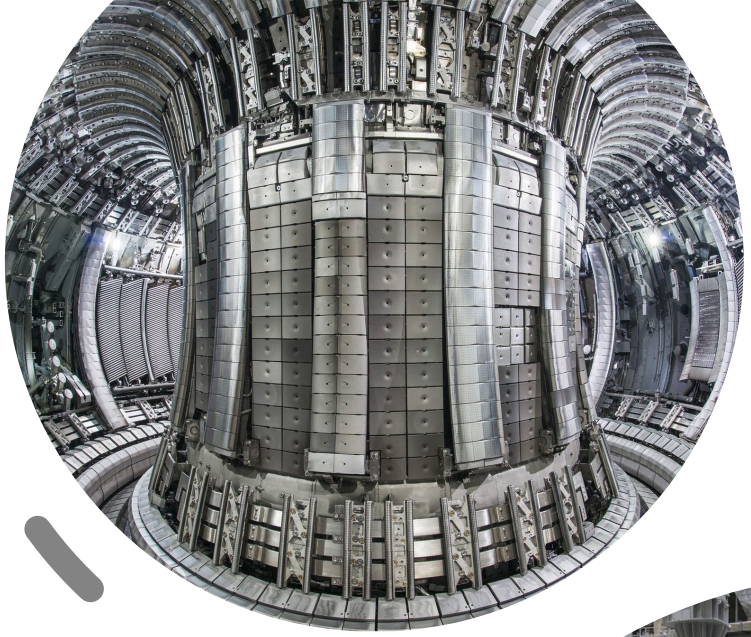
Characterisation of Damage Layers in JET Langmuir Probes

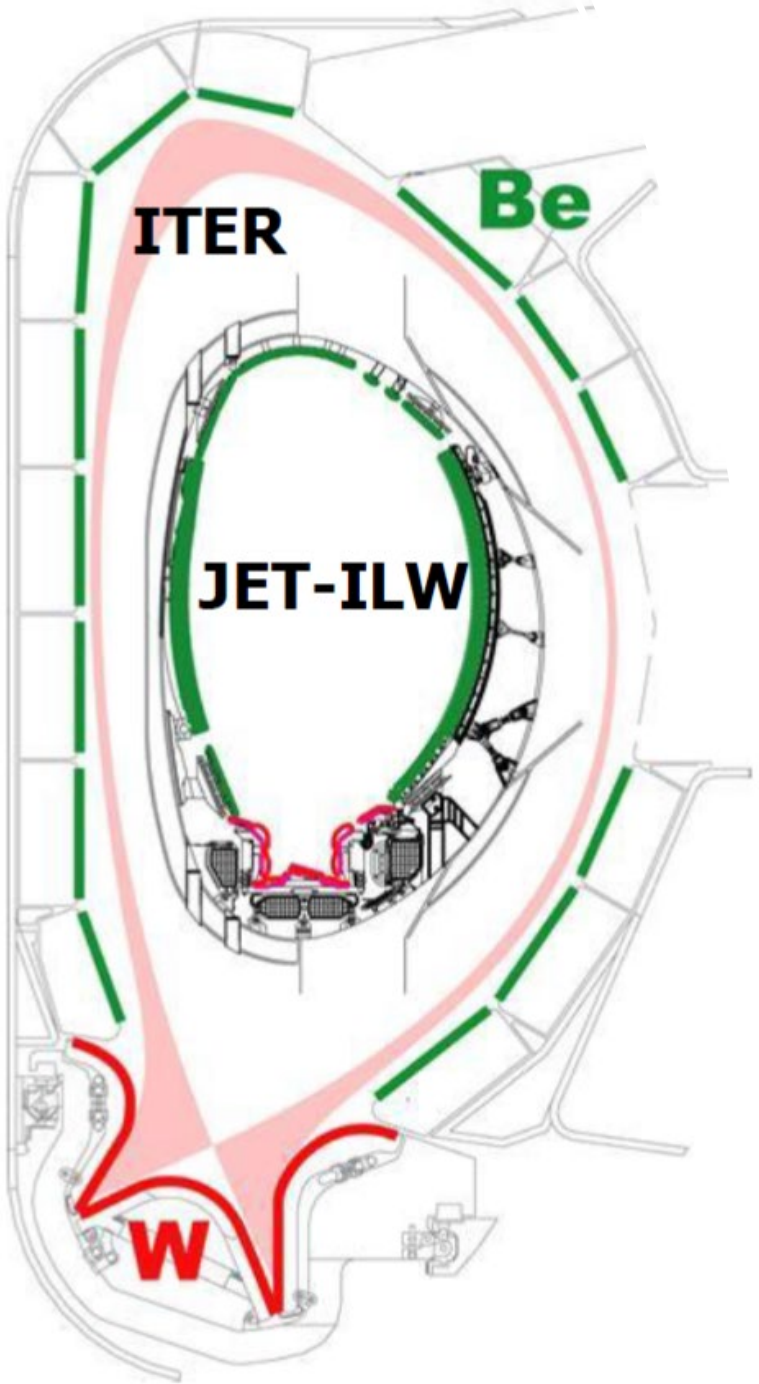
– An NNUF Funded Experiment

By Rob Kerr

My Research Project



- Third year **Fusion CDT** student based at the University of Oxford
- Working with Prof. David Armstrong, Prof. Sergio Lozano-Perez and Dr. Anna Widdowson (UKAEA)
- Looking at changes in microstructure and mechanical properties of **Plasma Facing Material** (PFMs) after plasma exposure in **JET**
- JET is the **Joint European Tokamak** at the Culham Centre for Fusion Energy, ITER-like Wall (ILW) campaigns 2011-2016
- **ITER** is the next generation of experimental fusion reactor



Material Description

- Samples taken from **JET divertor** tiles, are either solid **tungsten** or tungsten coated carbon fibre composites
- **Main chamber** samples are pure **beryllium**
- ILW campaigns used **deuterium plasma** which produces low activity samples
- **Beryllium** can be **toxic** if inhaled or absorbed as a soluble salt
- The **MRF** at Culham is the only facility equipped to handle such materials

NNUF Funded Access - MRF

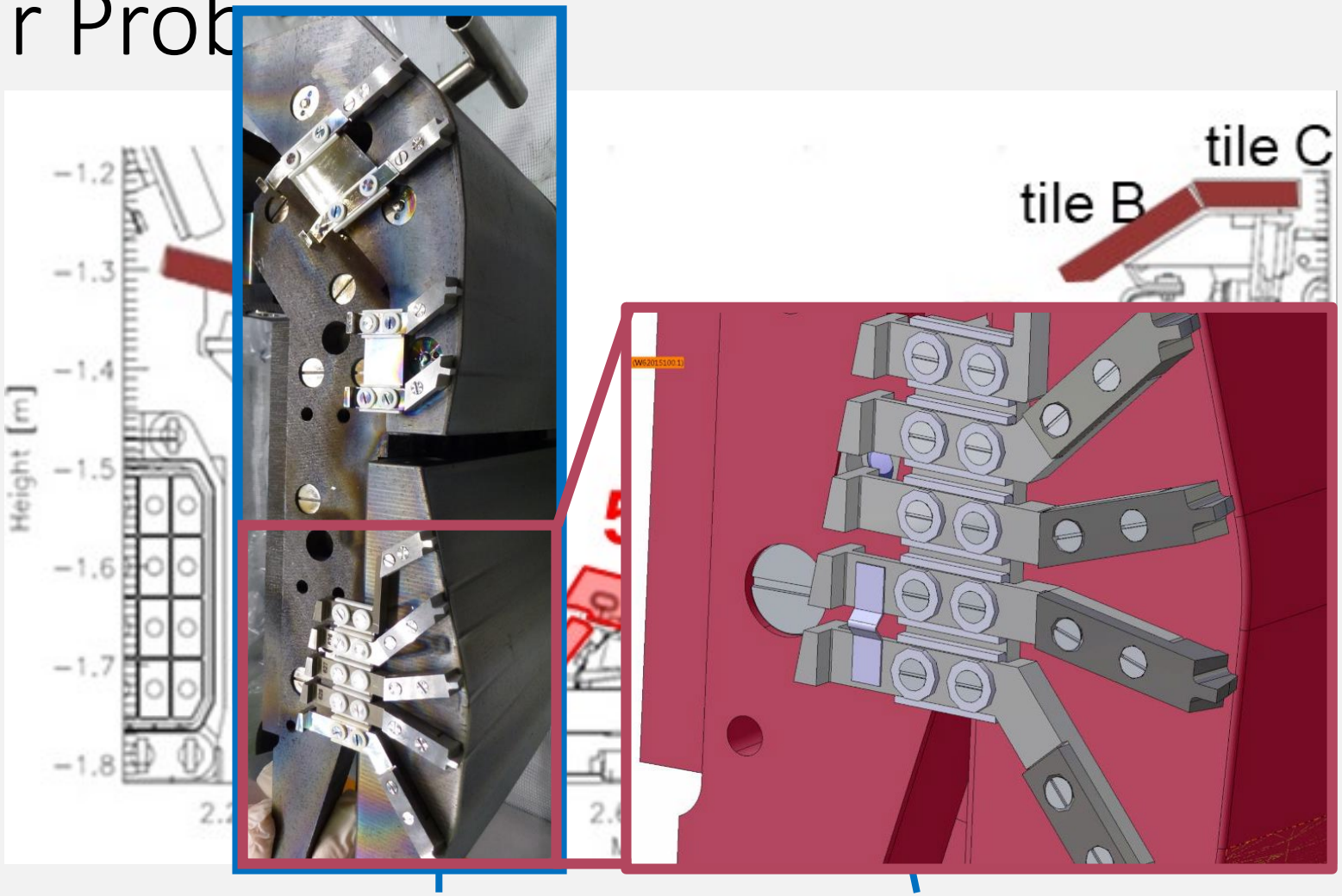
- Equipment accessed: SEM, Nanoindenter & FIB
- **Active sample preparation** was carried out by the MRF operations team
- Technical support was provided by the responsible officers for the equipment
- Instrument time booked through MRF coordinator

