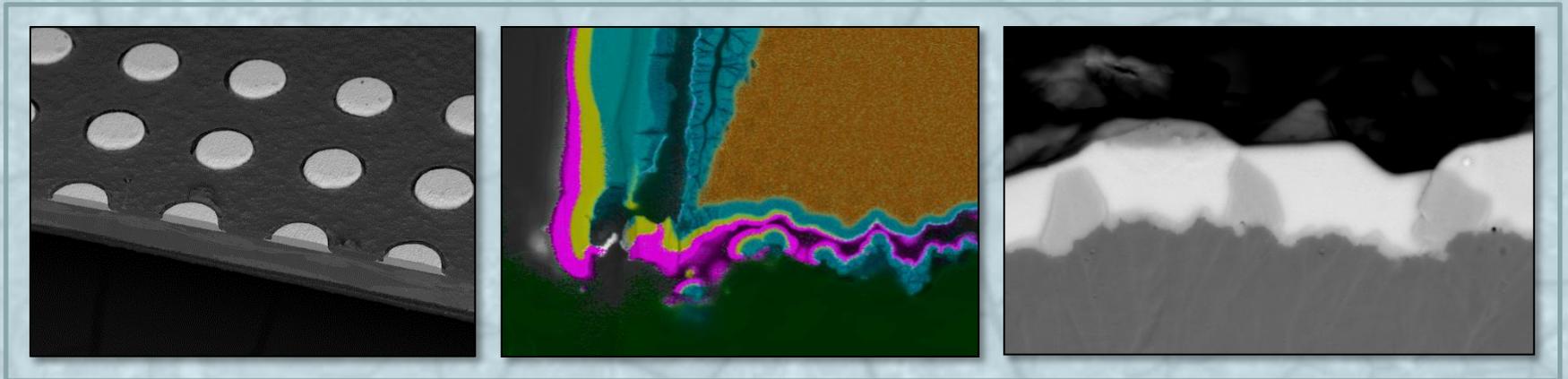


Quality Control and Problem Solving for PCBs

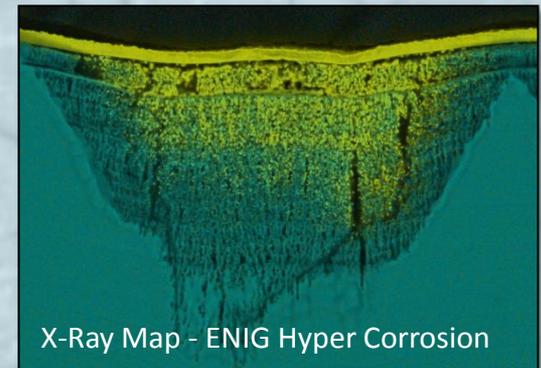
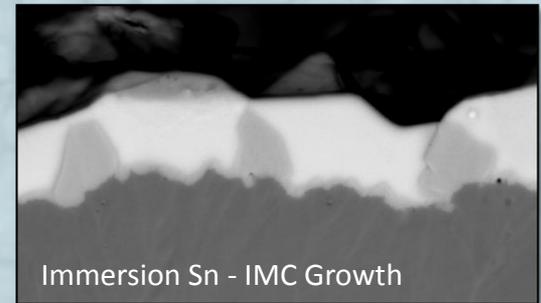
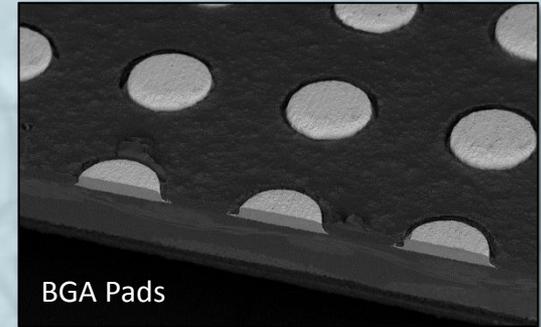
- Broad Ion Beam (BIB) X-Section Preparation
- High Resolution Imaging and Element Mapping



Broad Ion Beam Processing

A Powerful New Tool for PCB Analysis

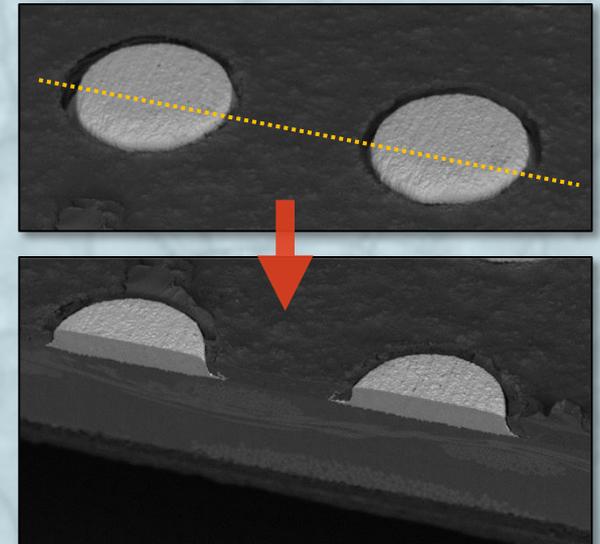
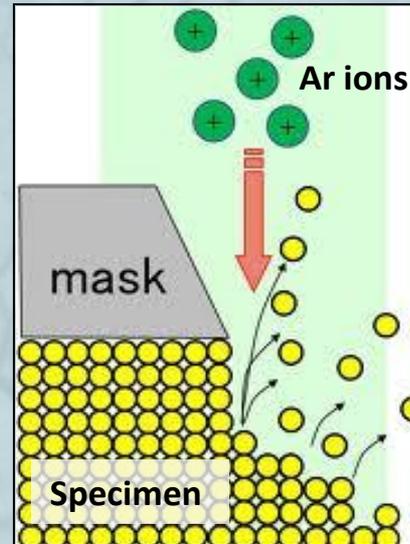
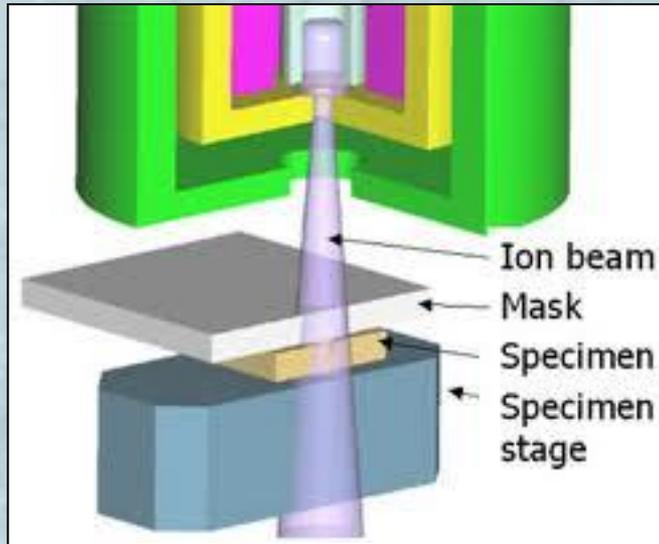
- ✓ 100% Deformation and Smear-Free Micro-Section Preparation
- ✓ No mechanical contact with the sample
- ✓ Preserves and reveals nanometre scale information
- ✓ Ideal for Process and Product Development
- ✓ Powerful failure analysis tool
- ✓ Capable of preparing large samples (mm's rather than μm)
- ✓ Gentle process, can be used on thin or beam sensitive samples
- ✓ Cryo-stage allows us to prevent phase changes in reactive samples
- ✓ Metallic, ceramic, polymeric and composite materials can all be processed
- ✓ Hard and soft materials can be cut simultaneously
- ✓ Ion beam etching reveals interface, phase and edge detail with incredible accuracy
- ✓ Ion beam etching allows us to simultaneously etch different materials
- ✓ Enables direct linear measurement of plated layer thickness
- ✓ Enables high spatial resolution elemental analysis (EDS)
- ✓ Suitable for preparation of all solderable finishes (including organic)



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Micro-Section Preparation - Broad Ion-Beam (BIB) System



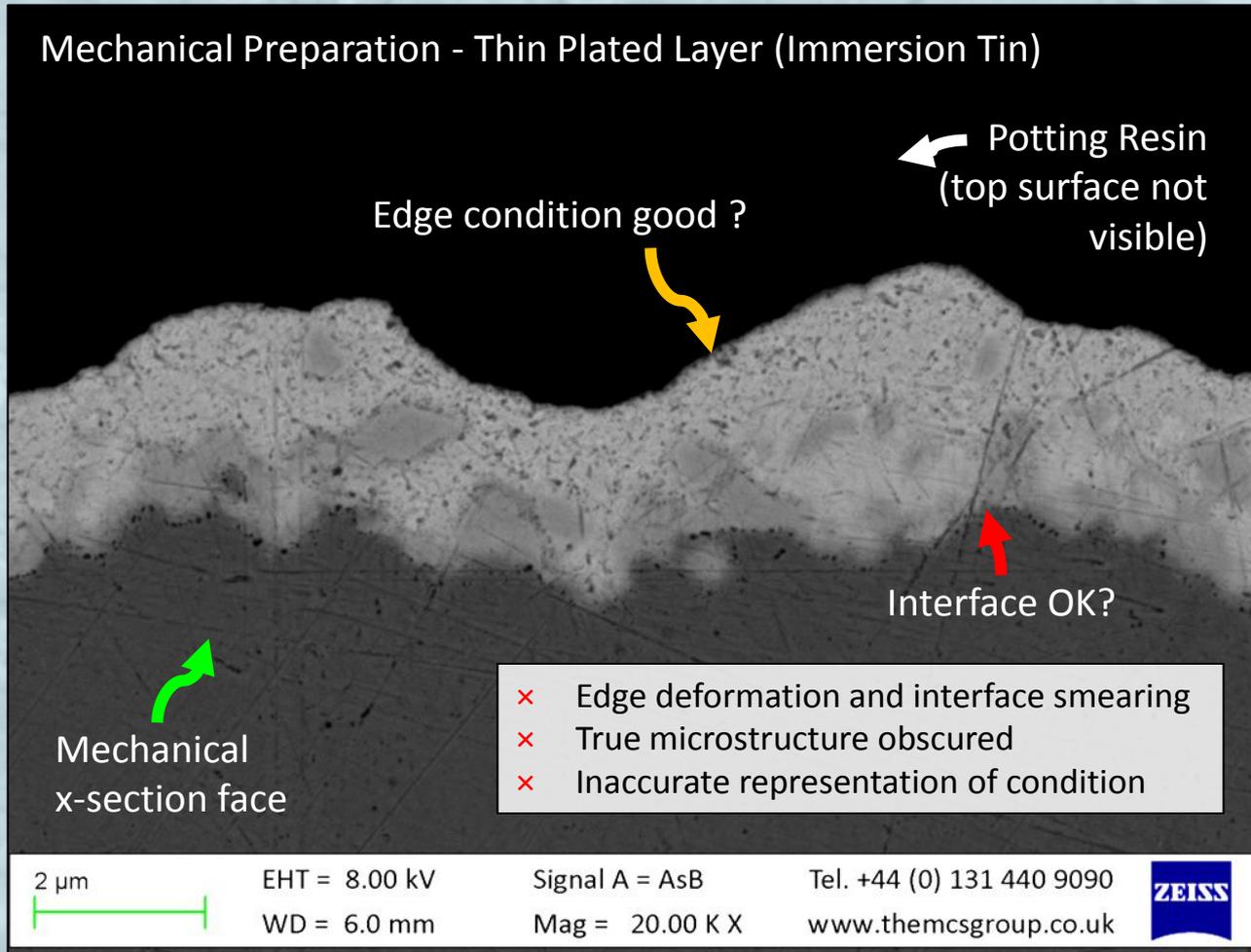
- Masked Broad Ion Beam (BIB) milling
- Uses three large (~1mm) ion beams to strip (sputter) away exposed sample
- A sputter resistant shield masks half the ion beam, creates a lateral sputtering plane that strips away a layer of the sample surface.
- The resulting planarised surface is topographically flat and free of artefacts.

Micro-Section Preparation - Mechanical vs. Broad Ion-Beam

	Advantages	Disadvantages
Mechanical	<ul style="list-style-type: none"> ▪ Fast (from 1 hr) ▪ Large sample capable - standard up to 100mm x 50mm ▪ Good for bulk, homogenous materials 	<ul style="list-style-type: none"> ▪ Potential for delicate sample damage / contamination (smearing, rounding of unsupported edges, drag-in polishing media) ▪ Requires chemical etching (highly selective) ▪ Requires sample embedding in polymer resin
Broad Ion Beam (BIB)	<ul style="list-style-type: none"> ✓ No smearing or sample deformation ✓ True microstructure revealed ✓ Unsupported edges and voids preserved ✓ Surface and x-section simultaneously ✓ Rel. large cut area (up to 5mm x 1.5mm) ✓ Accurate x-section positioning (+/- 2 μm) ✓ Enables high res EDX elemental analysis ✓ No drag-in of grinding / polishing media ✓ Cryo-stage allows beam sensitive material processing (including marshmallows!) ✓ Ion-beam etching less selective and highly controllable 	<ul style="list-style-type: none"> ▪ Slower process (from 3 - 8hrs) ▪ Some restriction on sample size

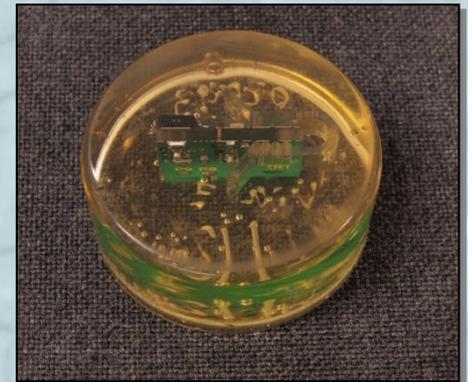


Micro-Section Preparation - Mechanical vs. Broad Ion-Beam



Mechanical Process:

- Encapsulate sample
- Grind to target (SiC, Diamond)
- Polish (Diamond, SiO_2 , Al_2O_3)
- Wet etch (selective)



Micro-Section Preparation - Mechanical vs. Broad Ion-Beam

Broad Ion Beam Preparation - Thin Plated Layer - Same Sample!

