



UK Atomic Energy Authority

Materials Research Facility

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HENRY
ROYCE
INSTITUTE



EPSRC
Engineering and Physical Sciences
Research Council

MRF is part of the National Nuclear Users Facility (NNUF)
and the Sir Henry Royce Institute for Advanced Materials



MATERIALS
RESEARCH
FACILITY

Content

- Introduction
- MRF current facility and capabilities
- Plan for facility extension
- Examples of materials research at MRF

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UKAEA-MRF



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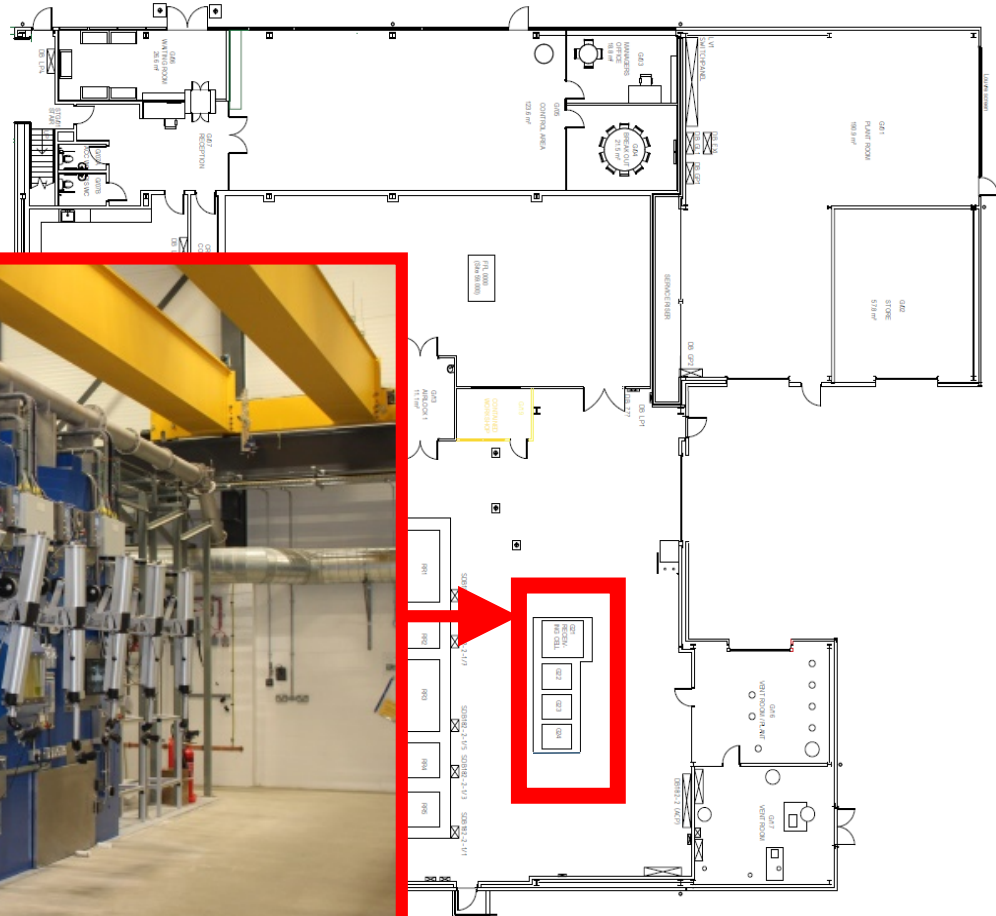


