

SEM/FIB DUAL BEAM MICROSCOPY

A Powerful Combination

Dave Soltz, PhD

April 30, 2020 11am PDT

COVALENT ACADEMY

EPISODE 5

RSVP at:
https://bit.ly.covalent05

Covalent Metrology



- **Founded 2016**
- **Testing, measurement & characterization Platform**
- **30 team members (13 PhDs)**
- **9,500 ft² lab in Sunnyvale**
- **1-Stop-Shop Source for Answers**
  - 30 instruments in-house
  - 6 partnerships with instrument makers
  - 11 partner labs
  - 6 corporate “tool shares”
- **>275 customers** (80% repeat)

Covalent Technical Groups and Organization

hello@covalentmetrology.com

Electron & Scanning Probe Microscopy

(SEM/TEM, AFM, EDS, EELS, Nanoindent, acoustic microscopy)

Surface Analysis

(XPS, Auger, ToF-SIMS, dSIMS)

Optical Microscopy & Spectroscopy

(Laser Confocal, White Light, Chromatic Dispersion, Spectral Ellipsometry, UV-Vis-NIR Spectroscopy)

Materials/ PC Board FA

(Cross Sections, Inspections, Dye & Pry)

X-Ray Characterization

(XRD/XRR, XRF, µCT)

Chemical Analysis

(ICPMS, GCMS, FTIR, Raman, Solid & Solution NMR, 2D NMR)

Nanoparticle Analysis

(DLS, PSA, Particle Zeta Potential)

Bulk Properties Characterization

(DSC, TGA, DMA, Rheometry, Tensile Test, Pencil Test, Surface Zeta Potential)

David Soltz, Ph.D. – Director, Scanning Probe & Electron Microscopy



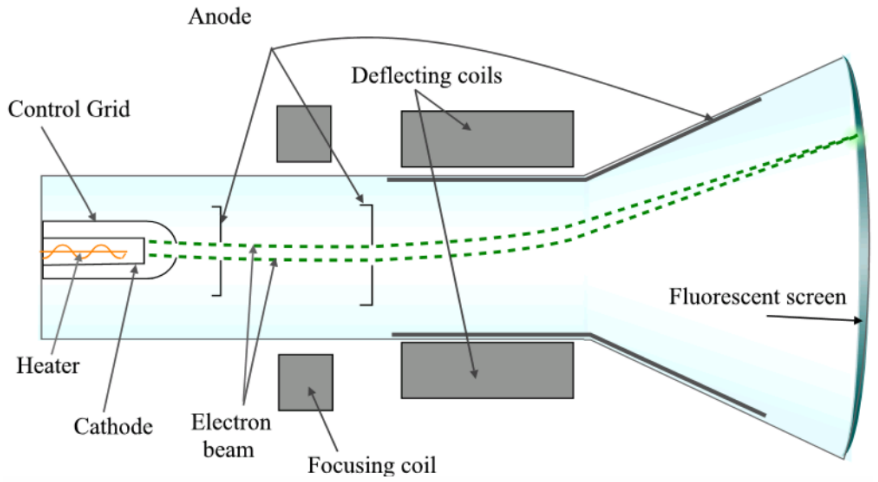
Dr. Dave Soltz supervises SEM Ebeam/FIB and Probe Metrology at Covalent Metrology. His specialties include: SEM, FIB, EDS, AFM, Nano-indentation and their various applications for materials' characterization in the fields of silicon chip, solar, LED, micro-optical, and aerospace. Dave obtained his BS from SUNY Syracuse in Chemistry with a specialization in polymers and MSc from the Weizmann Institute of Science in Structural Chemistry working with CuInSe2. He completed his PhD in Physical Chemistry working at the Fritz Haber Institute (part of the Max Plank system) in Berlin, and at the State University of Campinas; UNICAMP, concentrating on photoelectrochemical etching of microstructures on III-V materials. He also completed a post-doc at Colorado State University studying electron transfer at dye-semiconductor interfaces with scanning probe microscopy. Find Dave on LinkedIn

Episode 5 Overview

- Scanning Electron Microscopy (SEM) Basic Principles
- Ebeam-Sample Interaction and Detection
- Magnetic vs. Electrostatic Objective Lens
  - Thermo Fisher Helios 5 vs Scios
  - Advantages and Disadvantages of Each
- Detectors and Imaging
  - Topographical vs. Compositional Information
  - Chamber, In-Lens, In-Column, Annular, STEM
  - SE vs. BSE Imaging
- Charge Mitigation; Environmental SEM
- EDS; Theory, Spectra, in Combination with BSE
- FIB Intro

How an SEM works; Relationship to CRT (TV)
Principle of Magnification; Ratio of Scan Lengths

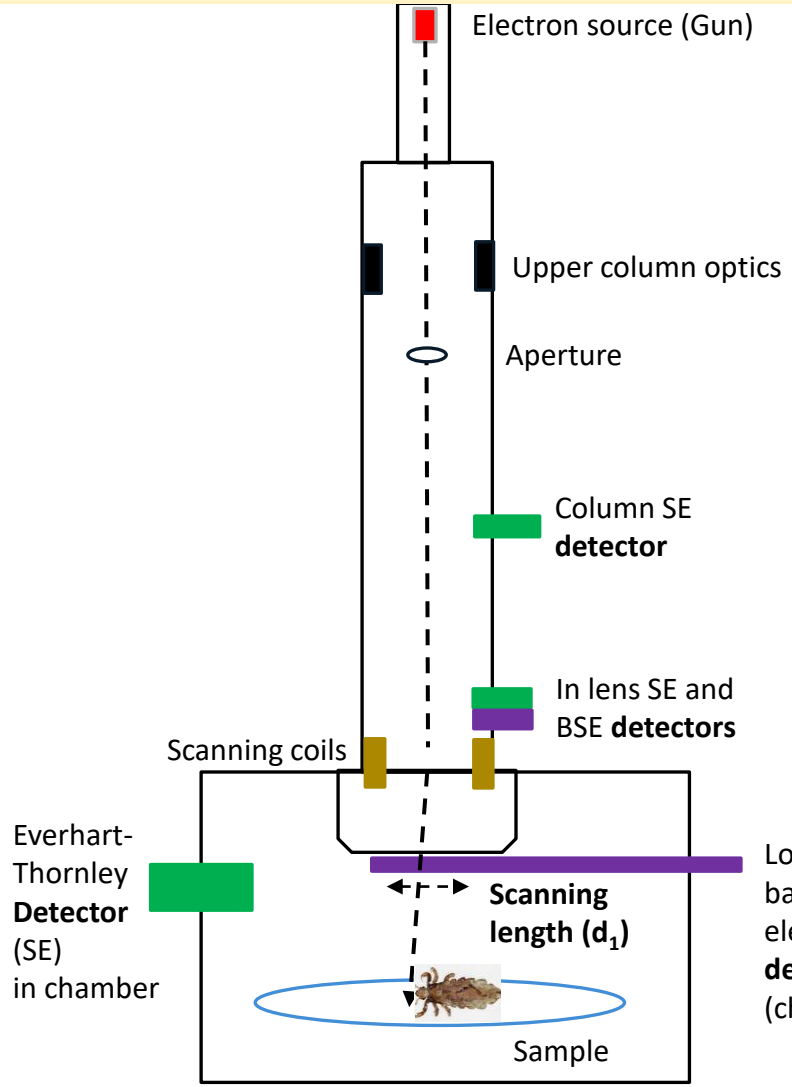
Cathode Ray Tube (CRT)





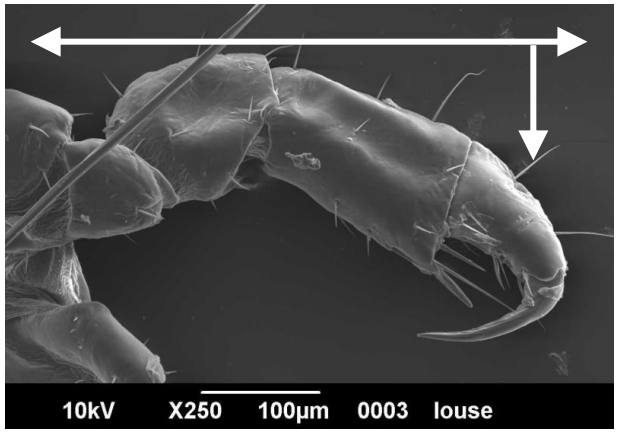
Displayed image

Scanning Electron Microscope (SEM)



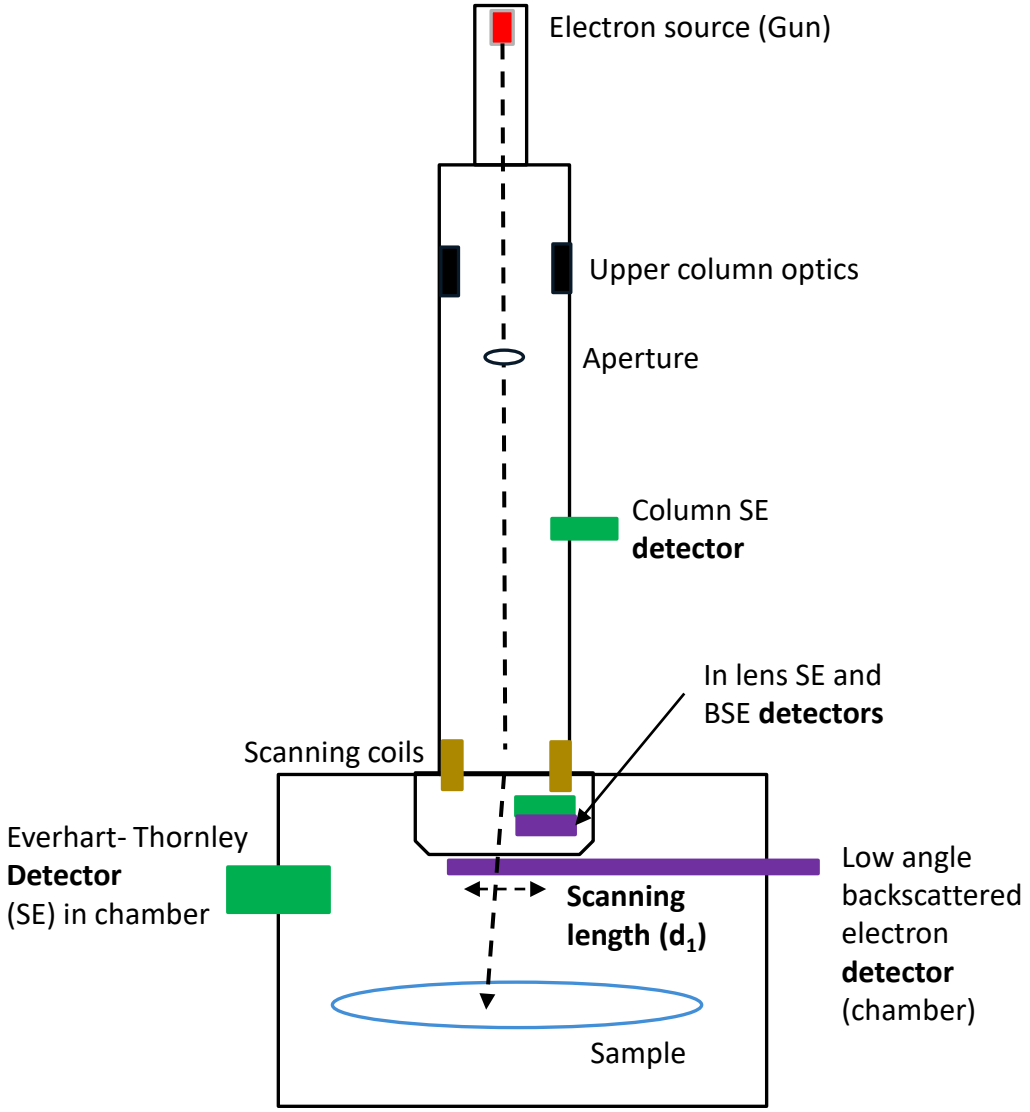
Magnification = d_2 / d_1

Scanning length (d_2)



Displayed image

Ebeam Source, Electron Optics, Aperture, Objective Lens

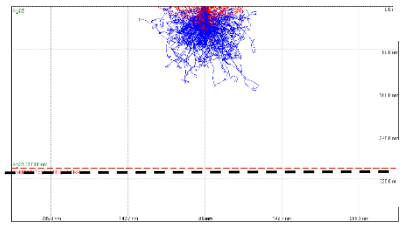




Scios Dual Beam

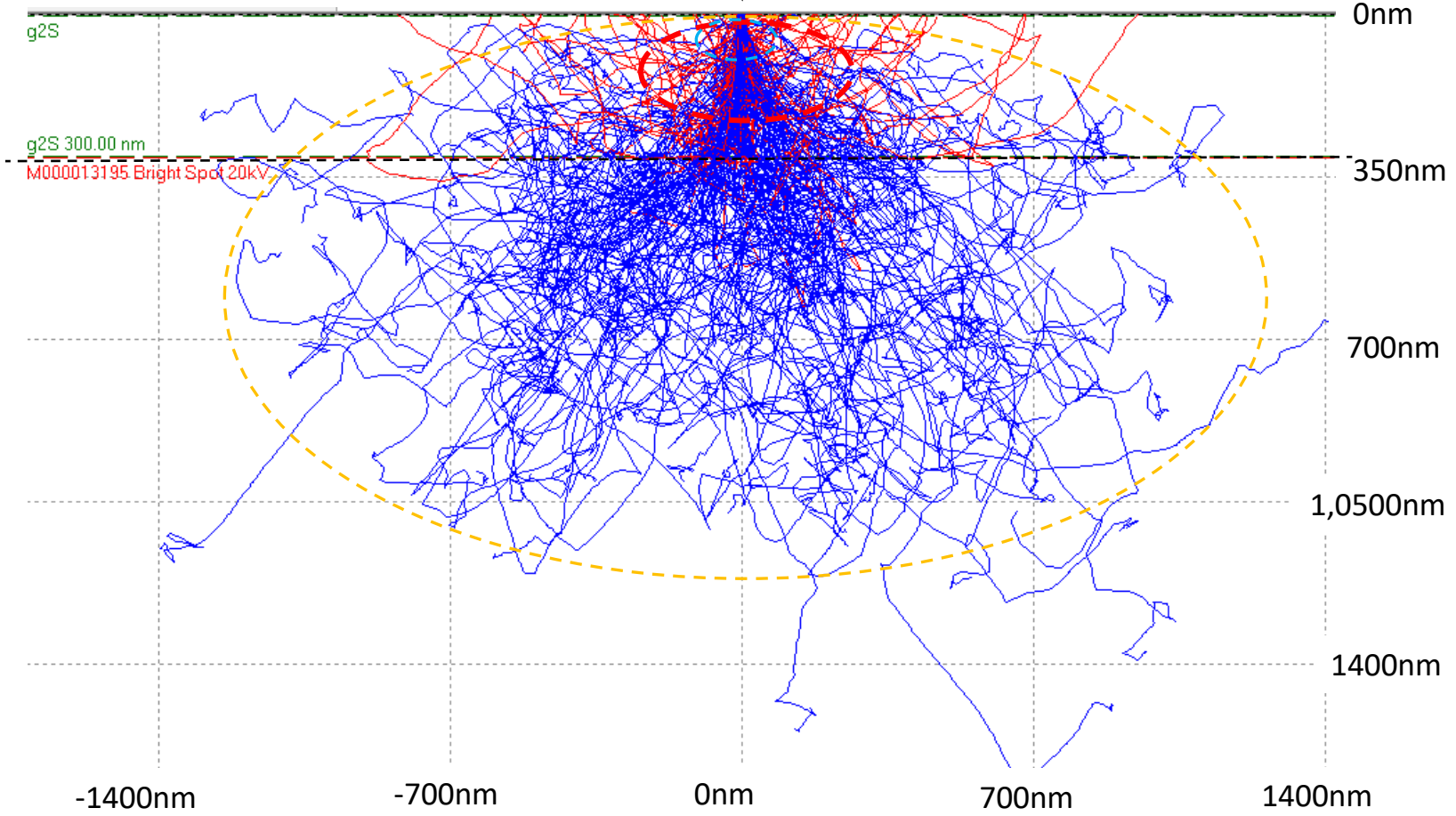
Casino Ebeam Penetration Simulation

5kV



Penetration depth ~40nm

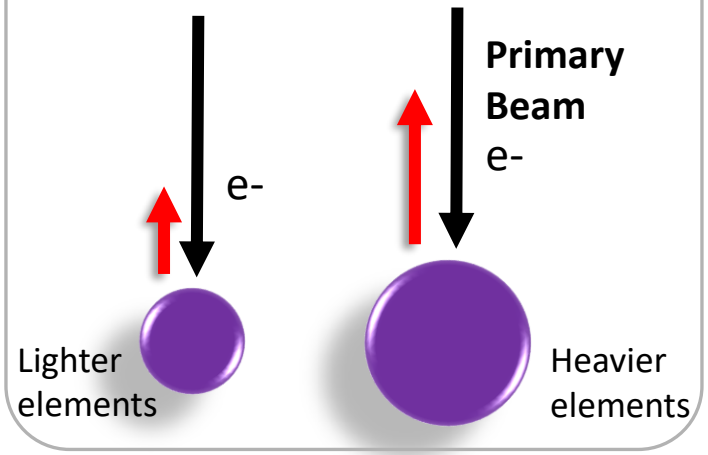
20kV



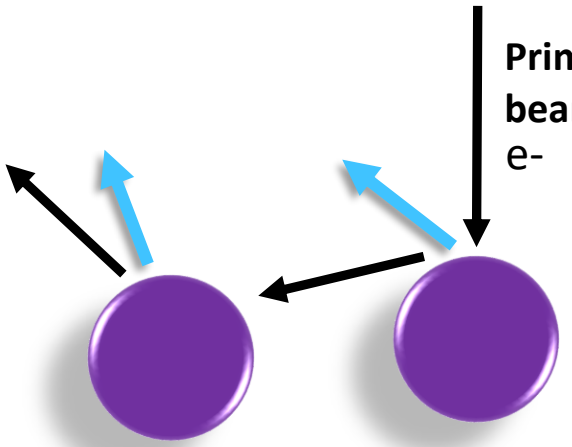
Penetration depth ~1,200nm

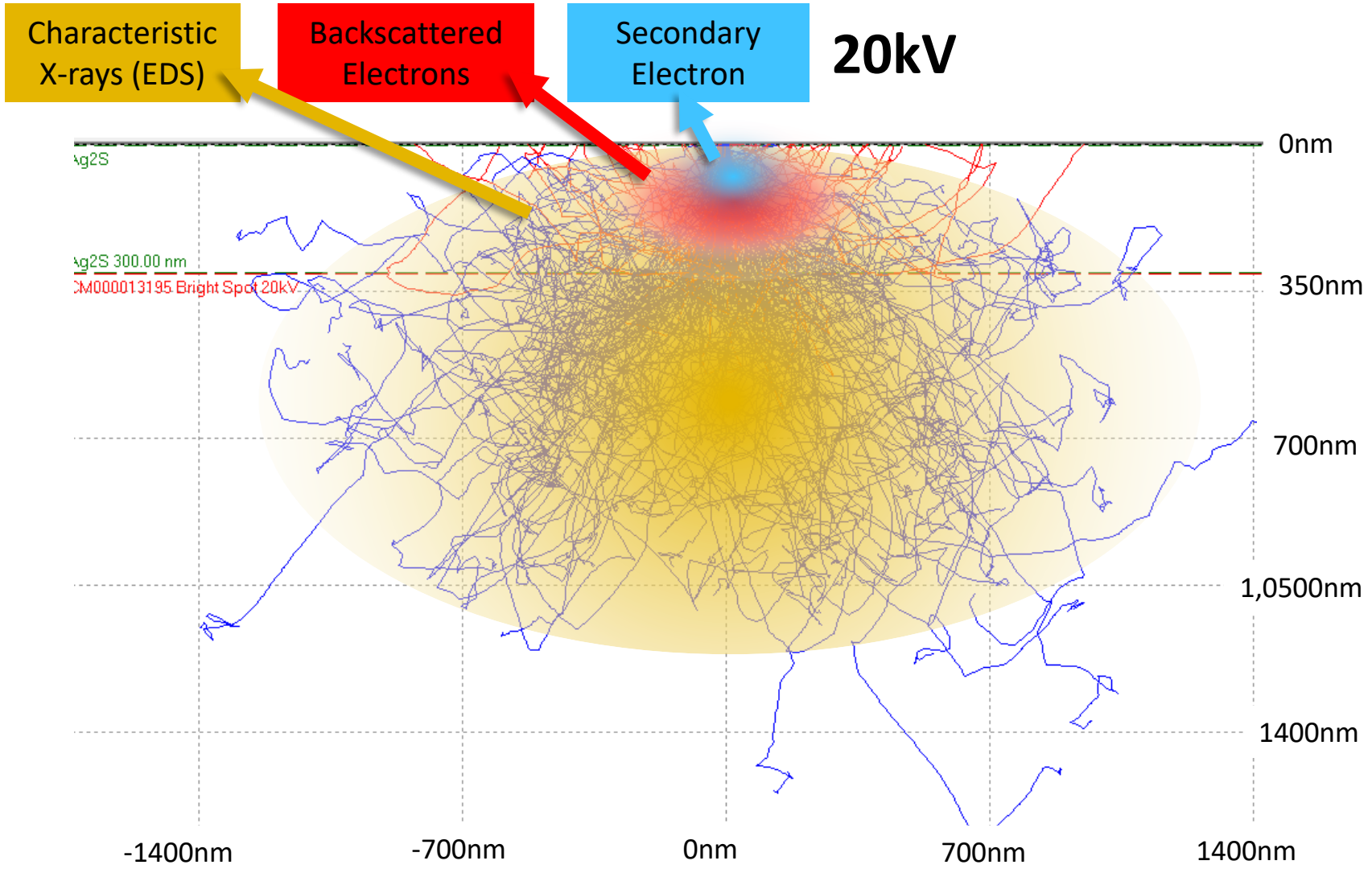
Backscattered vs Secondary Electron Generation Efficiency and Escape Depth