1. Edge condition - Perfect!

2. Original surface structure visible (no potting resin)

3. BIB X-section face (true microstructure)

- ✓ No deformation or smearing
- ✓ True microstructure revealed
- ✓ Correlate surface and x-section

1 μ m



EHT = 8.00 kV

WD = 6.0 mm

Signal A = AsB

Mag = 20.00 K X

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BIB Process:

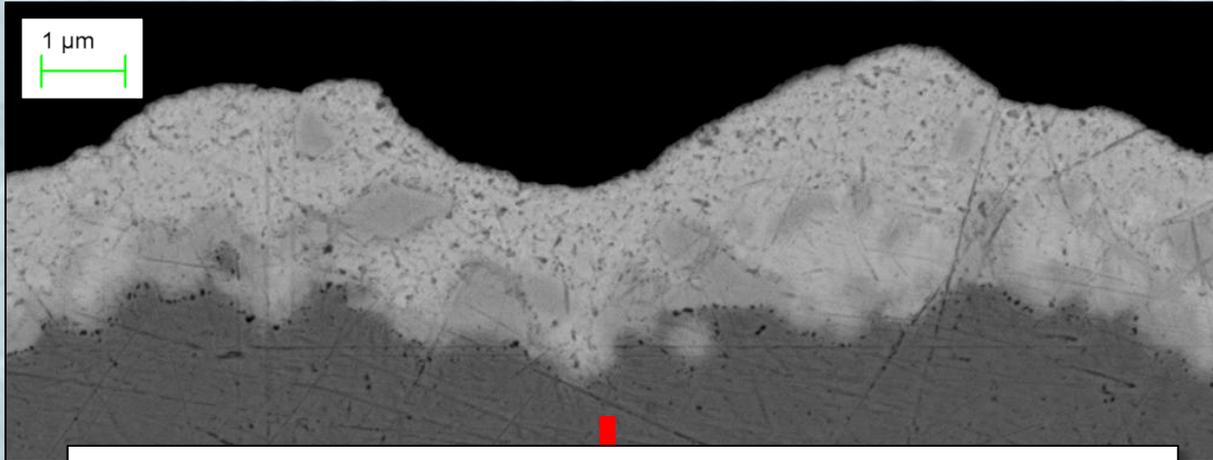
- Reduce sample to size (max 50x50x10 mm)
- Align mask (+/- 2 μ m)
- Ion beam cut (3-8hrs)
- Ion beam etch (2-3 mins)



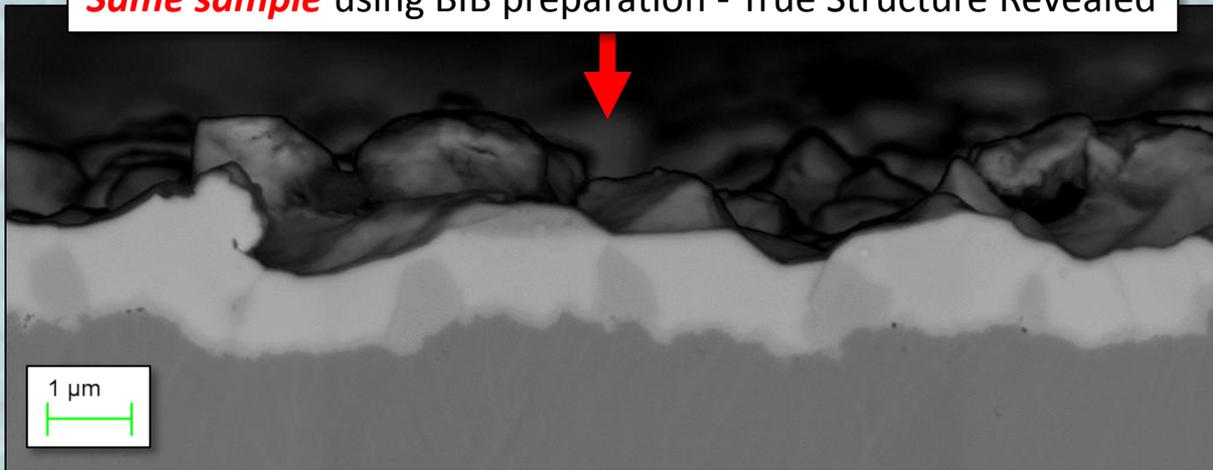
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Micro-Section Preparation - Mechanical vs. Broad Ion-Beam



Same sample using BIB preparation - True Structure Revealed

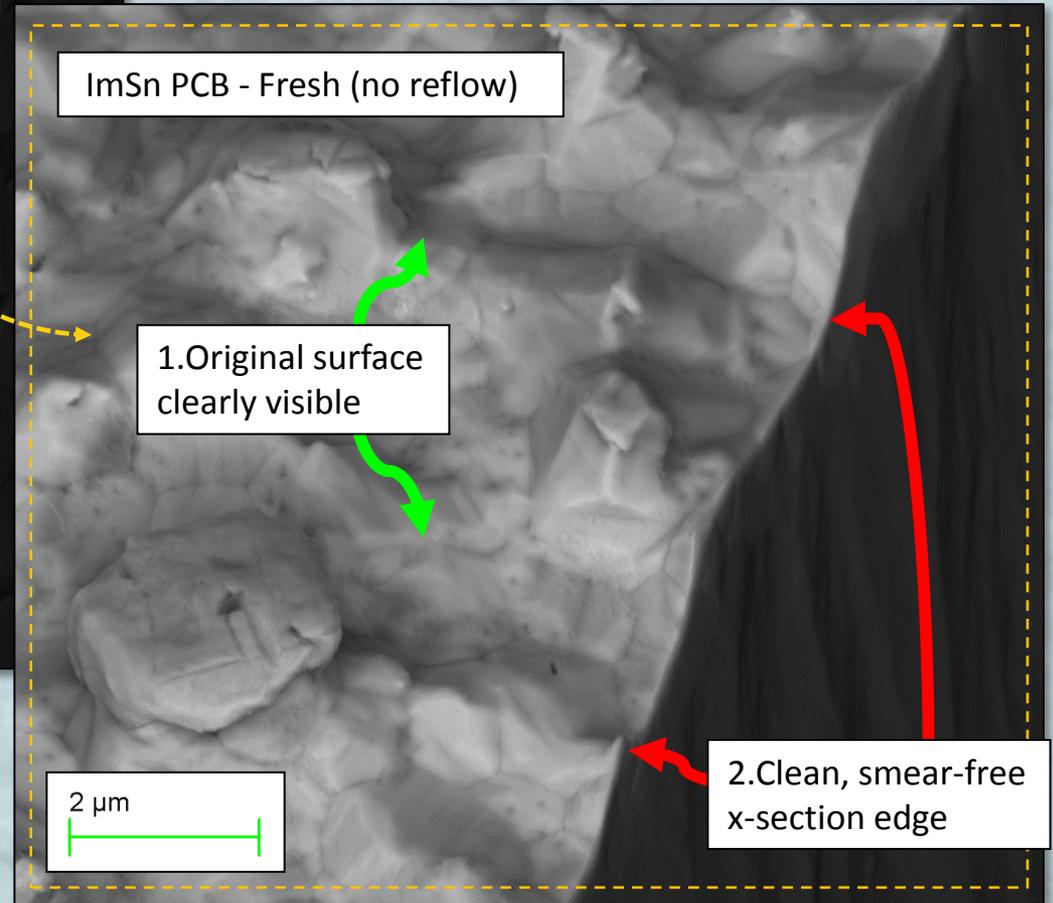
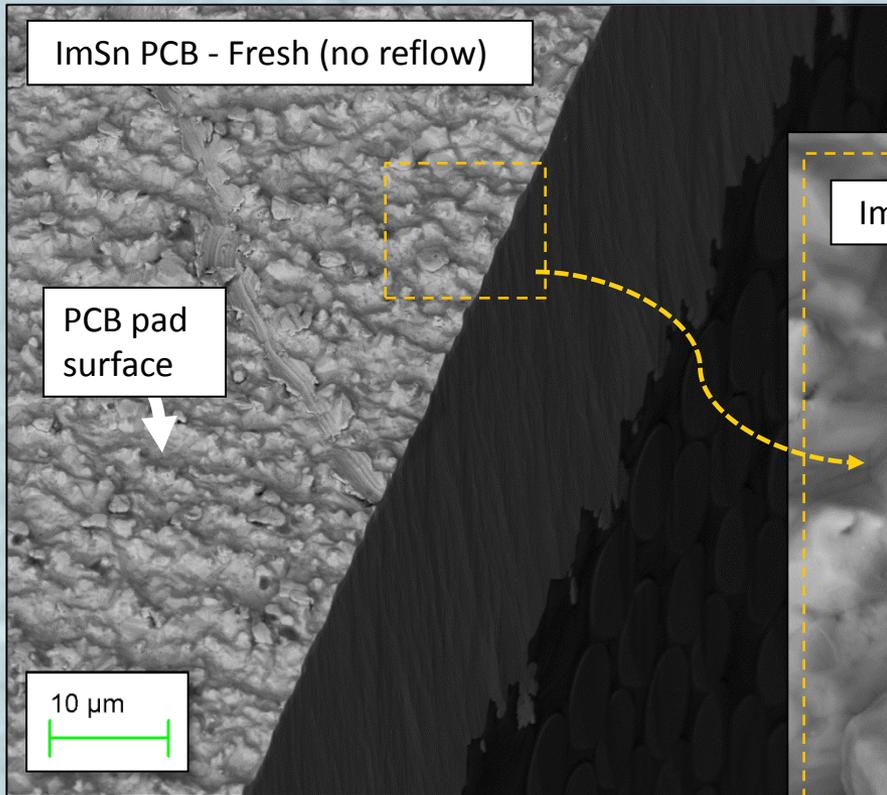


Mechanical X-Section

- × Edge deformation
- × Interface smearing
- × Microstructure obscured

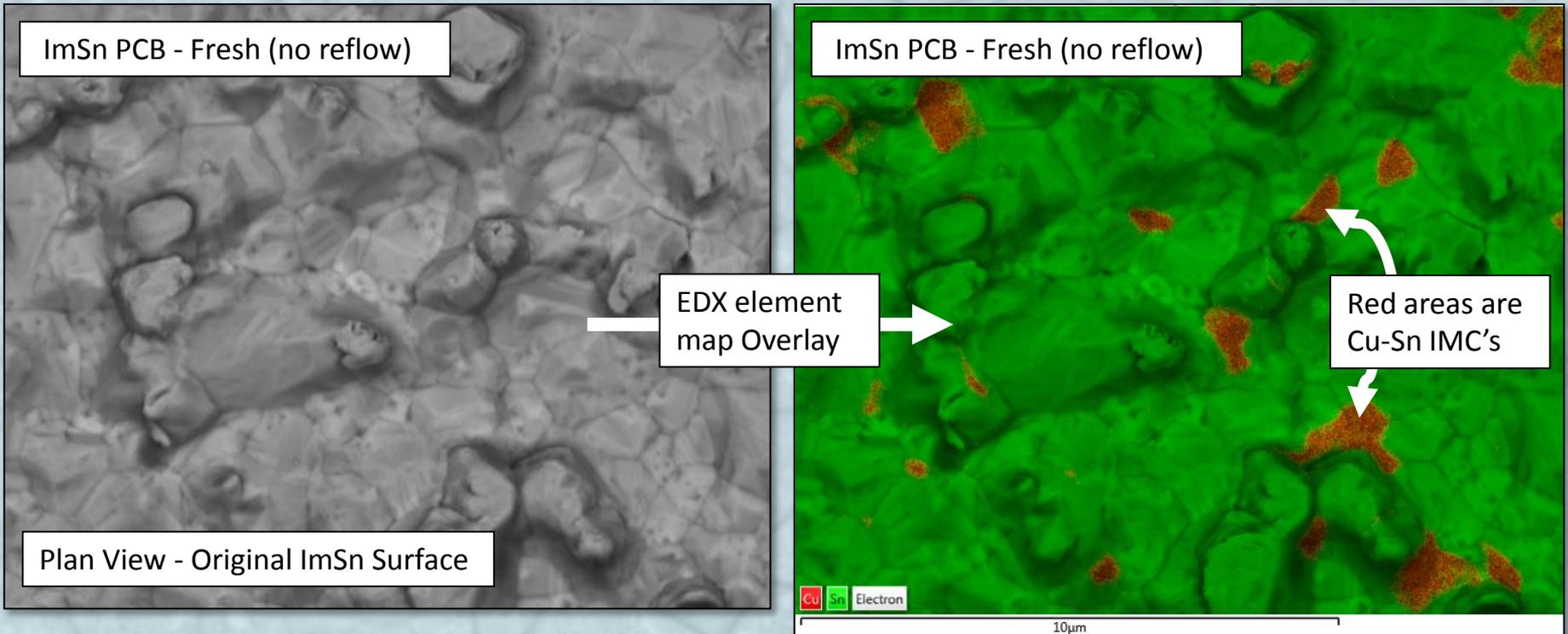
BIB X-Section

- ✓ No deformation or smearing
- ✓ True microstructure
- ✓ Surface **and** x-section
- ✓ Accurate analysis
- ✓ Real results



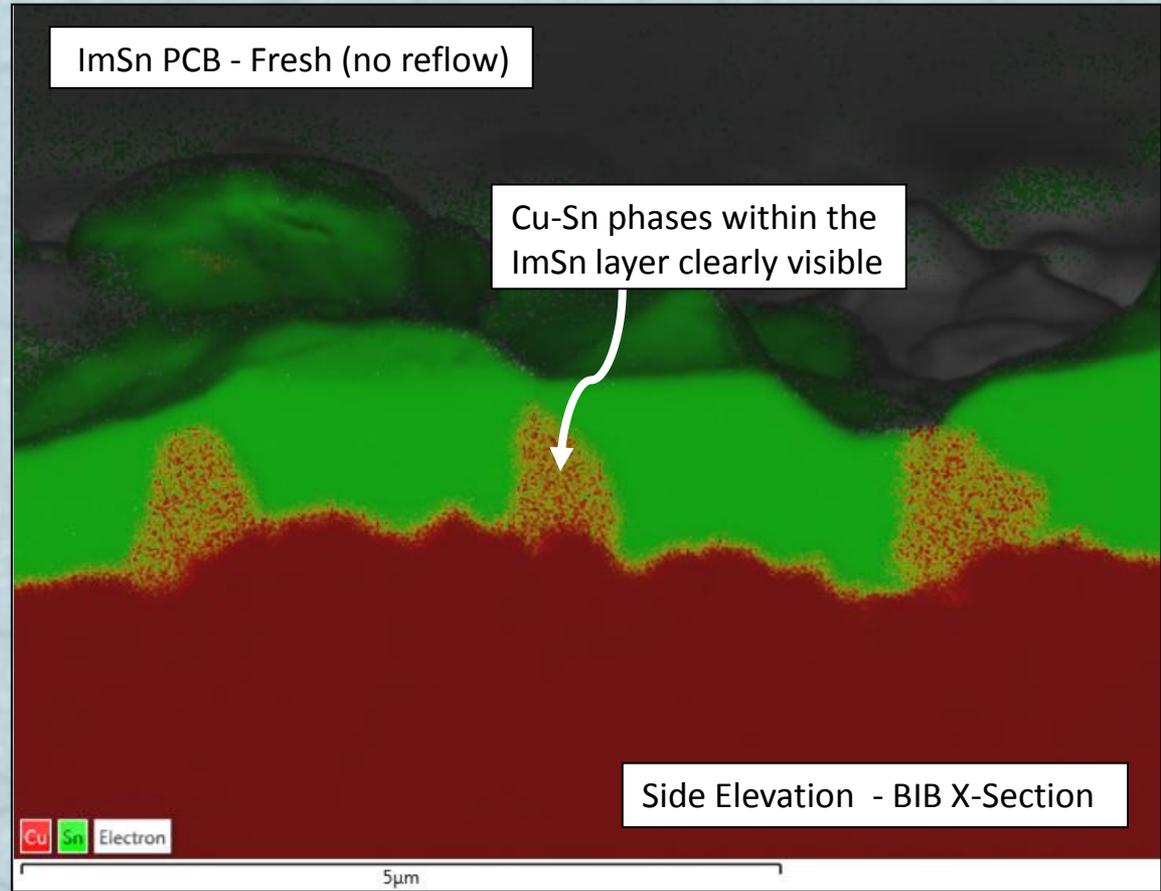
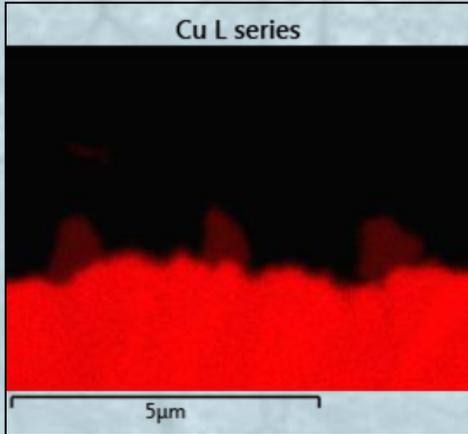
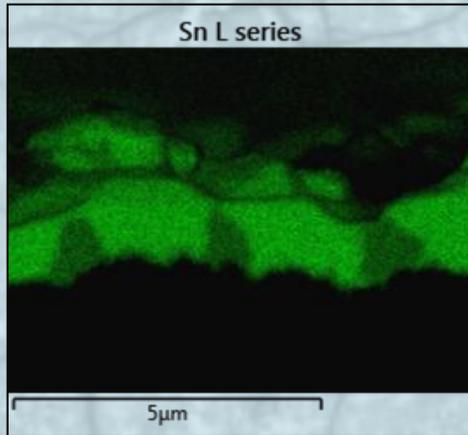
- Highest quality X-Section preparation
- Reveal true sample condition
- Simultaneous surface & x-secn analysis
- Accurate, unambiguous results

- Analyse Surface and Near Surface - Identify Cu-Sn IMC Phase Distribution
- Ideally we would like to correlate surface and sub-surface structures and composition
- Technique developed by MCS technique enables just that.....