UK Atomic Energy Authority



UKAEA MRF hot-cell line

Samples up to 3.75 TBq Co⁶⁰



UKAEA MRF Research Rooms

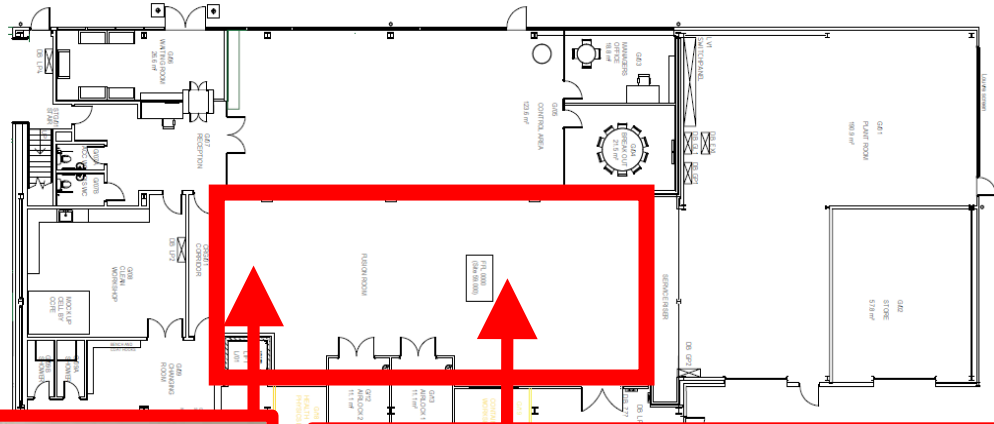


Samples up to 3.75 GBq Co^{60}



UKAEA MRF glovebox line

Samples up to 10 $\mu\text{Sv/hr}$

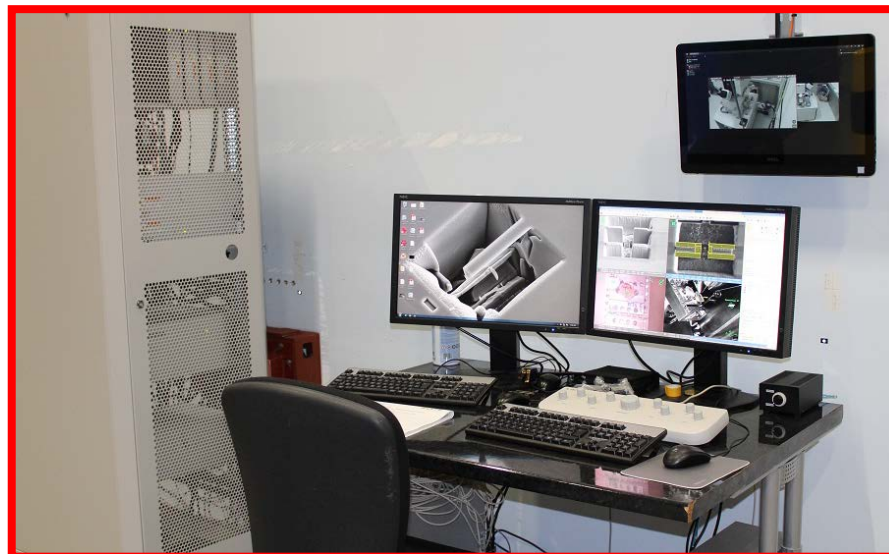




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Instrument integration in active area



UKAEA-MRF: Sample Preparation

Non active Sample prep lab

Cutting, grinding, polishing

Electro polishing

Optical microscopy

Non active sputter coater

PIPS-II ion polisher

Lab scale EDM

3mm disc punch

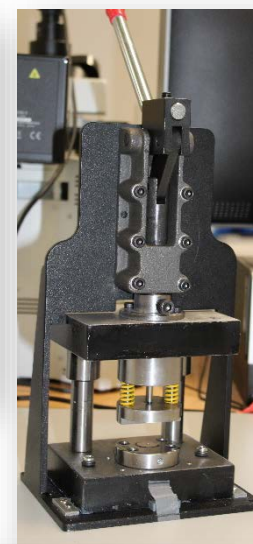
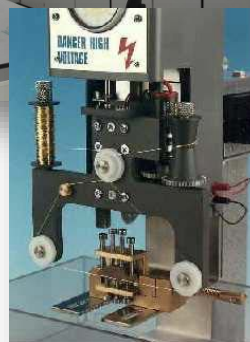
3 zone tube furnace 1200°C

Dimple grinder

Active sputter coater

Hot-cell lab-scale EDM

Glovebox cutting, grinding, polishing



Note:
Currently available
To be commissioned 2019/20

UKAEA-MRF: Microstructural Characterisation

FEGSEM

Tescan Mira XH
EDX, EBSD, TKD, WDS

Dual beam FIB

FEI Helios
GIS: Pt, W, C
Nano-manipulator for sample lift-out

AFM

Veeco D3100

PMI XRF

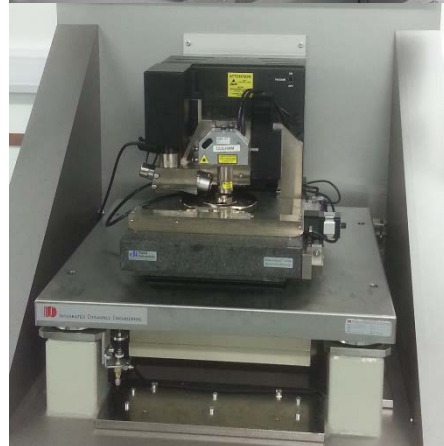
Olympus delta premium
PMI XRF

Scanning Confocal Raman Microscope

AFM
In-situ (e.g. Heating, liquid, & gas)