Tips

- Talk to Facility coordinators and NNUF administrators
- Try to accurately estimate experiment time – some flexibility
- Example: TEM training halted in Oxford Materials Department due to COVID, FIB time held for a couple of months

Results - Langmuir Prob

- Plasma Diagnostic
- Pure tungsten wire inserted into plasma
- Measures n_i, T_e, and V_f
- High number in divertor to control strike point position and to achieve detachment

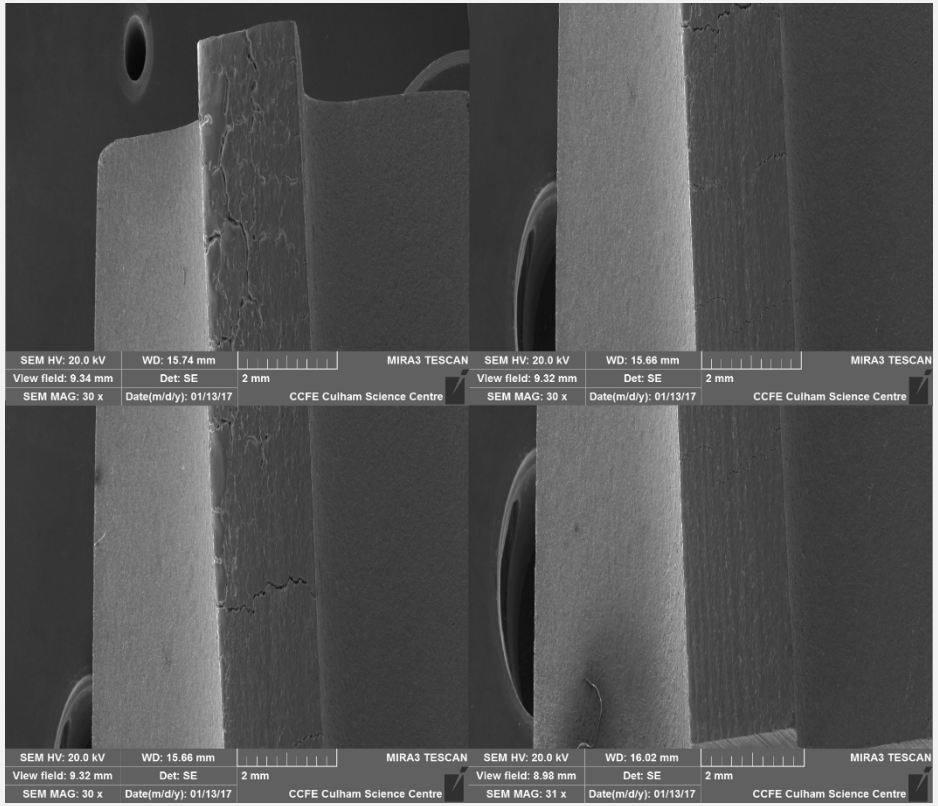


Module 17IN - Probe 8
Sample 1

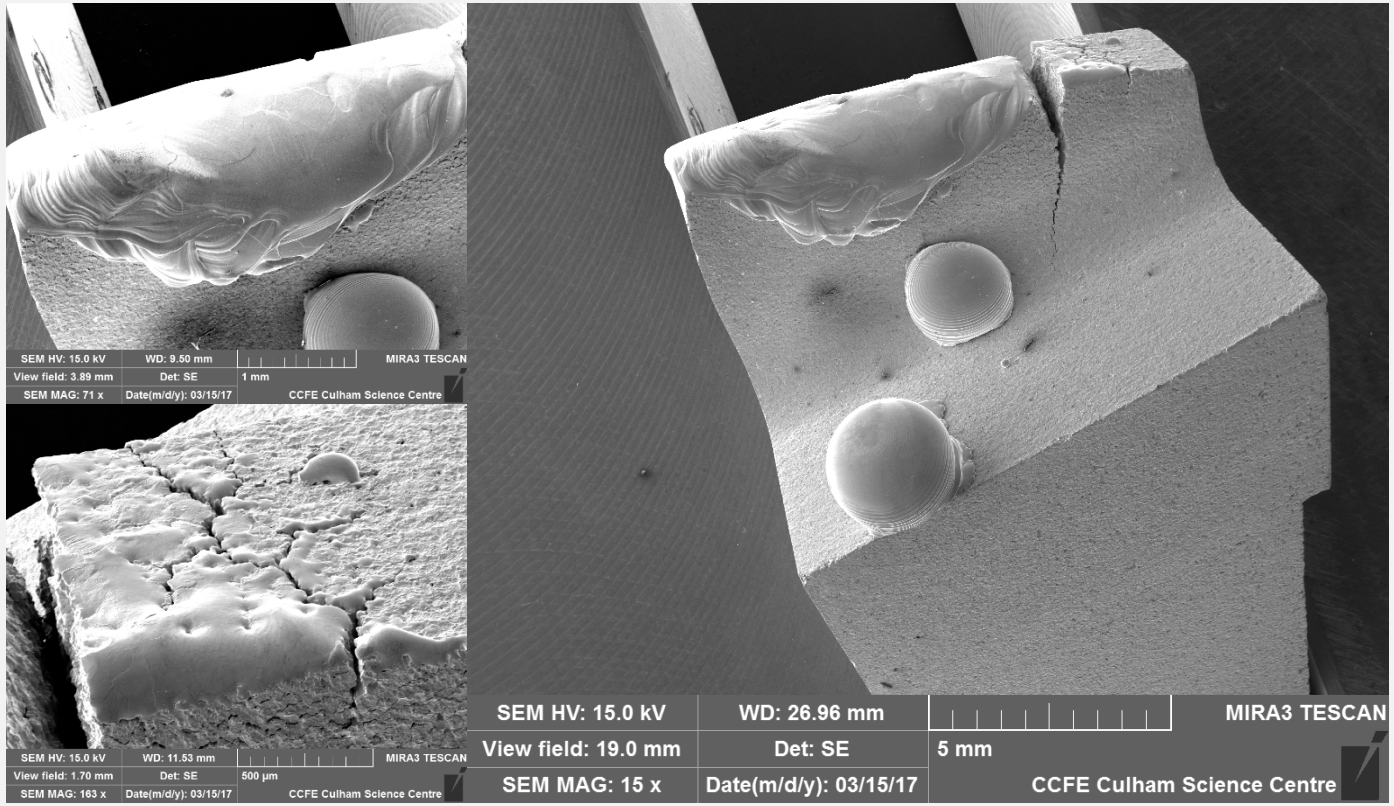
Module 15BW - Probe 26
Sample 2

SE Images of Exposed Surfaces

Sample 1

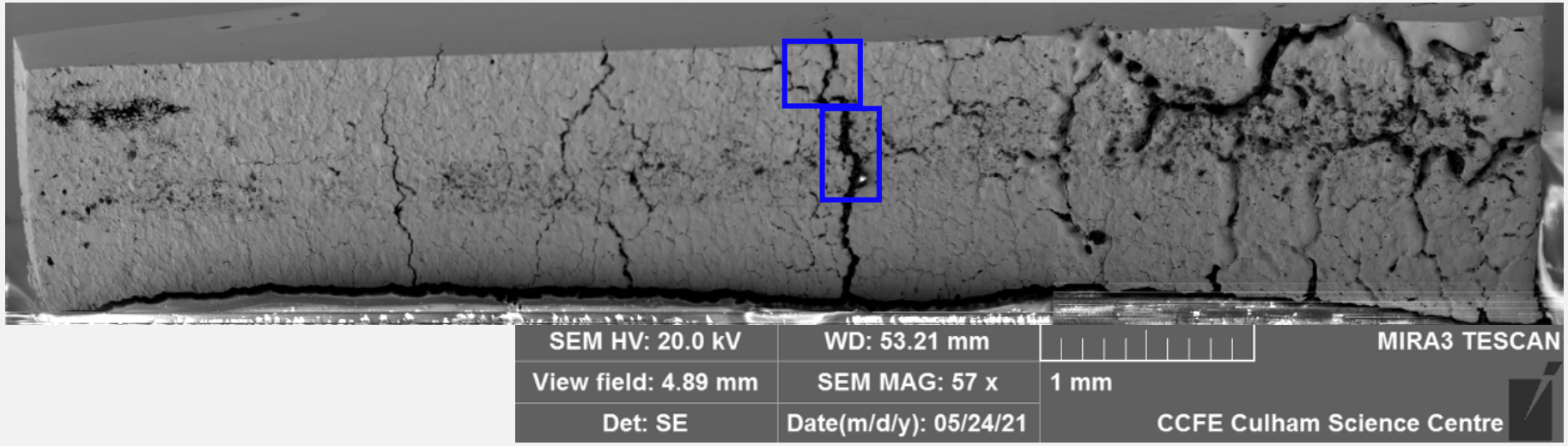


Sample 2

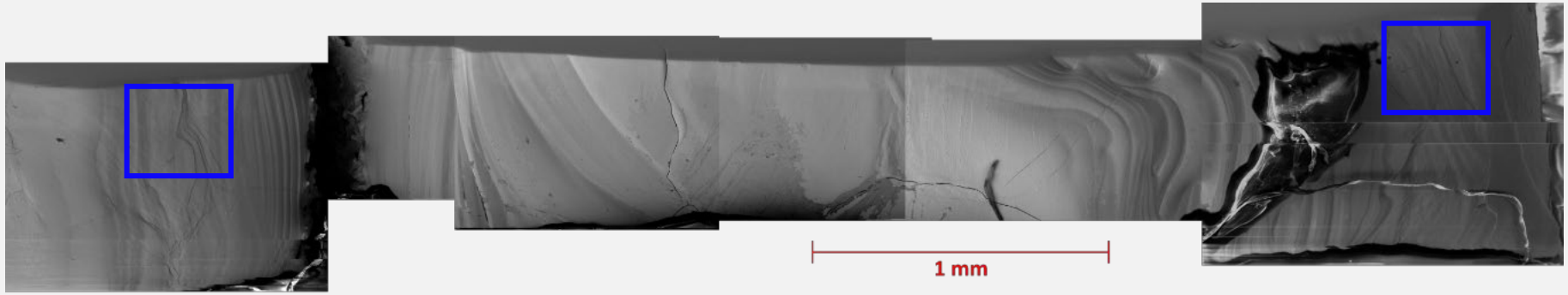


Exposed Surface EDX

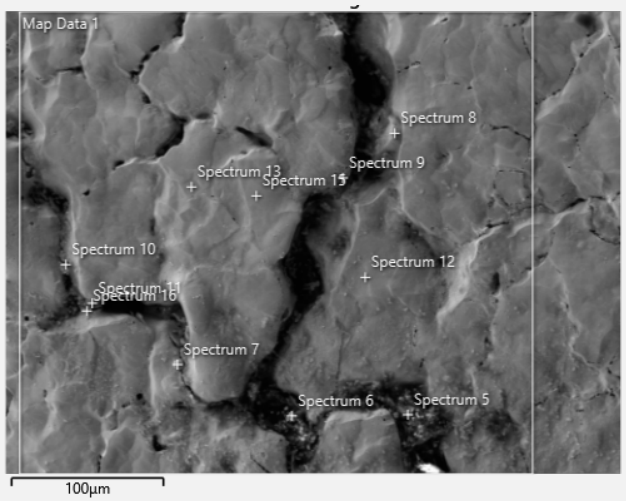
Sample 1

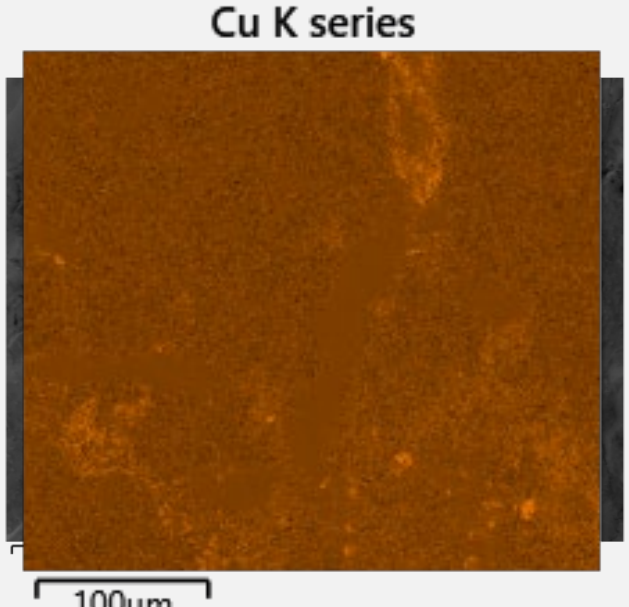


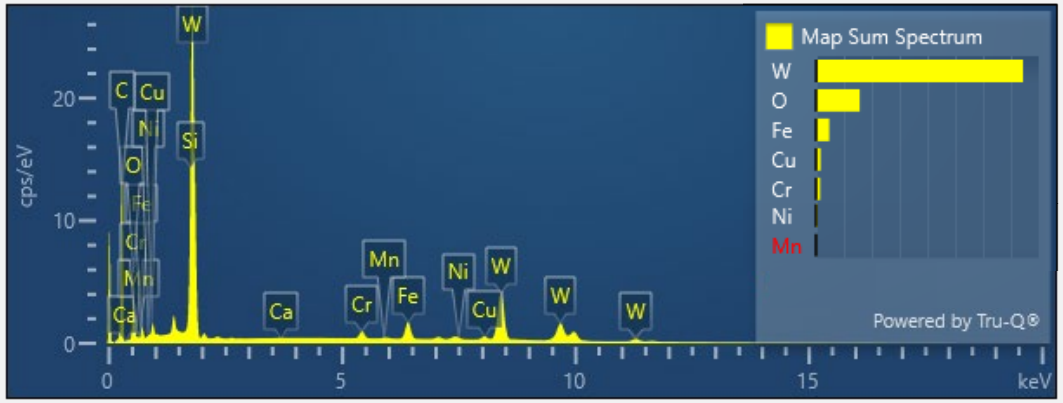