Backscattered Electrons



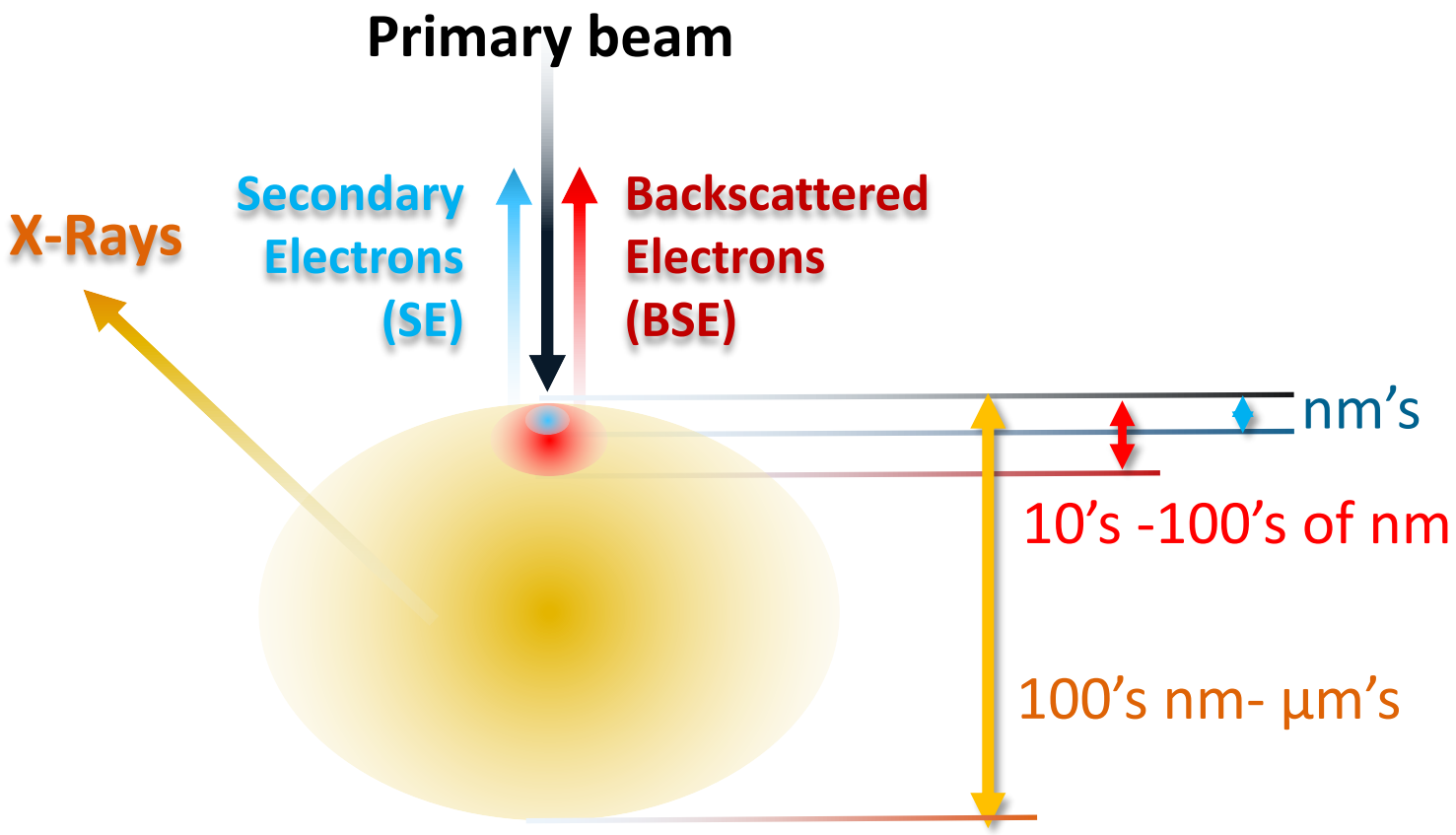
Secondary Electrons





Penetration depth of 20kV beam ~1,200nm

Depth of Signal Source; Secondary Electrons, Backscattered Electrons, and Characteristic X-Rays (EDS)



Secondary electron (SE)
Low energy < 100eV

Backscattered electron (BSE)
due to elastic scattering
High energy >> 100eV up to the energy of the primary beam (kV's)

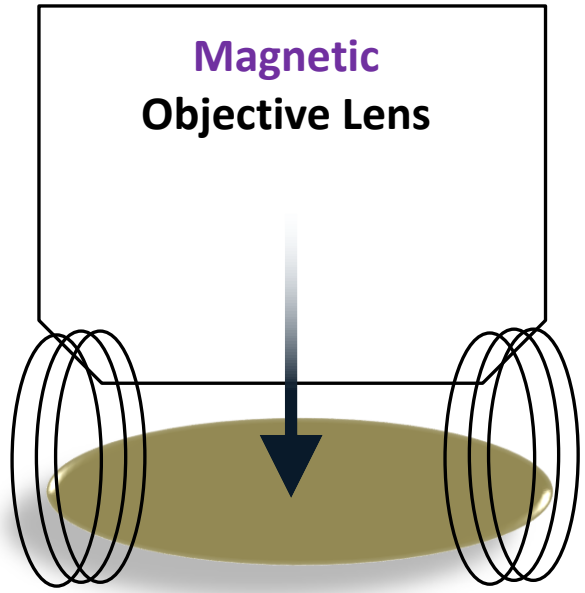
Characteristic X-Rays 100's eV up to 10's of kV

Magnetic Immersion vs Electrostatic Lens

Thermo Fisher

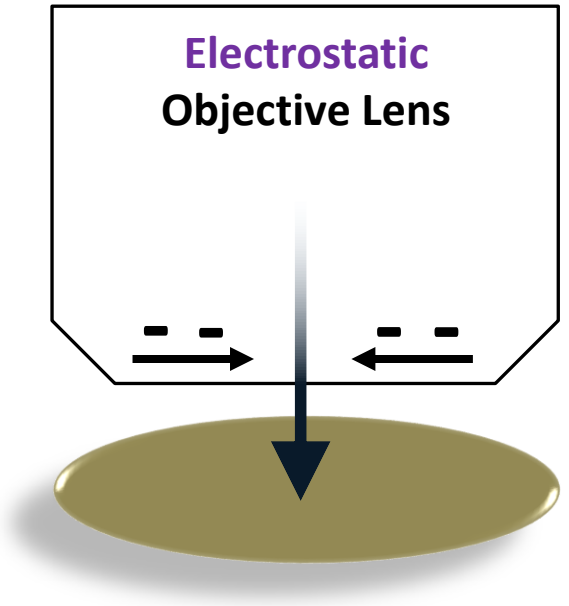
Helios 5 Dual Beam SEM/FIB

- Very high resolution, difficulty handling magnetic samples

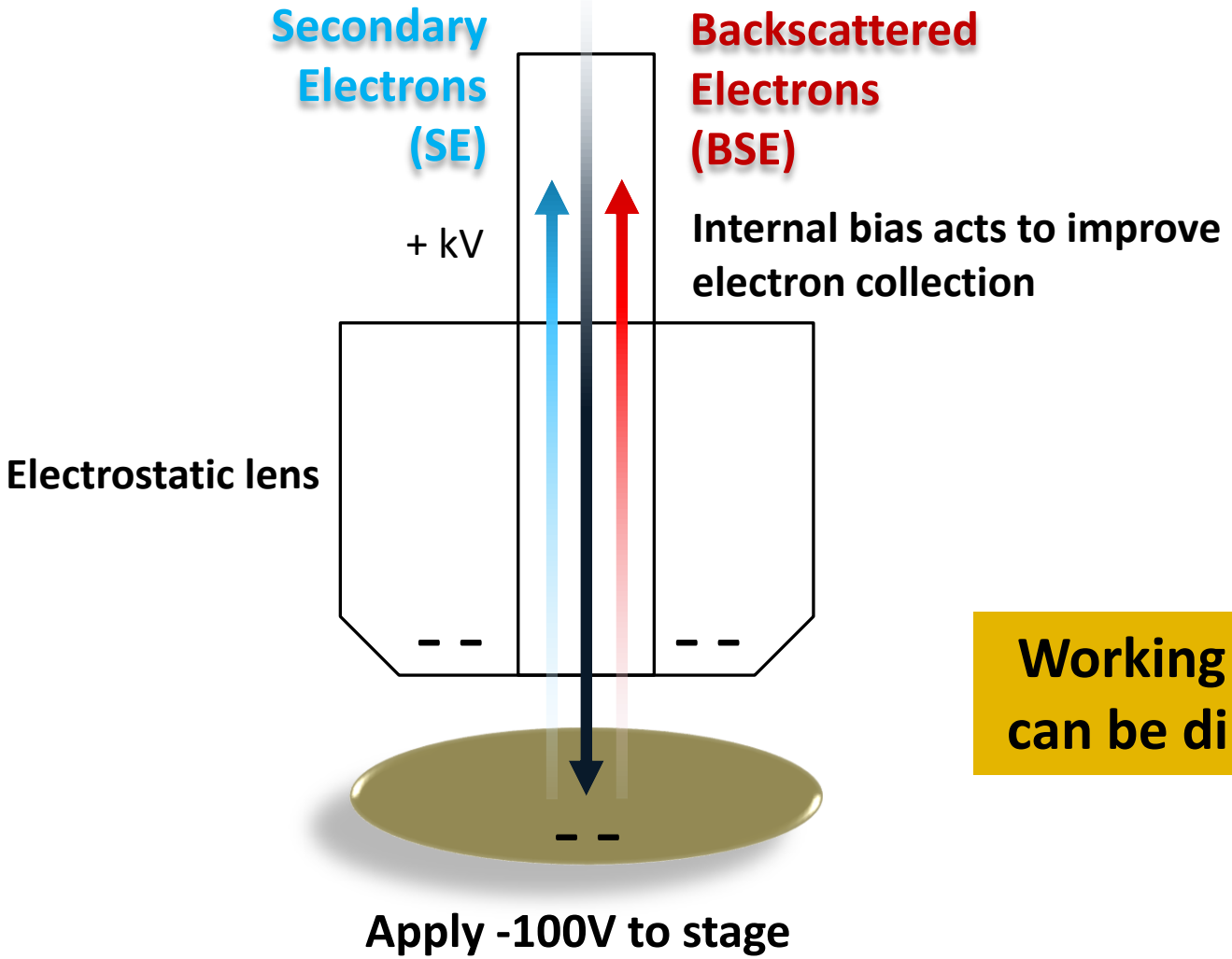


Scios SEM Dual Beam

- Slightly lower resolution, at lower landing energies
- Much easier to handle magnetic samples; avoid sample lift-off from stage.
- Also avoid repeated focus and stig adjustments



