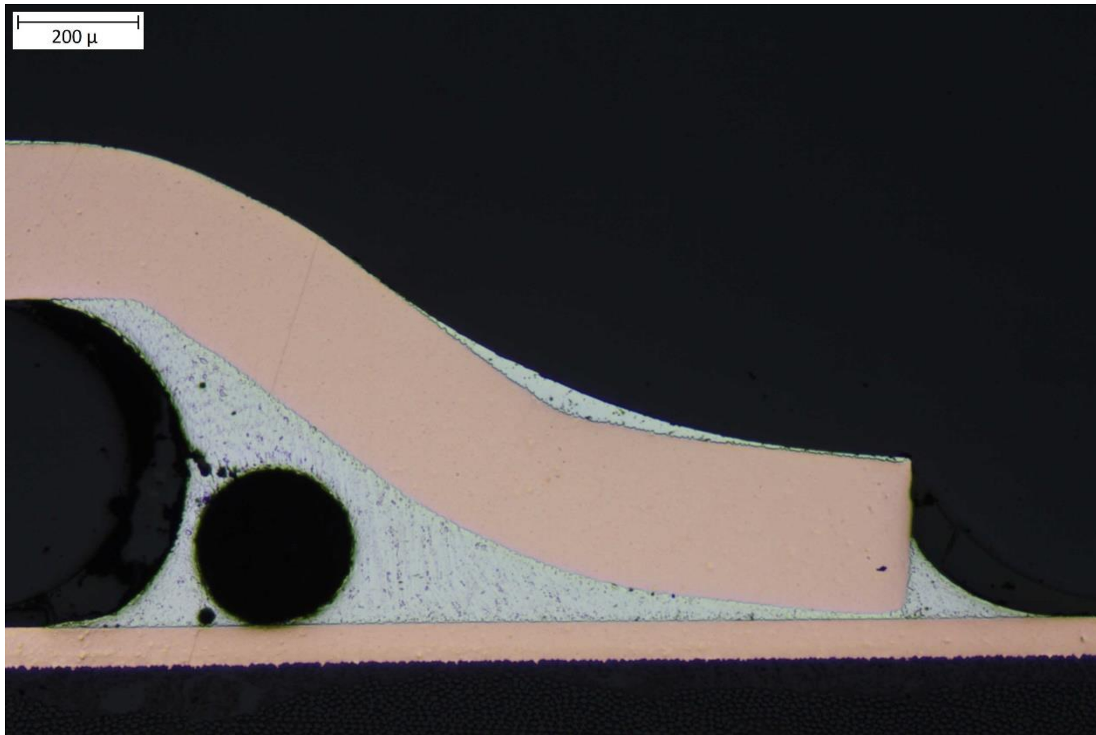

Figure 31. Specimen 4LP1 T101. This solder joint's cross-sectional area is 27.1% void. Typical Brightfield image used for most inspection work and reporting. Compare with Figure 32.