Sample 2

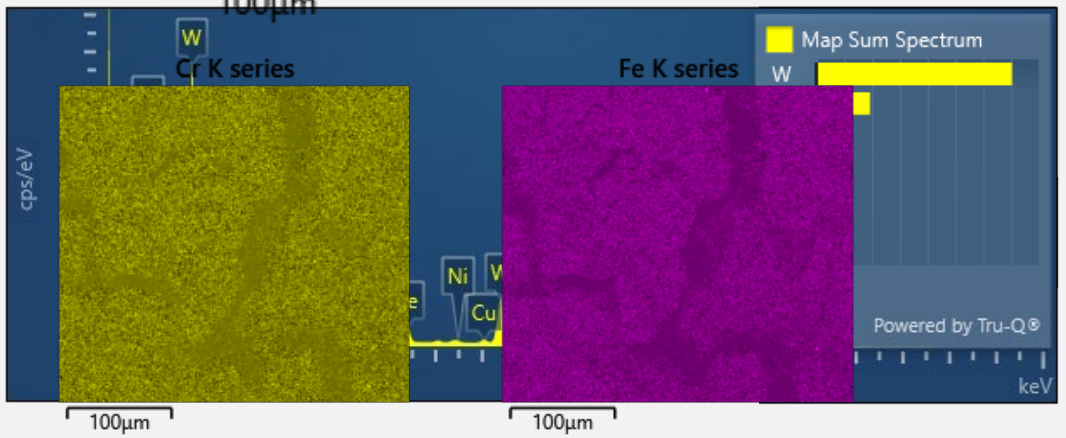


Exposed Surface EDX – Sample 1

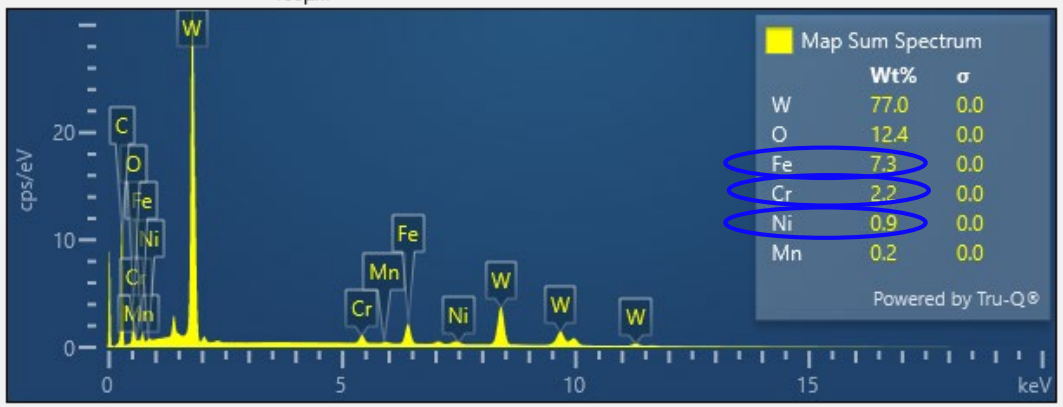


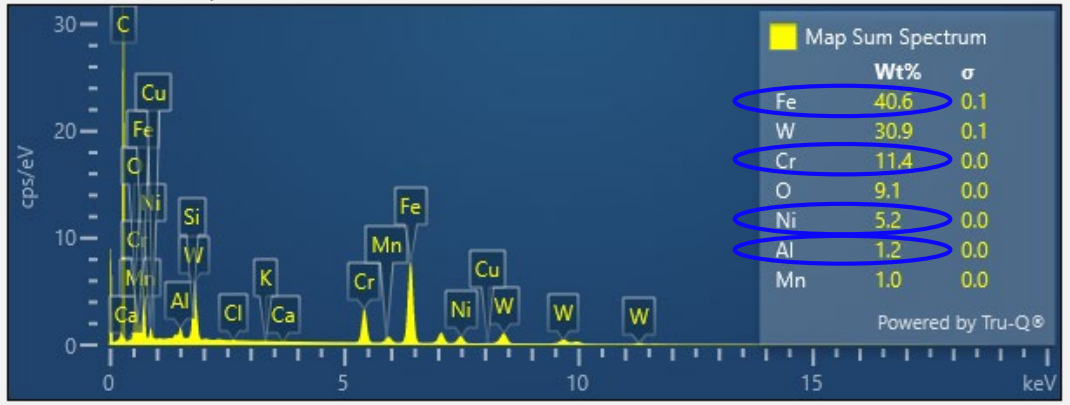






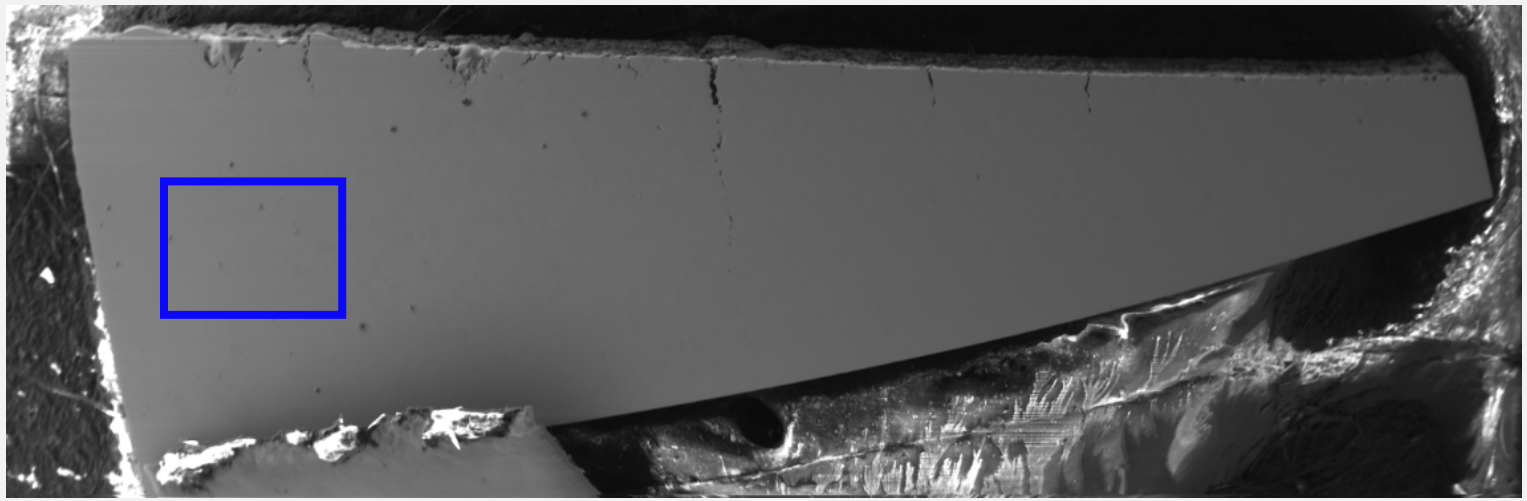
Exposed Surface EDX –Sample 2



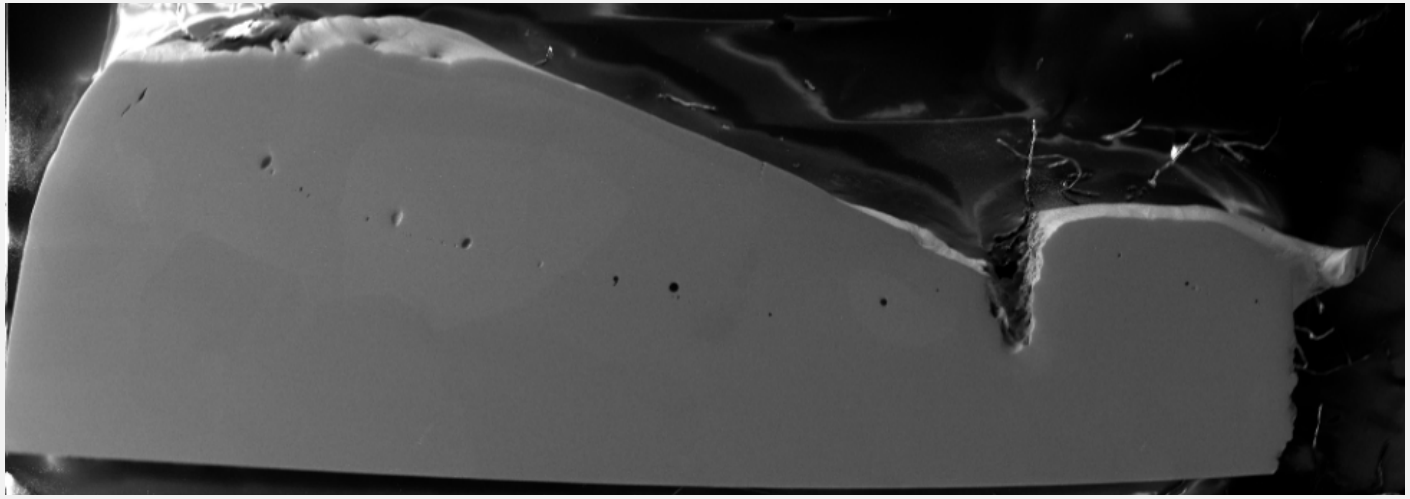


Cross Section EDX

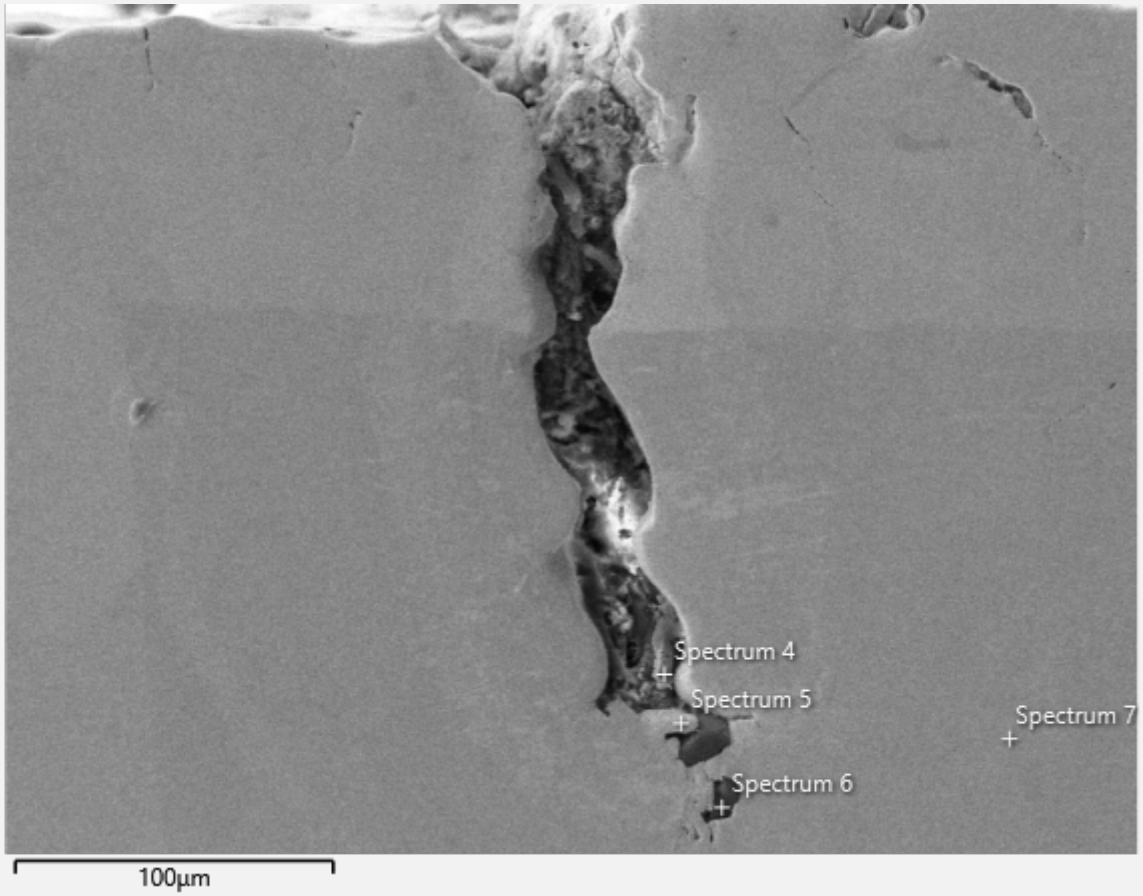
Sample 1

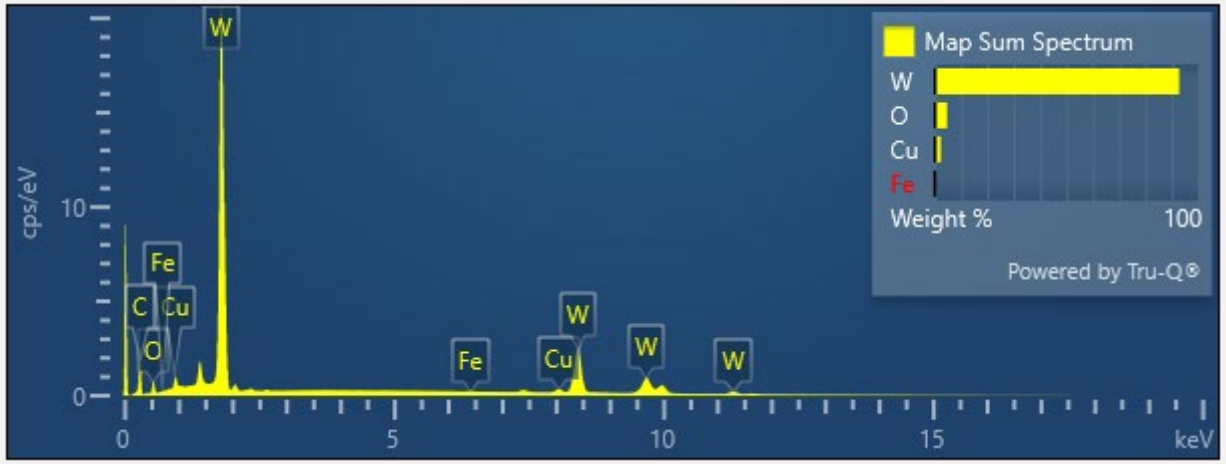


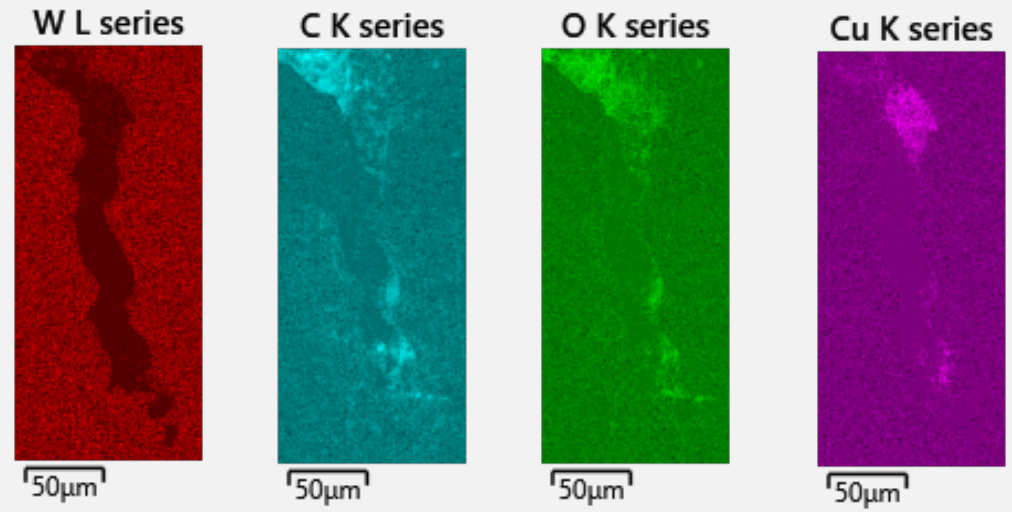