Methods for Improving Signal Collection and Reducing Sample Charging

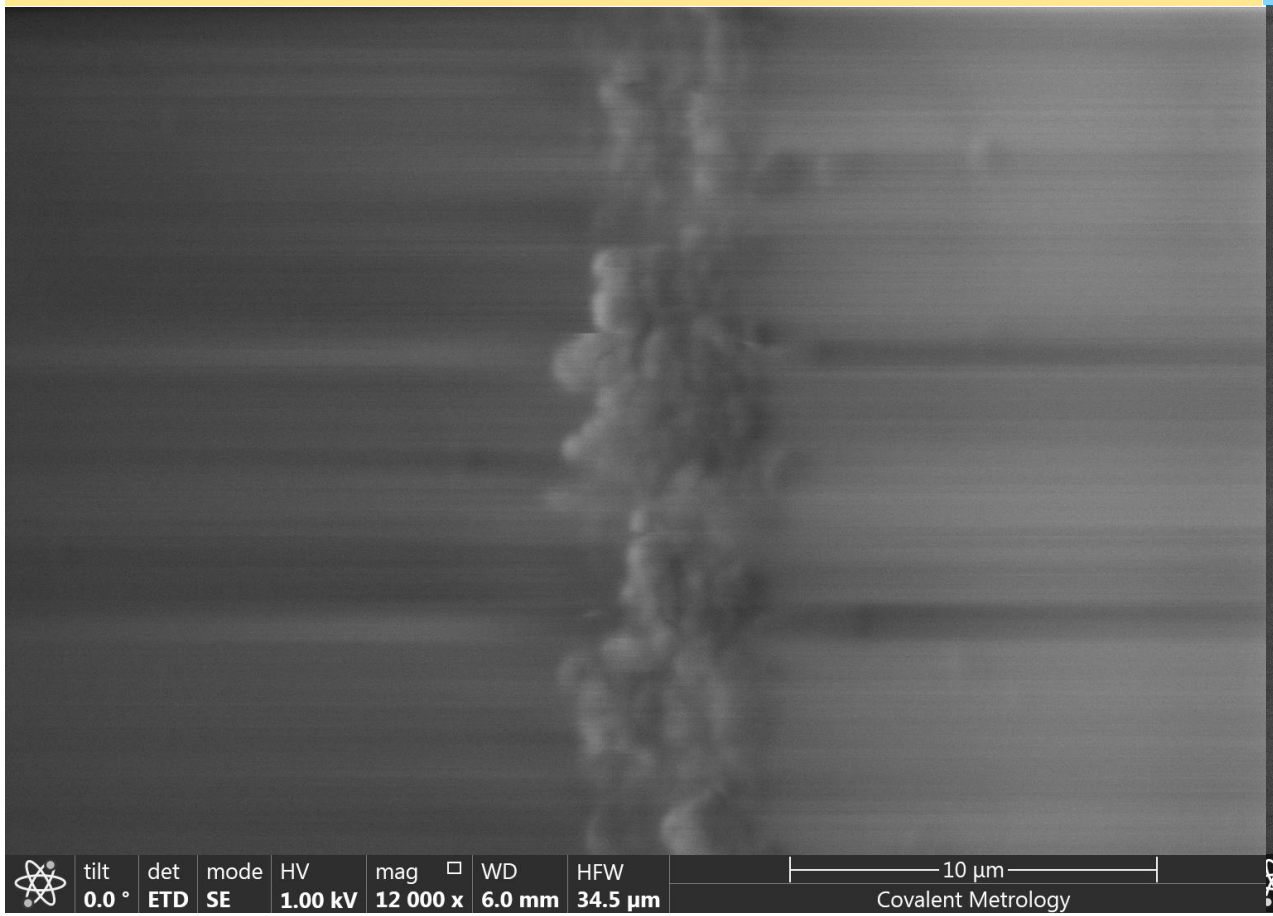


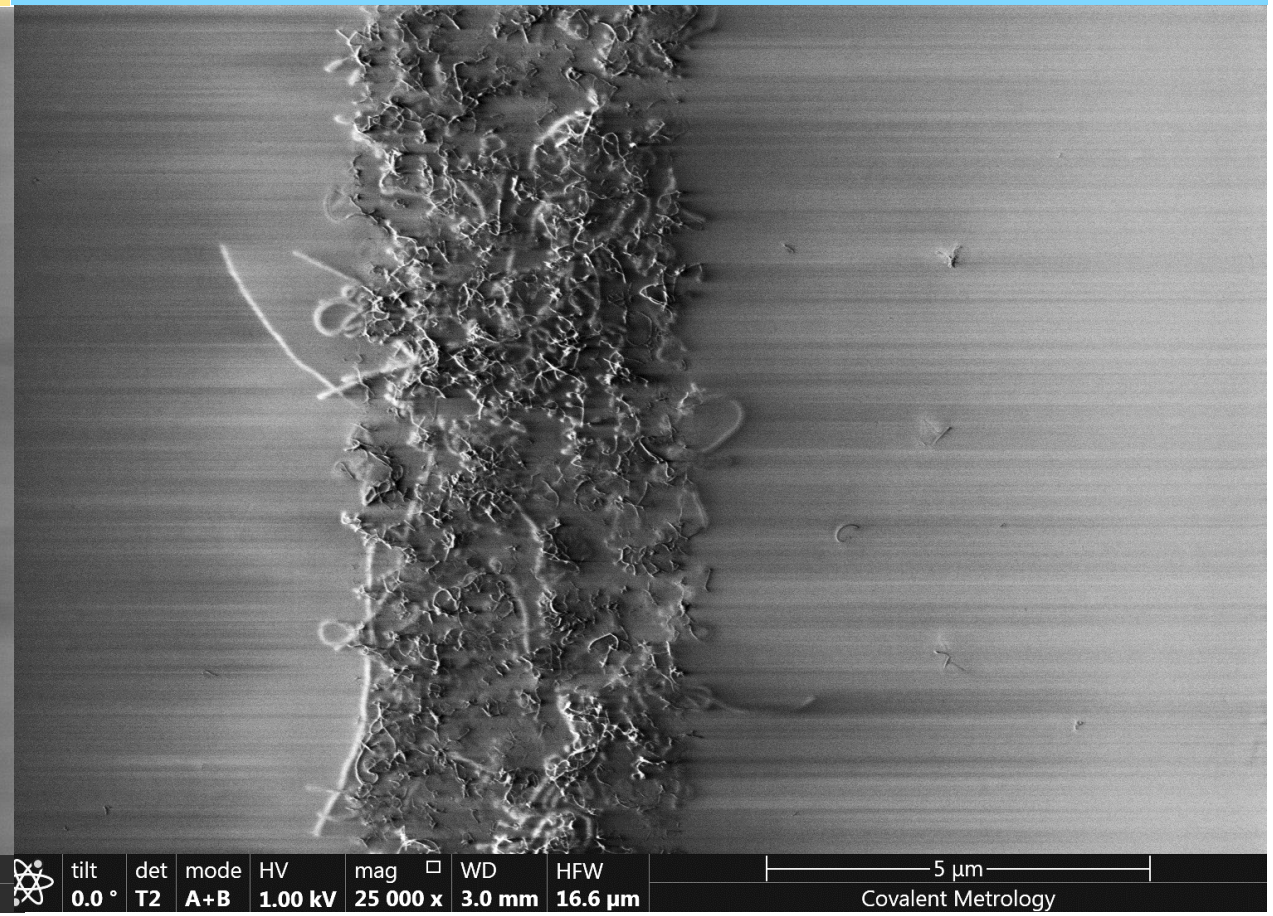
Working distance can be diminished

Introduction of Retarding Field, Reduction of Working Distance

WITHOUT Optimization

WITH Retarding Field + Reduced WD

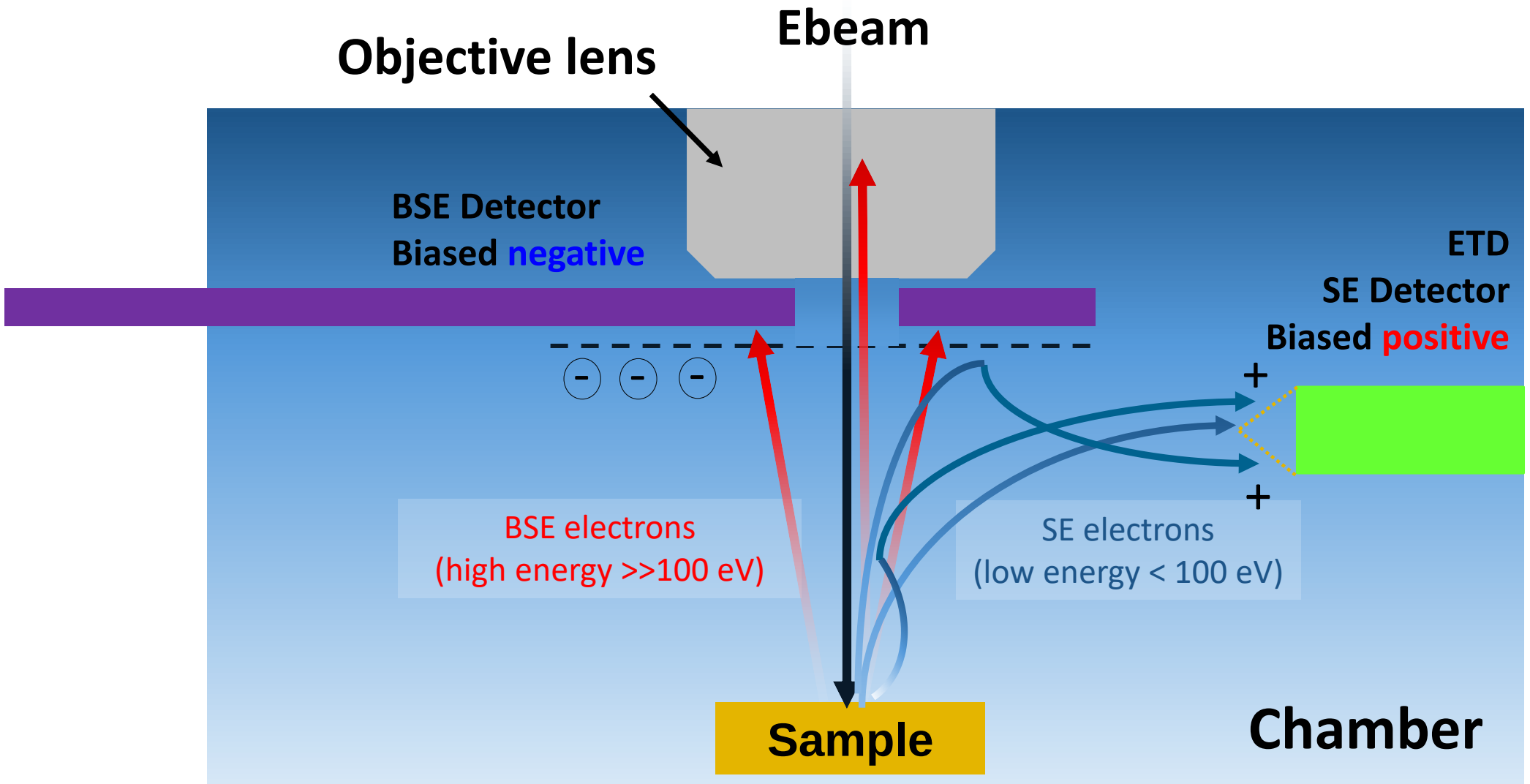




Customer Sample with Permission

Detectors and Imaging; Theory and Operation

COVALENT METROLOGY

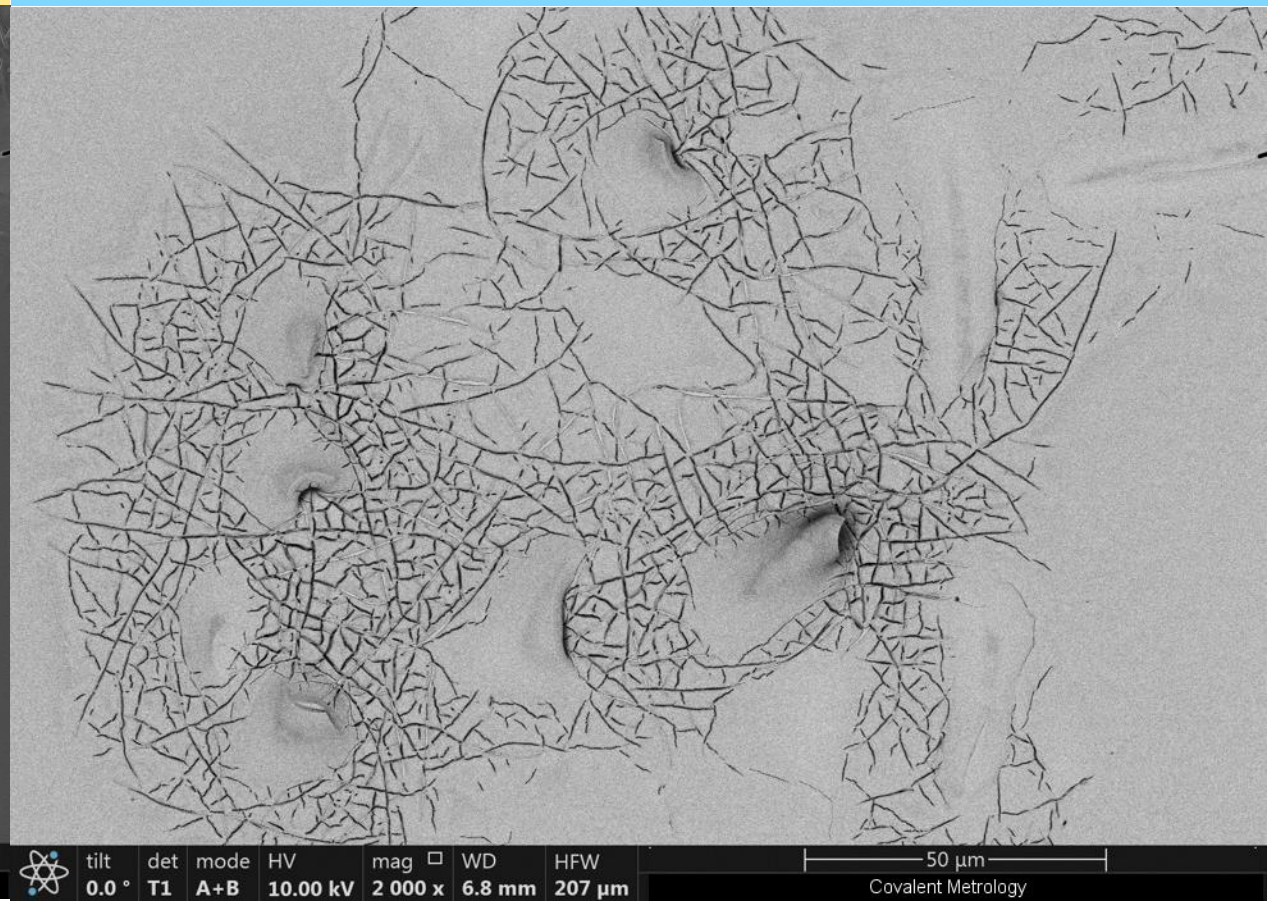


Secondary Electron (SE) vs Backscattered Electron (BSE) Top Down Image

Secondary Electron Image
(Topographical Information)



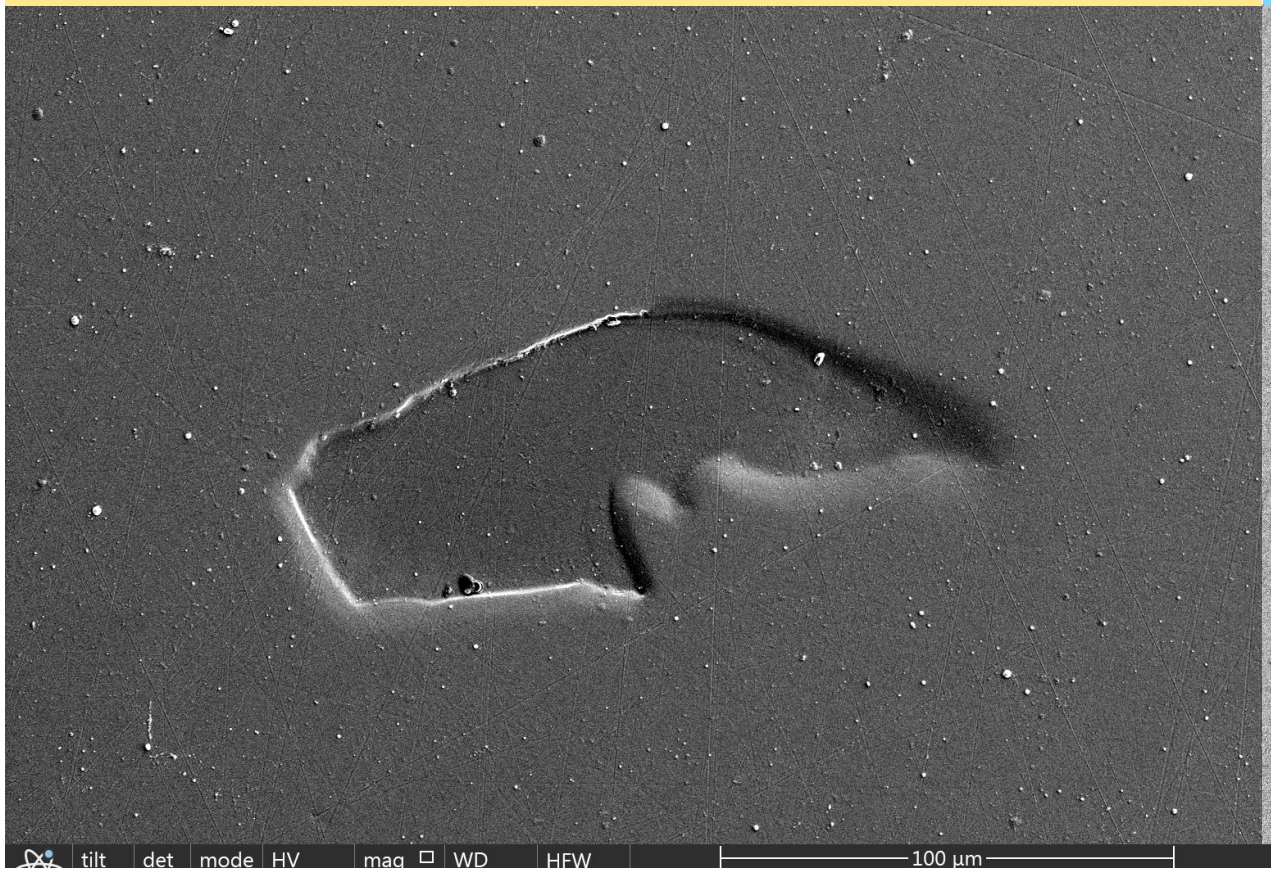
Backscattered Electron Image
(Compositional Information)



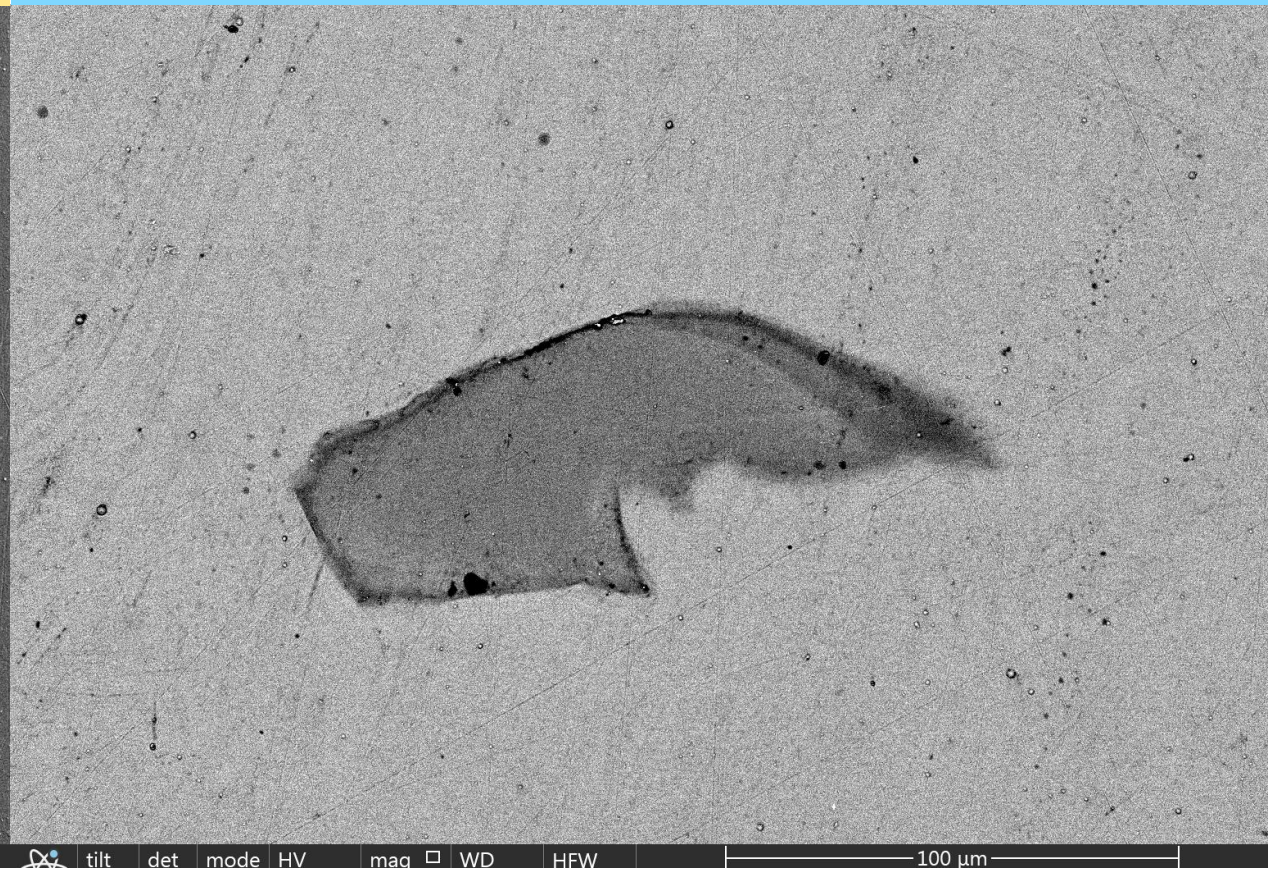
Customer Sample with Permission

Secondary Electron (SE) vs Backscattered Electron (BSE)

Secondary Electron Image
(Topographical Information)

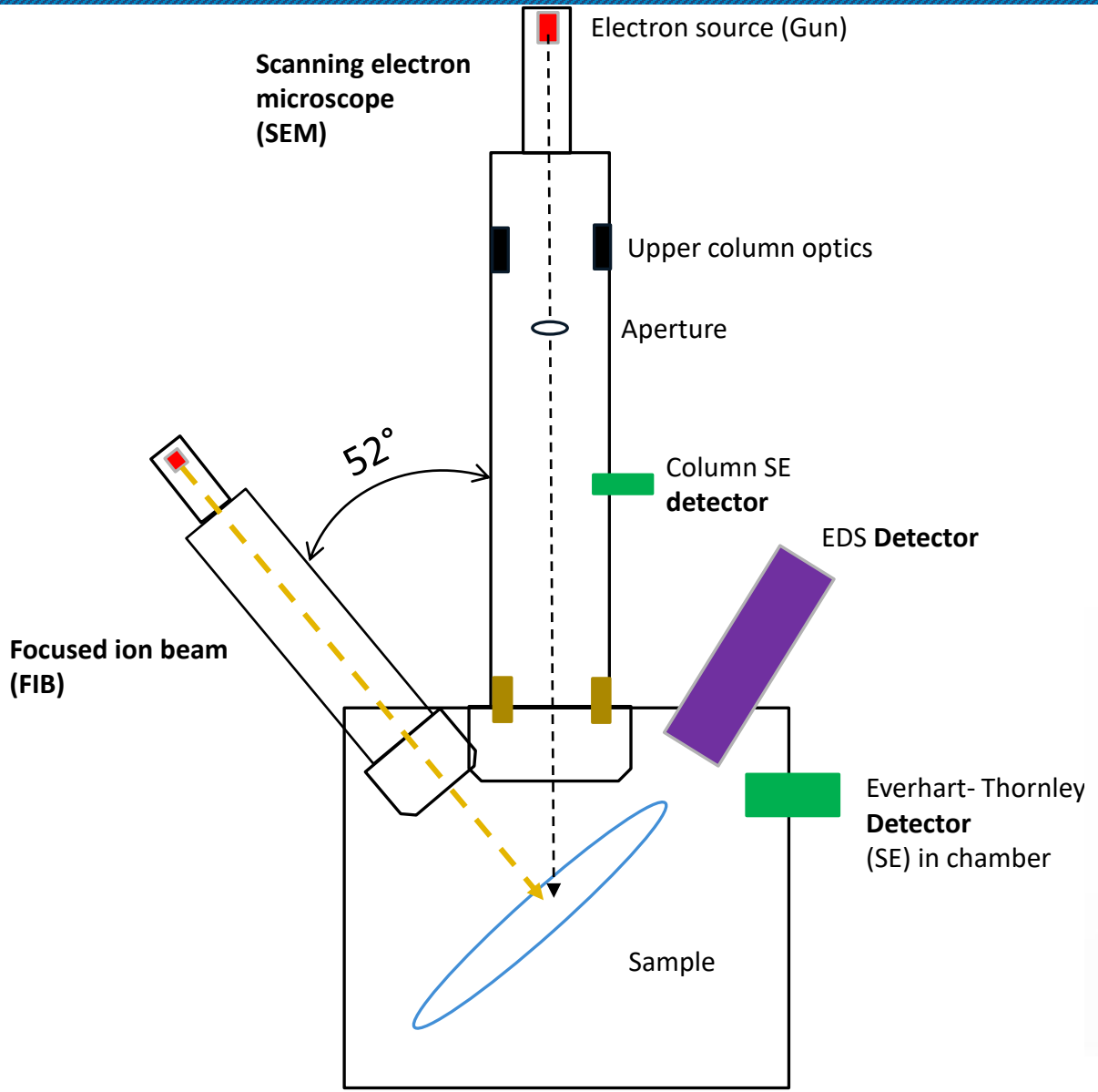


Backscattered Electron Image
(Compositional Information)



Customer Sample with Permission, Futek

Dual beam system: Scanning Electron Microscope (SEM) with Focused Ion Beam (FIB)