XRD goniometer

High brilliance X-ray source



Note:
Currently available
To be commissioned 2019/20

UKAEA-MRF: Thermo-physical Analysis

Thermal Desorption Spectroscopy

Hidden TPD workstation

Up to 1000°C

Gas Impregnation Technique

Ar, N₂, Air, He, D₂, **Tritium**

Ion energy < 500 eV, RT – 500°C

Dilatometer

Linseis L75V, dual pushrod

-150°C – 600°C and RT – 2000°C

Laser Flash Analyser

Linseis LFA 1000

-100°C – 500°C and RT – 2000°C

TGA/DSC

Linseis STA PT1600

-150°C – 500°C and RT – 1600°C

Gas pycnometry



Note:
Currently available
To be commissioned 2019/20

UKAEA-MRF: Mechanical Testing

Nanoindenter

Agilent G200

Static load frame 10 kN

Shimadzu AGS-x

Environmental chamber for up to 800°C

Dynamic load frame 15 kN

TA Electroforce 3500

Environmental chamber for up to 800°C

Small-punch testing

Vacuum chamber with induction heating

In-situ SEM load frame 5 kN

DEBEN MTEST

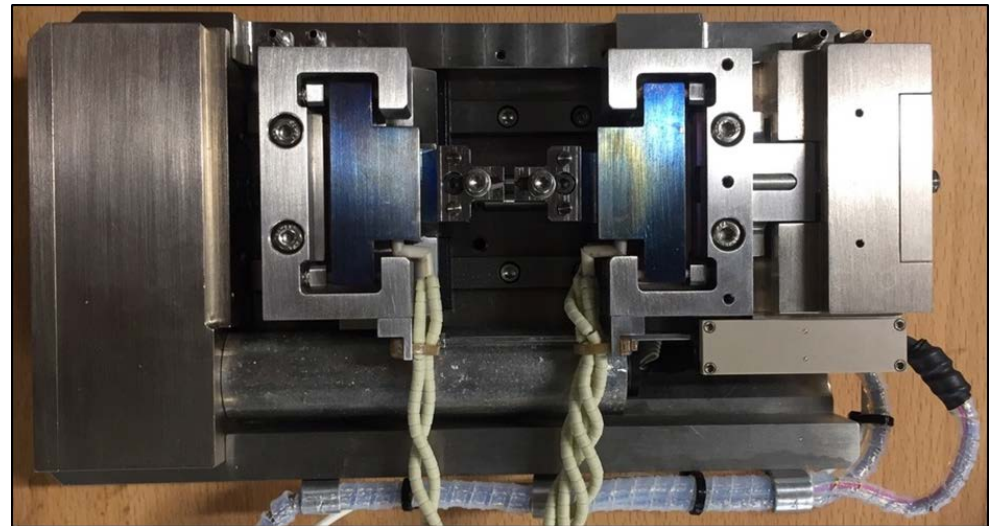
Clamp heating up to 600°C

Instrumented indenter

UltraSonic Fatigue Setup

DIC strain measuring system

Impulse excitation testing

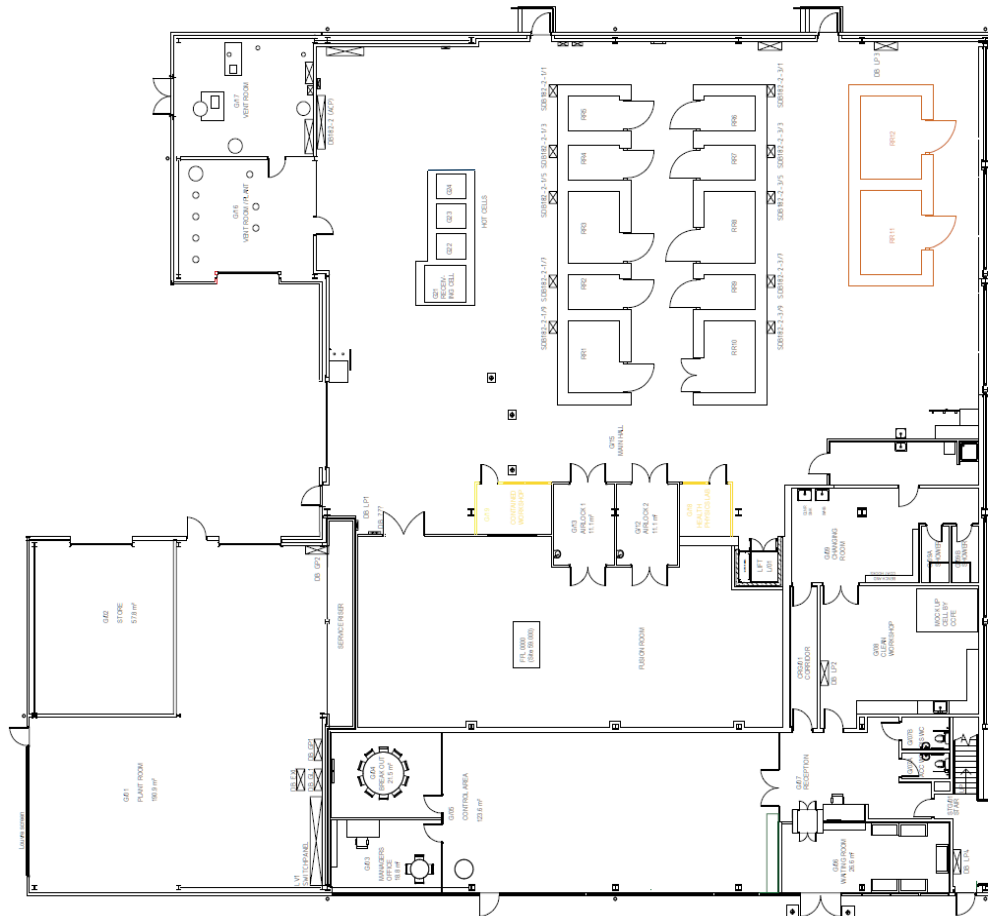


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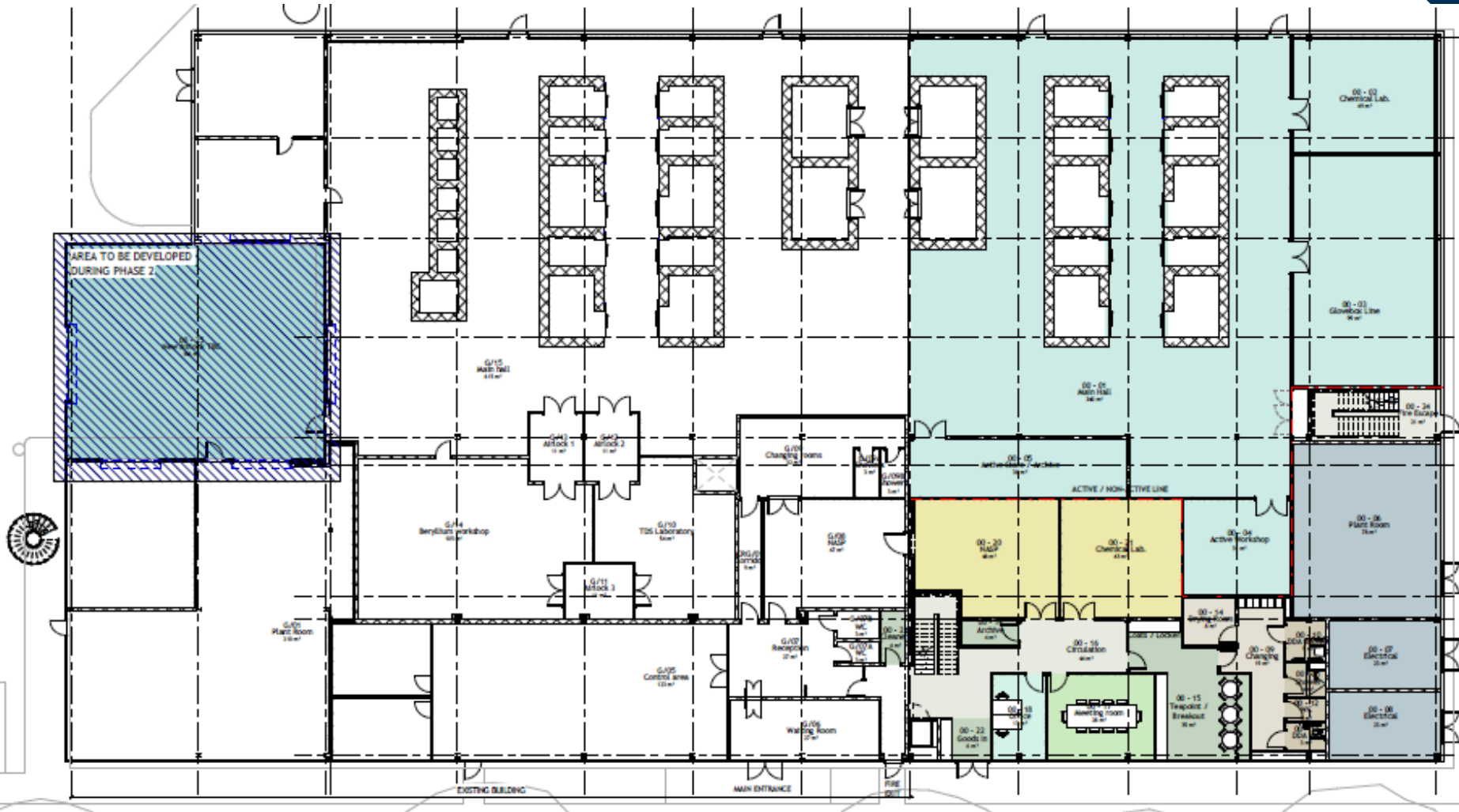
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UKAEA MRF hot-cell line