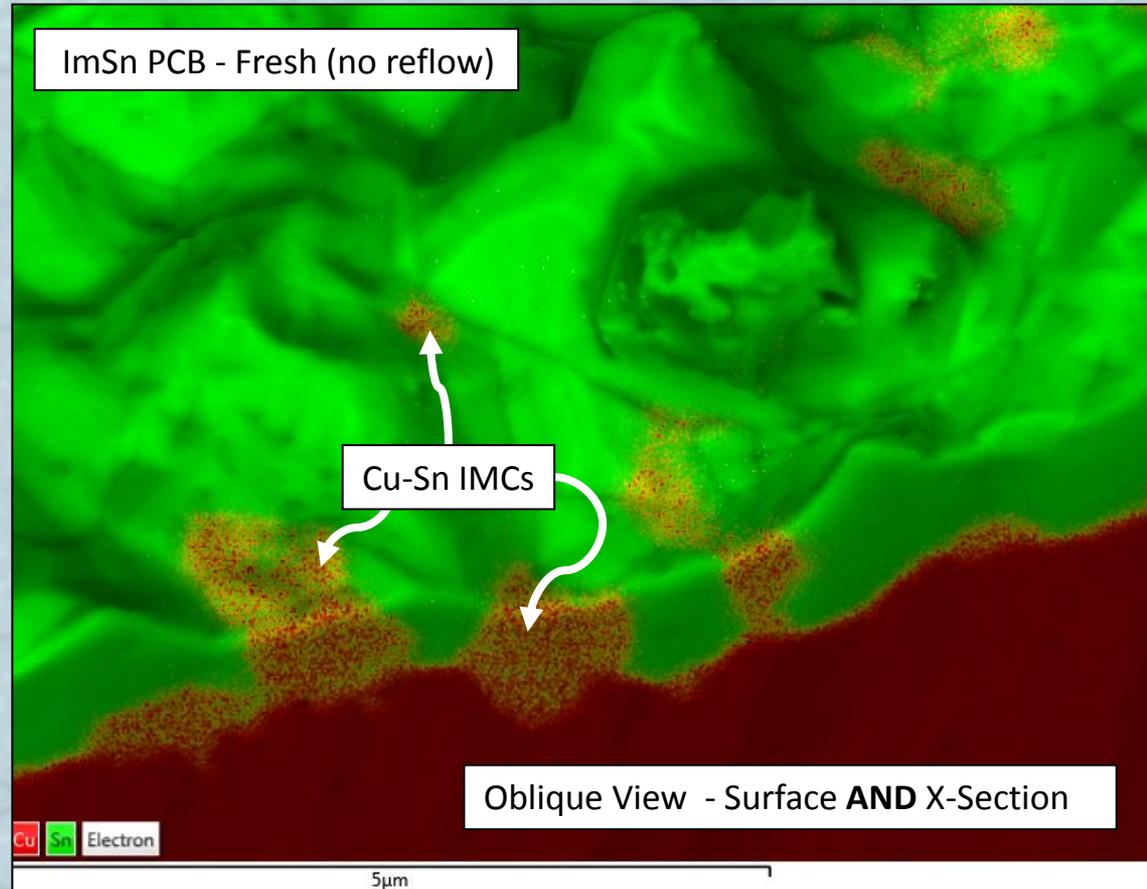
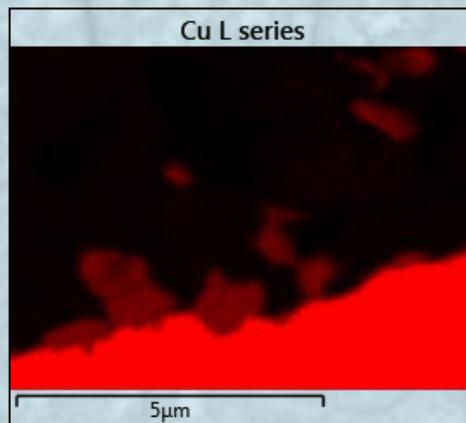
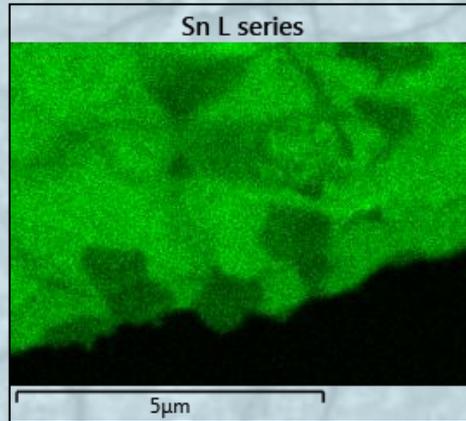
Micro-Section Preparation - Broad Ion-Beam X-Section (ImSnPCB)

- Analyse BIB X-Section - Identify Cu-Sn IMC Phase Distribution Through ImSn Layer

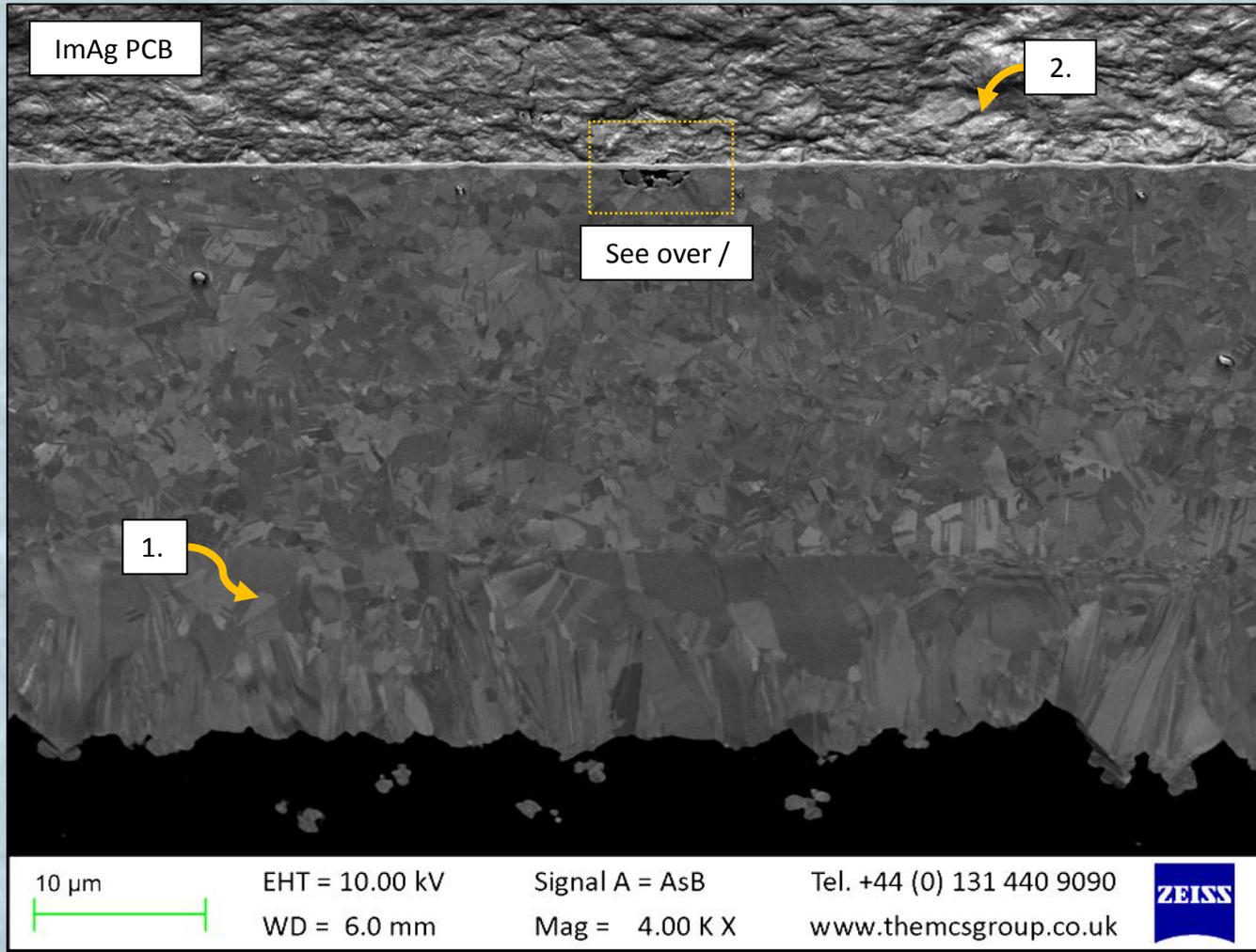


Micro-Section Preparation - Broad Ion-Beam X-Section (ImSn PCB)

- Oblique BIB X-Section Analysis - Investigate Relationship between Surface and Sub-Surface



Micro-Section Preparation - Broad Ion-Beam X-Section (ImAg PCB)



SEM micrographs illustrate typical BIB x-section (ImAg PCB Pad). Zero smear surface, accurate edge definition.

Note the following features:

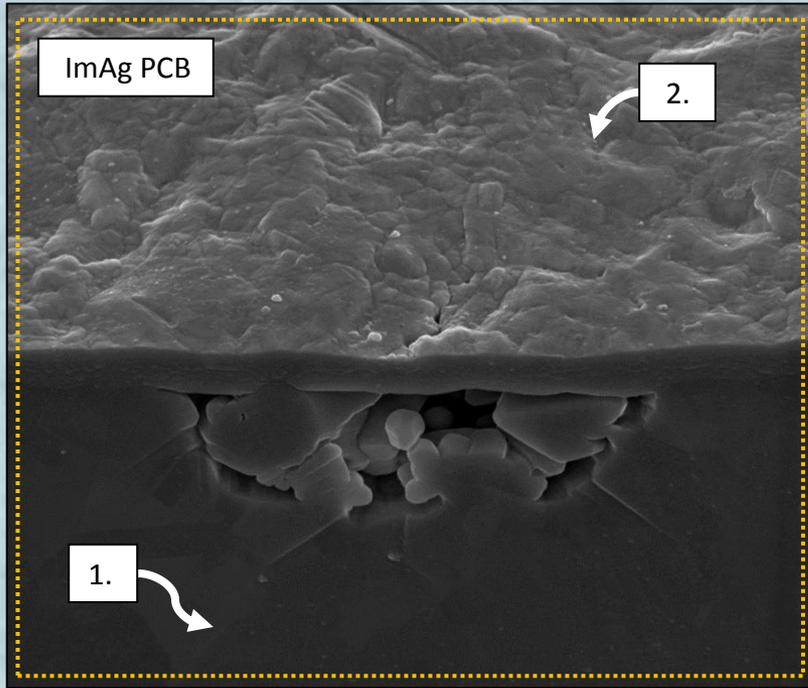
1. BIB x-section reveals grain structure in SEM
2. Original pad surface *and* x-section face visible
3. Allows us to correlate surface and sub-surface condition
4. Hidden damage revealed
5. Mechanism of damage identified



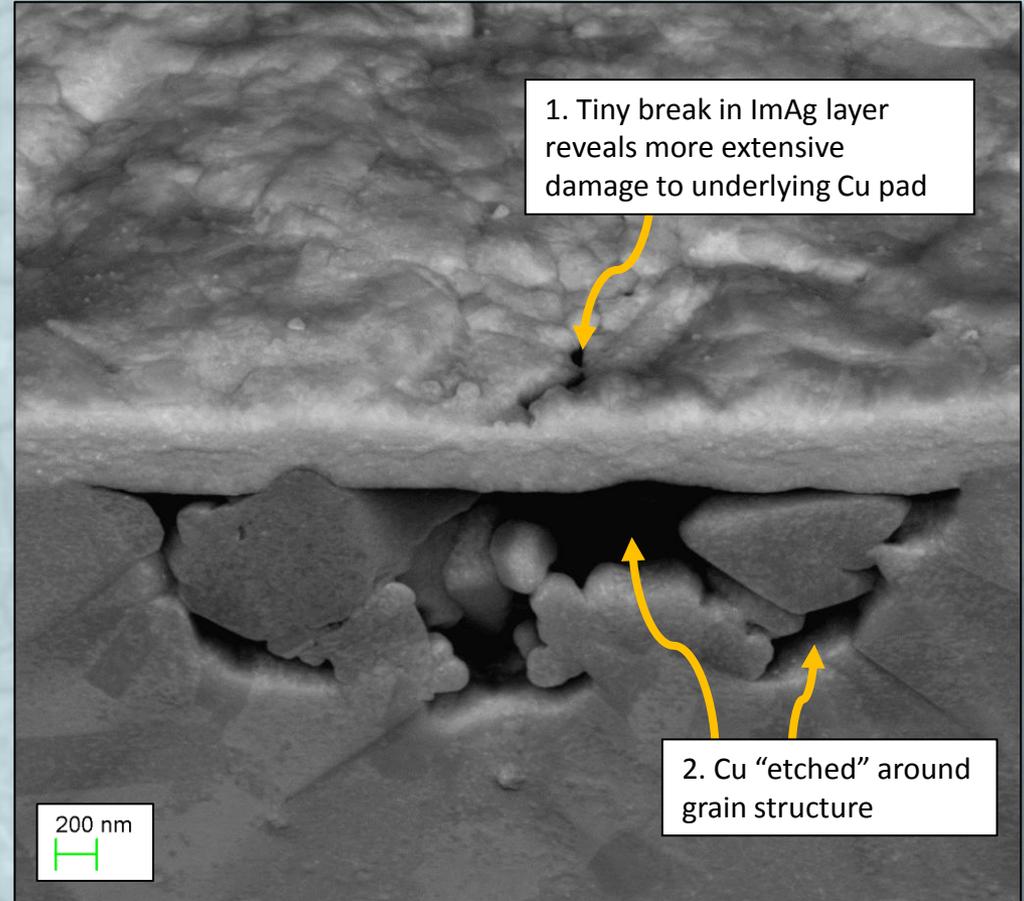
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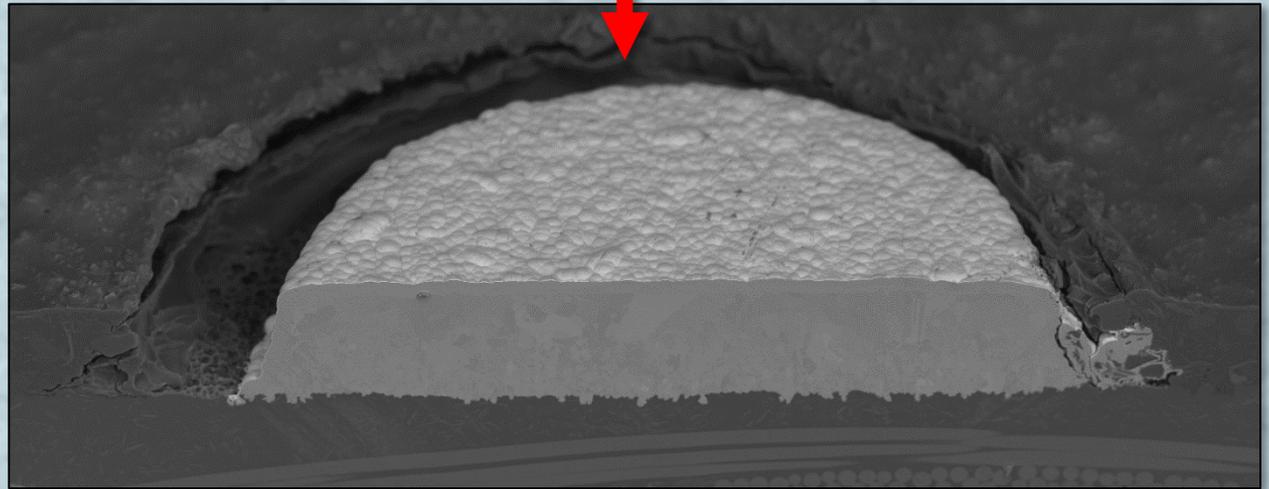
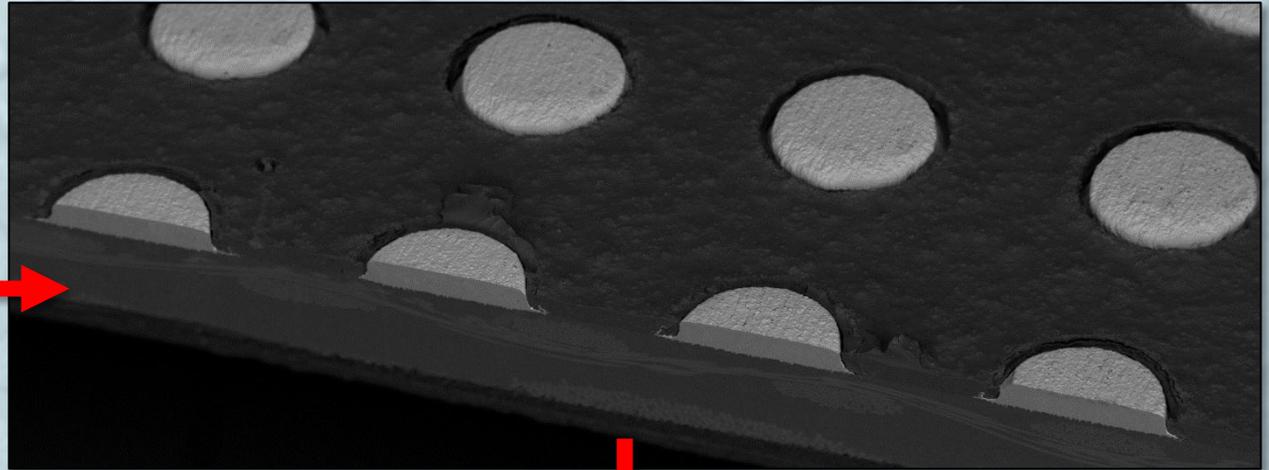
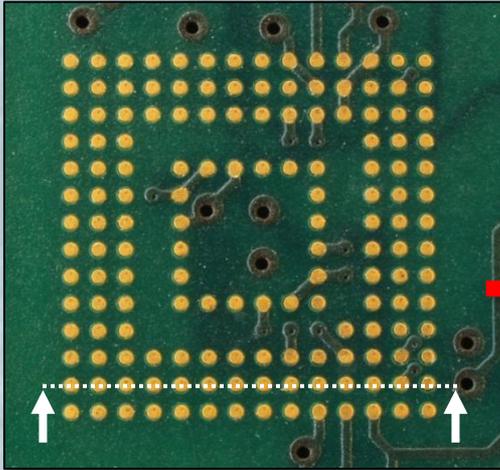
Micro-Section Preparation - Broad Ion-Beam X-Section (ImAg PCB)