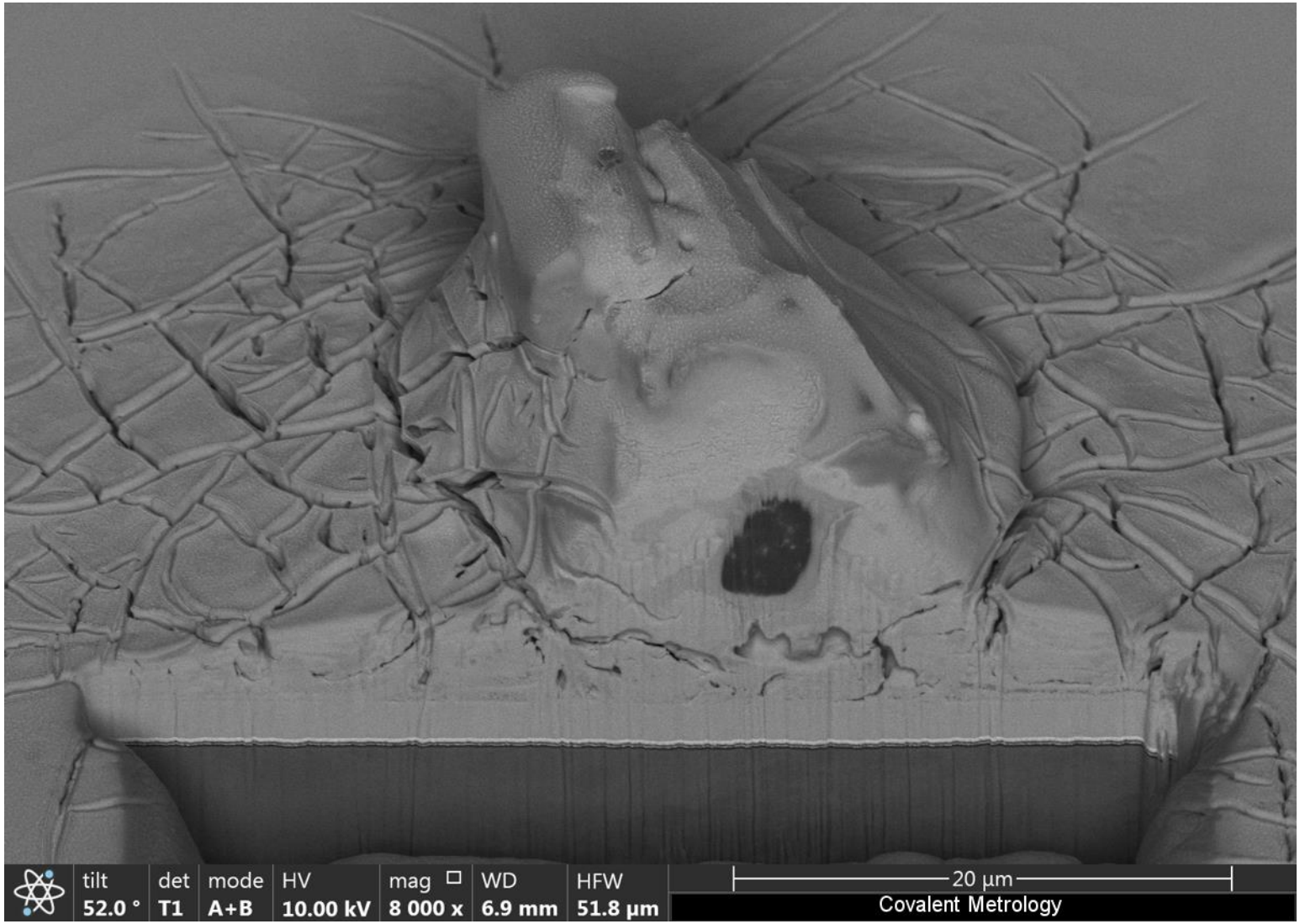


ThermoFisher SCIENTIFIC



Scios Dual Beam

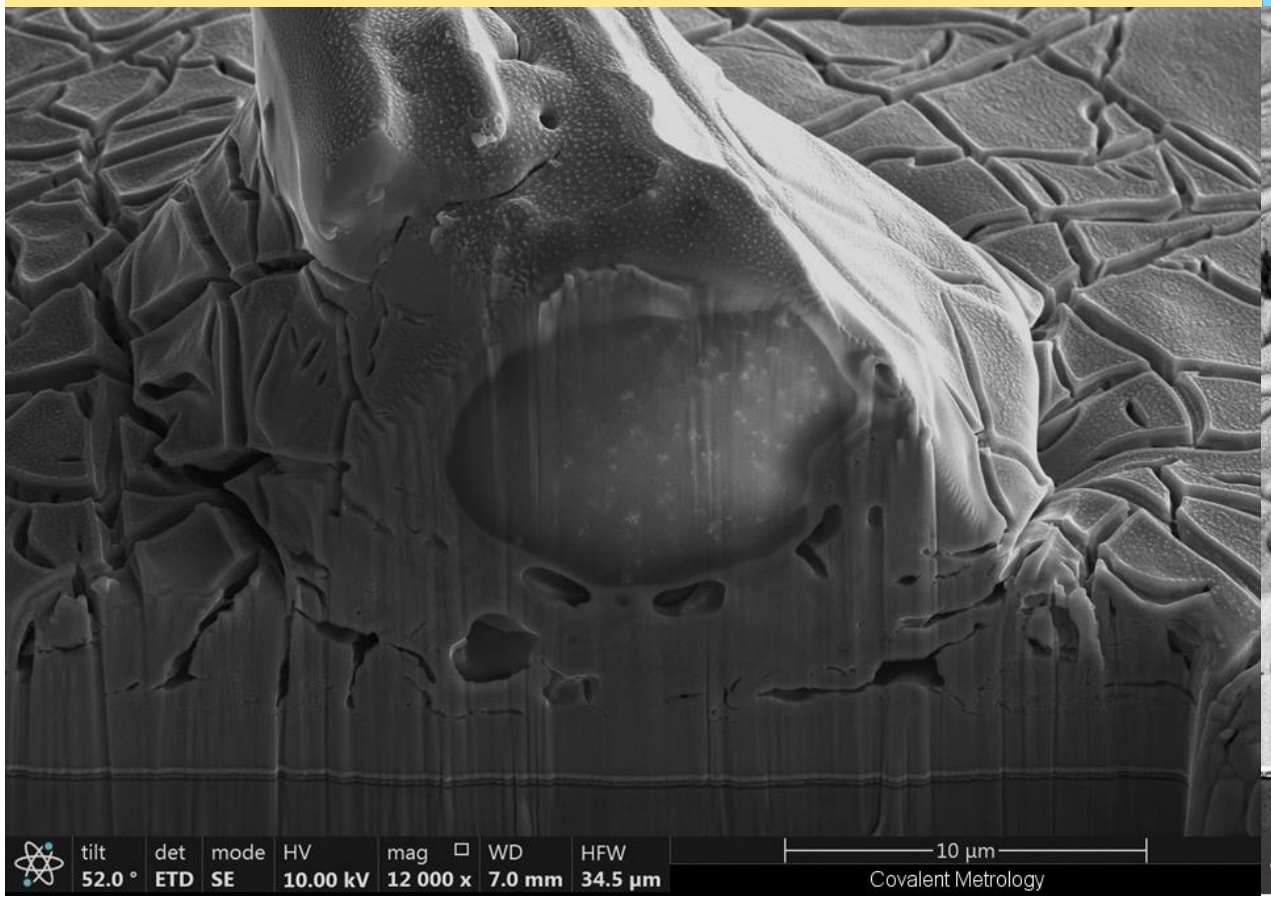
Image of a Trench Cut with a Focused Ion Beam (FIB)



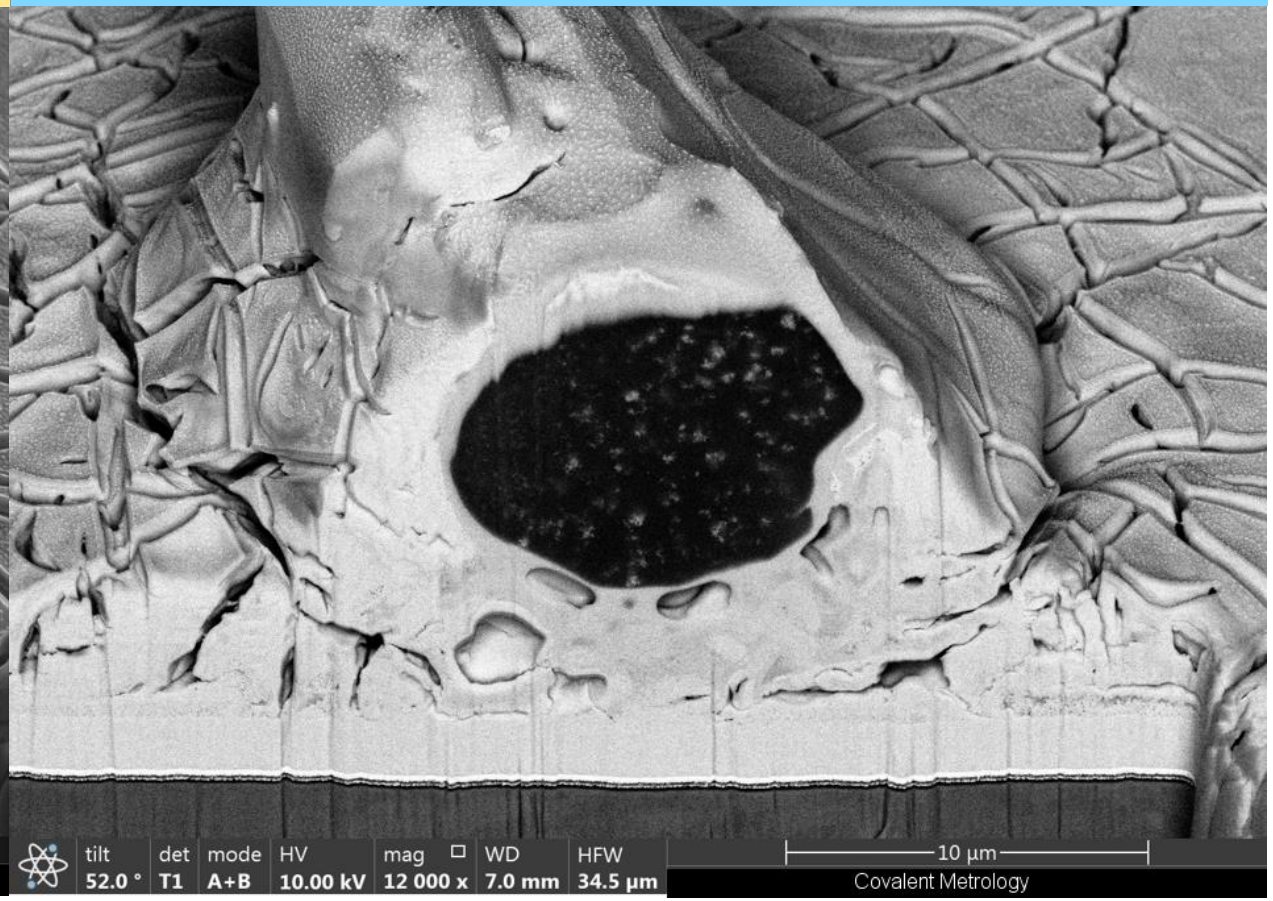
Secondary Electron (SE) vs Backscattered Electron (BSE) Cross-Sectional Images

COVALENT METROLOGY

Secondary Electron Image
(Topographical Information)



Backscattered Electron Image
(Compositional Information)

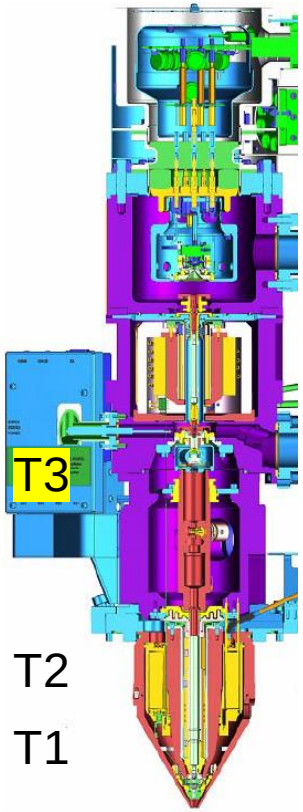


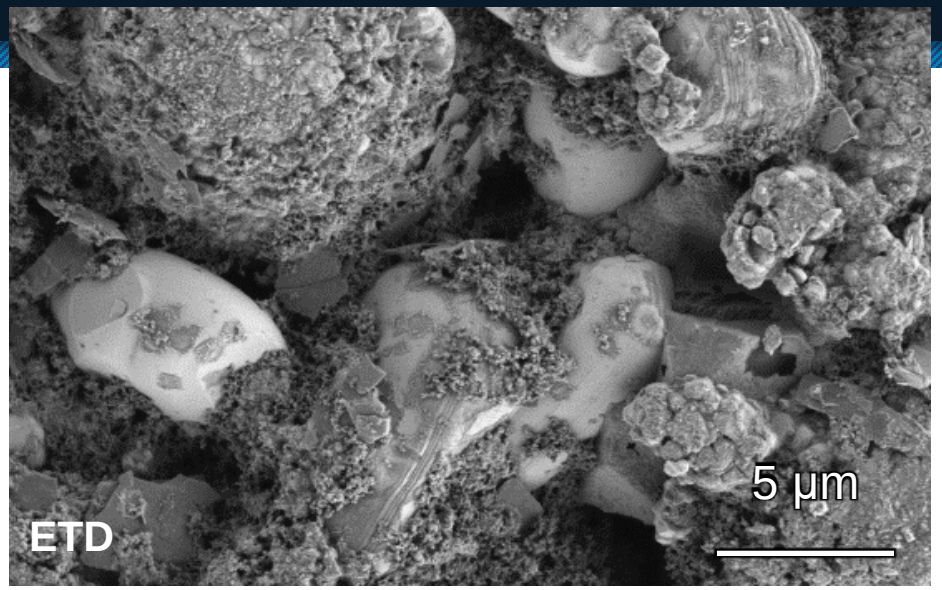
Customer Sample with Permission

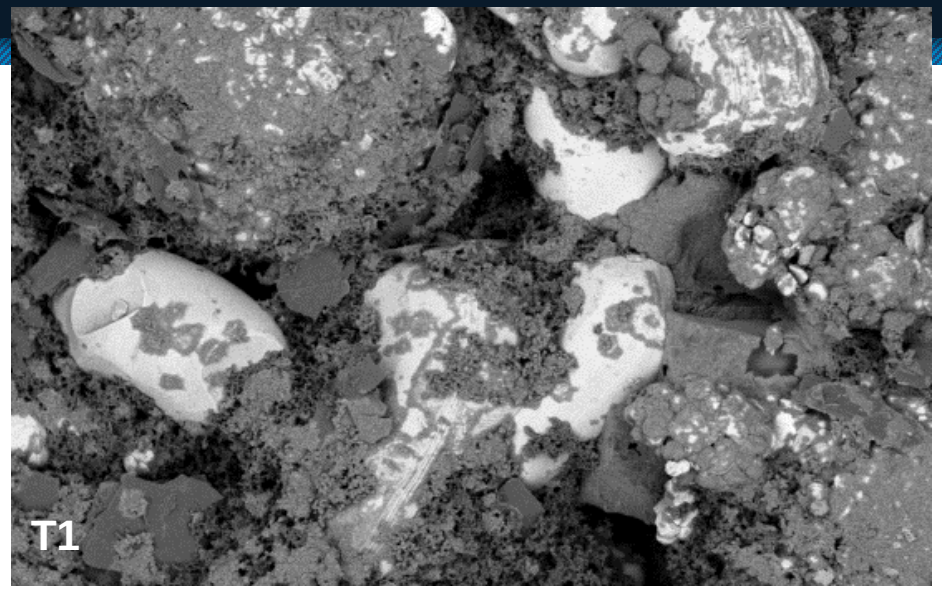
Scios 2's Trinity: Simultaneous Triple In-Column Detection

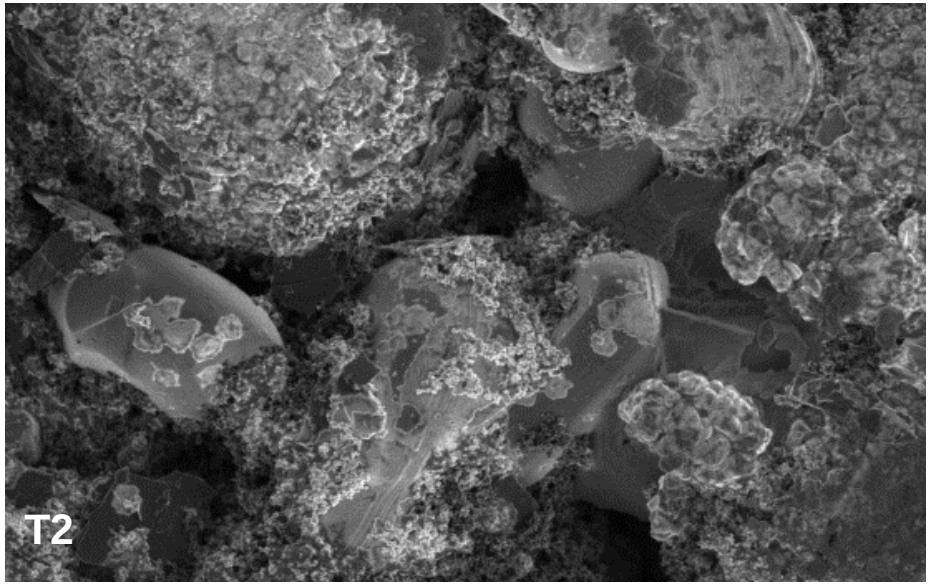
COVALENT METROLOGY

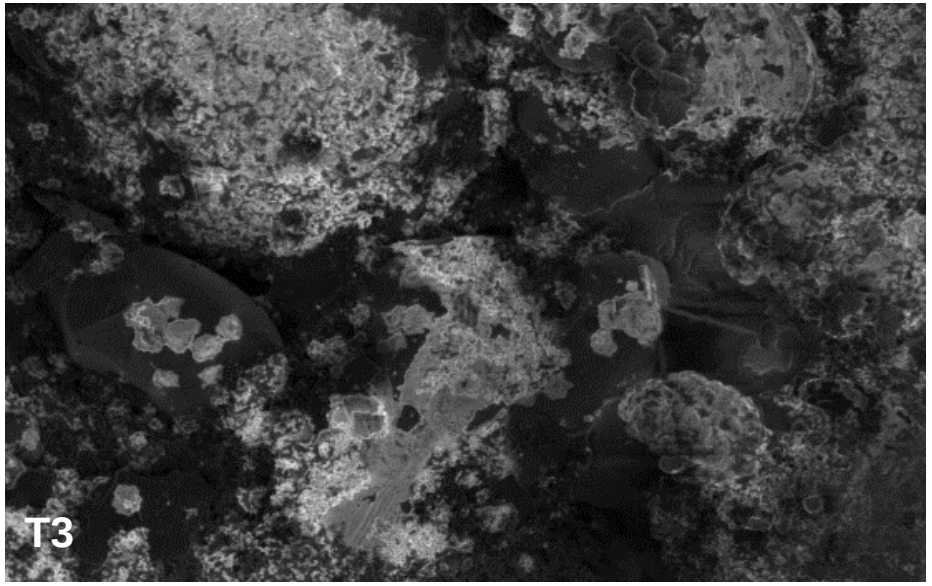
Information from every angle captured in a single scan.