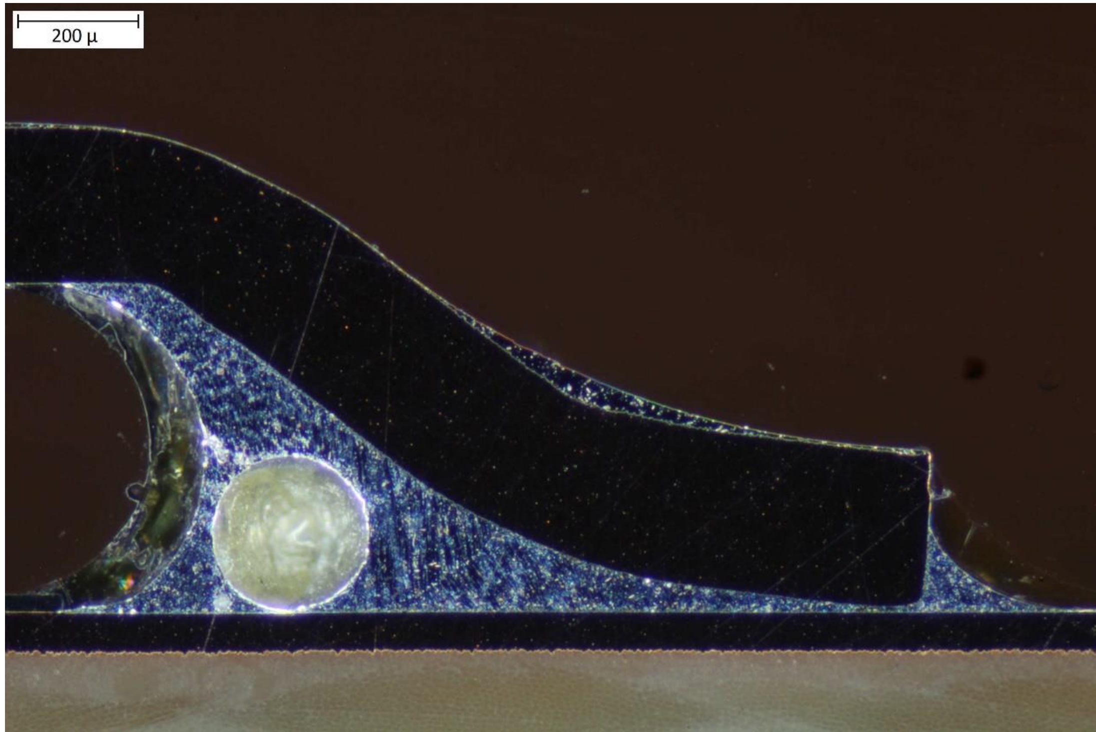

Figure 32. Specimen 4LP1 T101. Darkfield image. Darkfield imaging can reveal features not visible in brightfield. Compare with Figure 31.

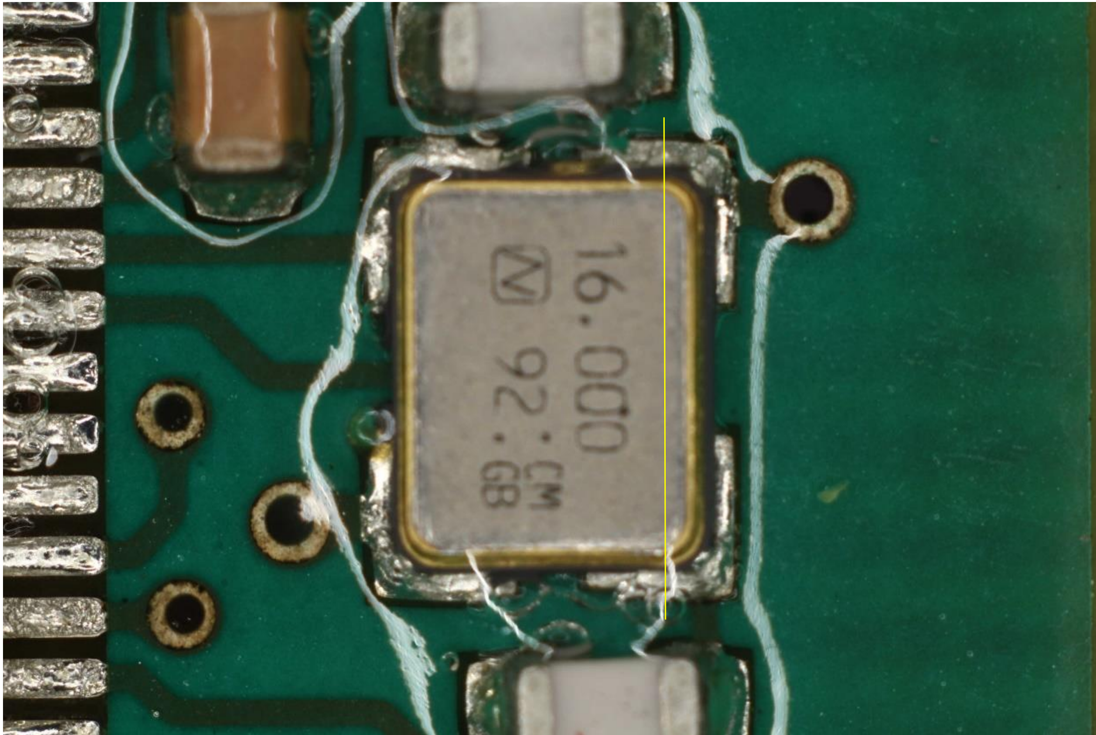

Figure 33. Specimen 4LP1 D313 Component overview. The yellow line indicates the cross section plane.