Building extension plans

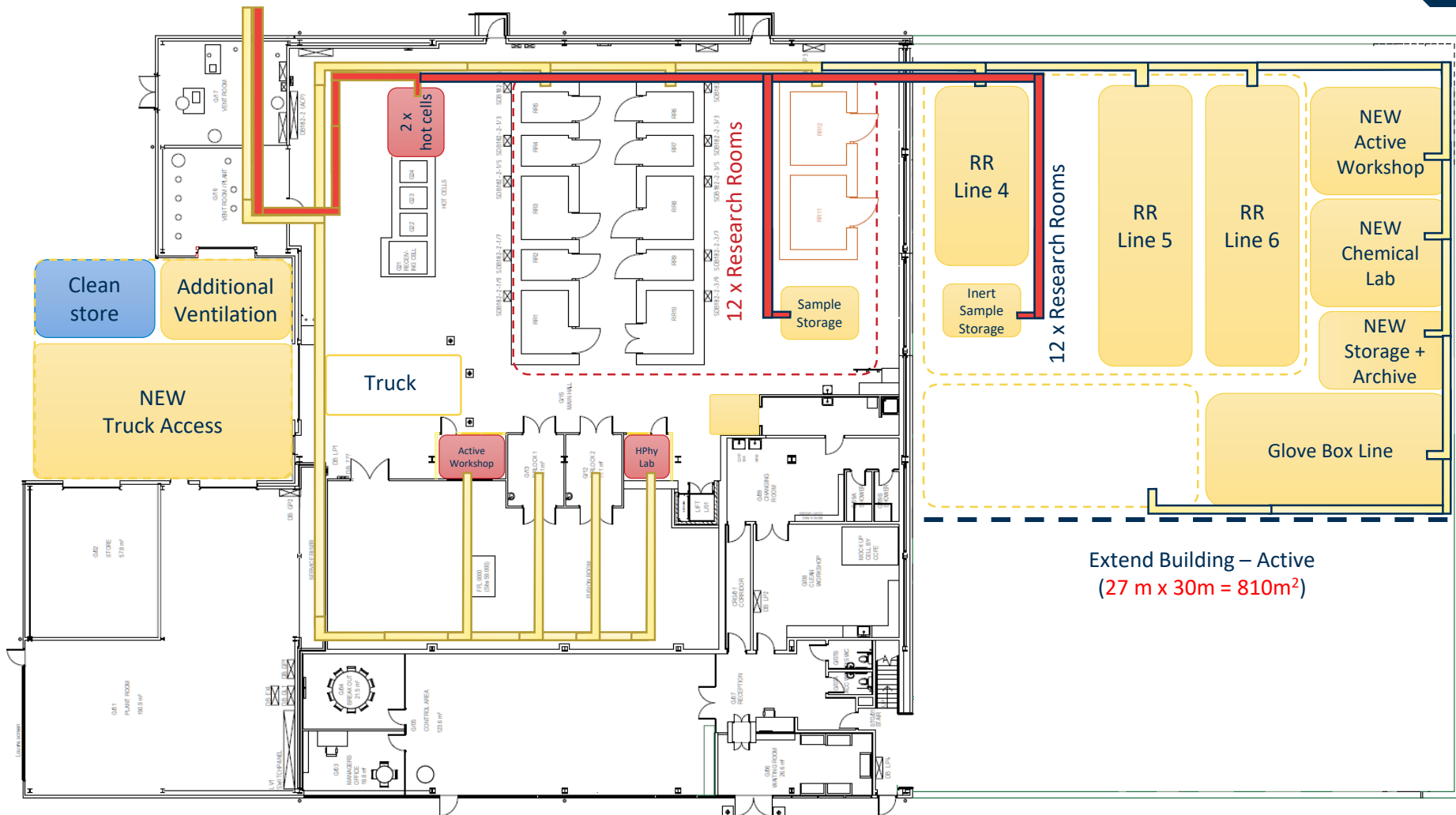




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MRF Summary – Active



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Relevant Expertise at the UKAEA-MRF

Sample preparation

FIB machining on all fusion relevant metals, expertise with low activity samples

TEM sample prep with FIB and PIPS on low activity materials, currently working towards electropolishing on active materials

Micromechanical testing

Nano-indentation, size effects

Different indenter geometries (Berkovich, Cube, Spherical, ...)

Post indentation AFM analysis of pile up and indenter contact area

Post indentation cross sectional analysis with SEM-TKD and TEM for plastic zone size determination

Micro-cantilever bending tests

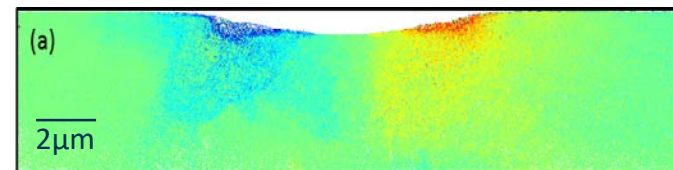
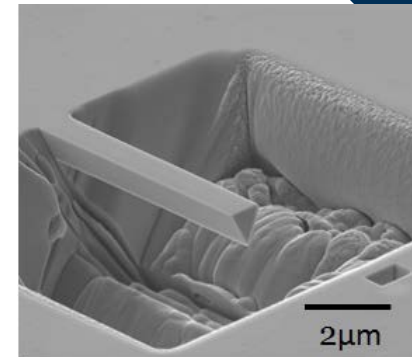
Nano indentation at RT, high T is top priority for future investment programs (18/19 onwards)

Microstructural Analysis

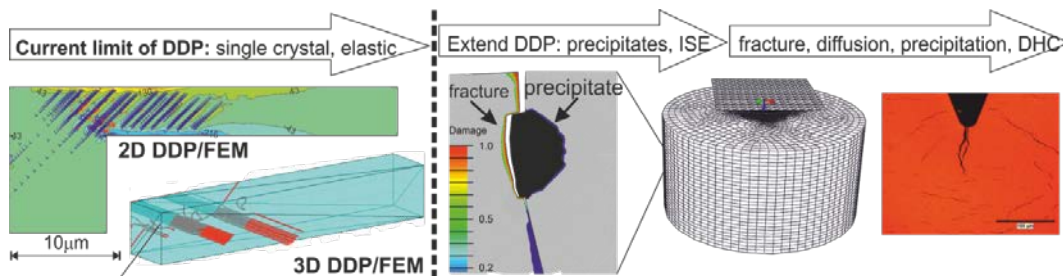
TEM, SEM, Raman imaging, XRD, etc..

Through collaborations

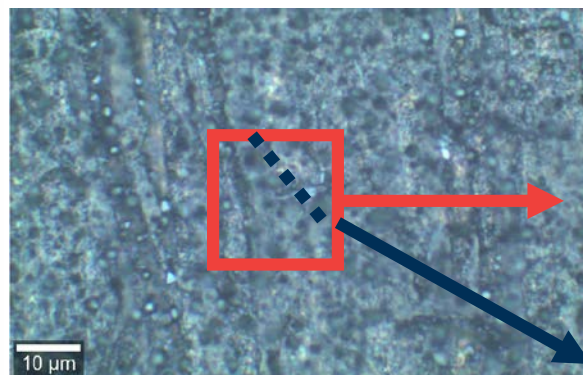
- APT (Oxford)
- Chemi-STEM (Manchester)
- Materials modelling at various length scales (CCFE, Imperial, Oxford)