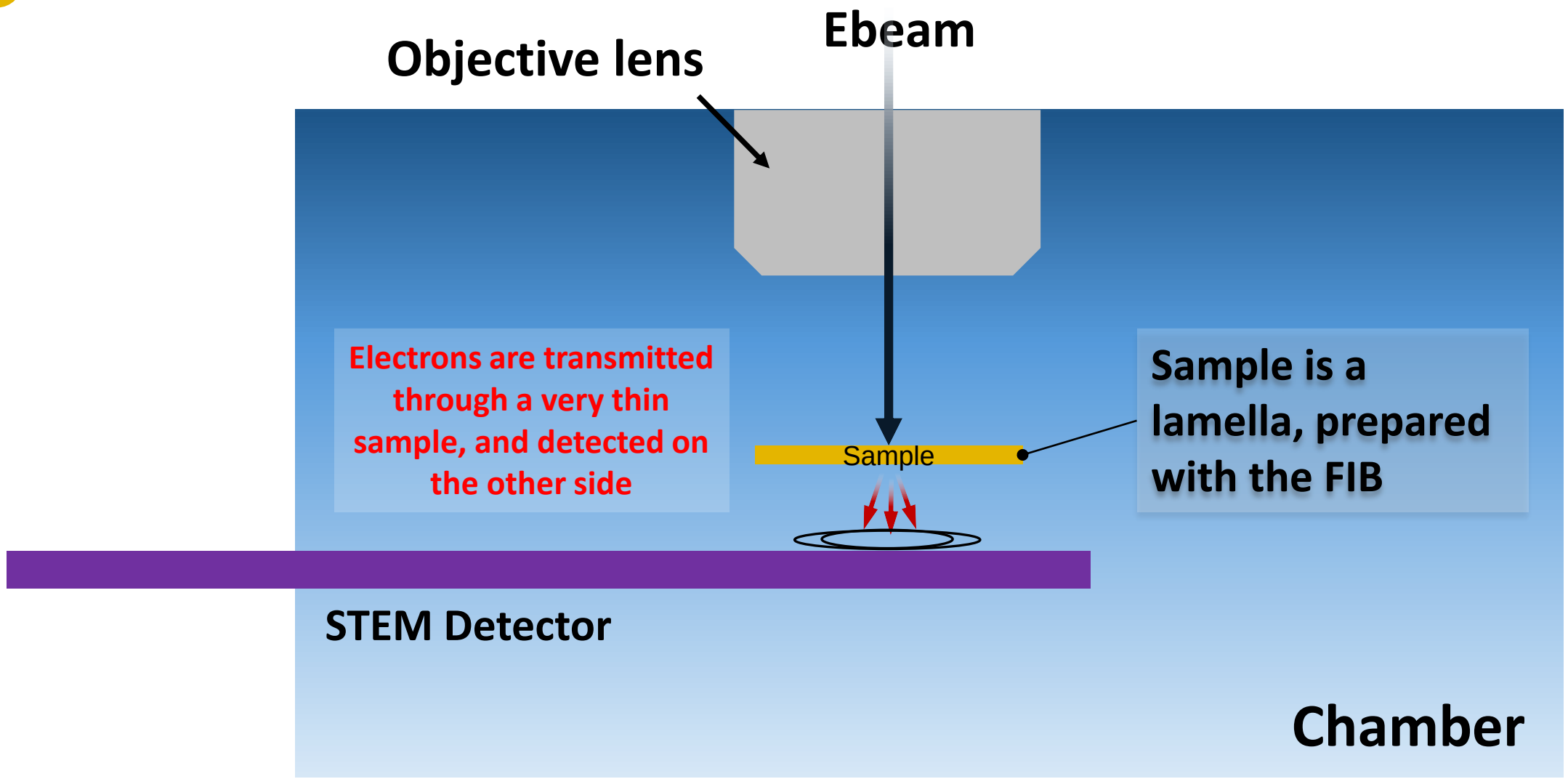






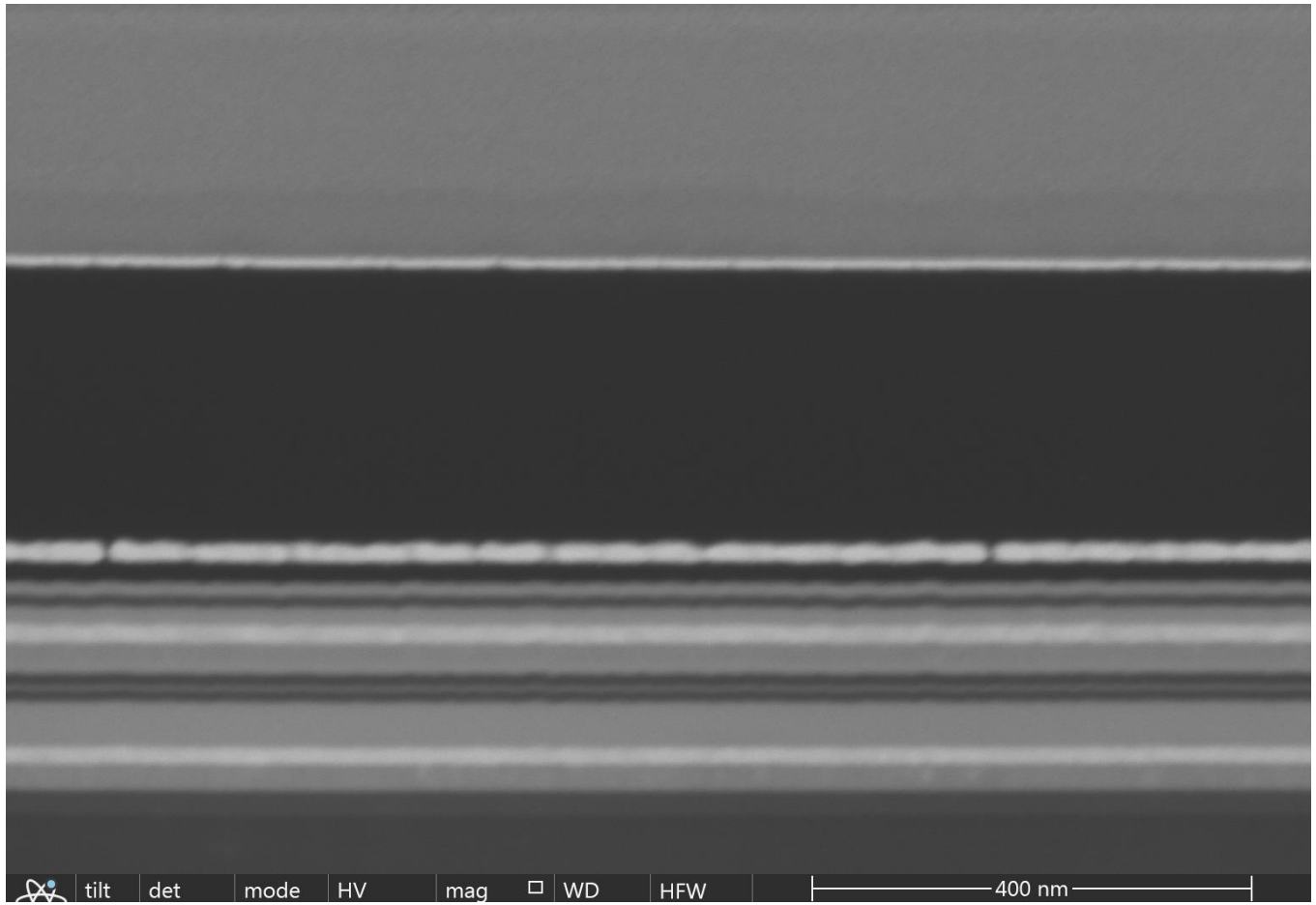
Lithium ion battery cathode Courtesy of T. Kazda, BUT. Images: Petr Wandro, via Thermo Fisher

STEM Detector

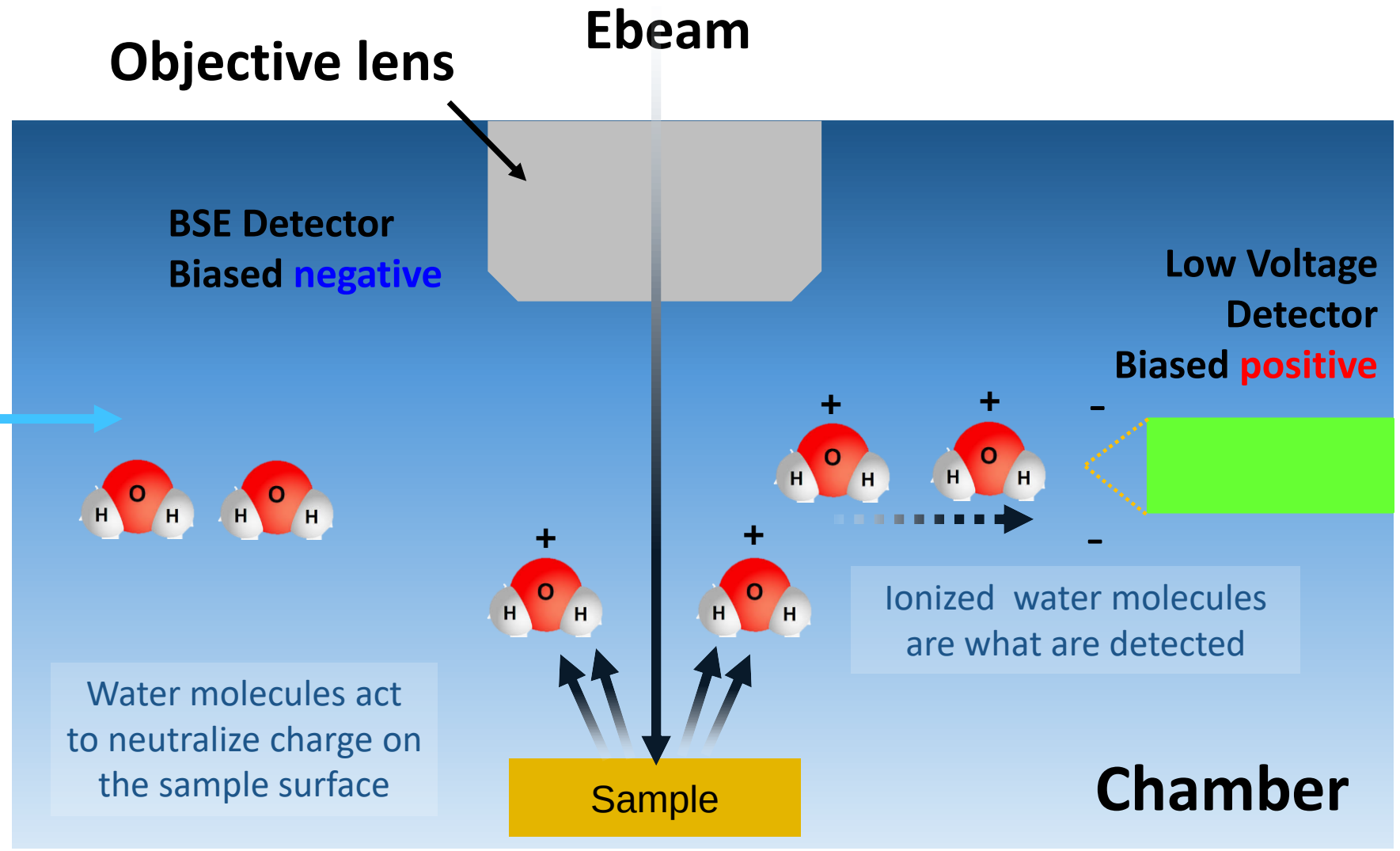


STEM Image of Coating

COVALENT METROLOGY

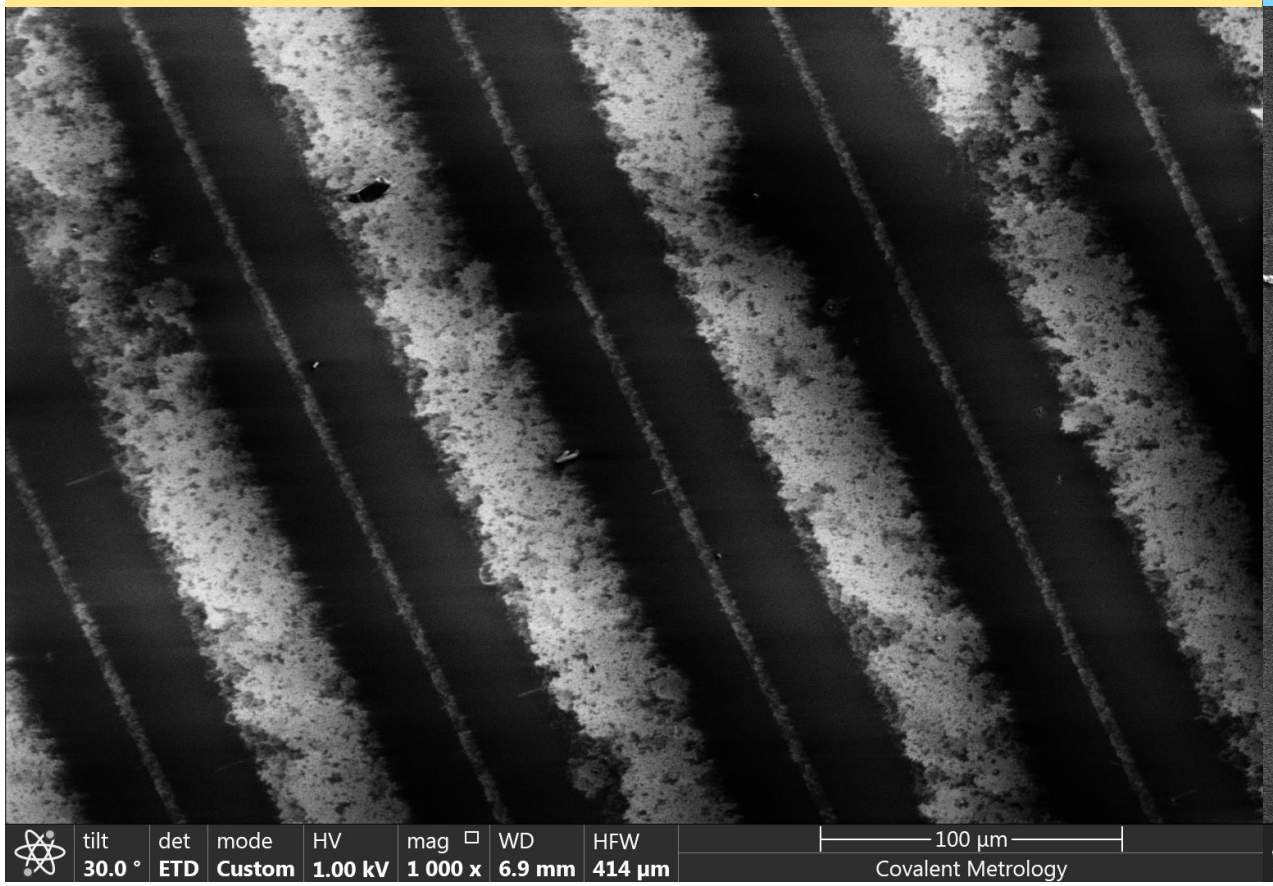


Charge Mitigation; Environmental SEM Theory of Operation

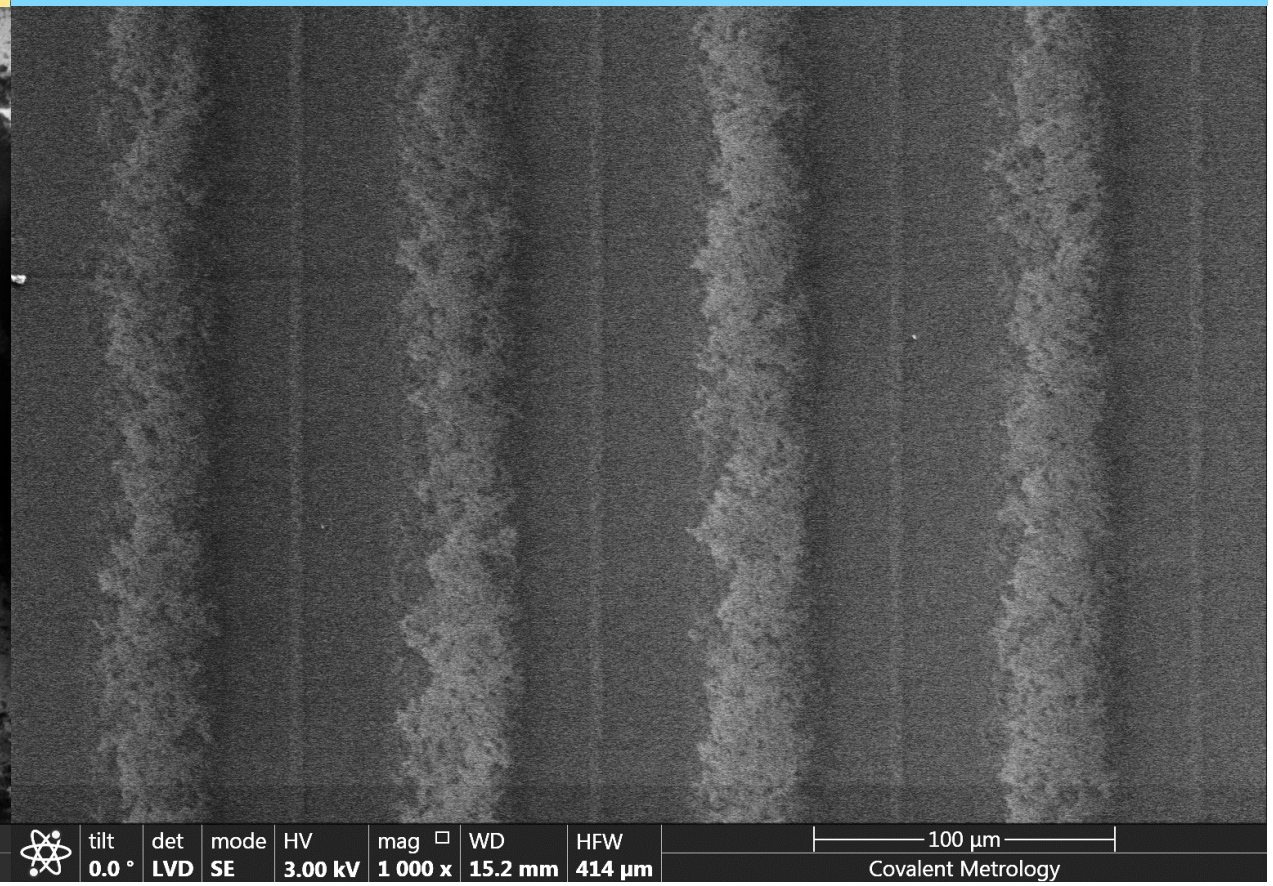


Charge Mitigation Using Environmental Mode in the SEM

WITHOUT Charge Mitigation

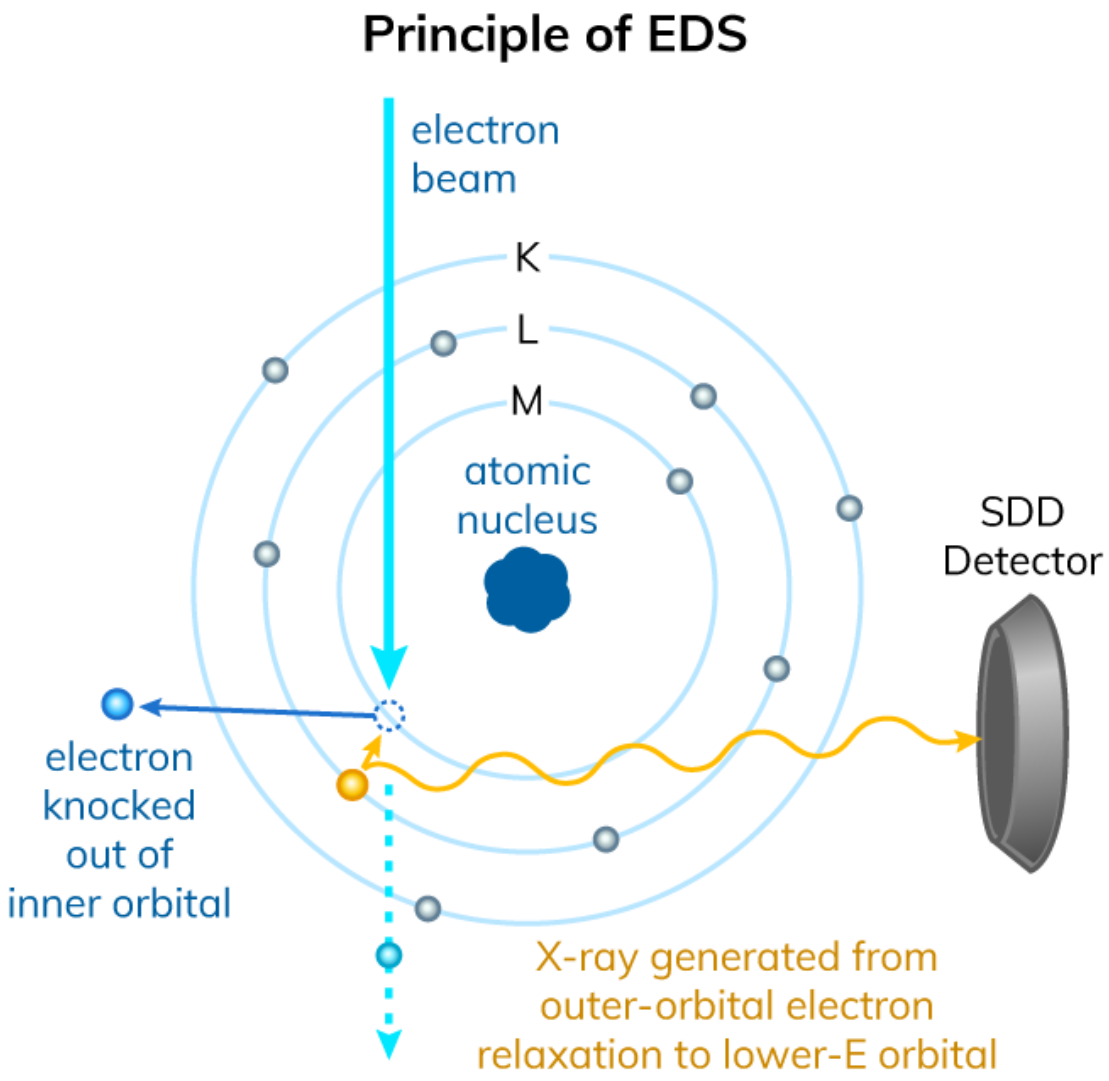


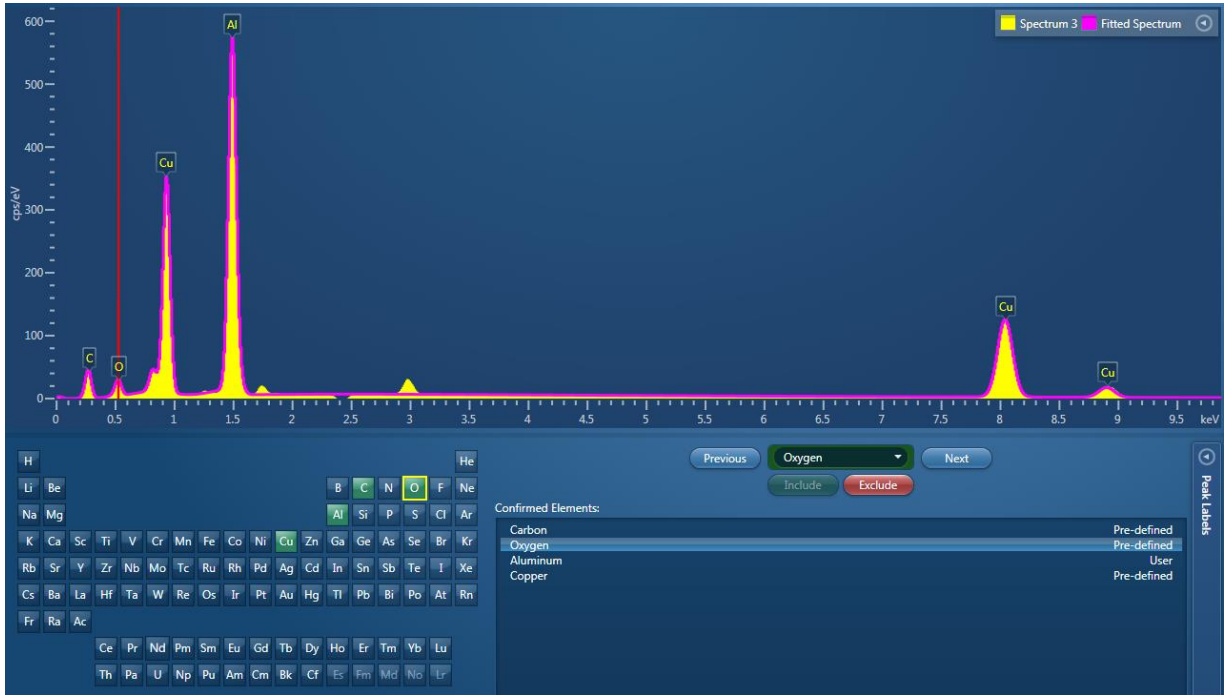
Environmental SEM WITH Charge Mitigation