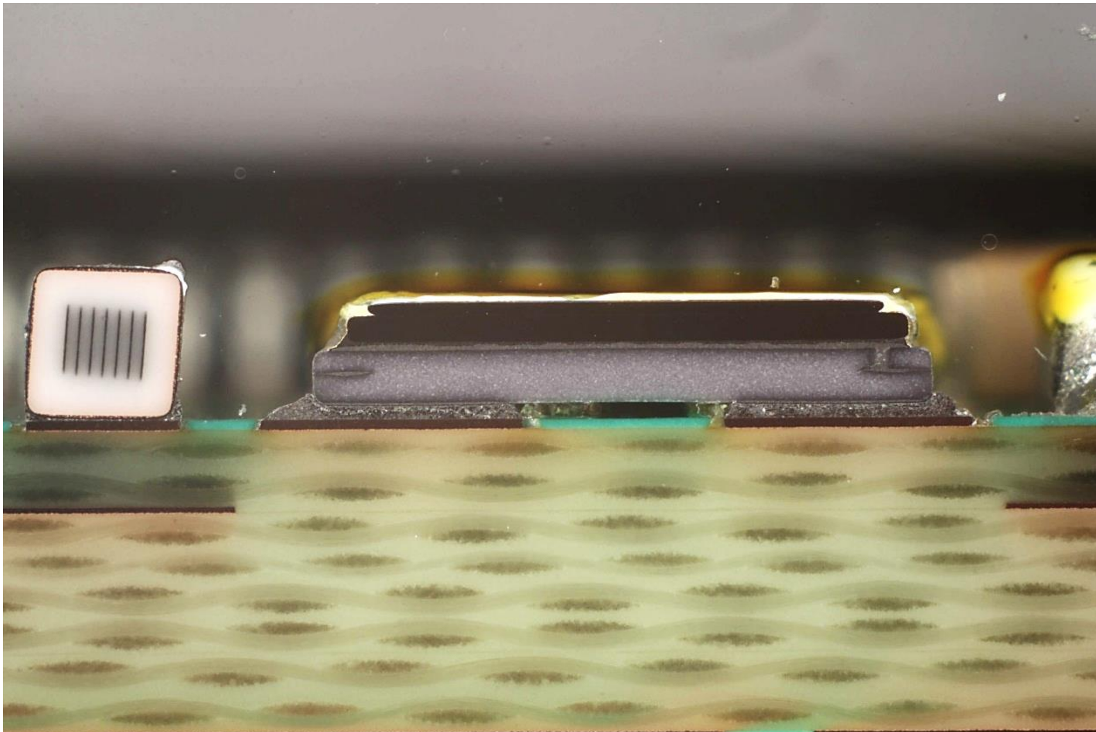

Figure 34. Specimen 4LP1 D313 Pin 1 Cross section overview.

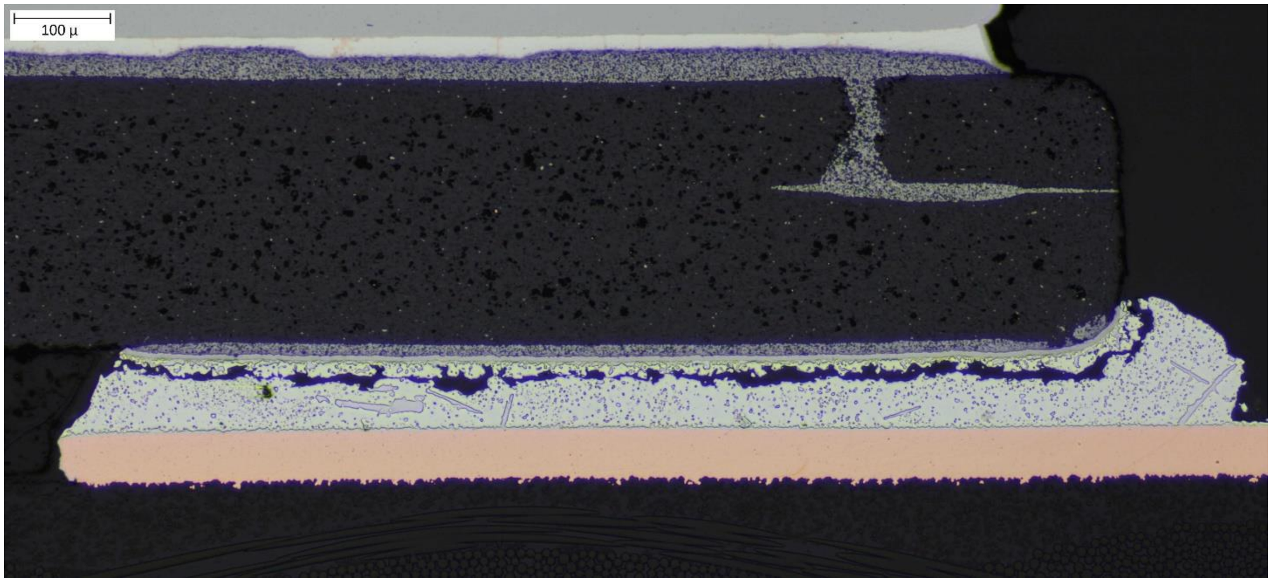

Figure 35. Specimen 4LP1 D313 Pin 1. This solder joint is 100% cracked.