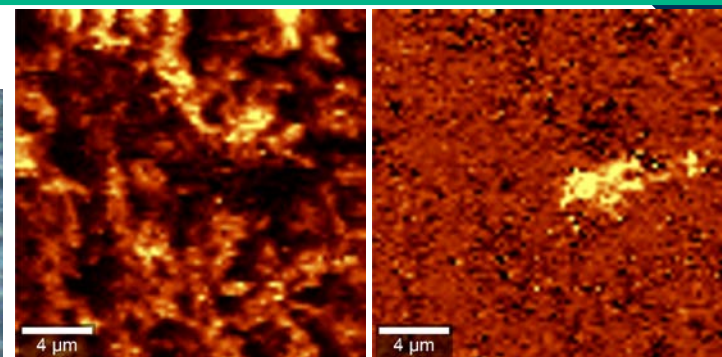
Strain mapping using Transmission Kikuchi Diffraction (TKD) techniques on indentation cross-section (first of its kind)



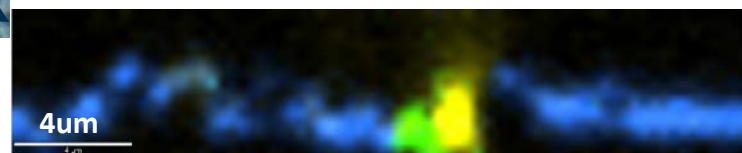
Advanced Laser Scanning Confocal Raman Microscope (LSCRM)



Optical Micrograph of
Alloy 625



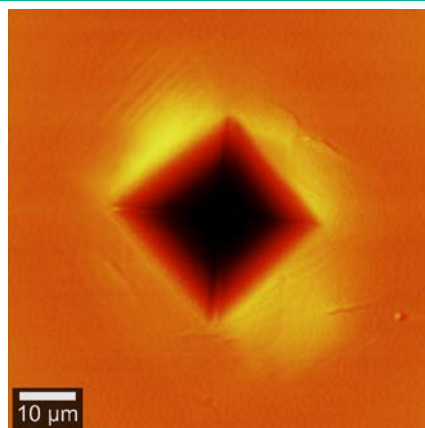
Raman SI (Comp. 1) Raman SI (Comp. 2)



3D depth Raman signal profile of the oxides



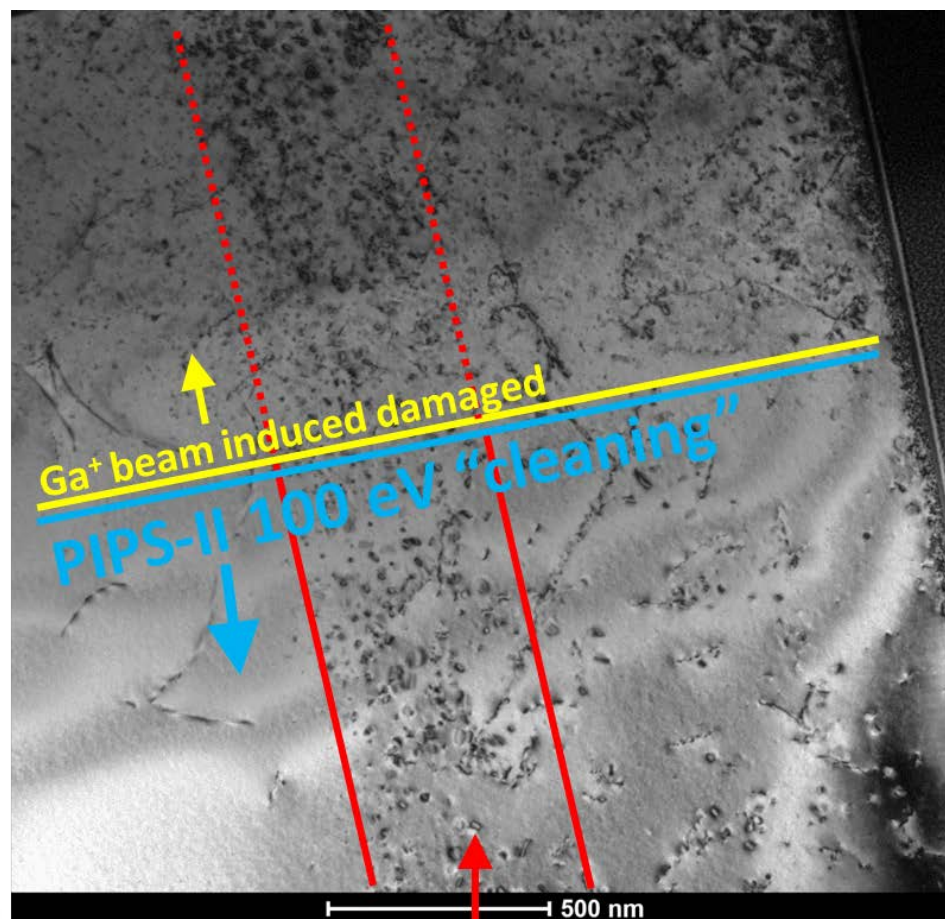
Liquid & gas heating stage
(up to 1300°C)