Customer Sample with Permission

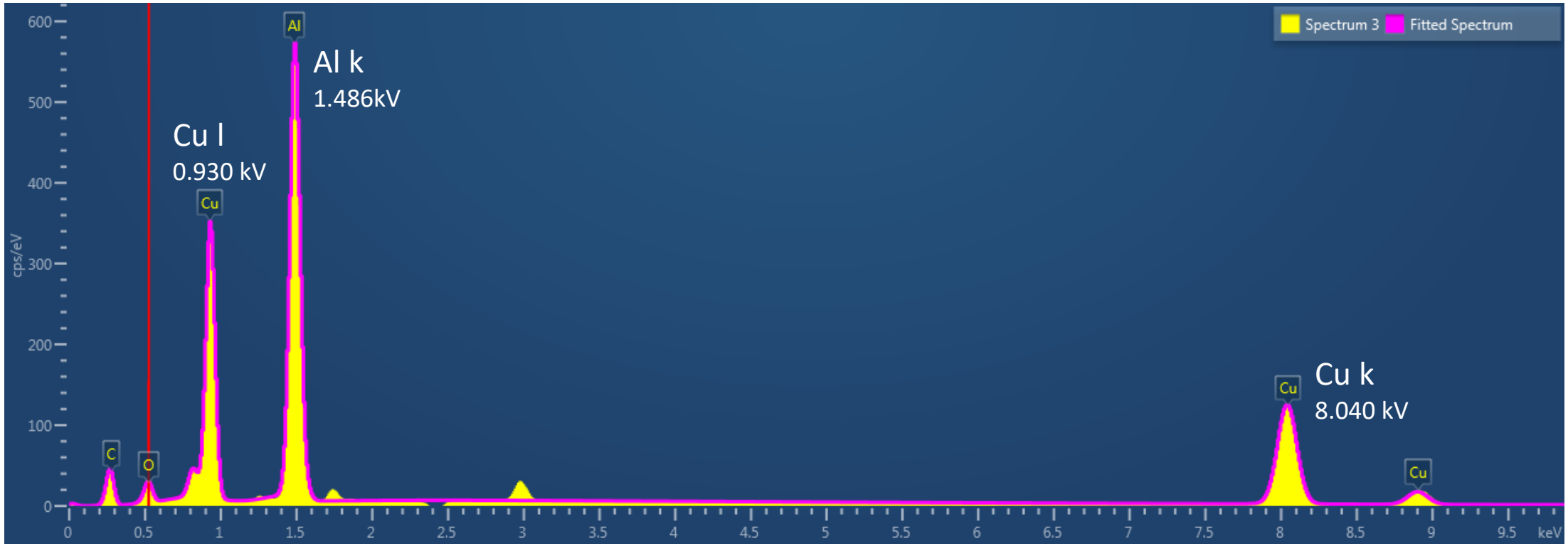
EDS Theory and Spectrum





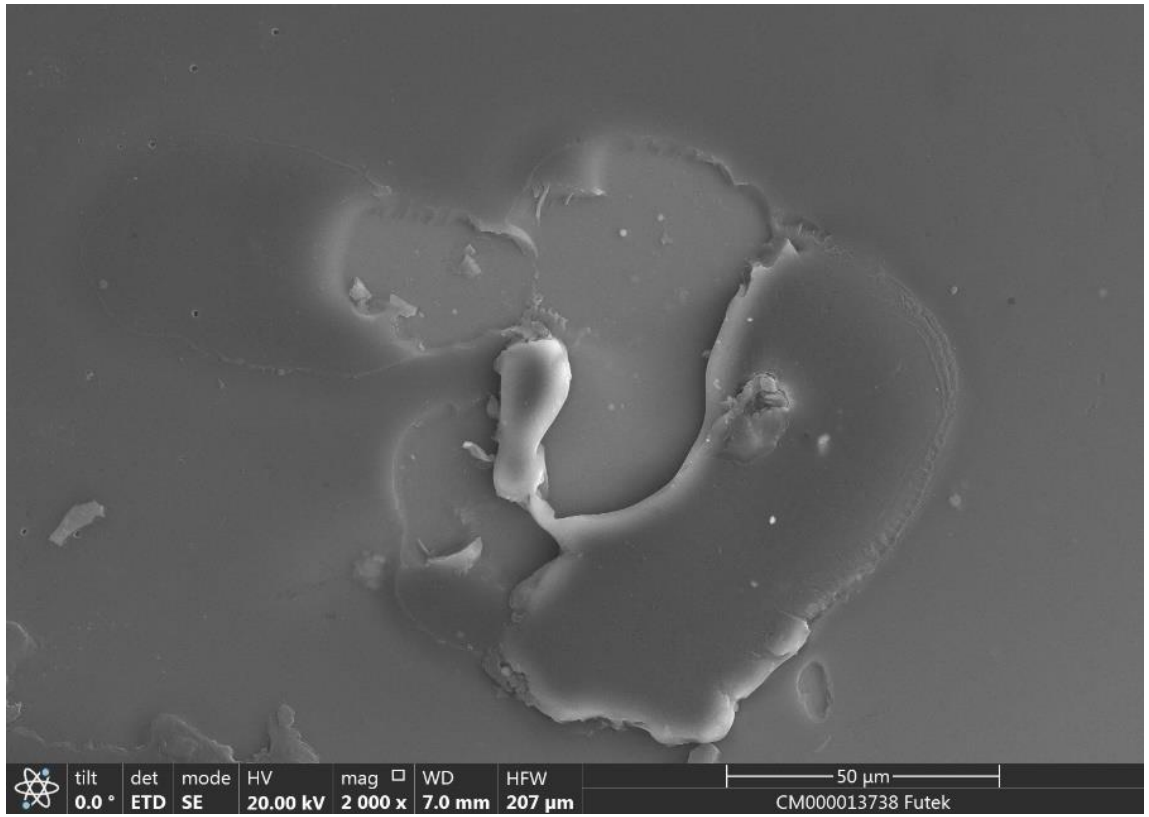
EDS Spectrum Showing Characteristic X-ray Lines