1. Original pad surface (2) **and** x-section face (1) visible
2. Allows us to correlate surface and sub-surface condition - hidden damage revealed.
3. Mechanism of damage identified



Micro-Section Preparation - Broad Ion-Beam X-Section (ENIG PCB)



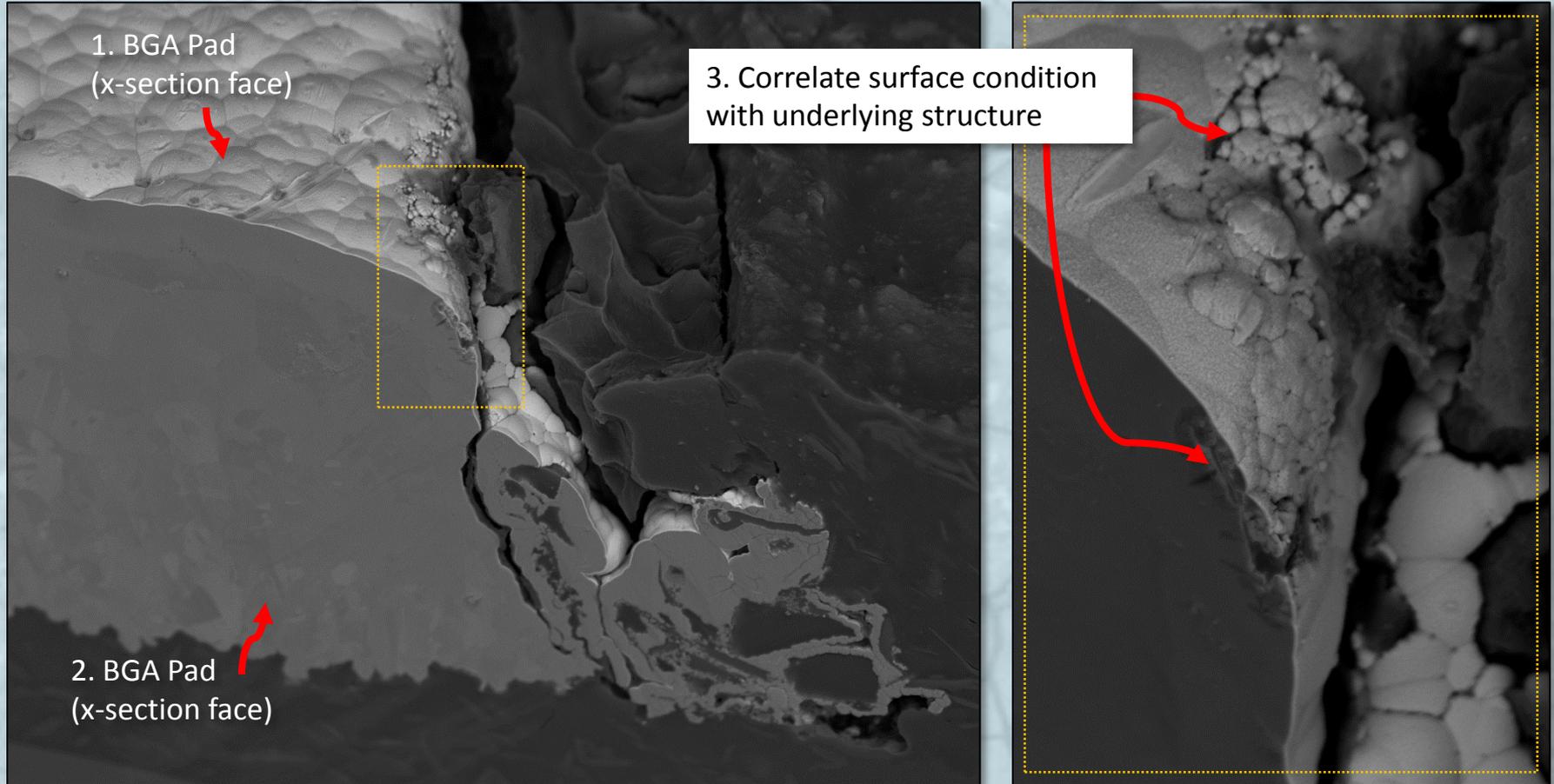
- Combine ion-beam precision with large sample size
- 100% ion beam x-sections up to 5mm in width
- Hybrid process can handle up to 30mm diameter x-section encapsulated samples
- Perfectly preserved to nanometer scale...



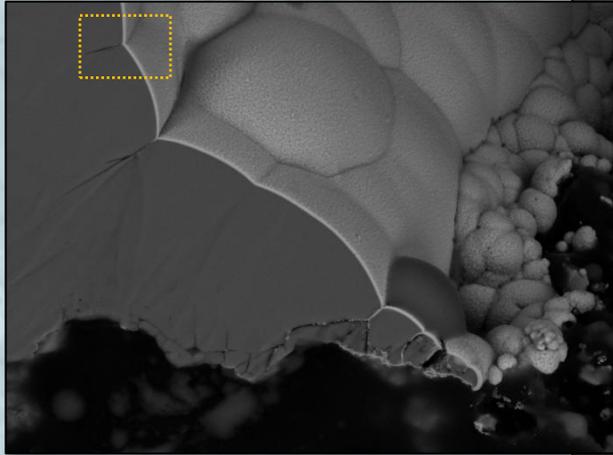
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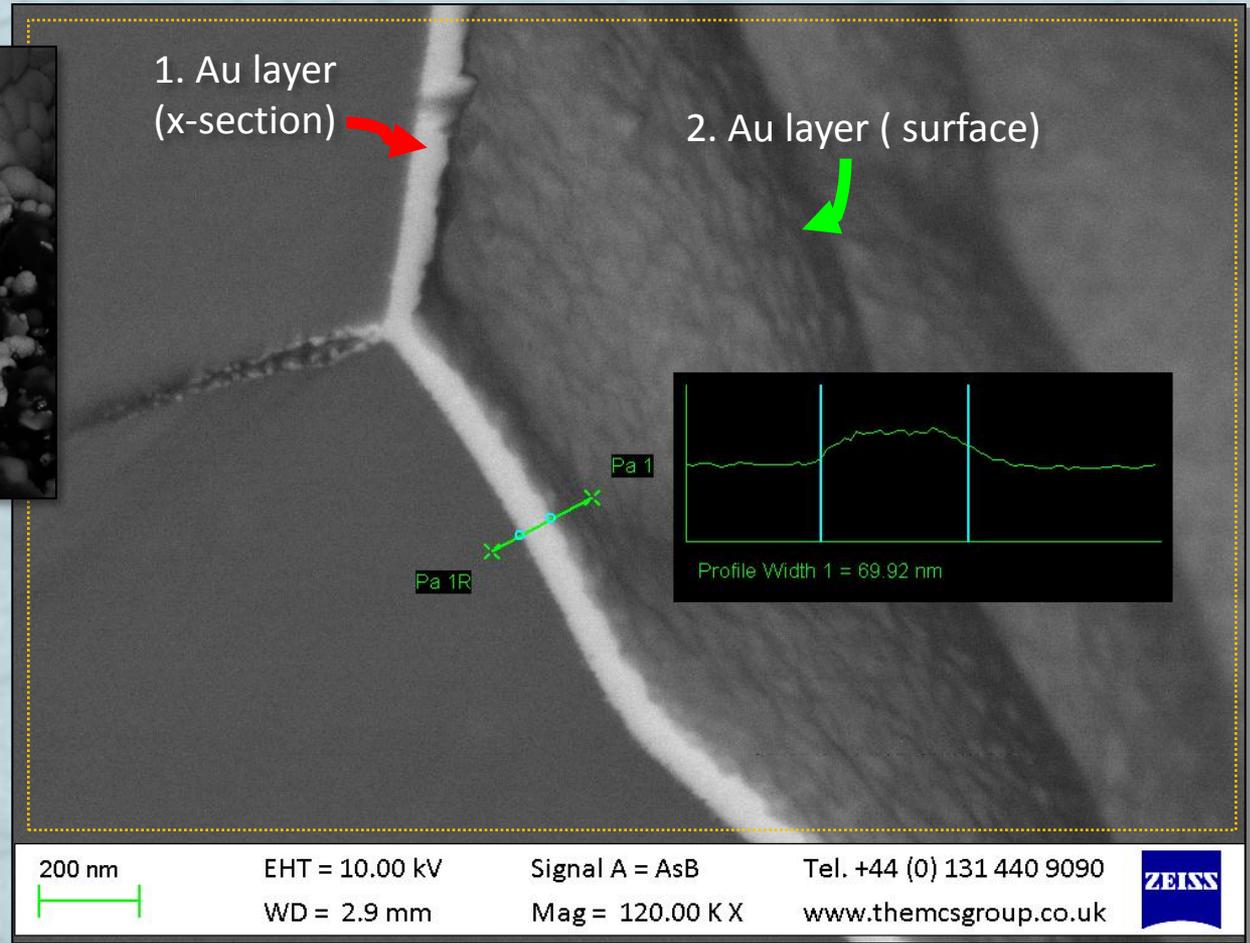
Micro-Section Preparation - Broad Ion-Beam X-Section (ENIG PCB)



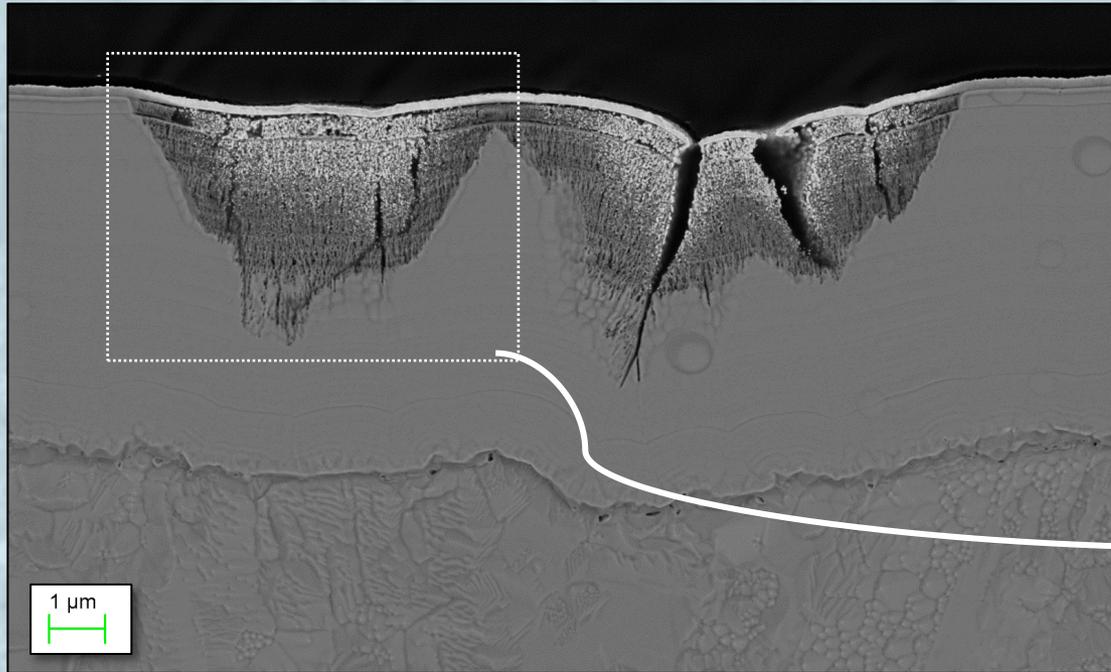
Micro-Section Preparation - Broad Ion-Beam X-Section (ENIG PCB)



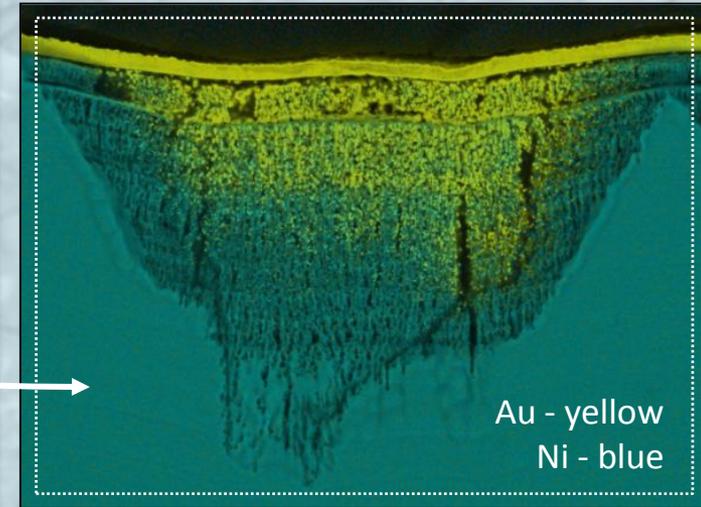
- No deformation - even on unsupported thin gold layer
- Accurate layer thickness measurement
- Correlate x-section and surface - investigate relationship



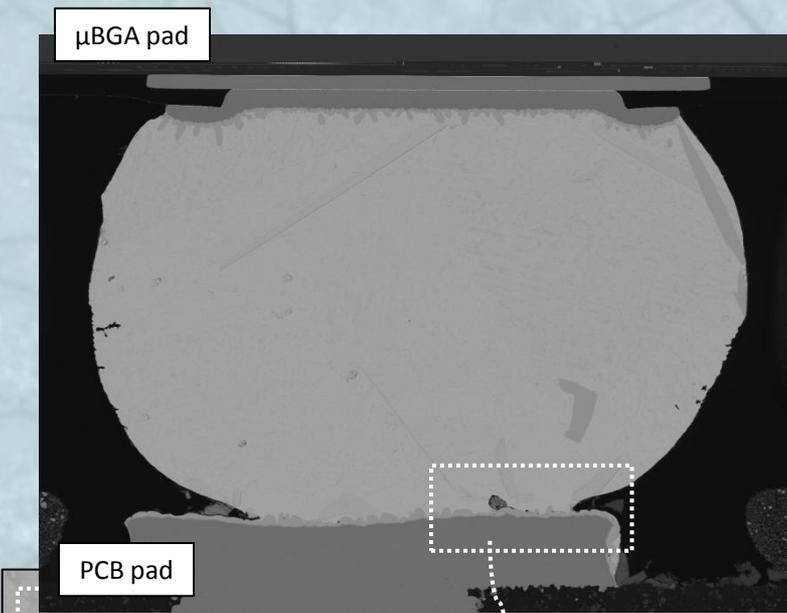
Micro-Section Preparation - Broad Ion-Beam X-Section (ENIG PCB)