High Res. surface topography
of a nano-indent on a Cu-alloy

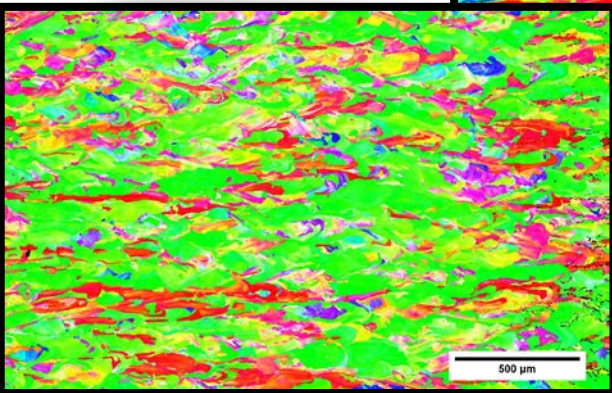
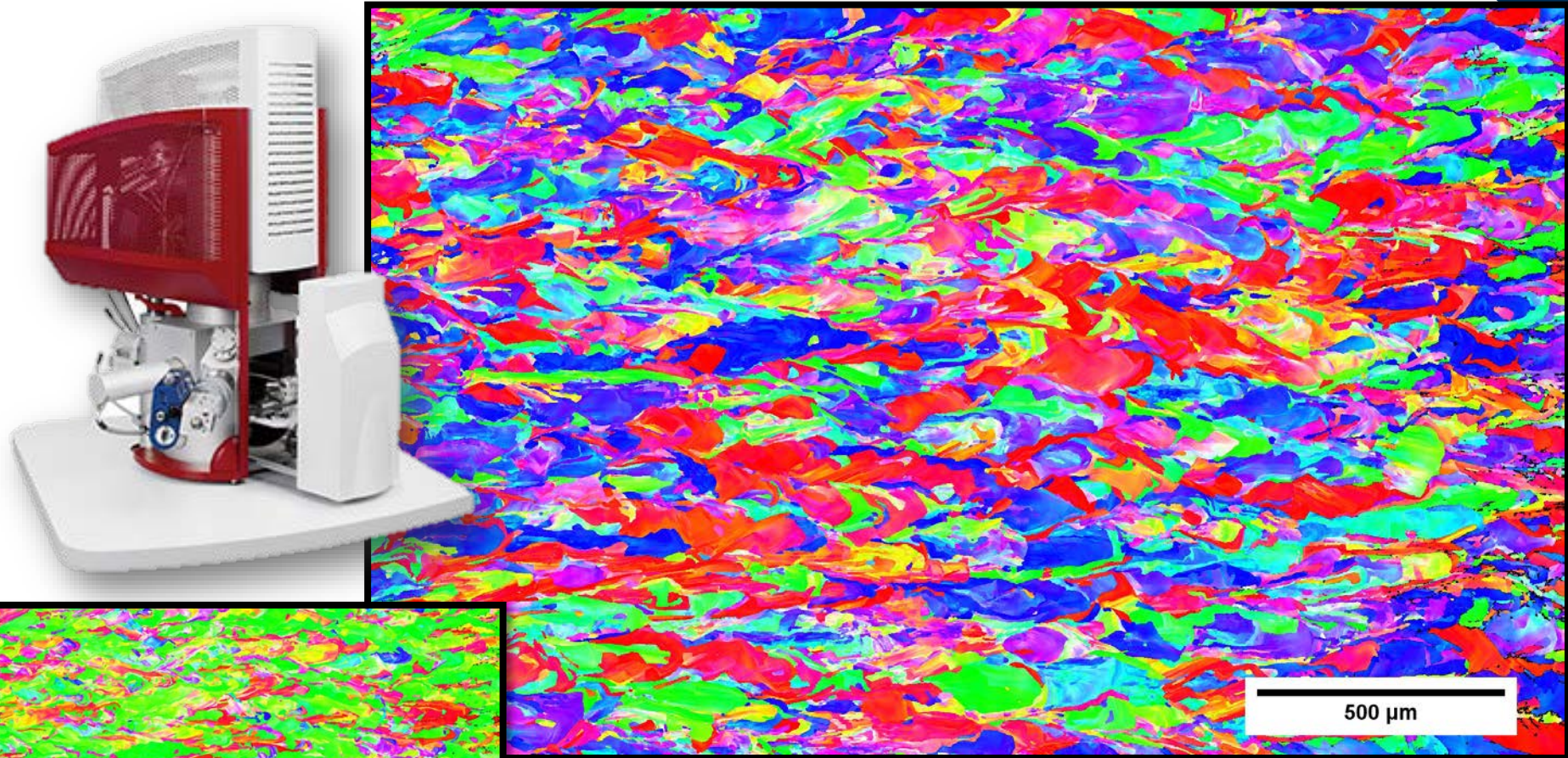
- High resolution 3D Raman imaging capability
- In-situ Raman imaging capability (at temperature, liquid and gas)

TEM Specimen preparation using ion beams (FIB & PIPS-II)

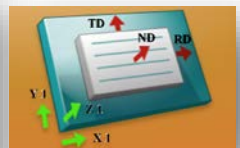
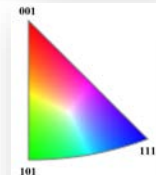


5MeV Fe²⁺ induced damage (Bragg Peak)

