Microscopy measurements of tokamak/stellarator and reference samples. Surface analysis capabilities.

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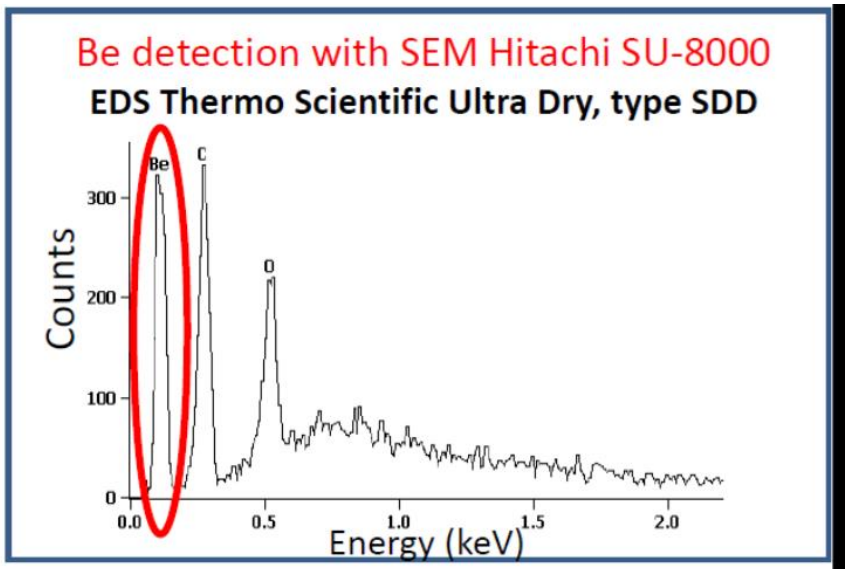
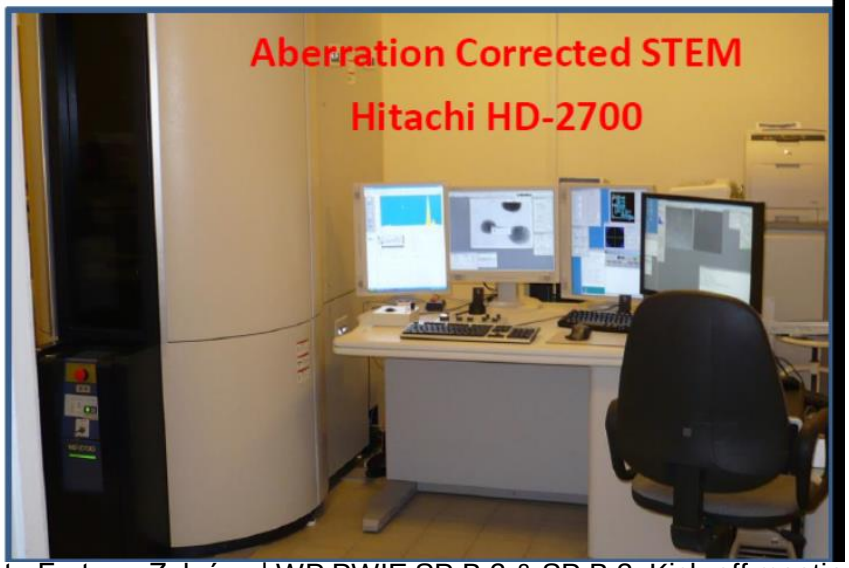
This work has been carried out within the framework of the EUROfusion Consortium, funded by the European Union via the Euratom Research and Training Programme (Grant Agreement No 101052200 — EUROfusion). Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Commission. Neither the European Union nor the European Commission can be held responsible for them.