X-Ray Map - ENIG Hyper Corrosion



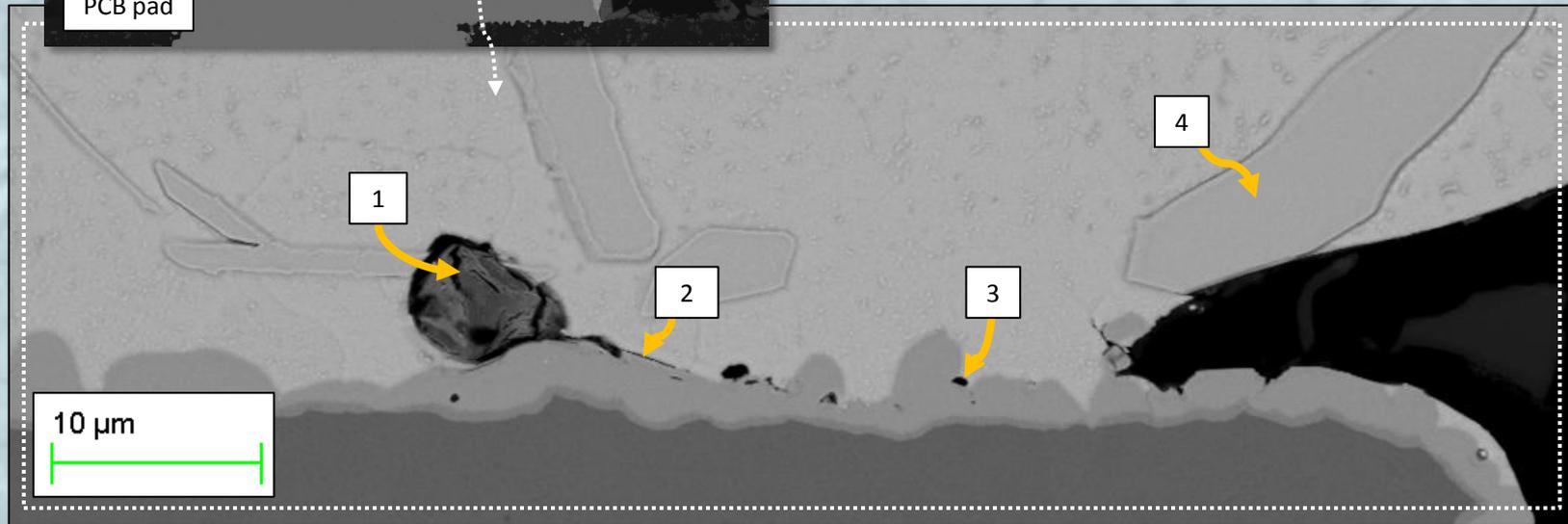
- Smear and Deformation free x-section through thin, soft immersion gold layer
- Identify location and structure of defects (in this example “hyper-corrosion” of electroless Ni layer)
- Unambiguous results enable root-cause identification

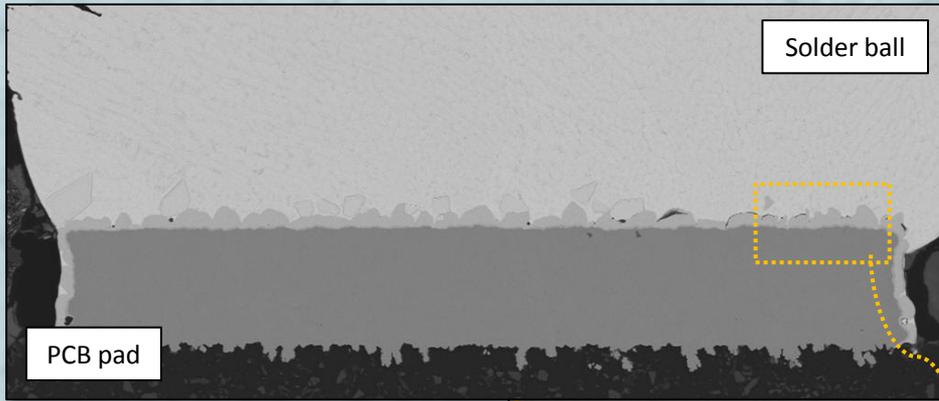


Broad Ion Beam Micro-Section and Etch

SEM micrographs illustrate typical BIB x-section (μBGA joint). Zero smear surface, accurate edge definition. Note the following features:

1. Inclusion clearly visible (since ion-beam cut, we can be sure that this is not a x-section prep artefact)
2. Non-wetting of Cu-Sn IMC surface
3. Voiding
4. Large silver-tin IMC's



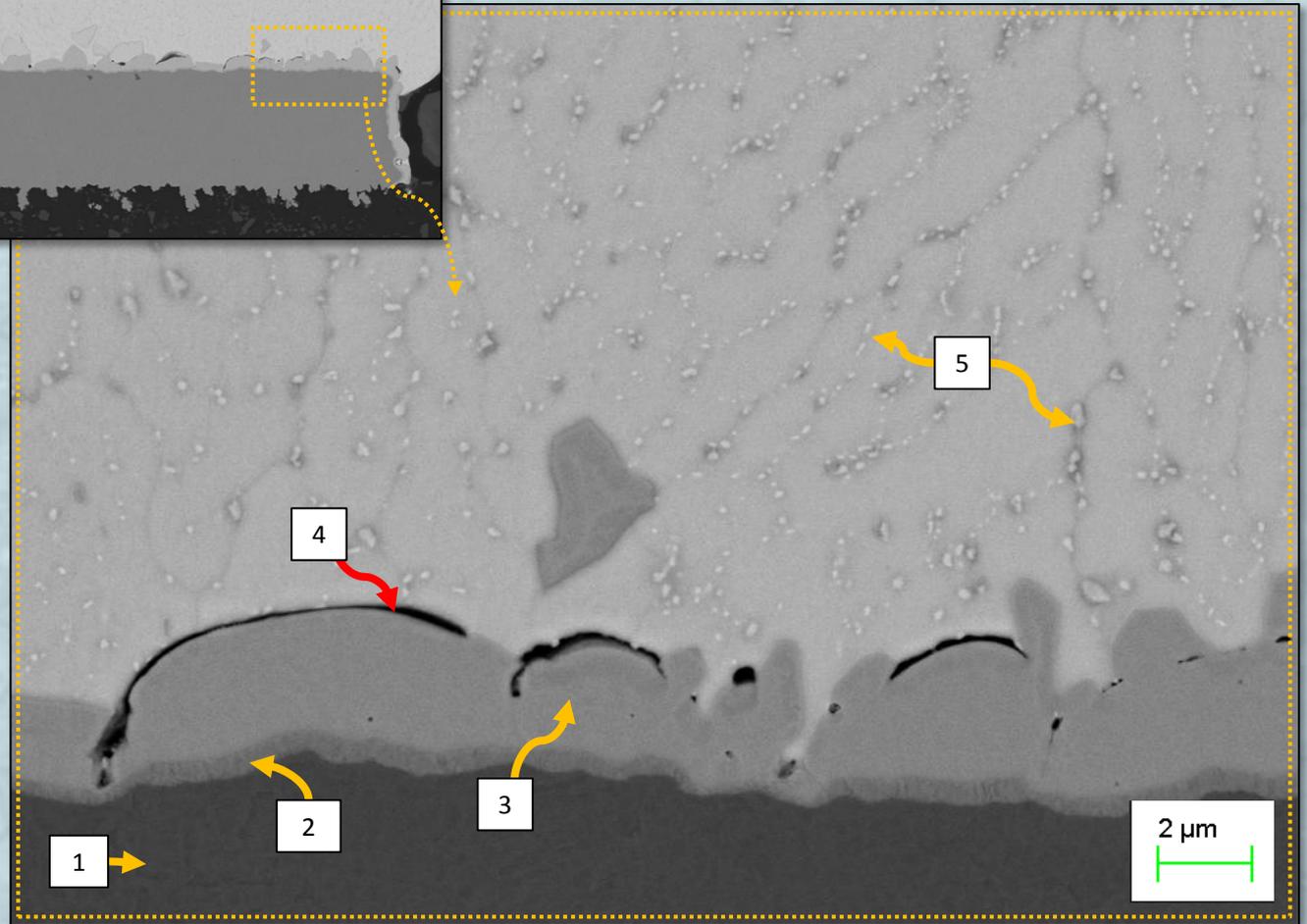


Broad Ion Beam X-Section and Etch

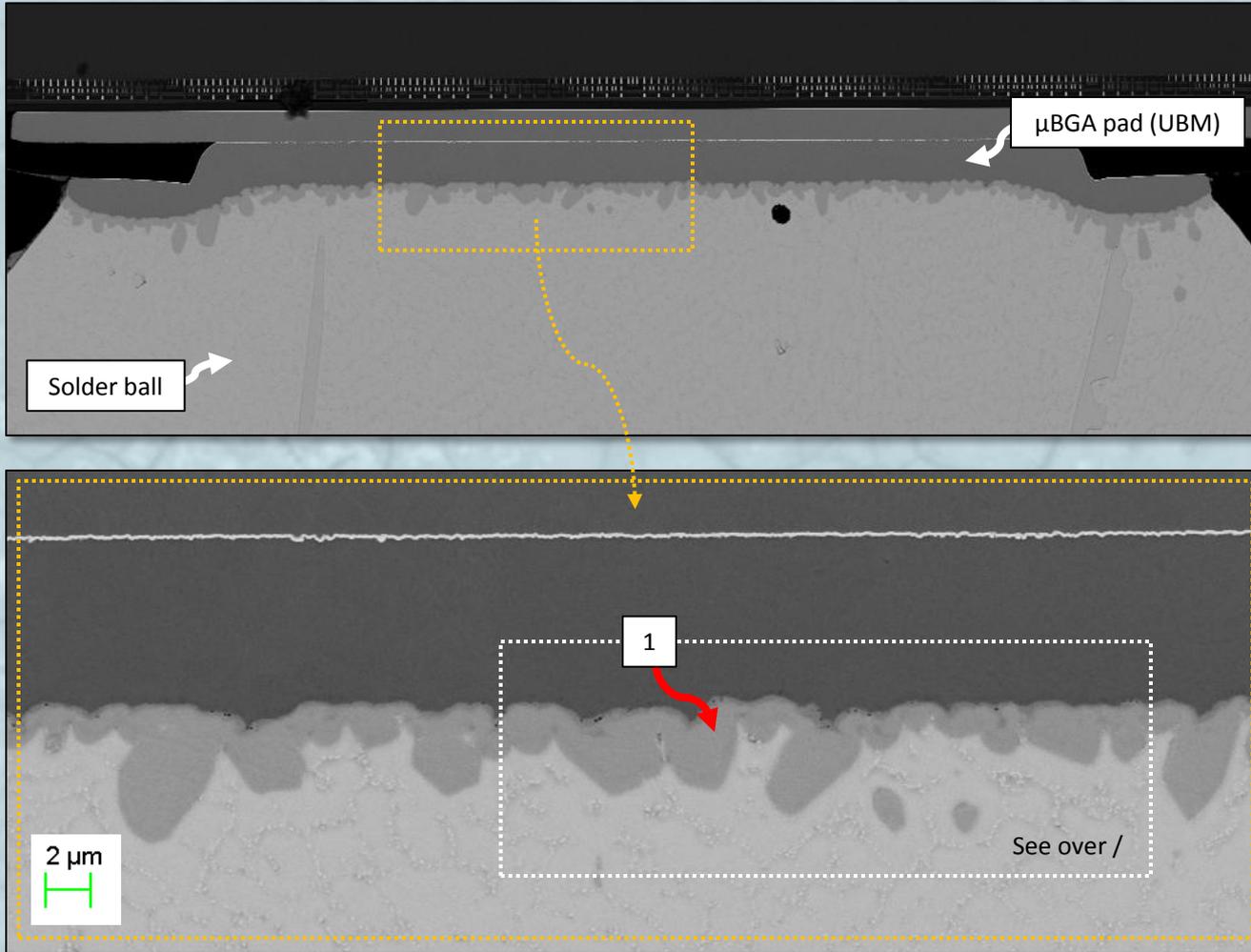
Typical BIB x-section (μ BGA joint). Zero smear surface, accurate edge definition.

Note the following:

1. Cu PCB pad
2. Cu-rich Cu-Sn IMC
3. Sn-rich Cu-Sn IMC
4. Non-wetting on Cu-Sn IMCs (note clearly visible separation)
5. Fine Ag-Sn and Cu-Sn IMC's through solder ball

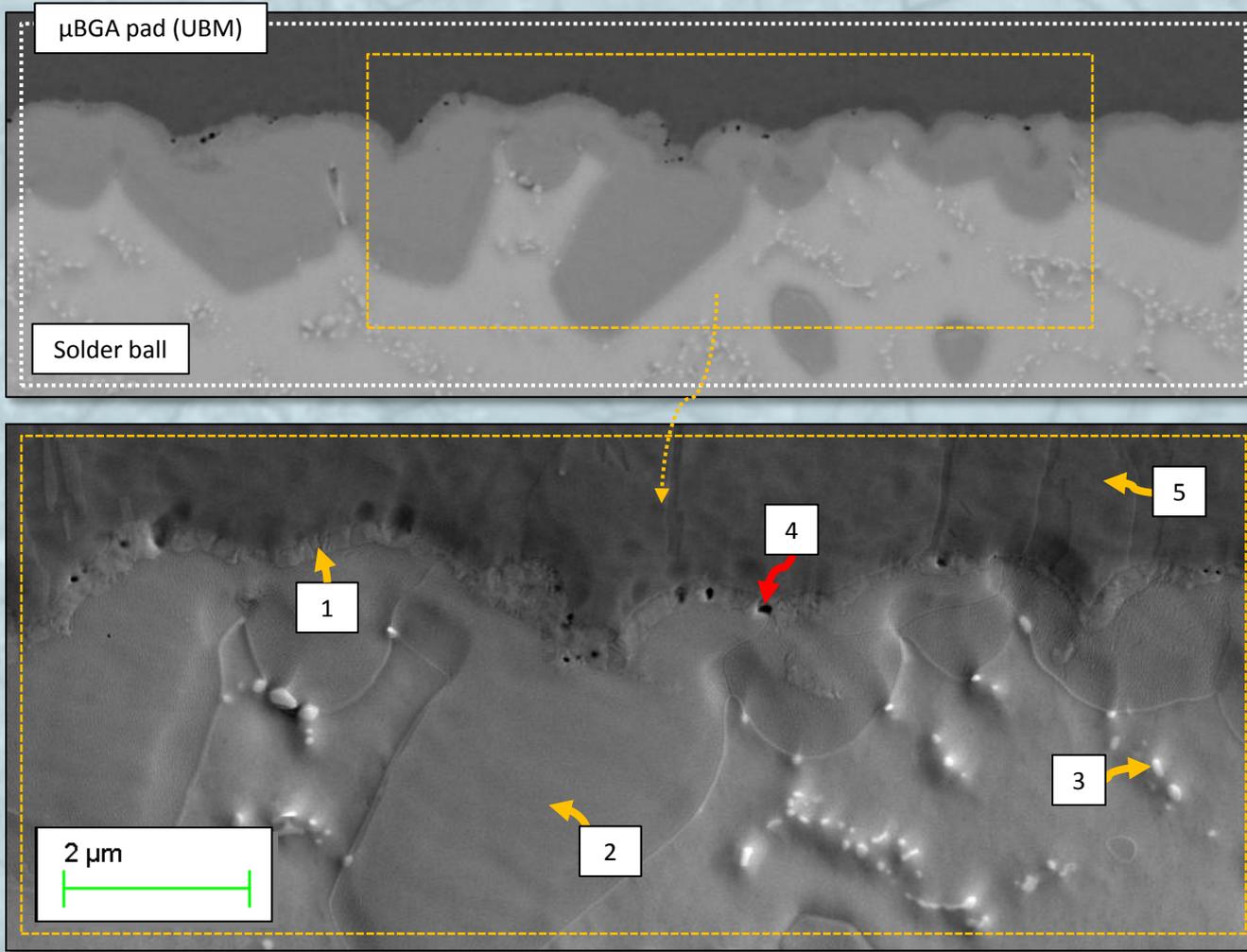


Broad Ion Beam Micro-Section and Etch



1. Typical BIB x-section (μBGA joint).
2. Zero smear surface, accurate edge definition.
3. The copper-tin (Cu-Sn) IMC phases are clearly revealed using the broad ion beam technique (1).
4. Very fine voids (in this case Kirkendall voids) are visible when viewed at higher magnification.
5. See over for further detail.