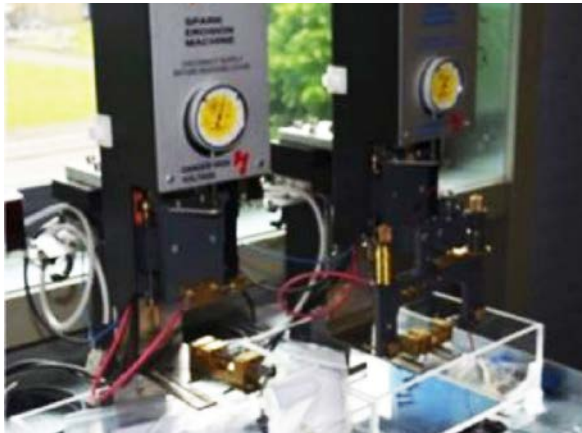
Large area EBSD mapping using SEM



EBSD grains orientation maps showing (a) grain orientation at direction of IPF-Z, (b) grain orientation along the deposition/melting direction, i.e. IPF-X or RD of a 3D printed stainless steel



IMPACT OF FABRICATION TECHNIQUES ON SMALL SAMPLE GEOMETRIES

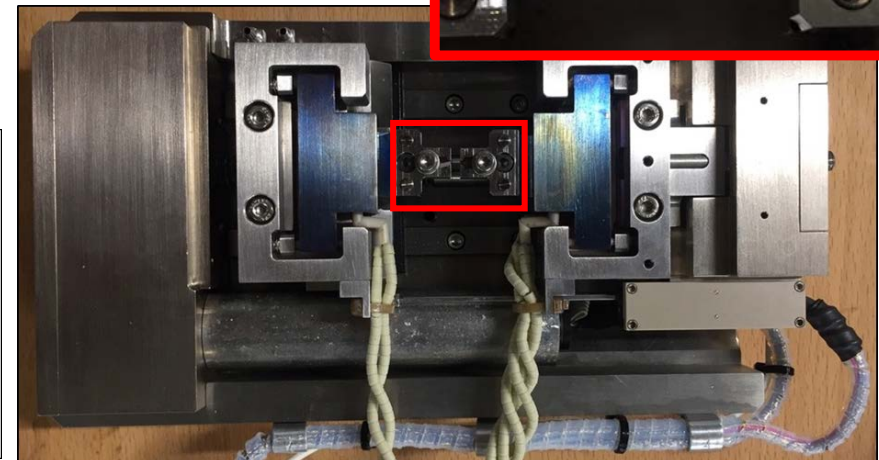
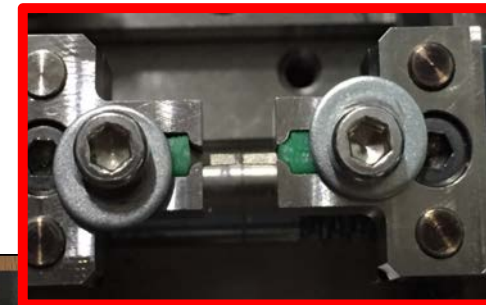


Technique comparison to qualify the lab-scale EDM (Electric Discharge Machining) samples (0.3 mm thick SS 316L) against Wire EDM cutting / Photo chemical etching / Laser cutting using tensile samples.

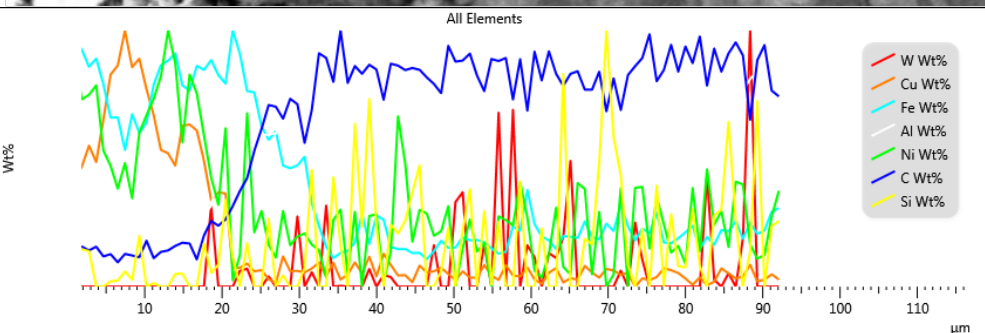
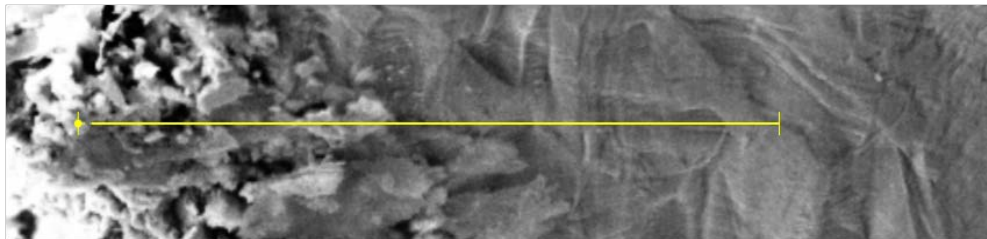


Tensile test & fracture surface evaluation:

GL = 5x1x0.3 mm



Cutting effect evaluation:



With thanks to **Abineeth Singh** (3 months summer student placement 2018; MSc Advanced Nuclear Engineering; Imperial College London)