COVALENT METROLOGY

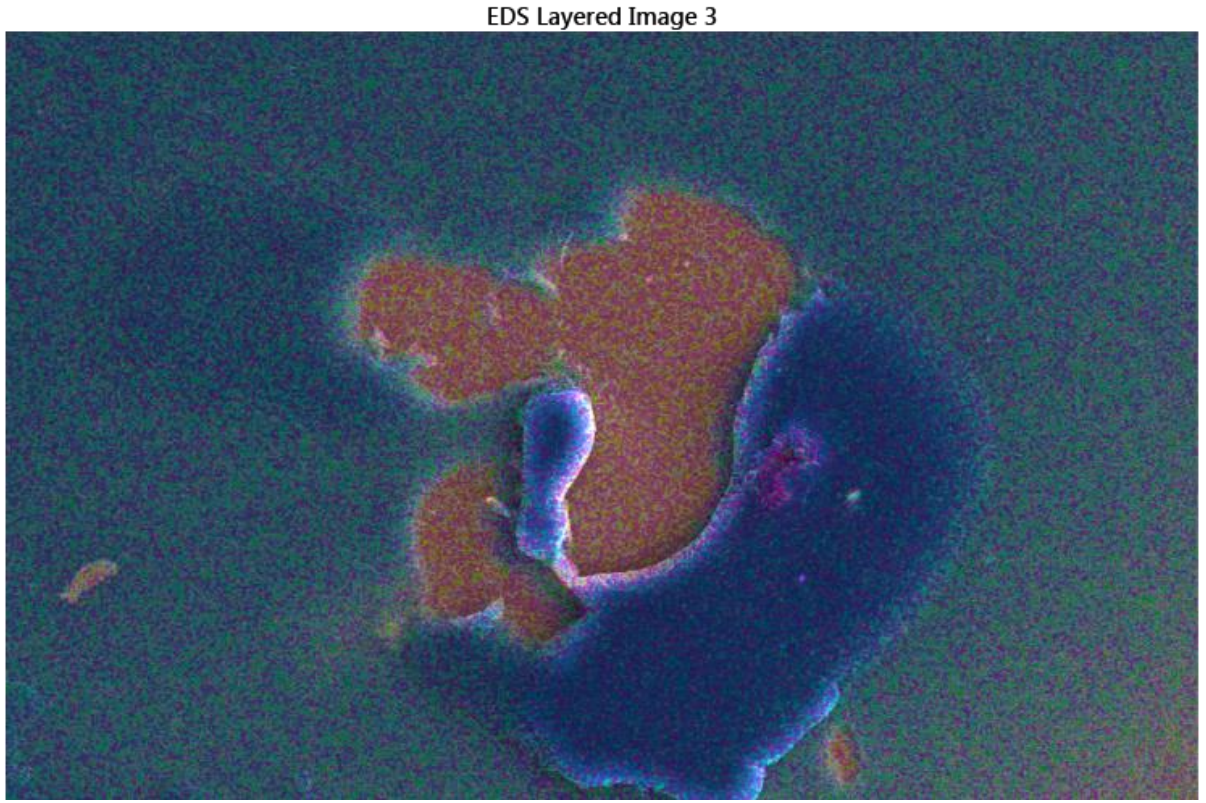


Elemental Mapping of a Defect

SEM Image

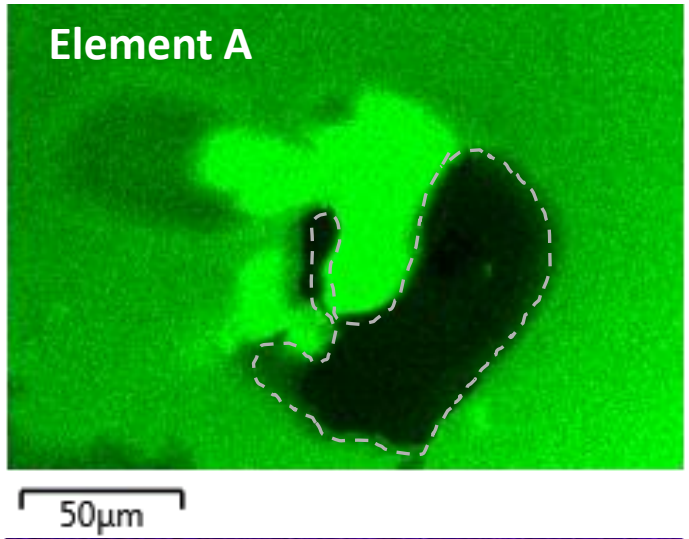


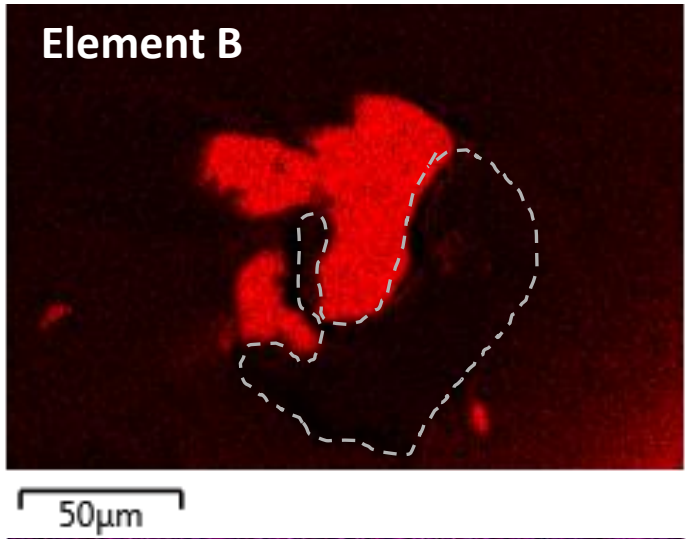
Composition Map

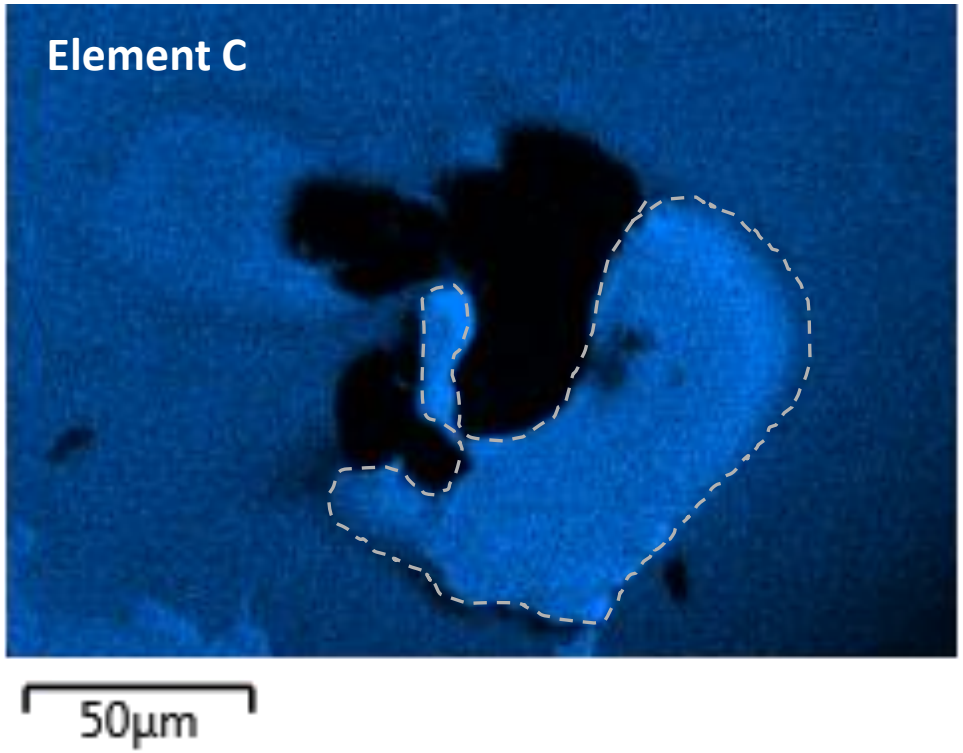


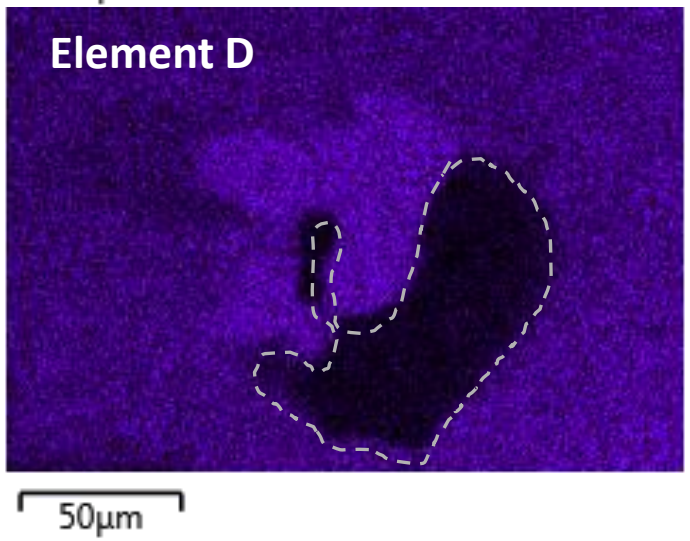
Customer Sample with Permission, Futek

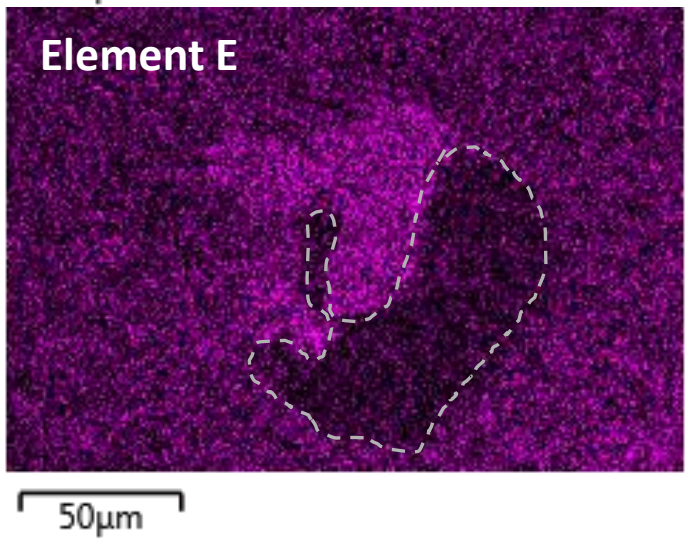
Elemental Mapping of a Defect







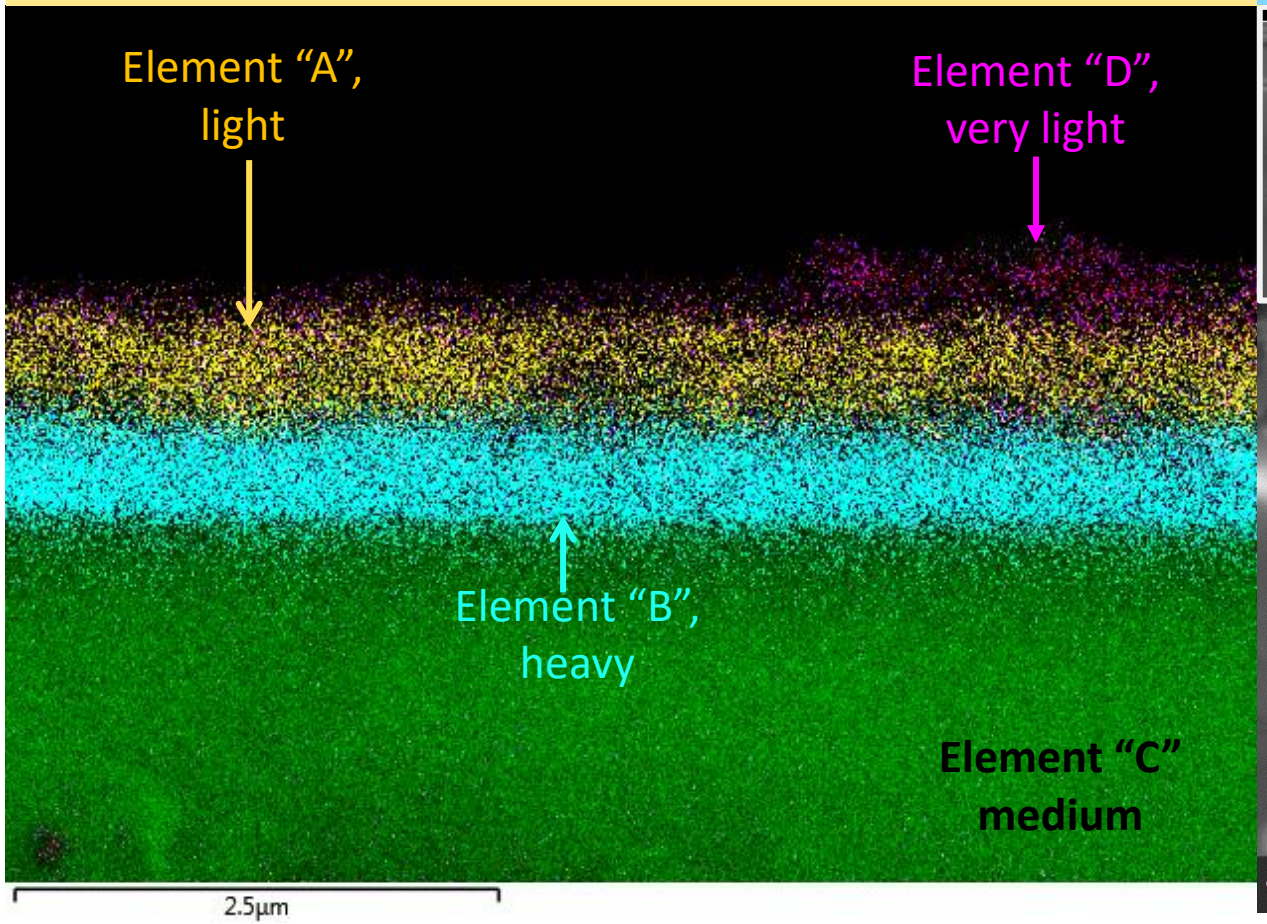




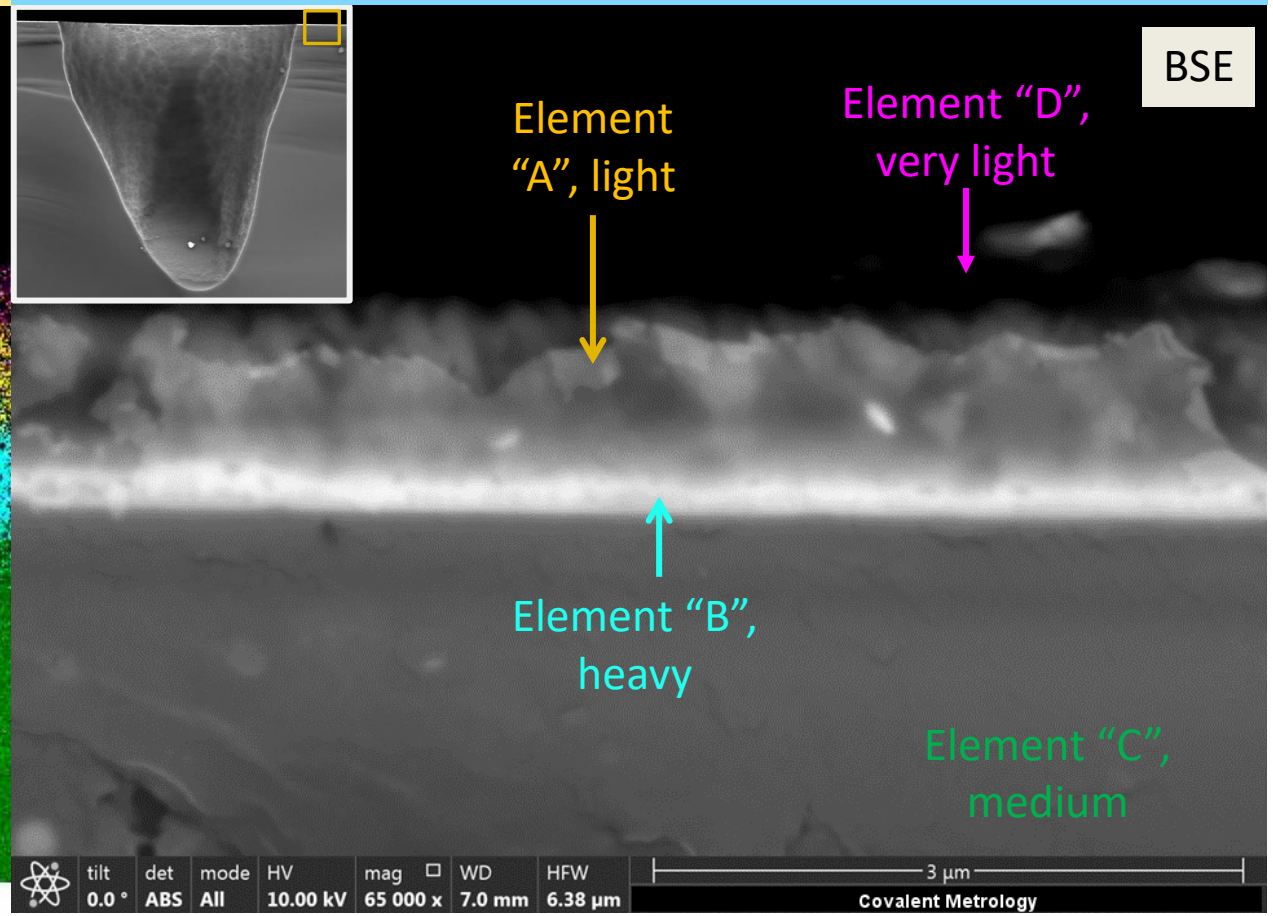
Customer Sample with Permission, Futek

BSE Image and Elemental Mapping

EDS X-Ray Elemental Mapping Overlay



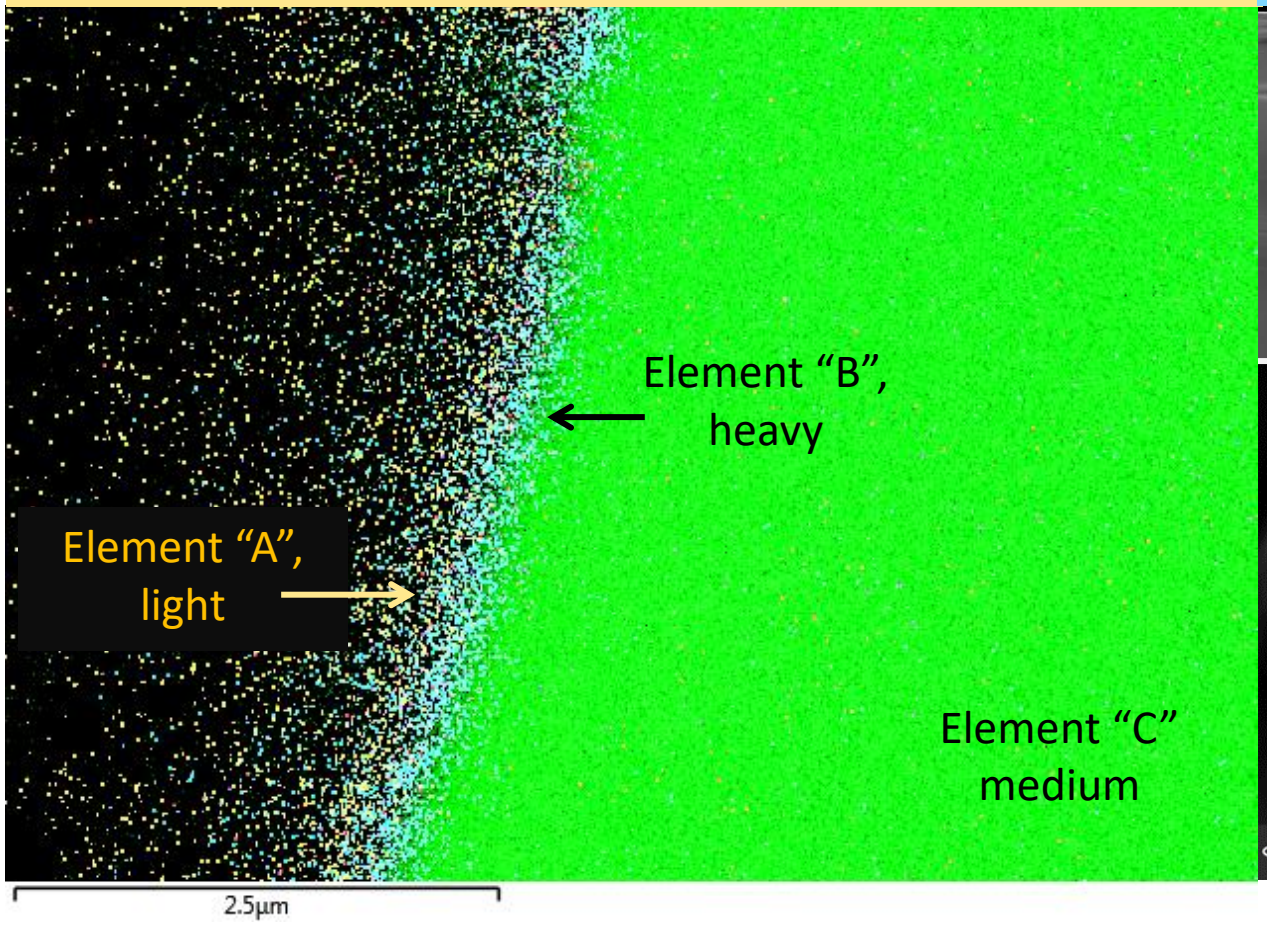
Backscattered Electron Image



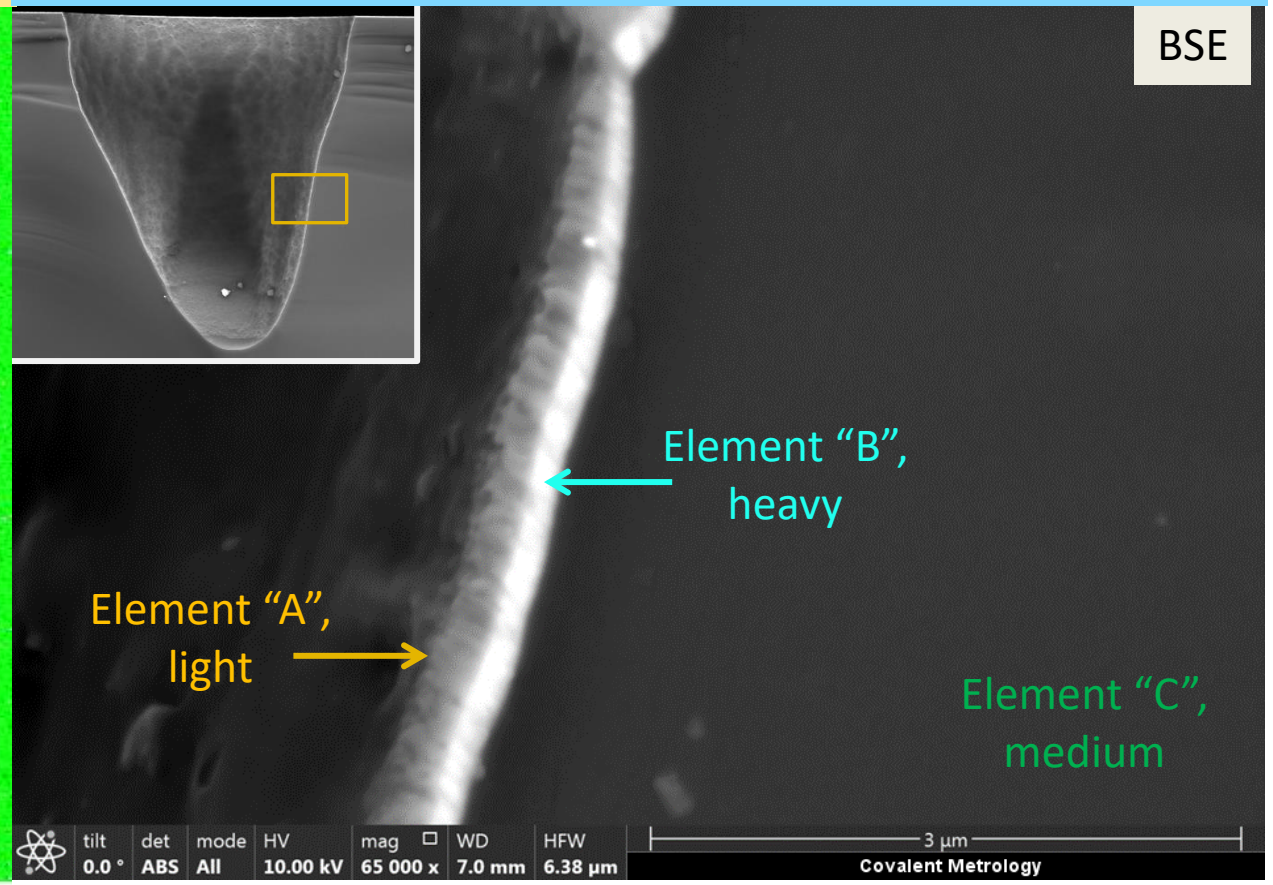
Customer Sample with Permission, Bleximo