Broad Ion Beam Micro-Section and Etch

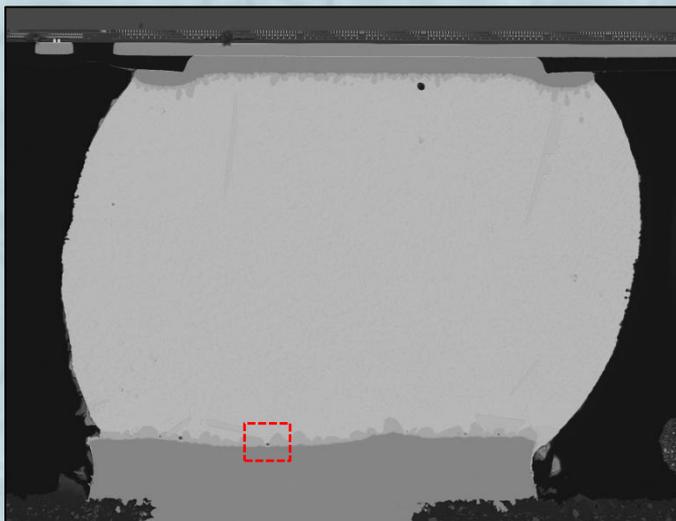


Typical BIB x-section (μ BGA joint). Zero smear surface, accurate edge definition.

Note the following:

1. Cu-rich Cu-Sn IMC
2. Sn-rich Cu-Sn IMC
3. Fine Ag-Sn and Cu-Sn IMC's through solder ball
4. Kirkendall voiding between pad and Cu-Sn IMC layers
5. μ BGA pad (UBM) - Cu

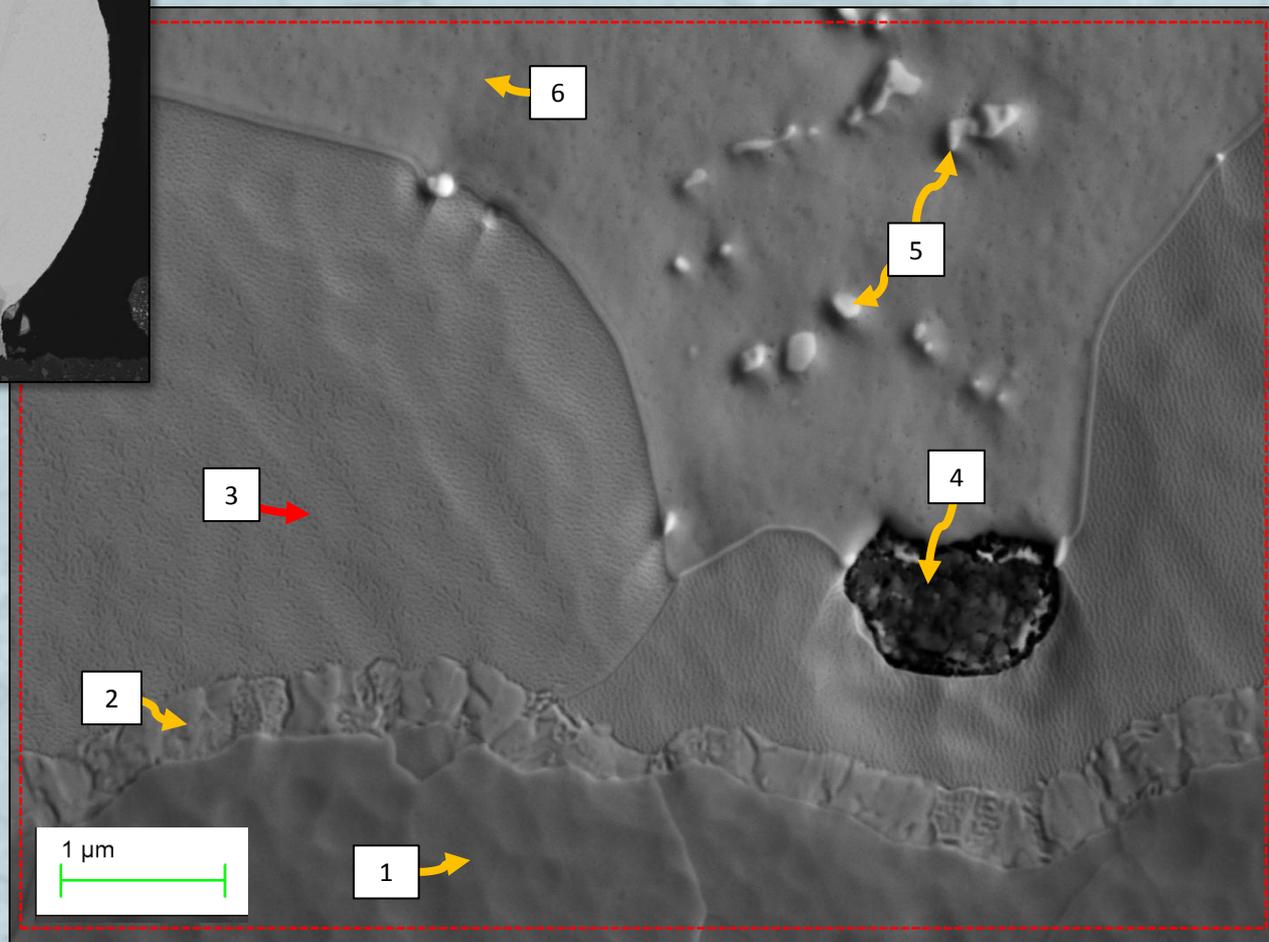
Broad Ion Beam Micro-Section and Etch



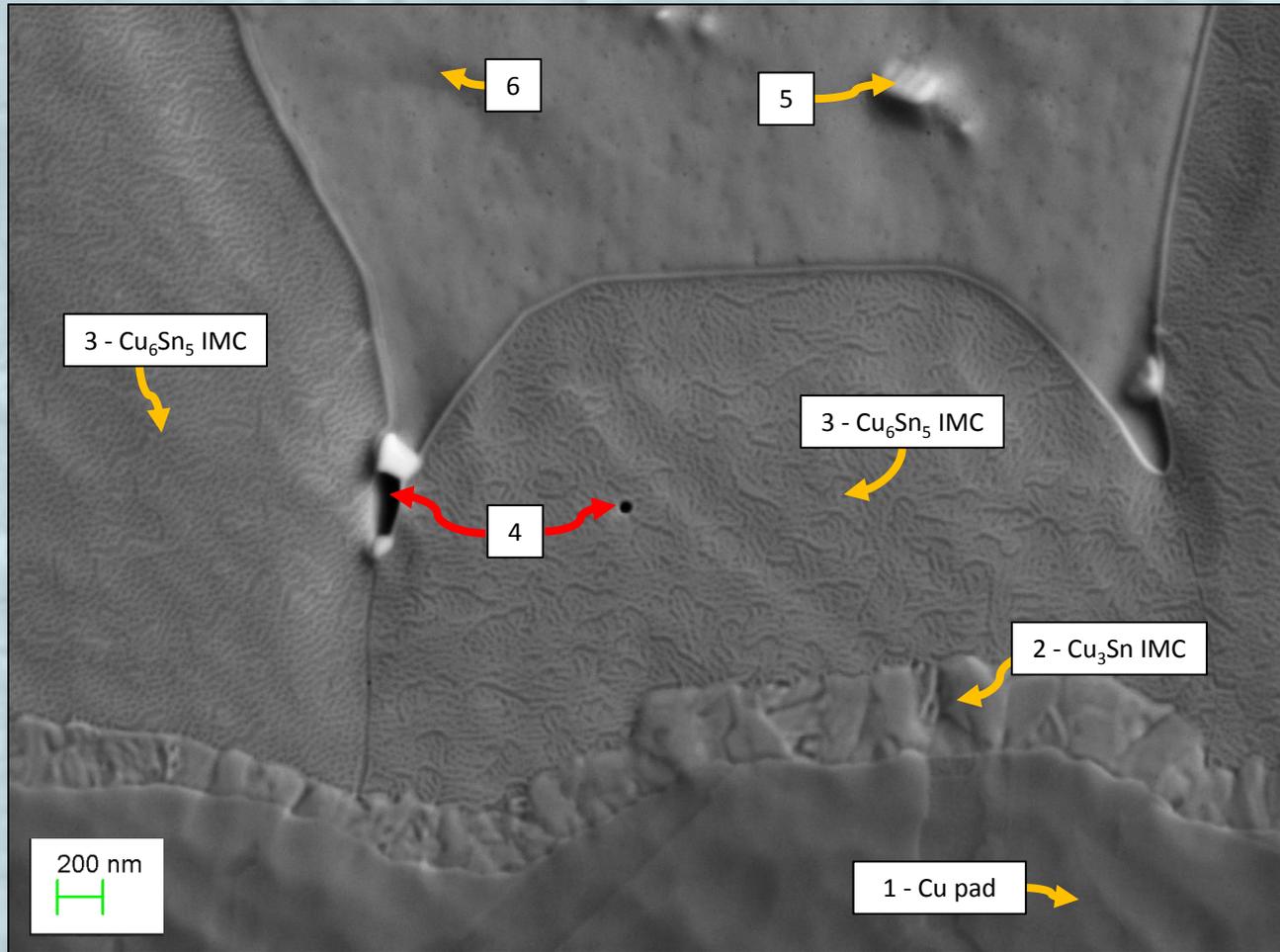
Typical BIB x-section (μ BGA joint). Zero smear surface, accurate edge definition.

Note the following:

1. Cu PCB pad
2. Cu-rich Cu-Sn IMC
3. Sn-rich Cu-Sn IMC
4. Inclusion (contaminant)
5. Fine Ag-Sn and Cu-Sn IMC's through solder ball
6. Sn phase (solder matrix)



Broad Ion Beam Micro-Section and Etch



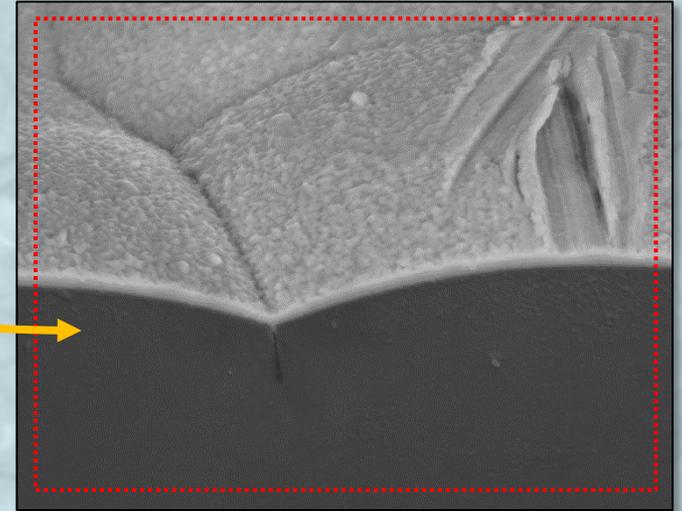
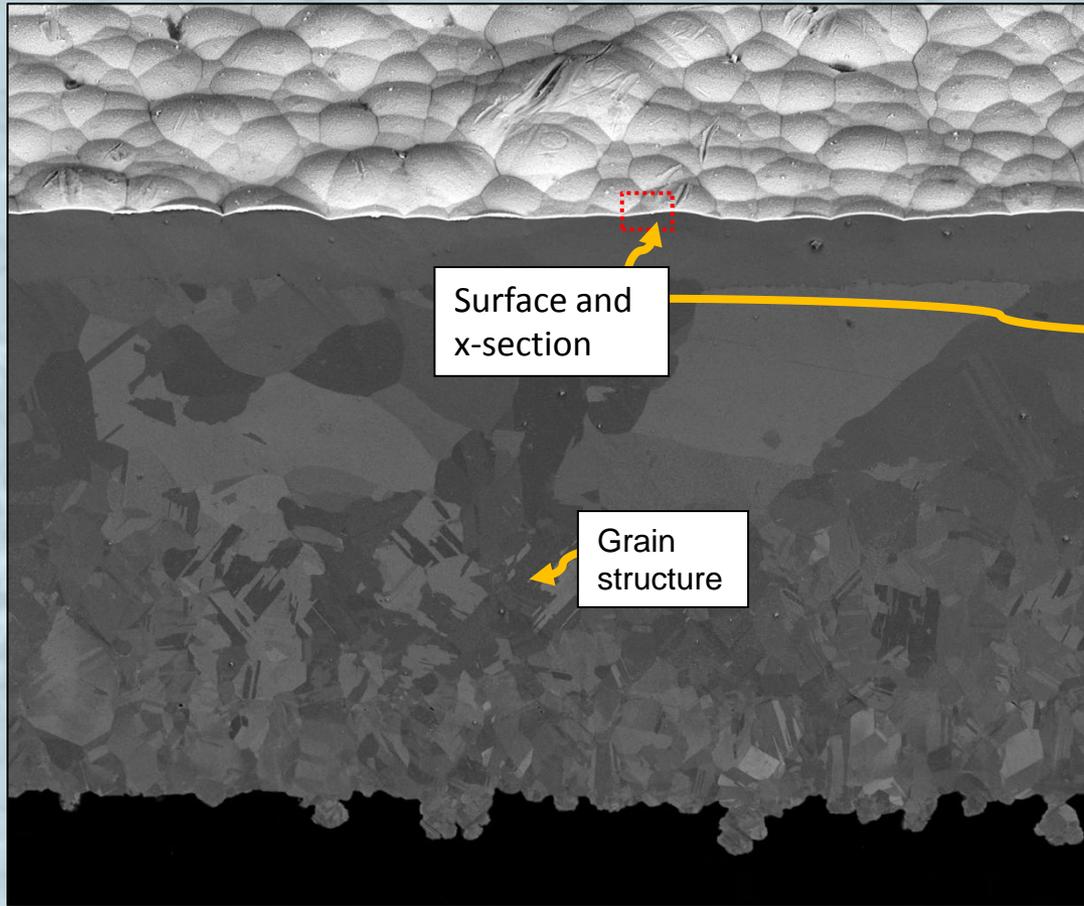
Typical BIB x-section (μ BGA joint). Zero smear surface, precise edge definition.

Clearly delineated IMC phases. At high mag (50,000x), we can clearly see the microstructure of the joint between solder and substrate.

Note the following:

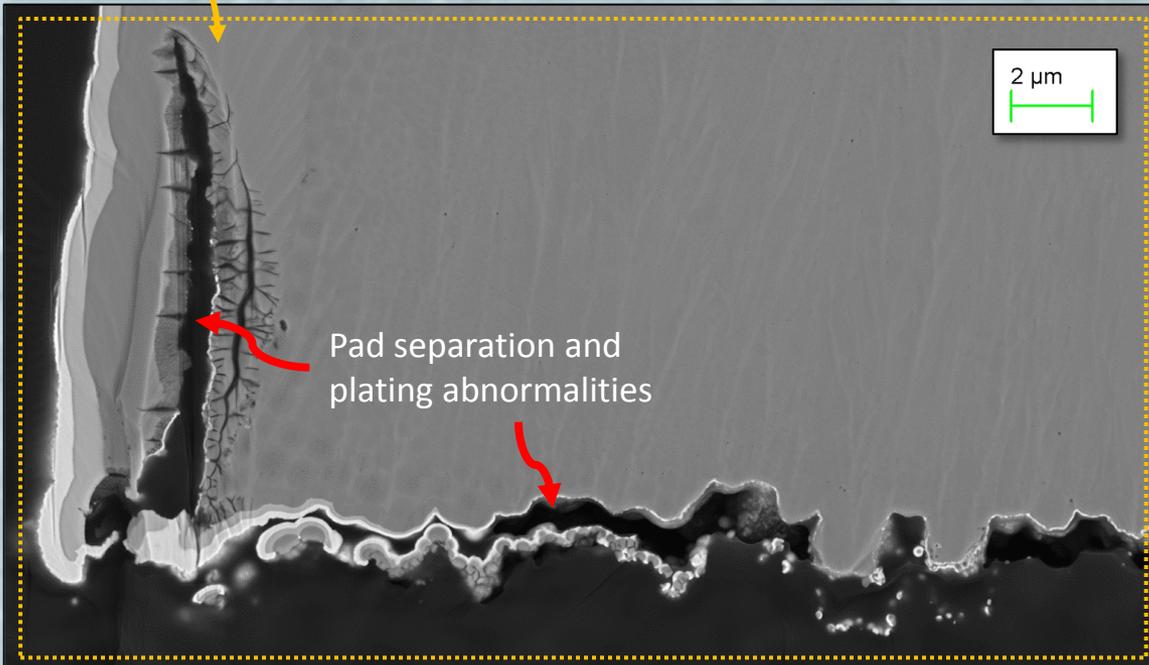
1. Cu PCB pad
2. Cu-rich Cu-Sn IMC
3. Sn-rich Cu-Sn IMC
4. Nano-scale voiding
5. Fine Ag-Sn and Cu-Sn IMC's through solder ball
6. Sn phase (solder matrix)