Sample 2



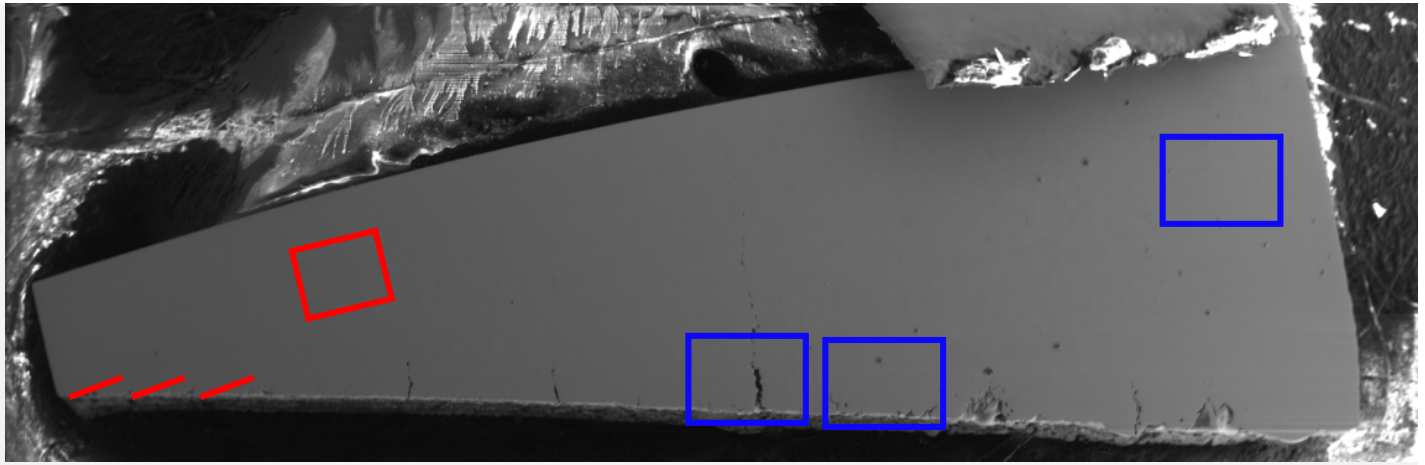
Large Crack – Sample 1



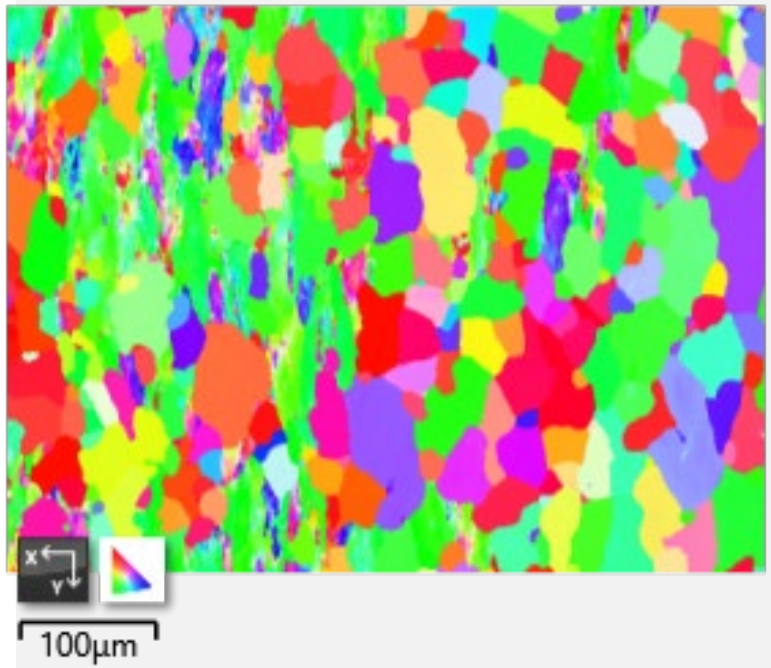




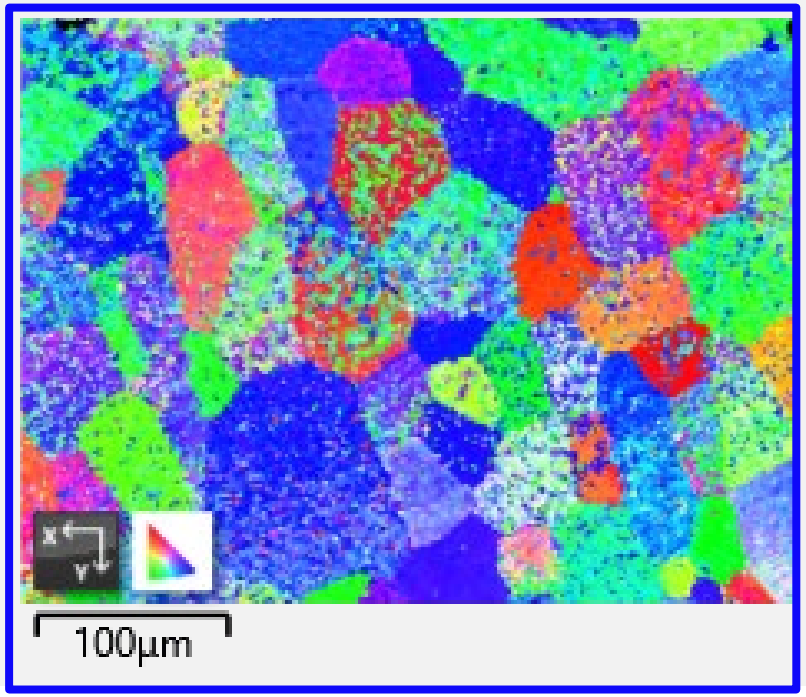
Cross Section EBSD – Sample 1



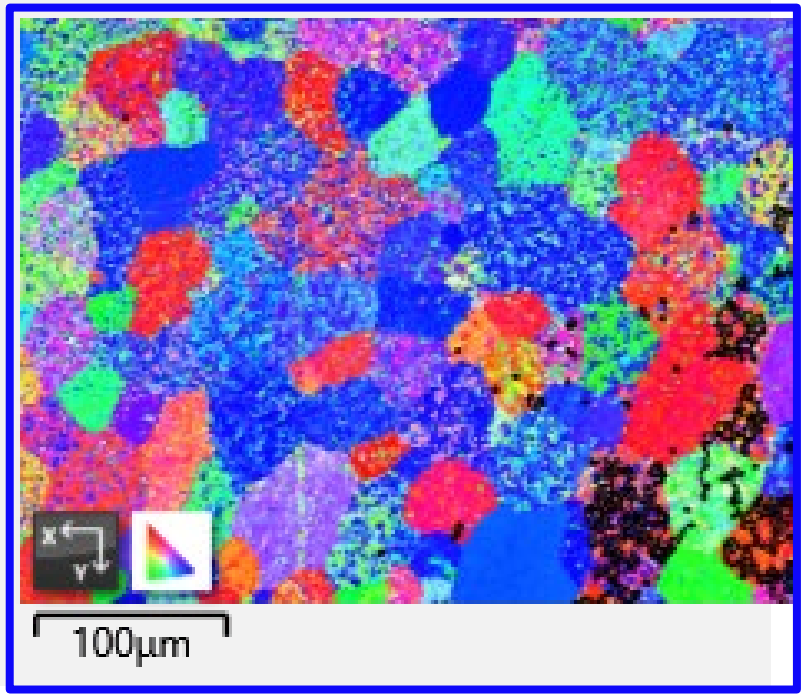
As Received – 33.1 µm



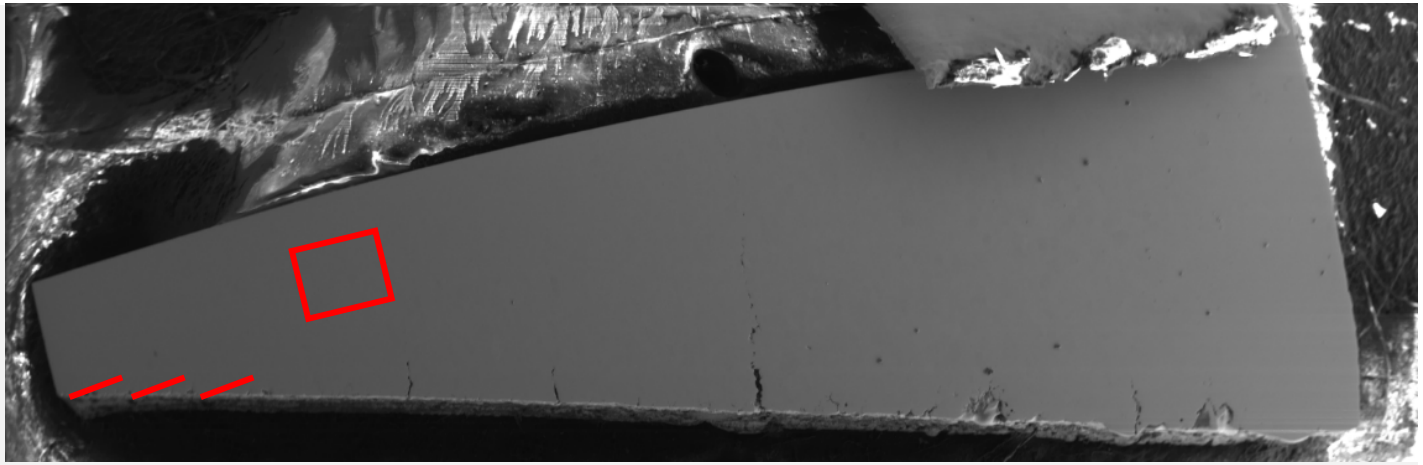
Surface - 39.6 µm



Bulk - 27.8 µm



Indentation – Sample 1

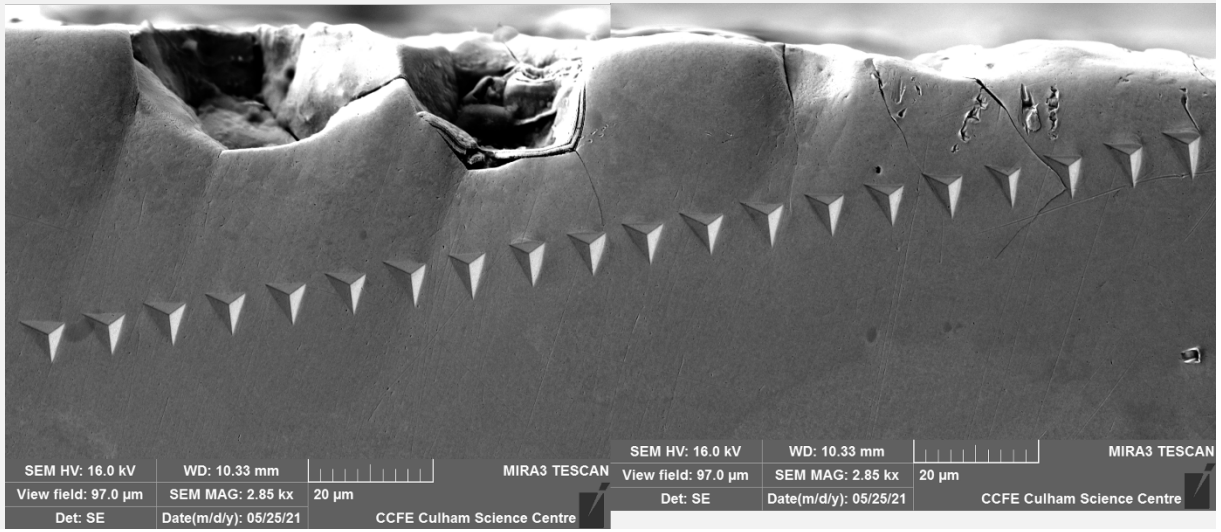


As Received Hardness