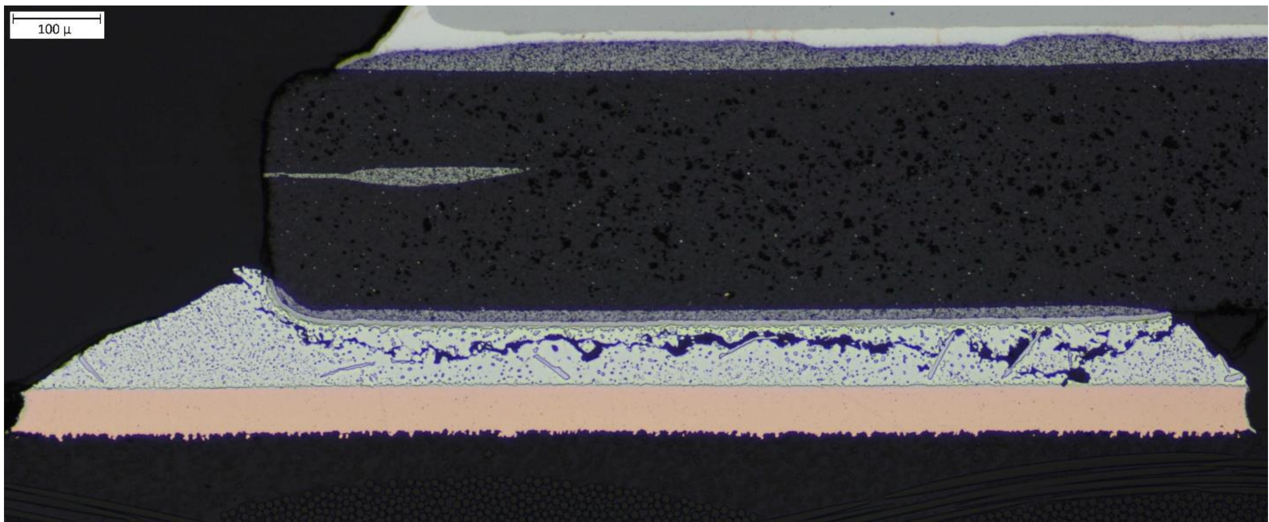

Figure 36. Specimen 4LP1 D313 Pin 2. This solder joint is 99.4% cracked.

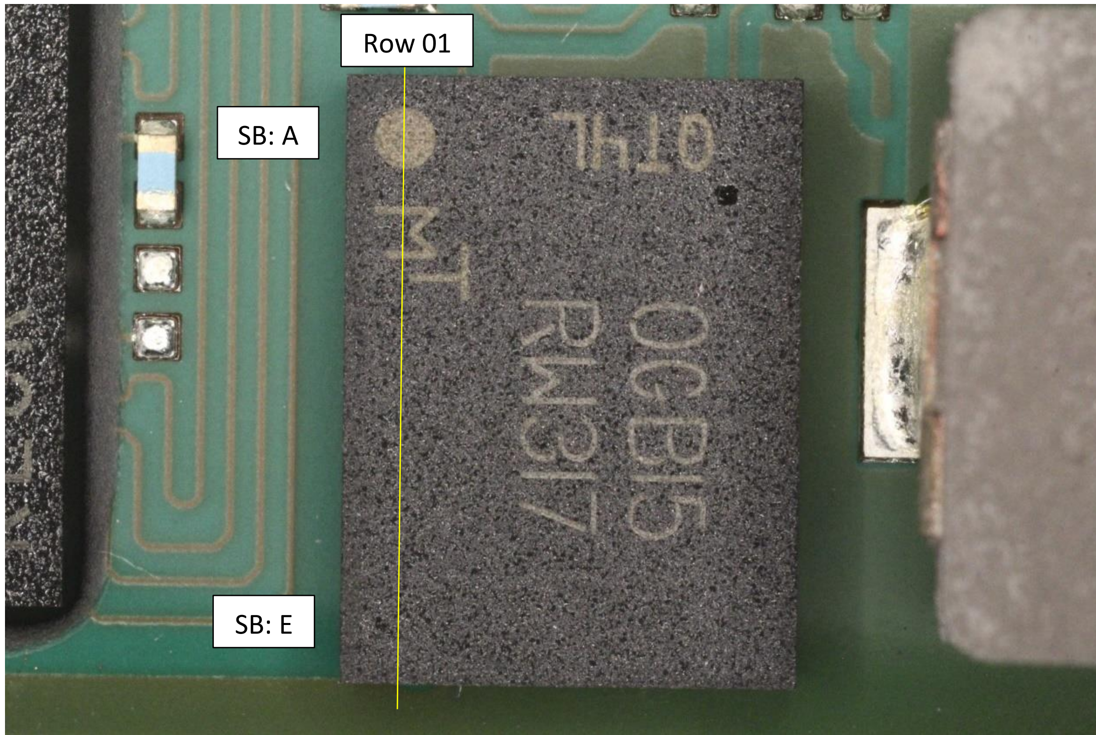

Figure 37. BGA Sequence. Specimen 4LP1 IC3 Component overview. The yellow line indicates the cross section plane.