Micro-Section Preparation - Broad Ion-Beam X-Section (ENIG PCB)



- Surface topography *and* micro-section preparation
- Grain contrast clearly revealed in copper layers (mechanical preparation deforms surface and obscures this information)

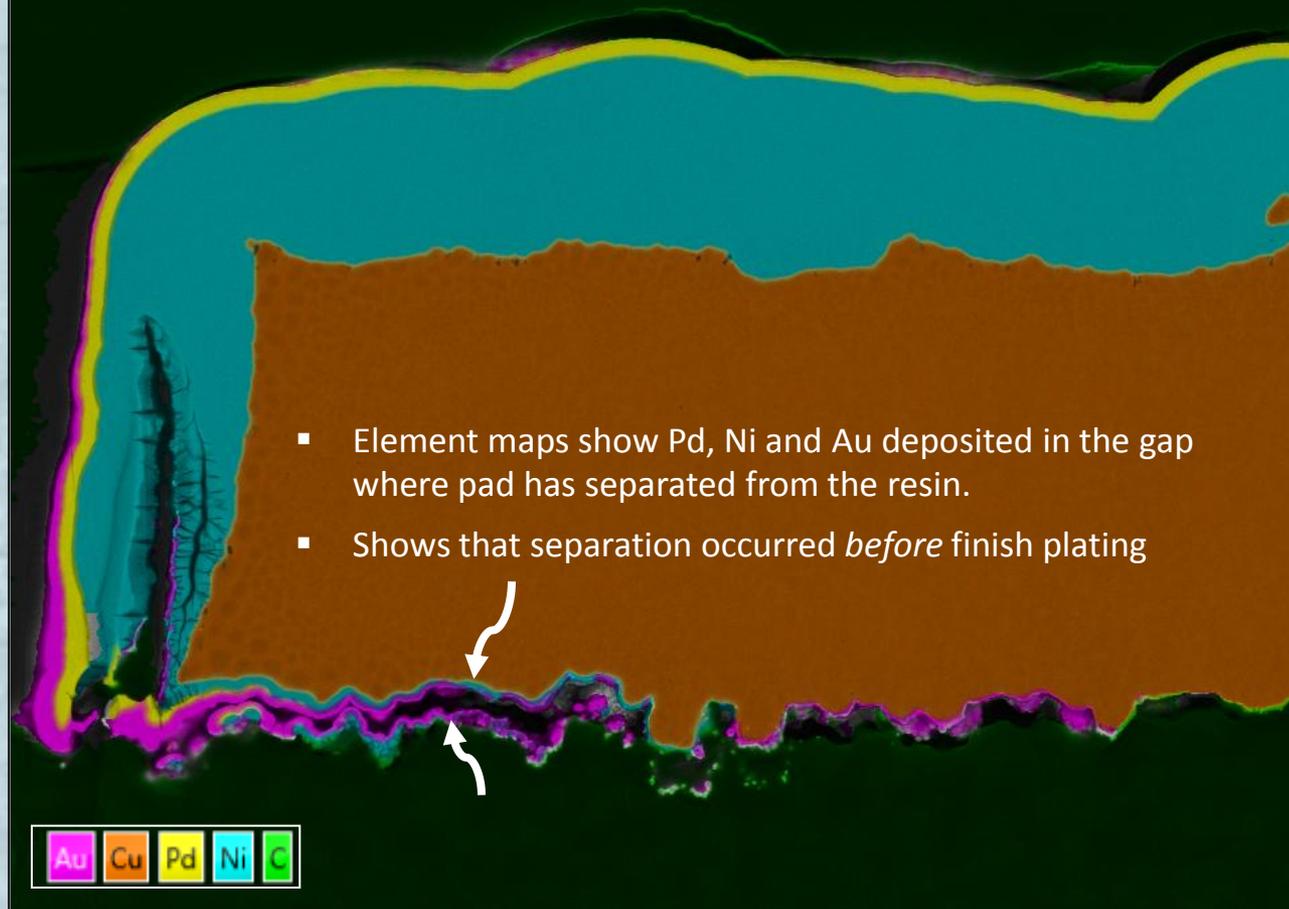
Micro-Section Preparation - Broad Ion-Beam X-Section (ENEPIG PCB)



- Previous mech x-section inconclusive (interface damaged - voids filled)
- BIB X-Section reveals layer separation and plating abnormalities
- Unsupported edges perfectly preserved
- No material drag-in
- Thin layers metal deposits prepared without deformation
- Clear definition of sample condition

Micro-Section Preparation - Broad Ion-Beam X-Section (ENEPIG PCB)

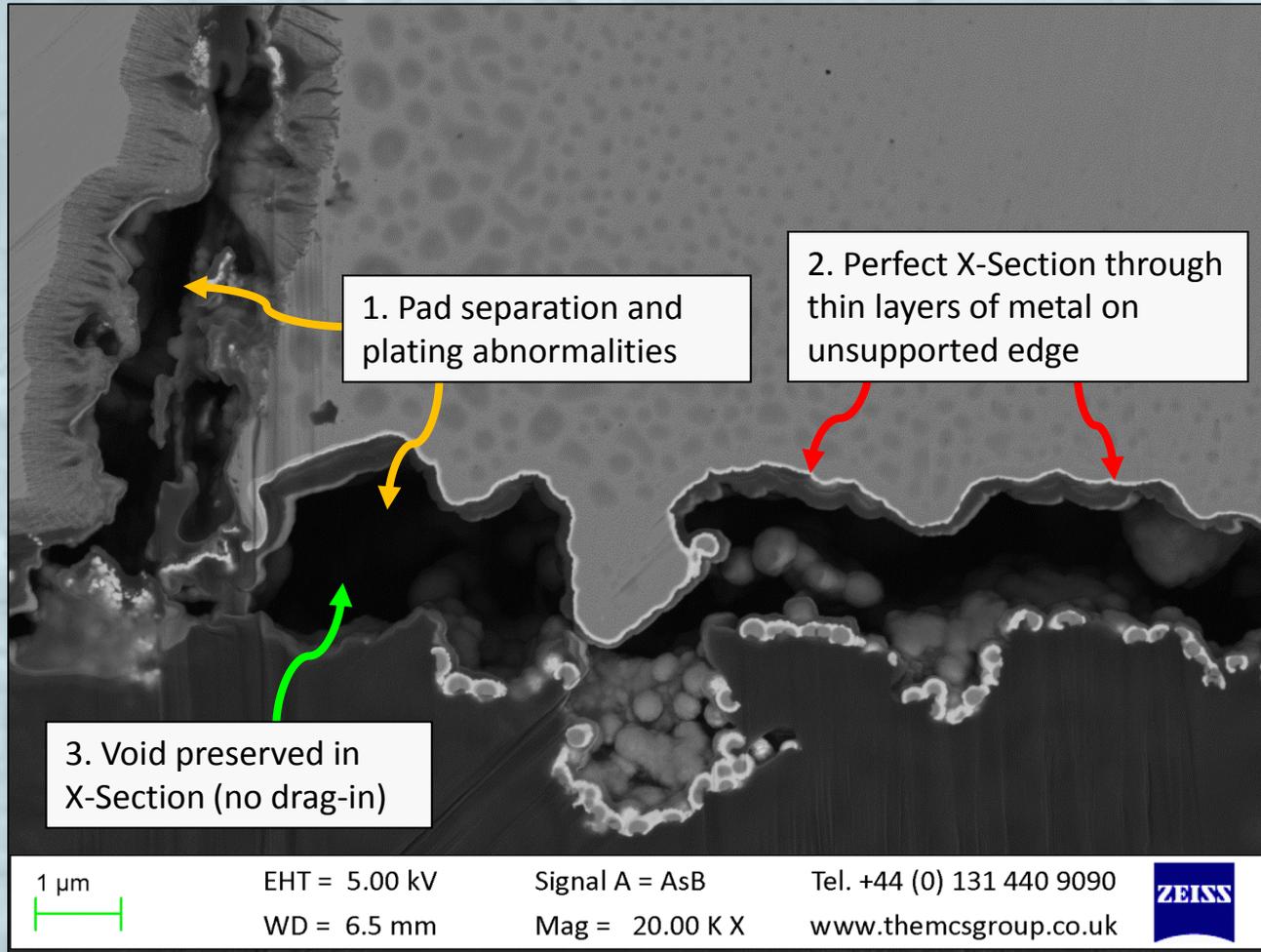
EDX Element Map Overlay - 8kV



Element Mapping (EDX):

- Identify all elements
- Optimise spatial resolution
- Identify type and distribution (mapping)
- Note Pd, Ni and Au deposited *under* edge of pad
- Shows that separation occurred *before* finish plating

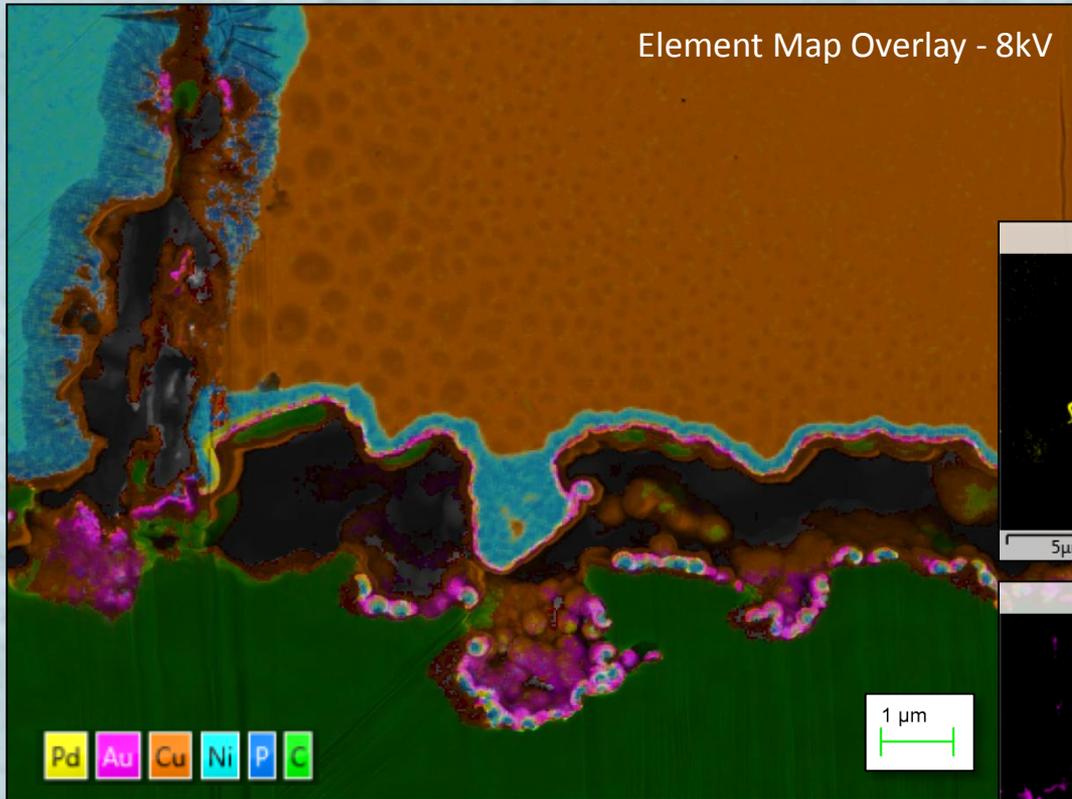
Micro-Section Preparation - Broad Ion-Beam X-Section (ENEPIG PCB)



- BIB X-Section reveals separation and plating abnormalities
- Unsupported edges perfectly preserved
- No material drag-in
- Thin layers metal deposits prepared without deformation
- Clear definition of sample condition
- EDX element mapping...

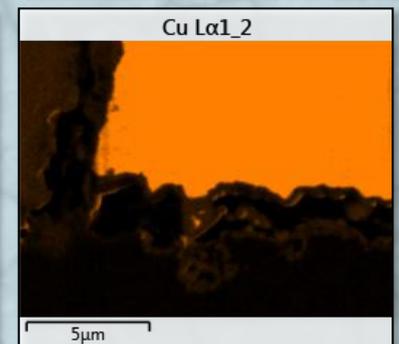
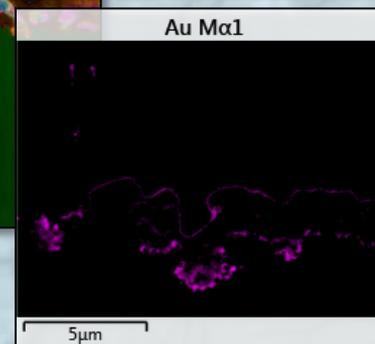
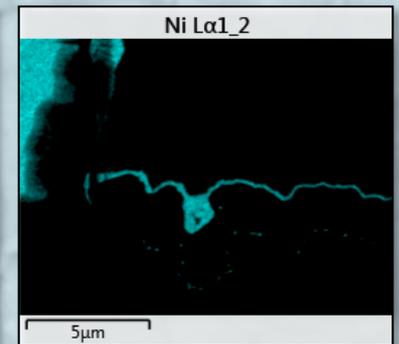
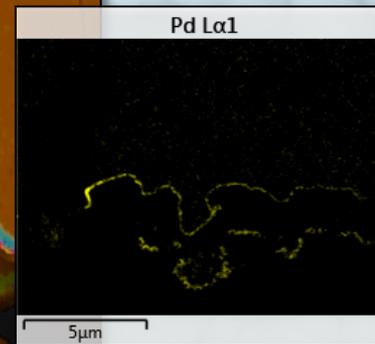
Micro-Section Preparation - Broad Ion-Beam X-Section (ENEPIG PCB)

Element Map Overlay - 8kV

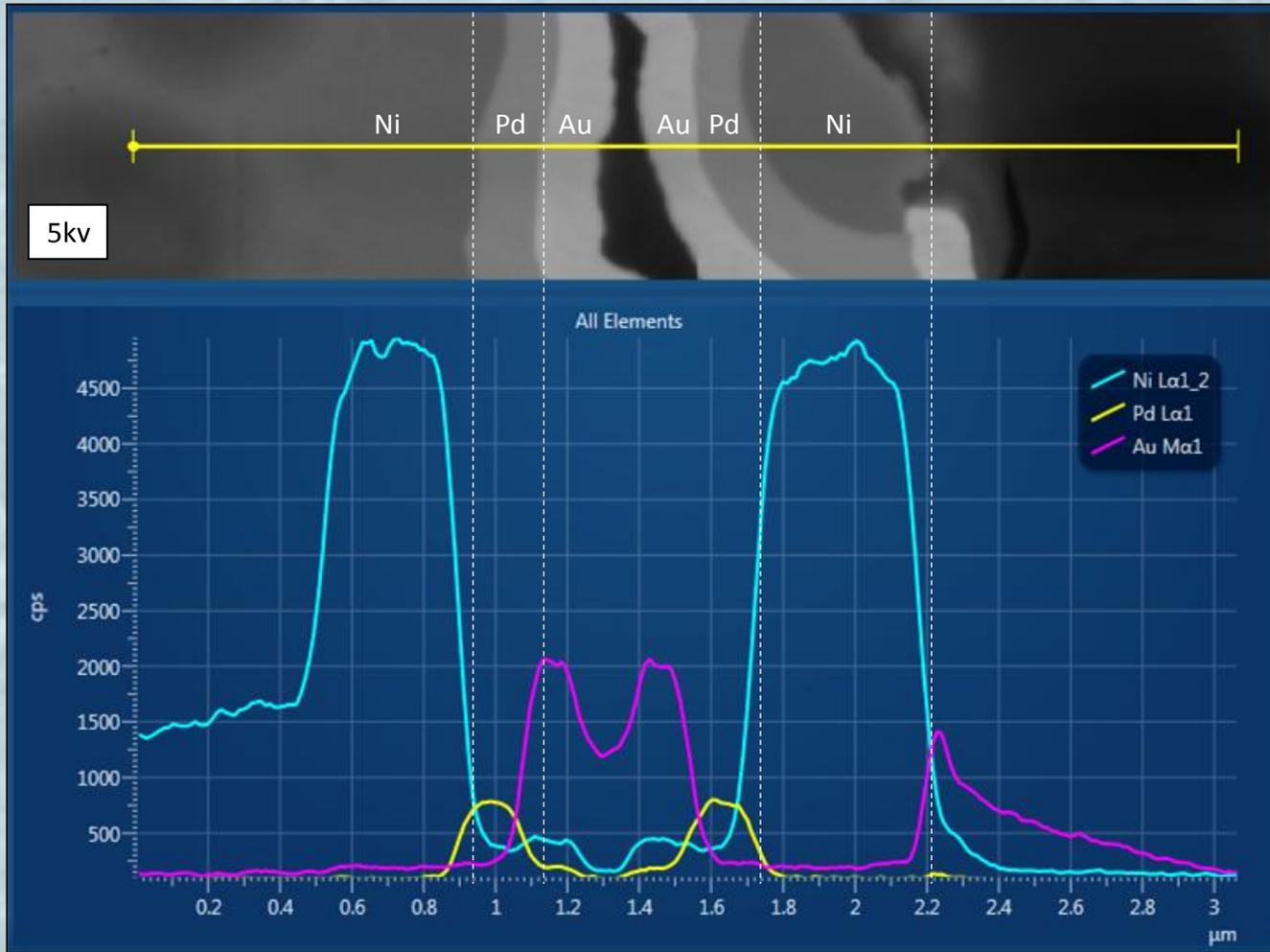


EDX Results Various Formats:

- Individual element maps
- Multiple element map overlay



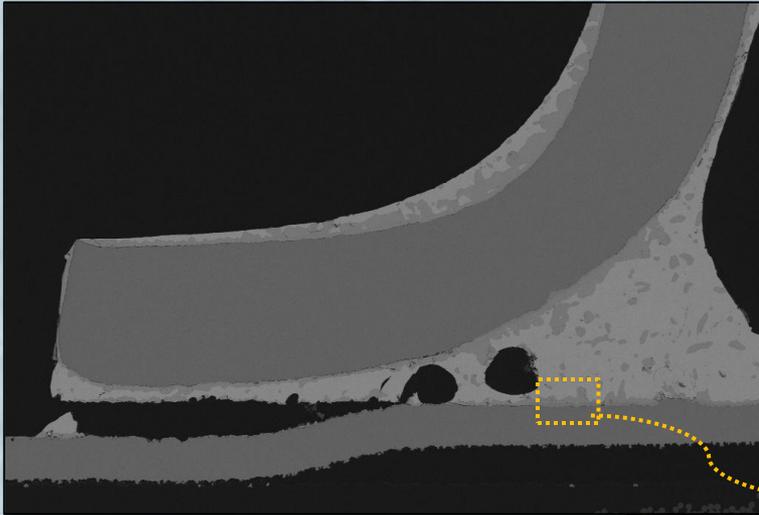
Micro-Section Preparation - Broad Ion-Beam X-Section (ENEPIG PCB)



EDX Results Various Formats:

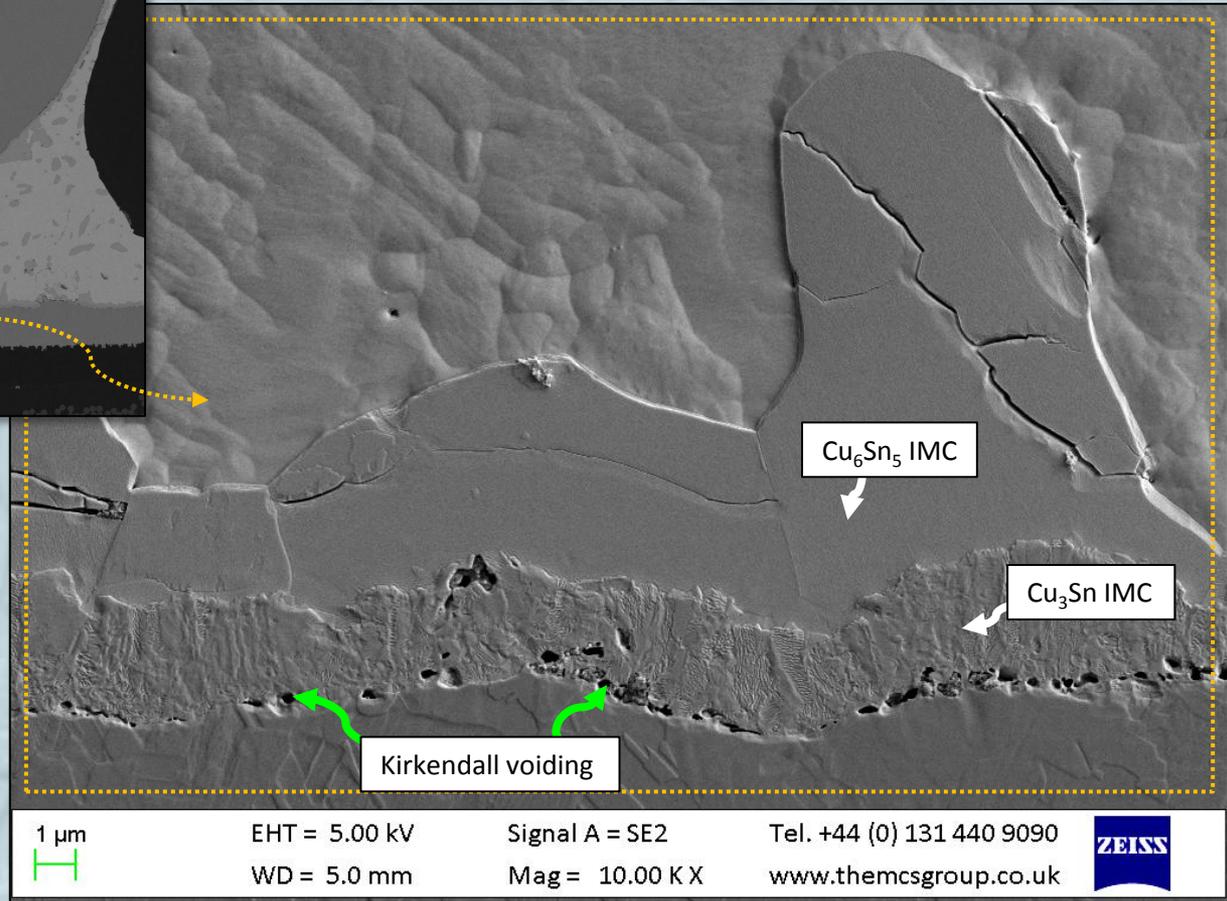
- Line profile analysis – illustrates changing composition along a line of choice
- Excellent for identifying complex multi-layer structures
- At lower kV, higher spatial resolution
- Routine sub-micron resolution

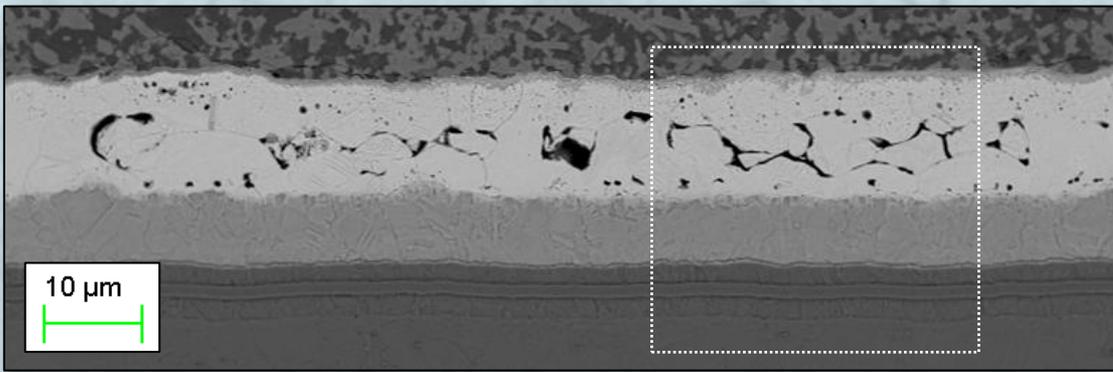
Micro-Section - Broad Ion-Beam X-Section (Aged Joint on ImSn PCB)



Ion Beam X-Section and Etching:

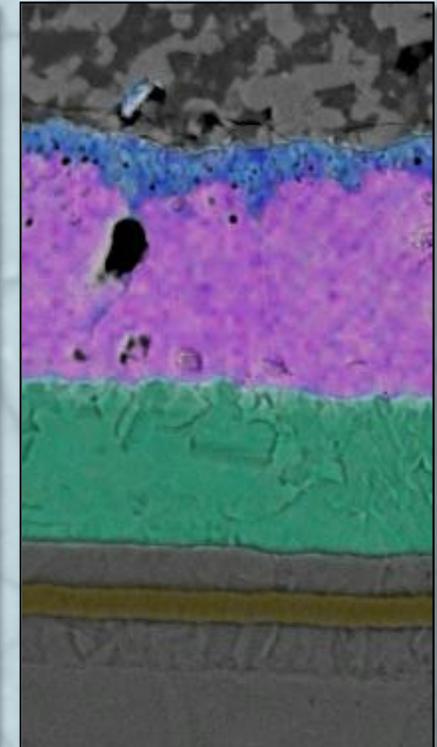
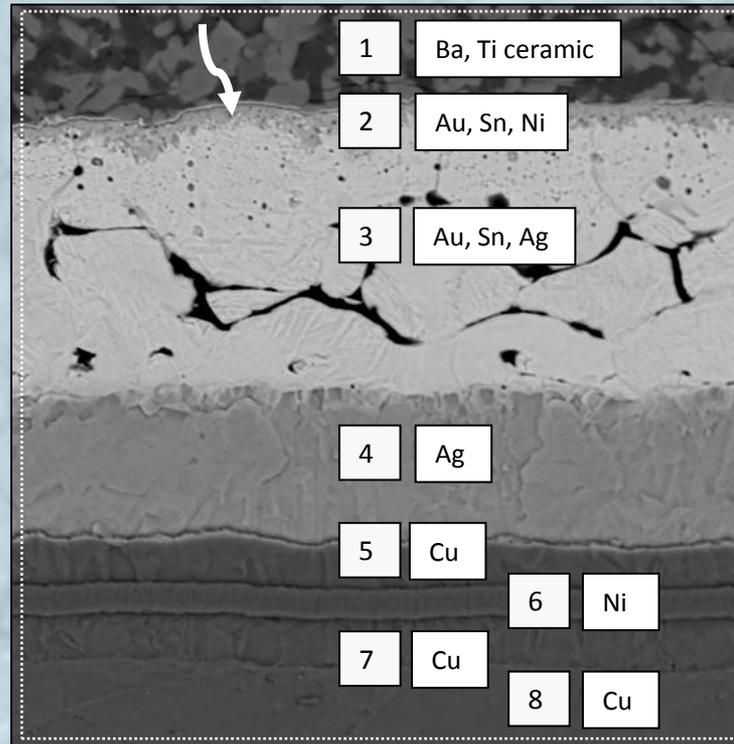
- Study bond formation and ageing on PCB pads
- Etch reveals different IMC phases
- Routine sub-micron resolution reveals Kirkendall voiding and cracks in Cu_6Sn_5 IMC phase



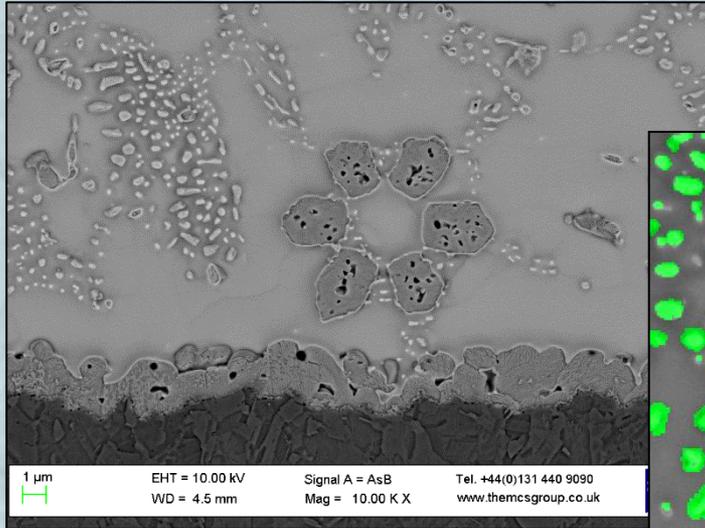


Ion Beam X-Section and Etching:

- Simultaneous etching of all layers across complex plated and bonded structure
- 8 layers clearly demarcated (note no smear, precise edge definition)
- Reliable, controllable and repeatable etching
- Similar results difficult or impossible using wet chemical techniques

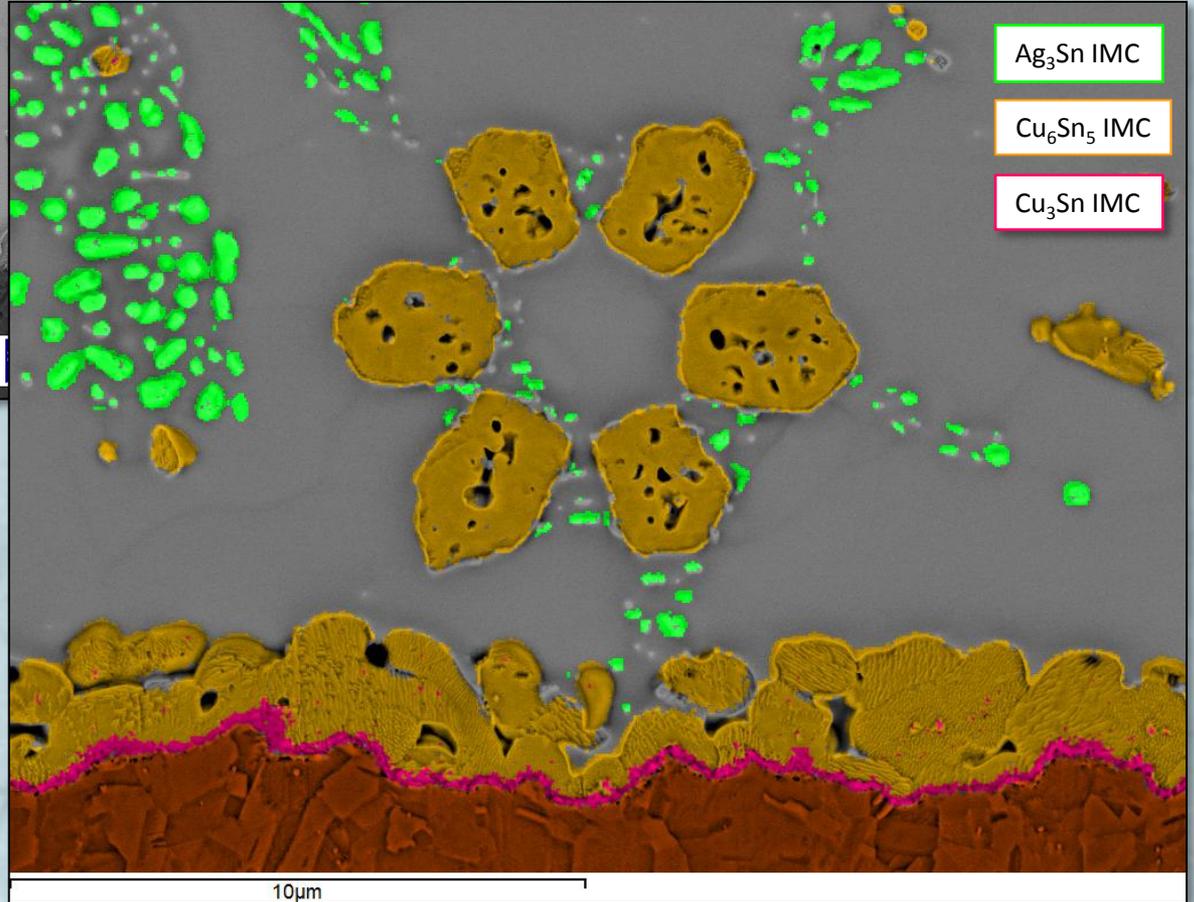


Micro-Section - Broad Ion-Beam X-Section (Aged Joint on ImSn PCB)



Ion Beam X-Section and Etching:

- Combine with element analysis to determine identity of key structures
- Coloured image formed by phase maps overlaid on area of analysis
- Clearly highlights different phases at PCB pad interface and through solder joint



- ✓ Broad Ion-Beam x-section process enables analysis of samples where mechanical preparation cannot (fundamental change in capability)
- ✓ Broad Ion-Beam x-section preparation and analysis services are available now at MCS
- ✓ Please contact us for further information:
e. stewart@materials-consult.co.uk
t. +44(0)131 440 9090



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