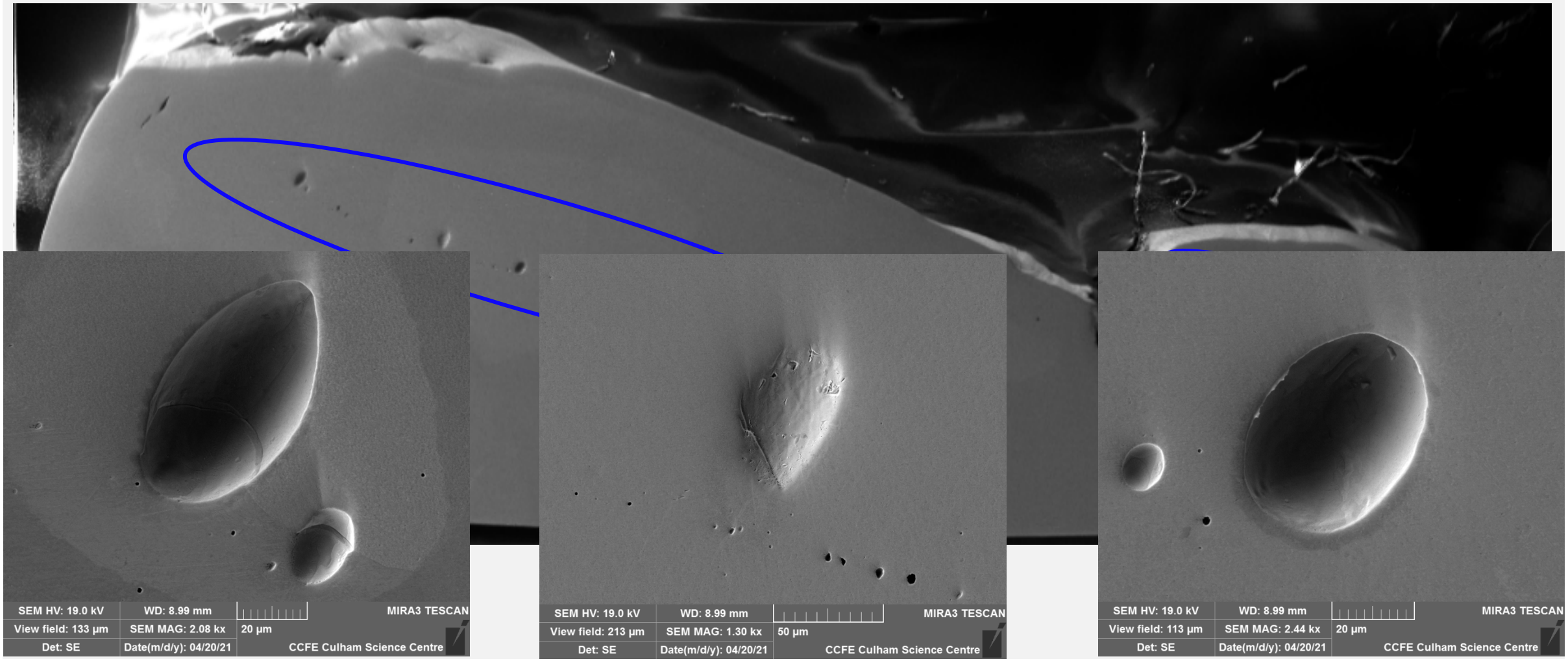
6.3 ± 0.4 GPa

Sample 1 Hardness

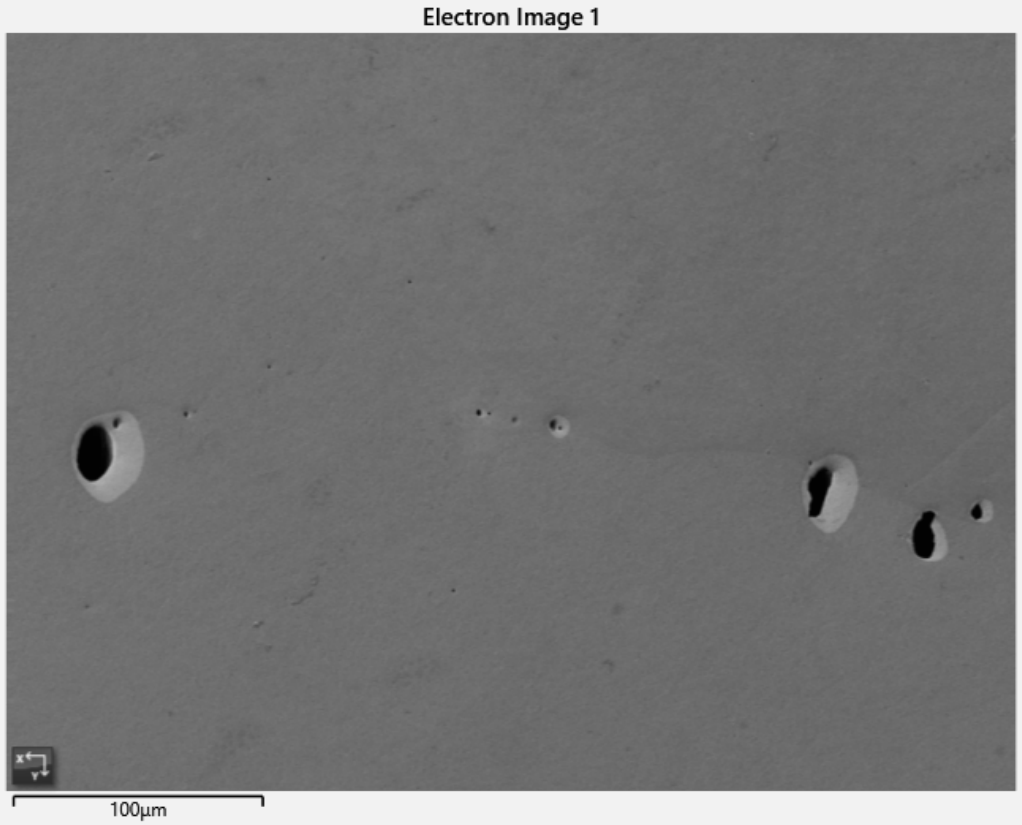
5.5 ± 0.4 GPa

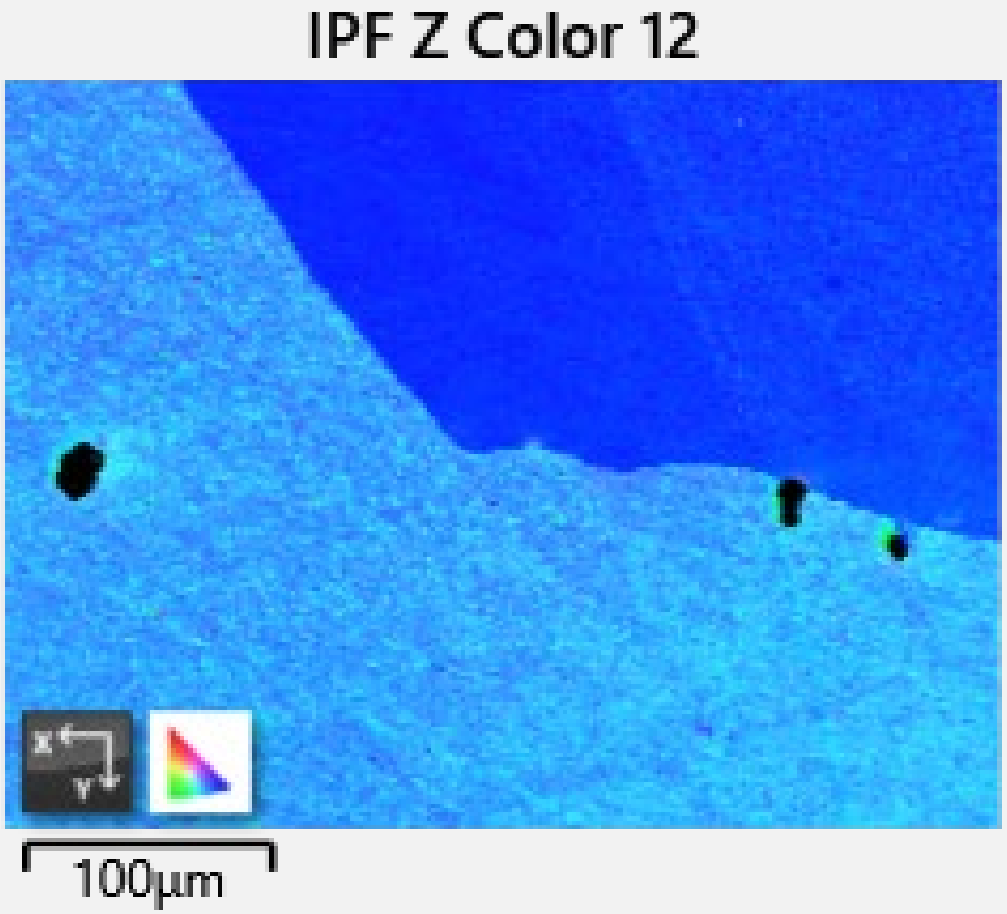


Cross Section – Sample 2

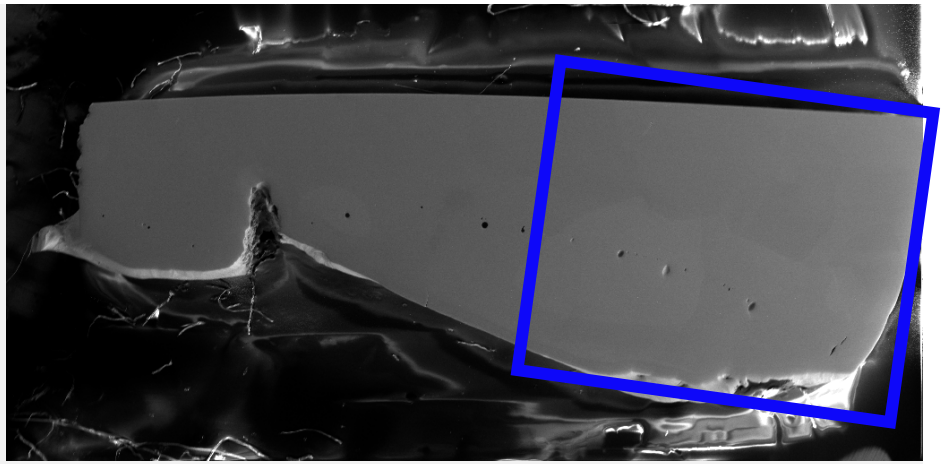


EBSD at Void Line – Sample 2

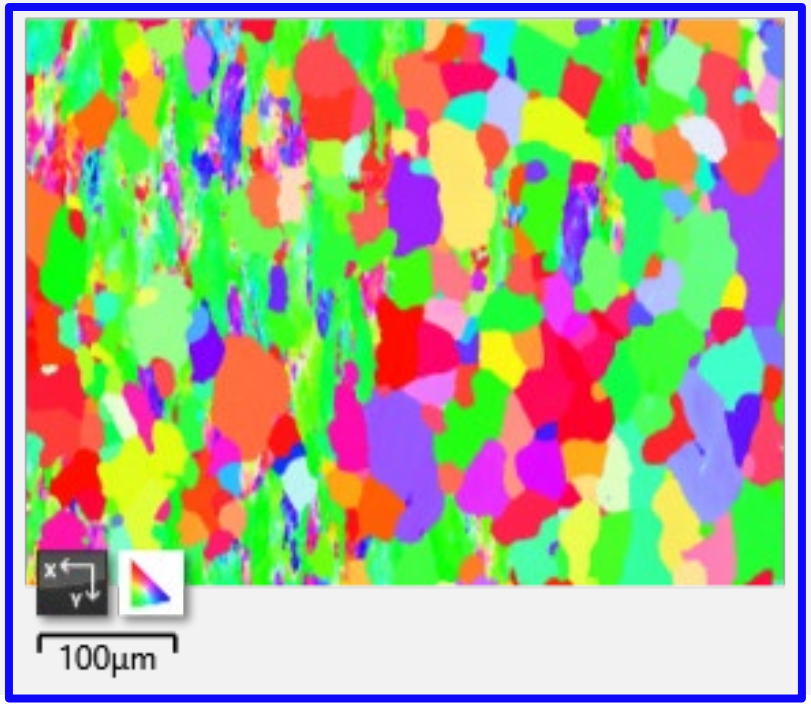




EBSD Overview – Sample 2

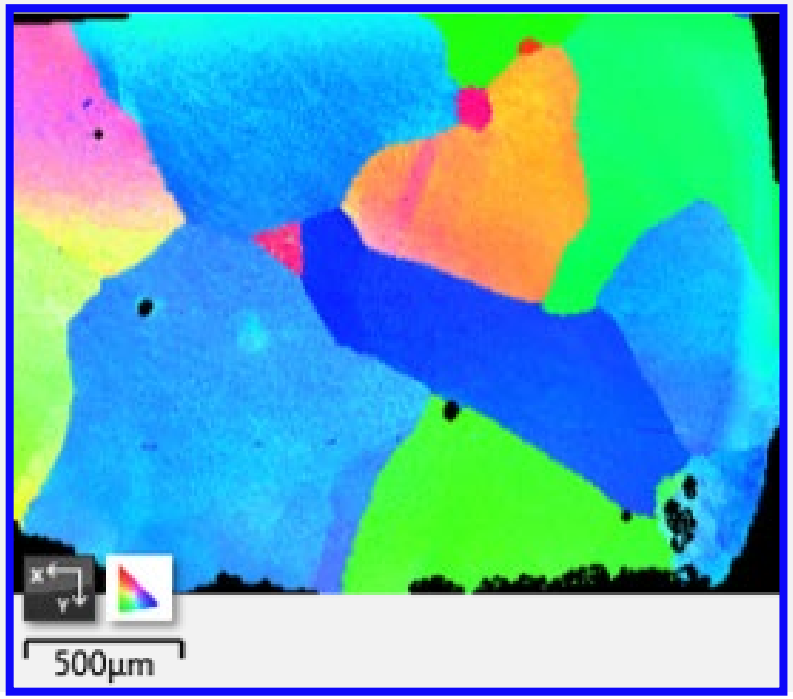


As Received – 33.1 µm

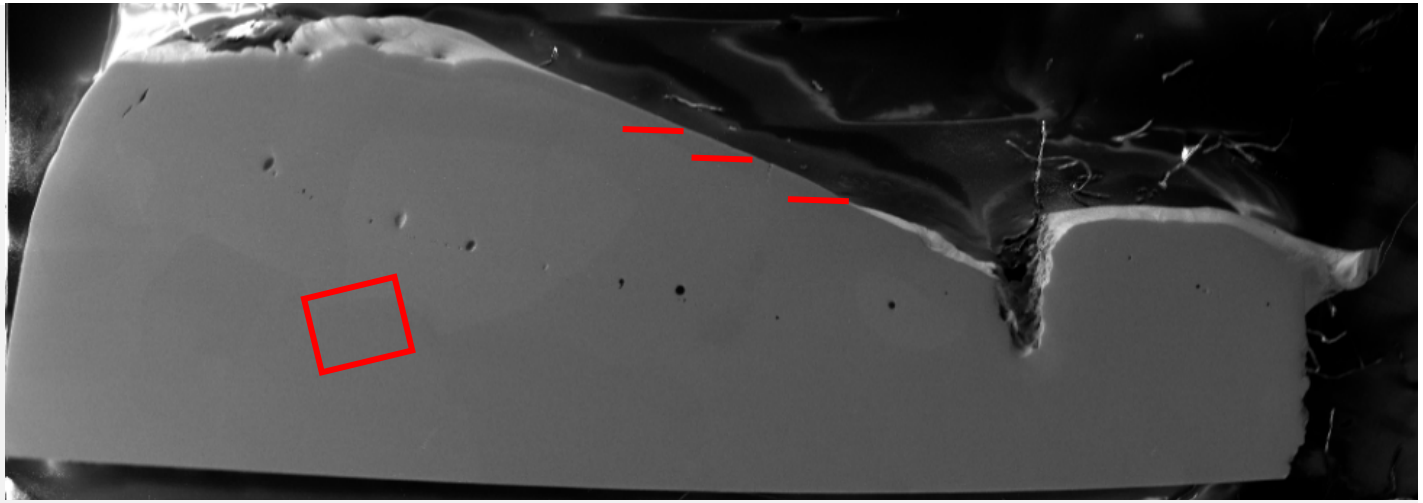