BSE Image and Elemental Mapping

EDS X-Ray Elemental Mapping Overlay



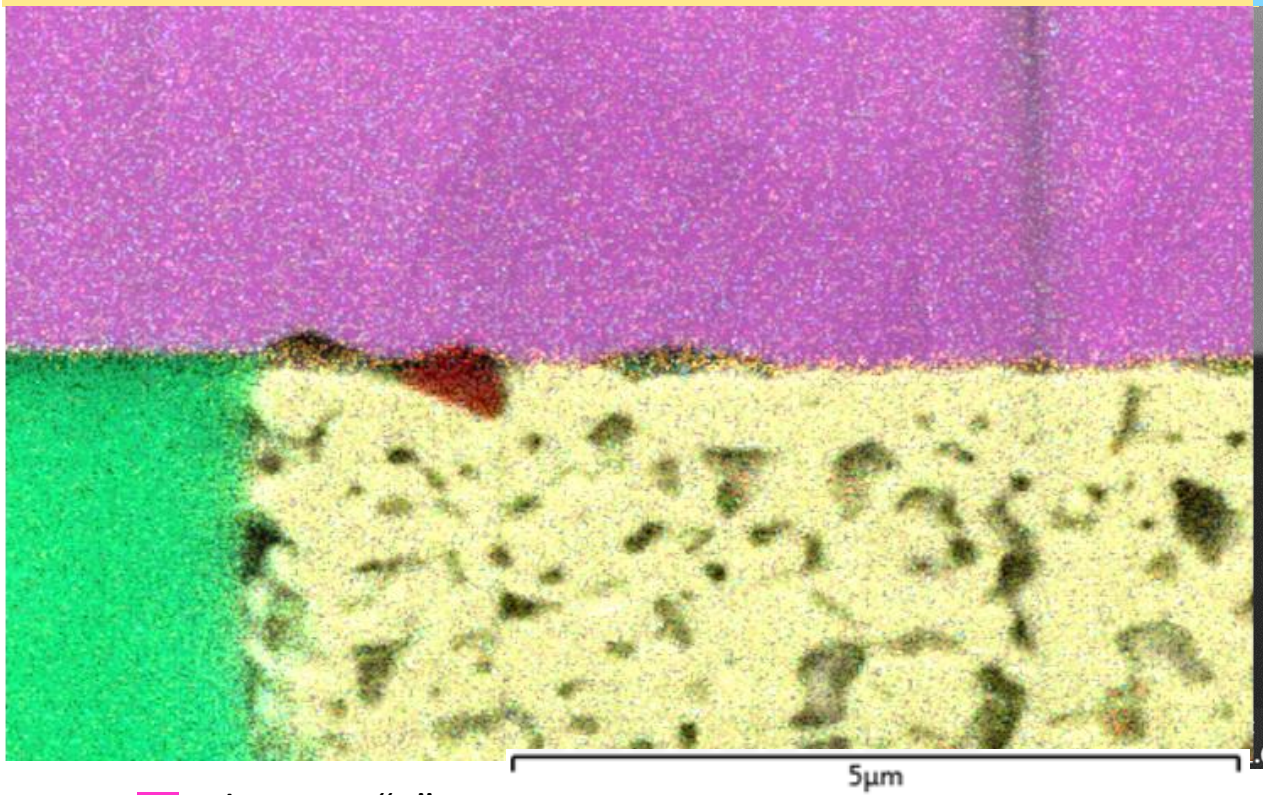
Backscattered Electron Image



Customer Sample with Permission, Bleximo

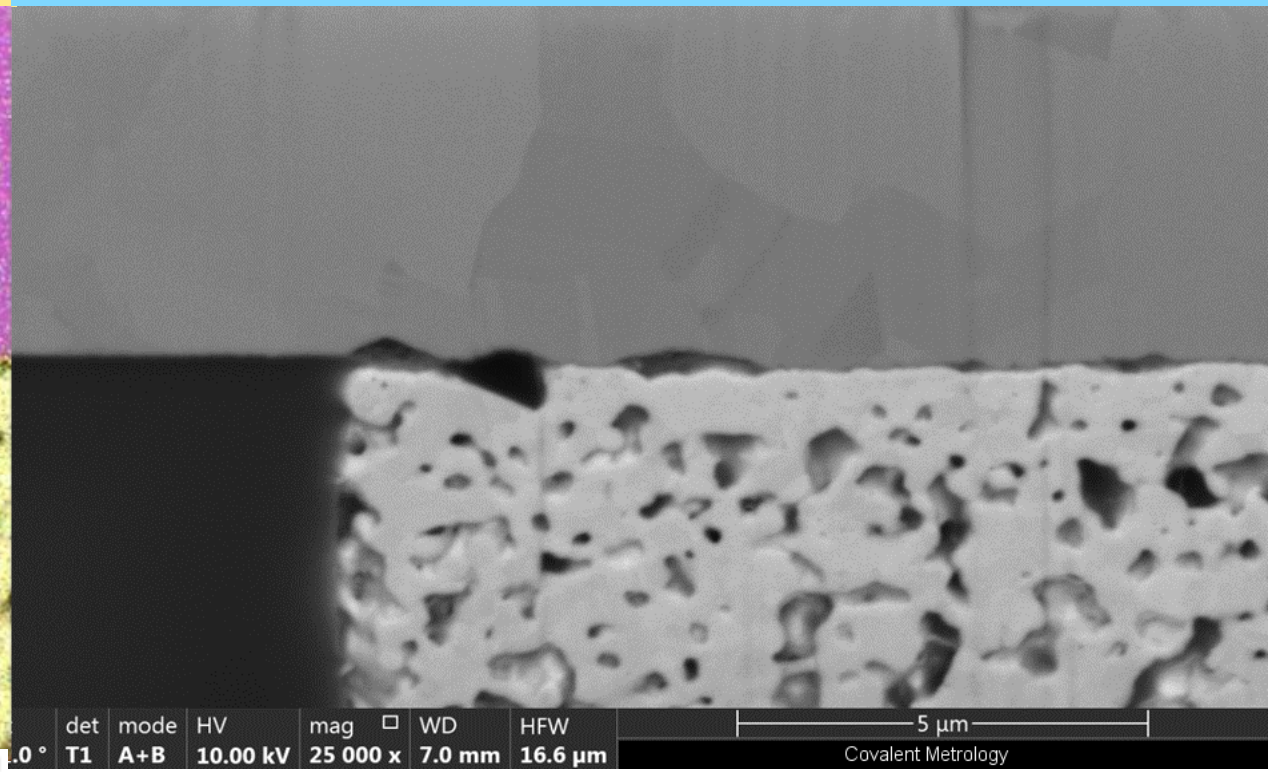
Cross-Section of Feature

EDS X-Ray Elemental Mapping Overlay



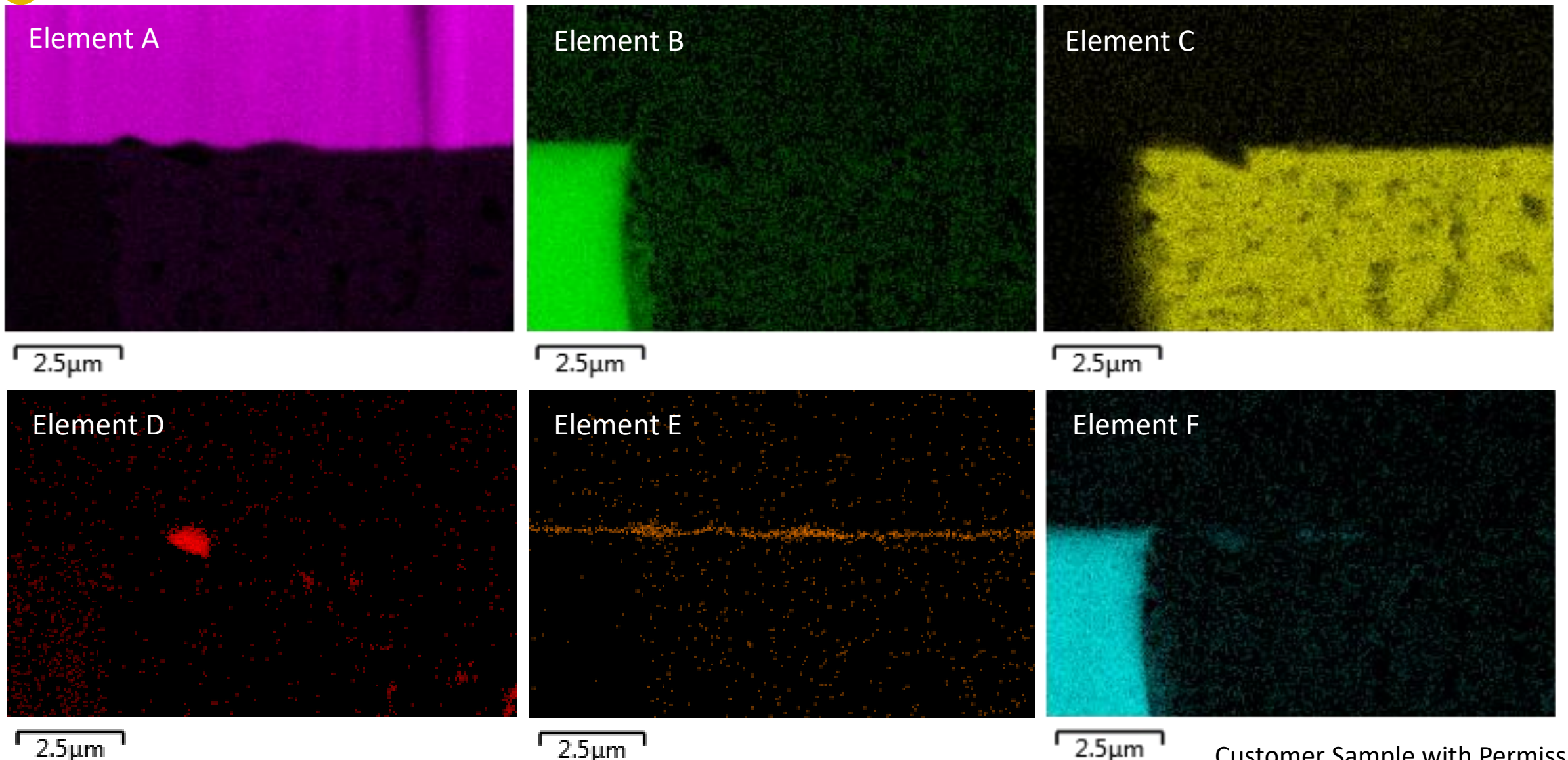
- Element “A”
- Element “E”
- Element “C”
- Element “D”

Backscattered Electron Image



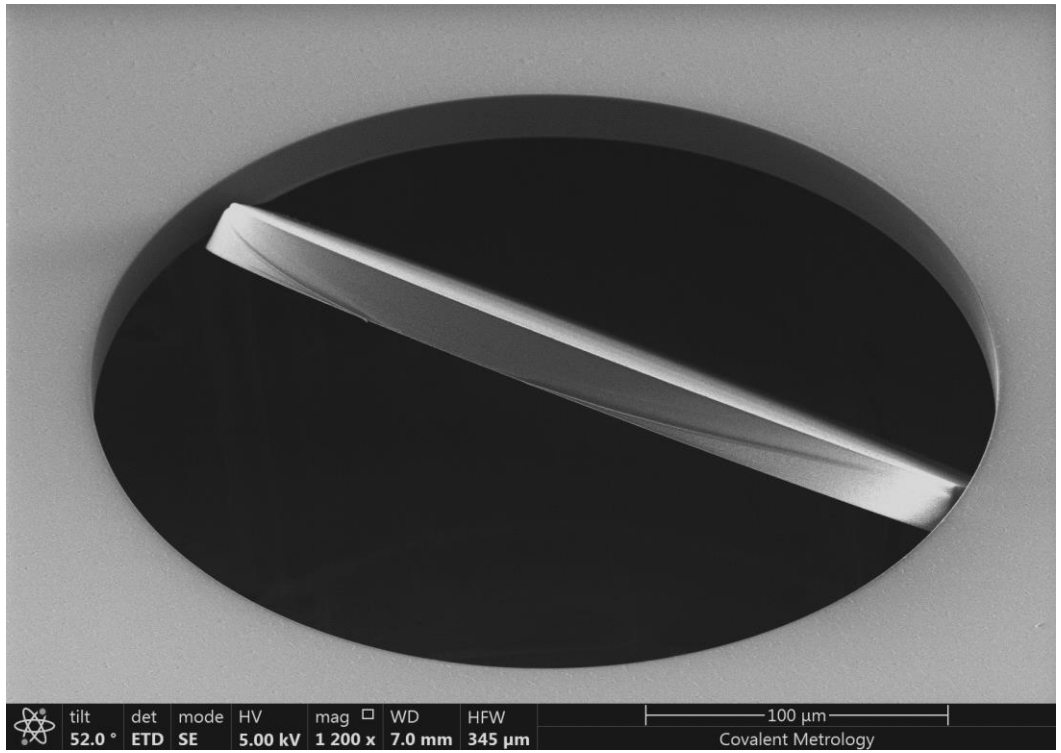
Customer Sample with Permission

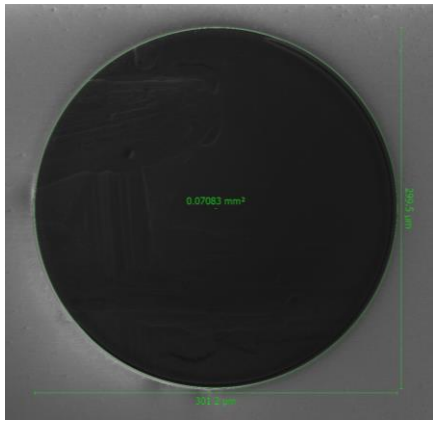
Cross-Section of Feature – Elemental Mapping

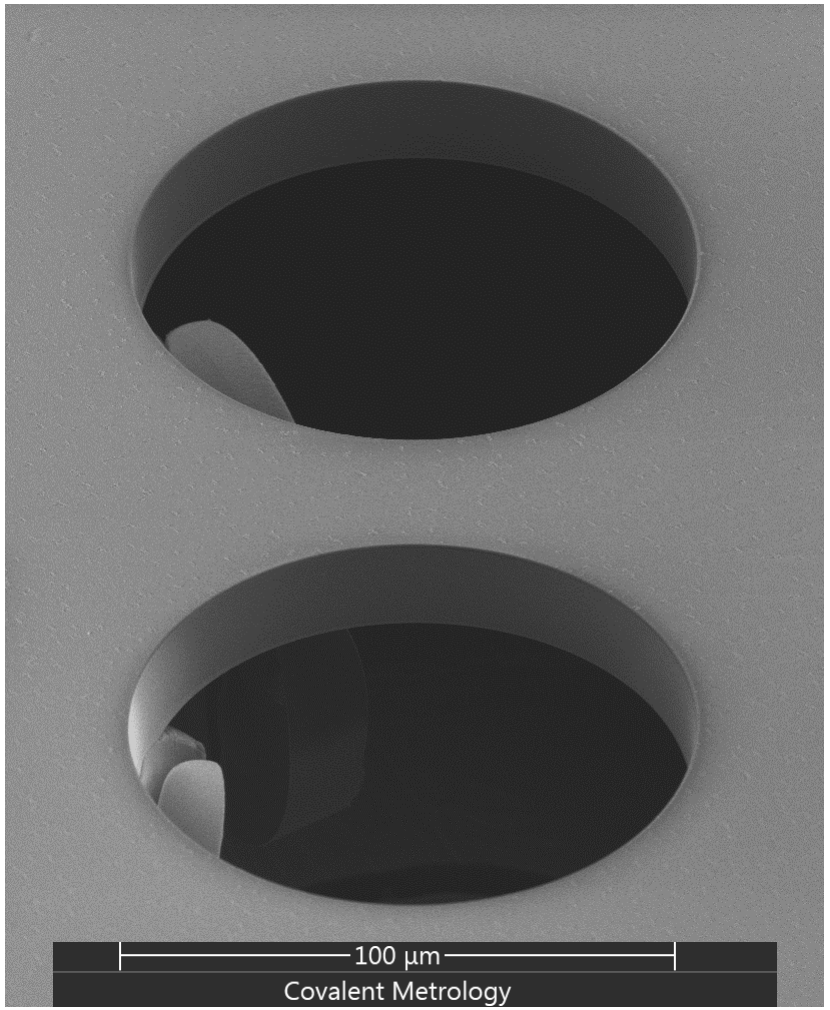


Customer Sample with Permission

Micro-Machining Using the Focused Ion Beam

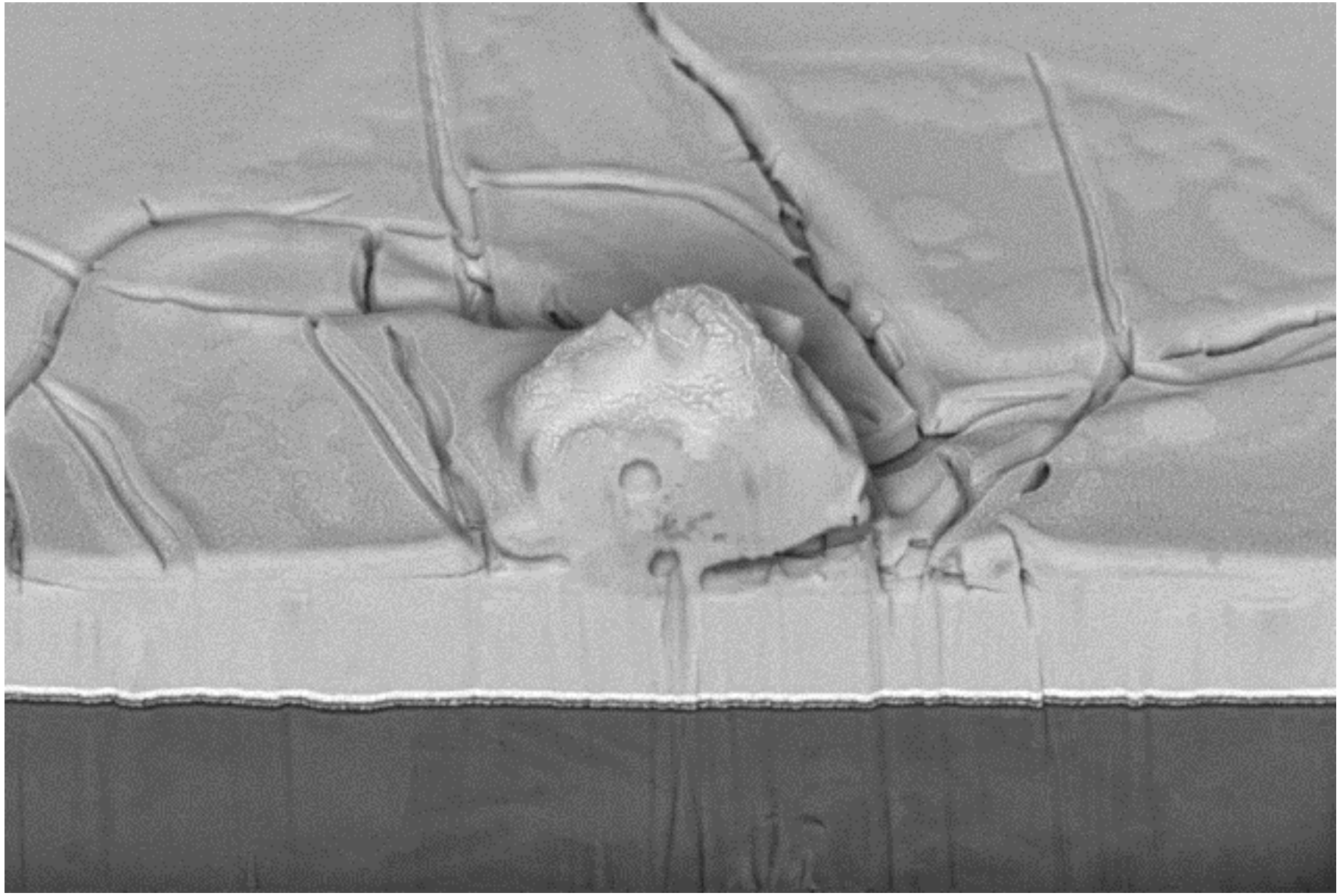






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Profiling of a Defect in BSE Mode



Defect is approximately 15µm in depth.

Commercial Summary Slide

- Price table for SEM services

NEW Product name	Price	Billing Unit
SEM: Scanning Electron Microscopy (per hour)	$ 225	(per hour)
EDS surcharge - add-on to SEM (per hour)	$ 50	(per hour)
HR-SEM: High-Resolution Scanning Electron Microscopy (per hour)	$ 375	(per hour)
EDS surcharge - add-on to HR SEM (per hour)	$ 25	(per hour)
FIB-SEM: Focused Ion Beam (Dual Beam FIB-SEM) cut and imaging (per hour)	$ 375	(per hour)
EDS surcharge - add-on to FIB-SEM (per hour)	$ 25	(per hour)
SEM: Scanning Electron Microscopy - self use (per hour)	$ 125	(per hour)
SEM: Large Area SEM (per hour)	please call	
FIB-SEM: large area FIB-SEM (per hour)	please call	
SEM: SEM with a heated stage (per hour)	please call	
Magnetic samples	please call	

Acknowledgements

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- Doris Chun
- Hasti Majidi
- Wayne Skelcher

Advancements in Instrumentation Series

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X-RAY COMPUTED TOMOGRAPHY

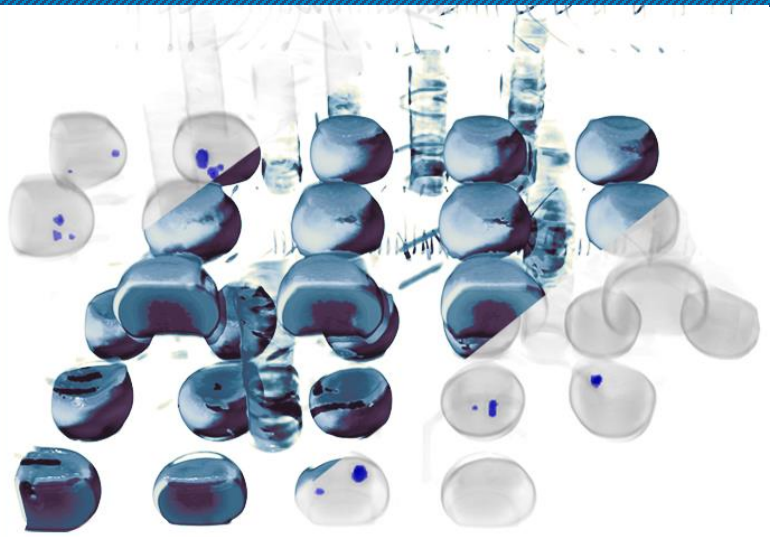
The Superpower System

Guest Speaker:

Aya Takase
Director of
X-Ray Imaging,
Rigaku Americas Corp.

May 7, 2020 11am PDT

Rigaku
COVALENT METROLOGY

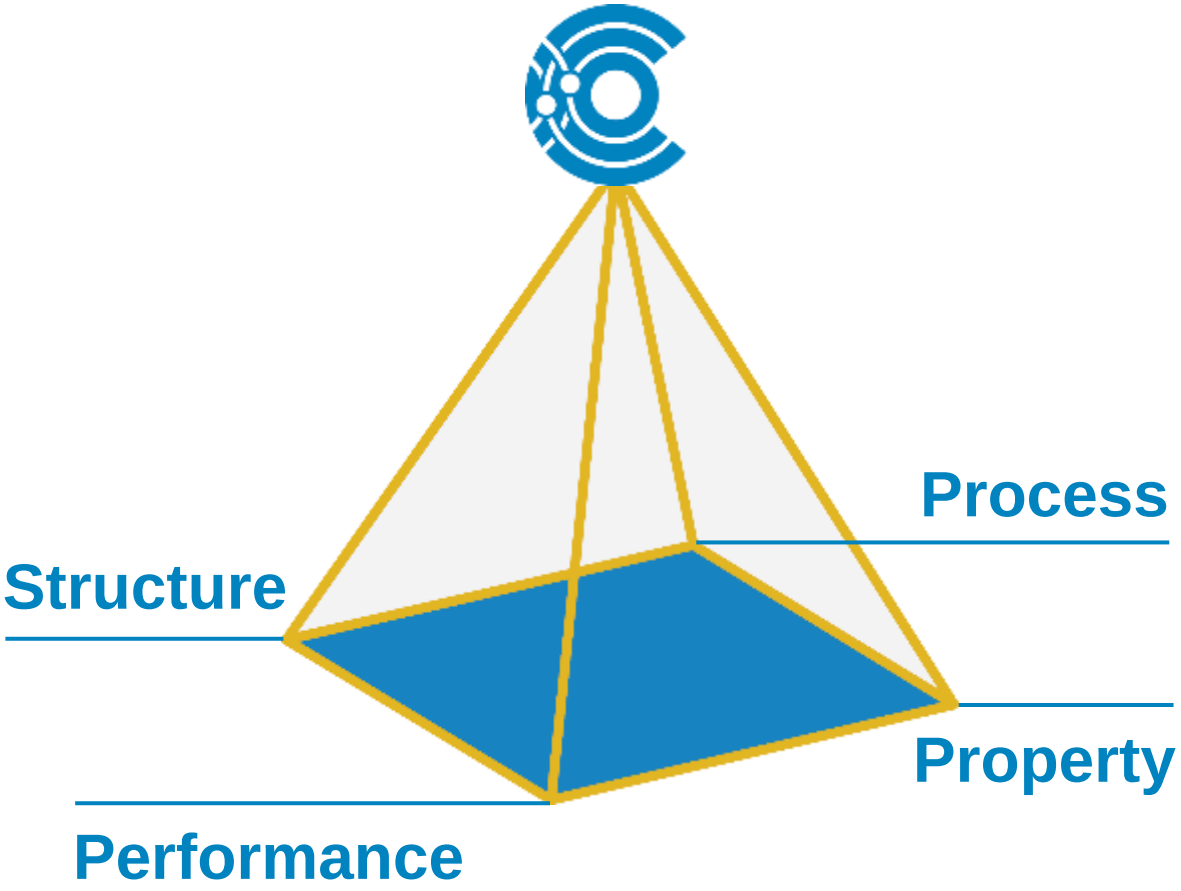


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