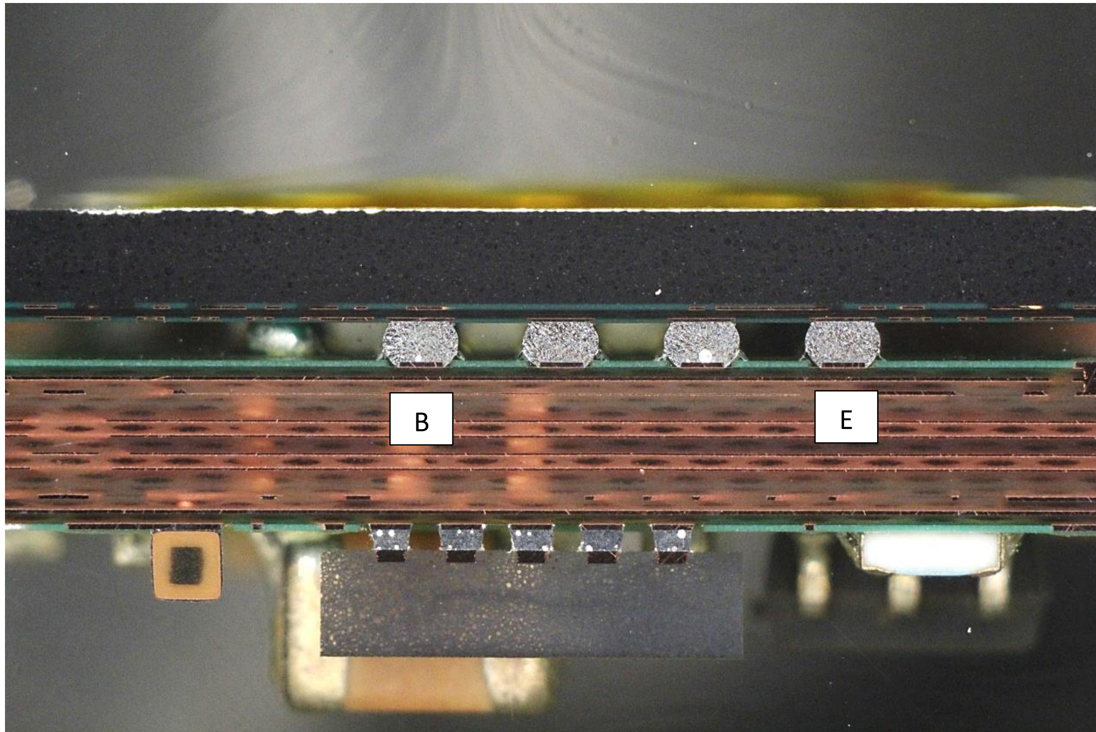

Figure 38. Specimen 4LP1 IC3 Row 01 Cross section overview. Solder ball A is not populated on the first row of the BGA.

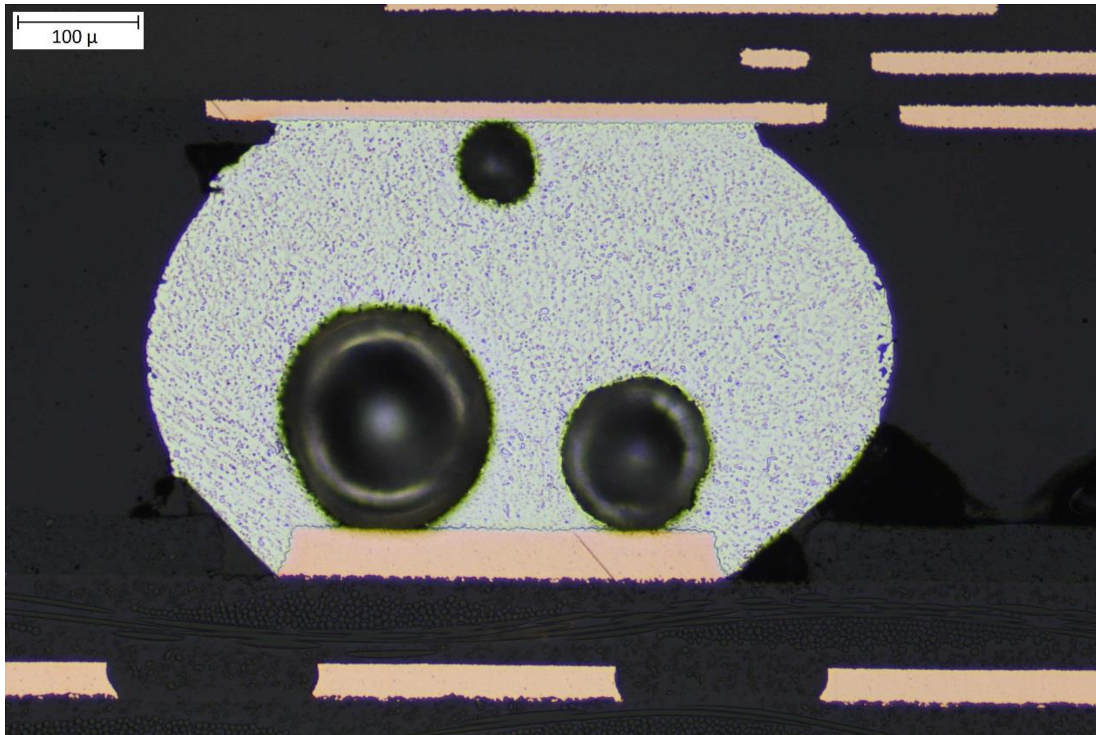

Figure 39. Specimen 4LP1 IC3 Row 01 Solder ball B. This solder joint's cross-sectional area is 22.8% void.