Plasma Exposure

Sample 2 – 516.8 µm



Indentation - Sample 2



As Received Hardness

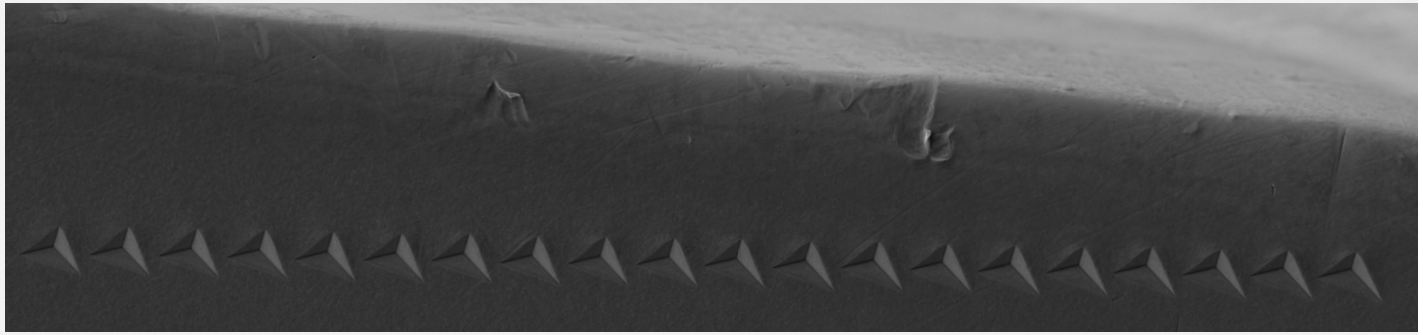
6.3 ± 0.4 GPa

Sample 1 Edge Hardness

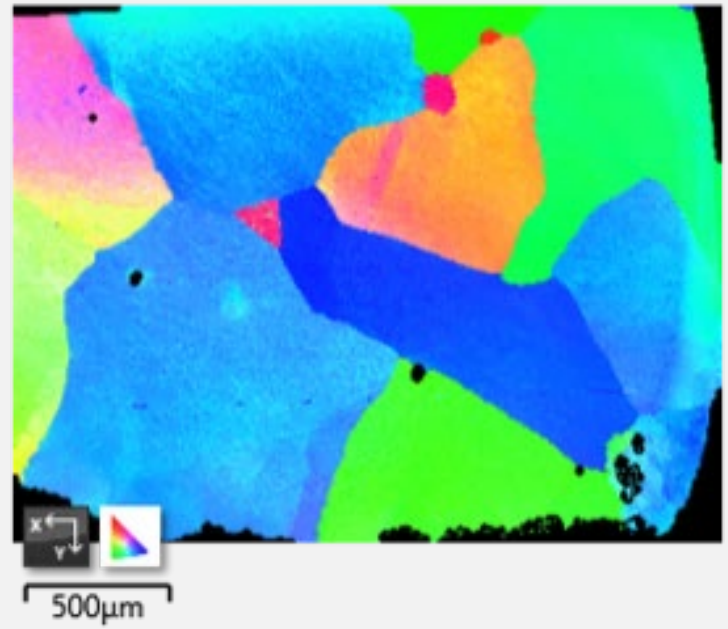
6.1 ± 0.4 GPa

Sample 1 Bulk Hardness

5.7 ± 0.4 GPa



Summary



- Sample 1 was positioned near **tile 3** and many **large cracks** had formed across the exposed surface and into the bulk
- Sample 2, placed near **tile 6**, showed clear signs of **melt damage**, suggesting exposure to higher heat loads
- EDX points to the deposition of **Fe, Cr & Ni** on both samples and **Cu** in sample 1
- Grain size had increased from **33 µm** in the as received to **40 µm** at the surface in sample 1
- Sample 2 was completely recrystallized to a grain size of **517 µm**
- Indentation suggests **larger grains** are the reason for the **reduction in hardness**