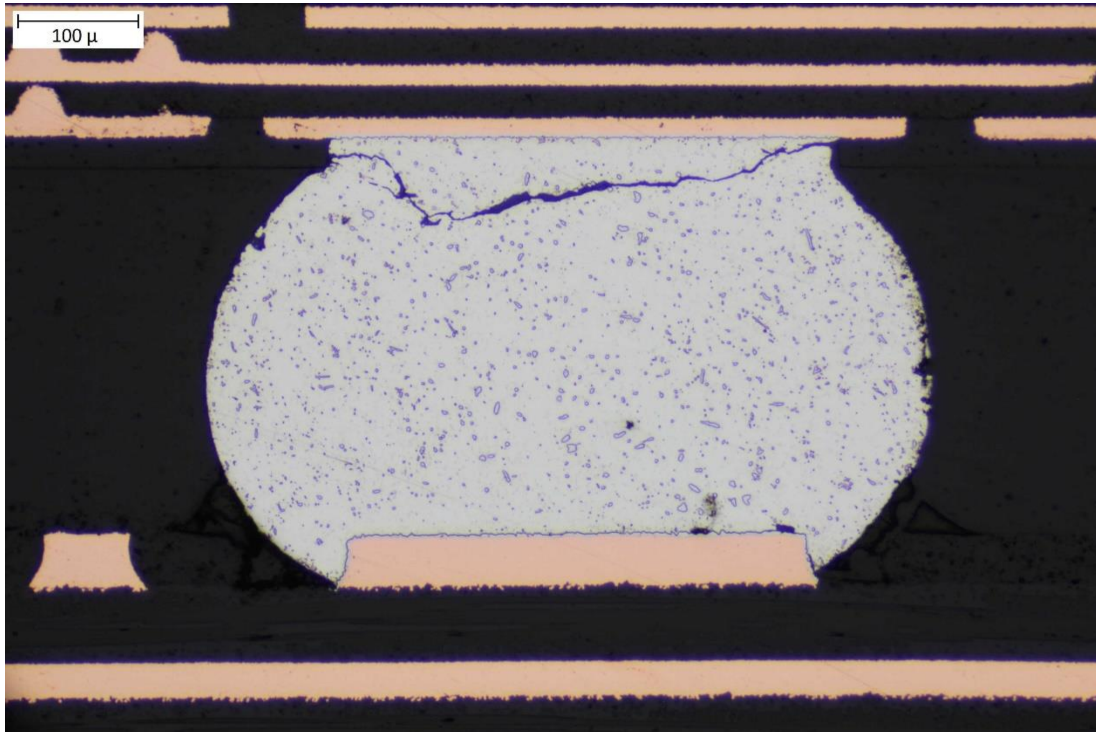

Figure 40. Specimen 4LP1 IC3 Row 01 Solder ball E. This solder joint is 100% cracked.

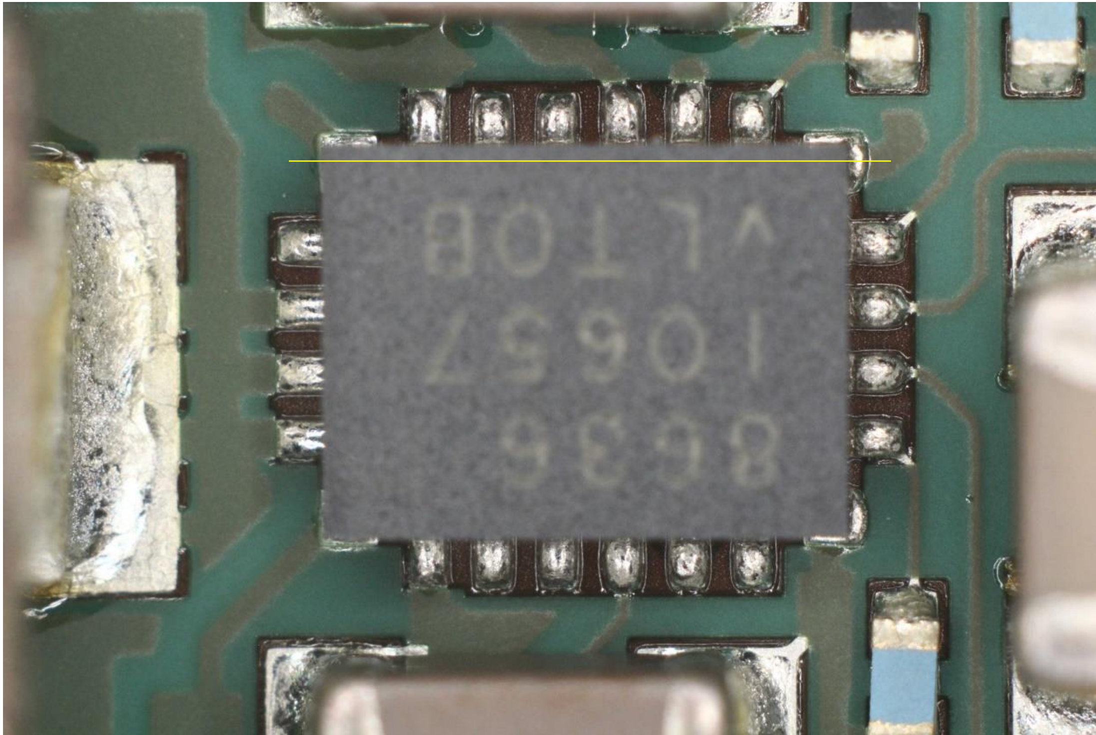

Figure 41. Specimen 4LP1 IC7 Component overview. The yellow line indicates the cross section plane.

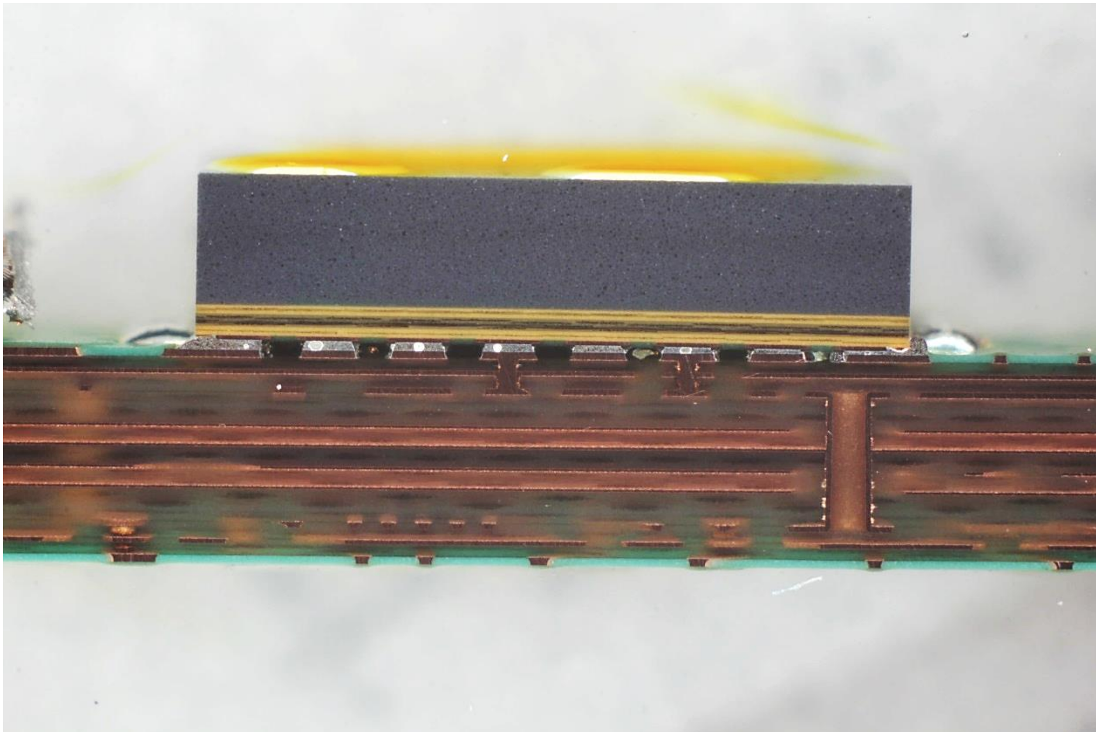

Figure 42. Specimen 4LP1 IC7 Cross section overview.

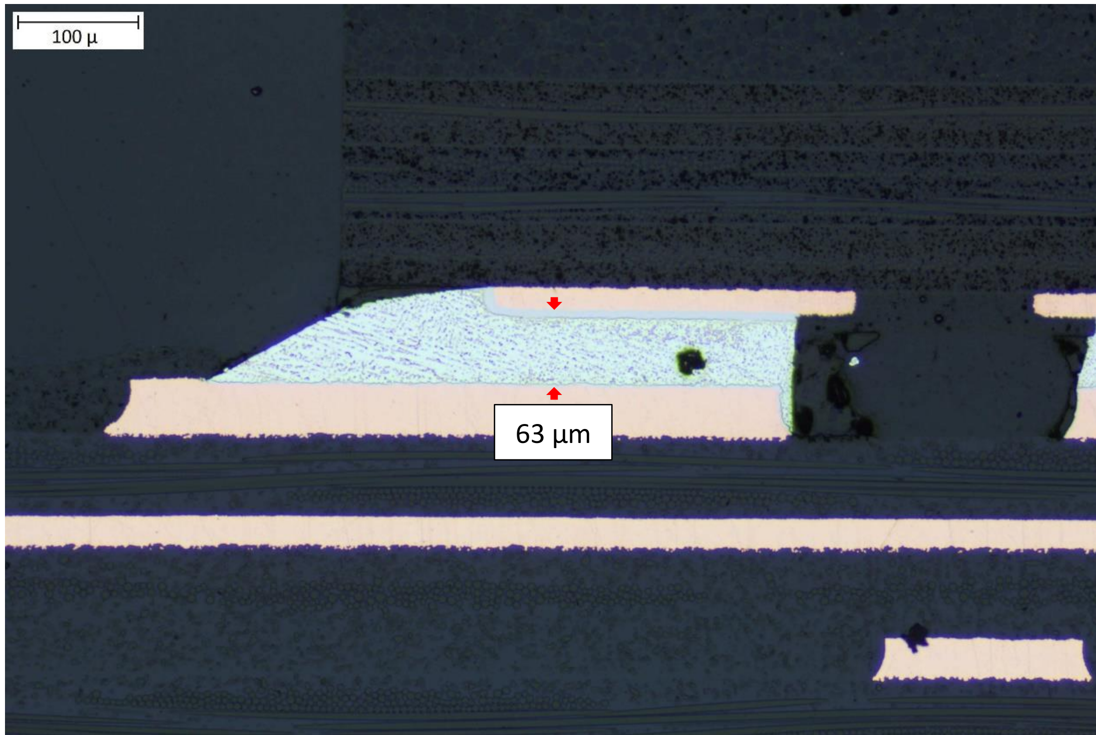

Figure 43. Specimen 4LP1 IC7. Standoff height is 63 µm.

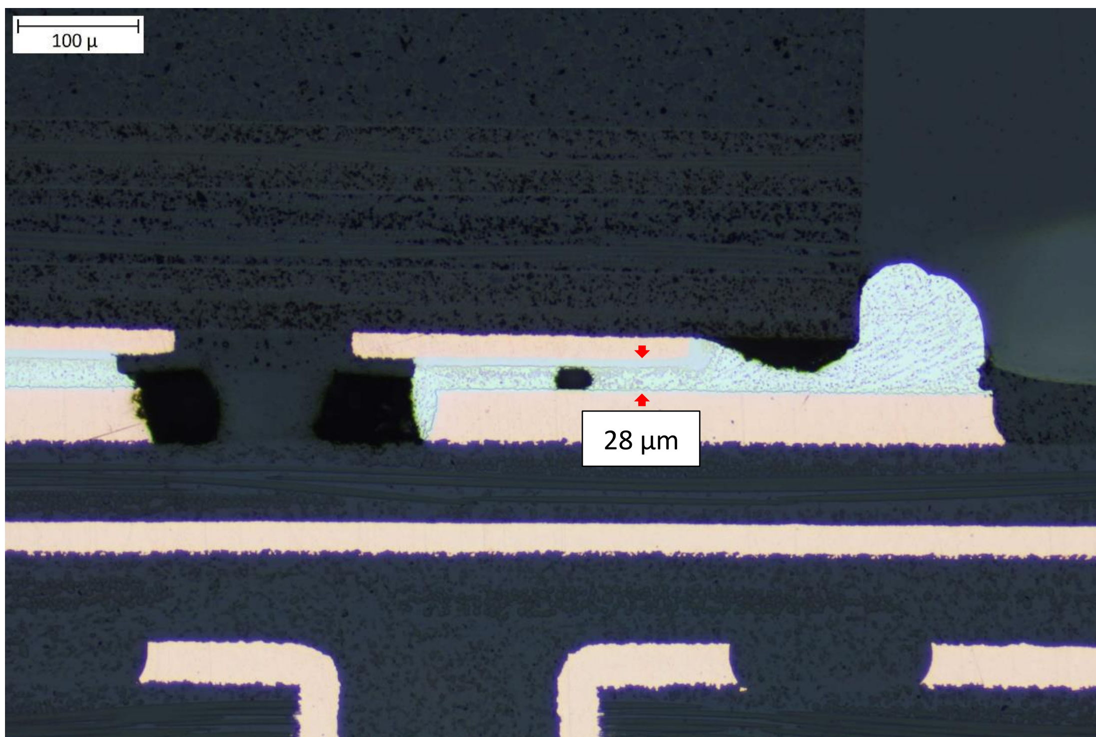

Figure 44. Specimen 4LP1 IC7. Standoff height is 28 µm.