Outlook

- WUT microscopy and analytical equipment
- Main research areas
- Plans for 2023

WUT equipment





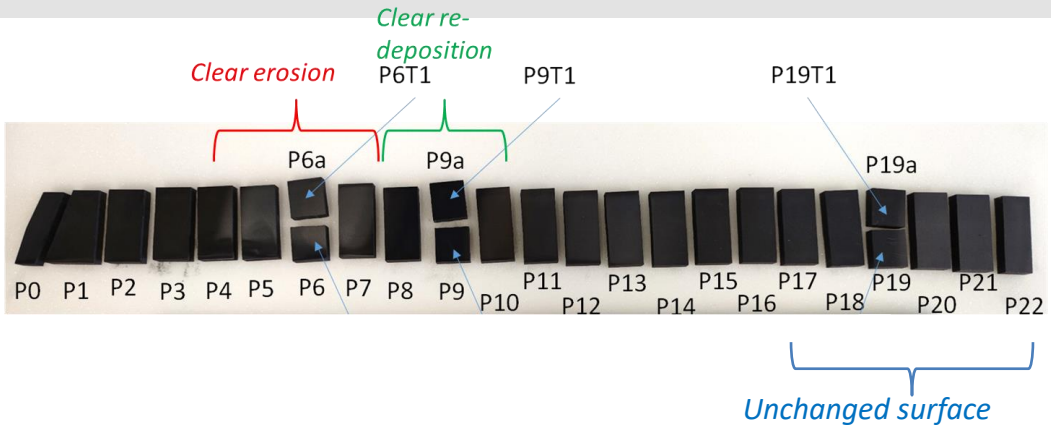
List of microscopes

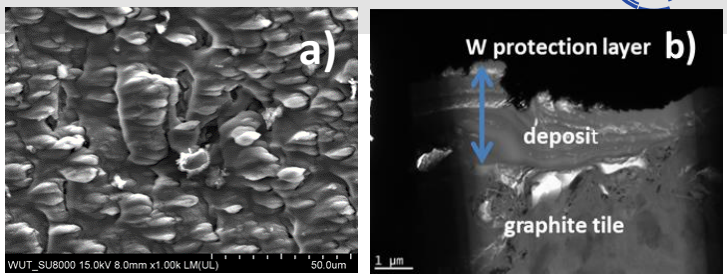
- **HD-2700 STEM (200 kV, C_s corrected) – High resolution, analytical, dedicated STEM**
- **JEM1200 TEM (120 kV) – Conventional TEM, in-situ heating, straining**
- **SPECTRA 200 S/TEM Thermo Fischer Scientific**
- **S-5500 FE-SEM - High-Resolution SEM, Low accelerating voltage S(T)EM**
- **SU-70 FE-SEM – Analytical SEM**
- **SU-8000 FE-SEM - Low accelerating voltage SEM**
- **S-3500N SEM – Low vacuum observations, in-situ tensile test**
- **TM-1000 SEM – Tabletop microscope**
- **TM-3000 SEM – Tabletop microscope**
- **FB-2100 FIB – Single beam scanning ion microscope**
- **NB 5000 FIB-SEM – Dual-beam scanning microscope**
- **Other equipment for sample preparation etc.**

Other equipment

- **XRD, Bruker D8 Discover X-ray diffractometer**
- **Optical profilometer Veeco NT9300 for non-contact 3-D measurements of surface topography**
- **Hysitron Ti-900 triboindenter (Young's modulus, hardness, in situ SPM)**
- **Micro-CT (microtomography) Systems**

W7X samples - *tile HM19TM400hTE2*

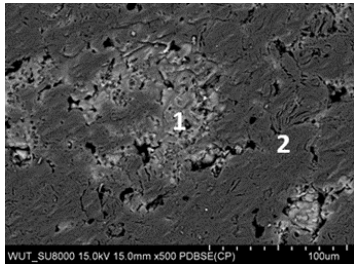




a) SEM image of the morphology of the re-deposited zone, b) TEM image of re-deposited layer, sample 9a.

The aim of the work: (i) assess surface modification of the material caused by the plasma–wall interactions (erosion/deposition pattern), (ii) study the co-deposits formed and (iii) analyze the dust particles found.

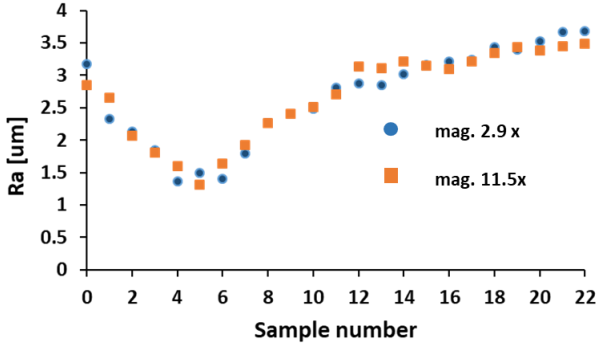
Techniques used: SEM, TEM, STEM, FIB, EDS, and surface profilometry



SEM image of clear erosion zone morphology, sample 7. Traces of deposit in the shallow cavities (shadowed areas designated as 1). Strongly smoothed surface (area 2).

Main results:

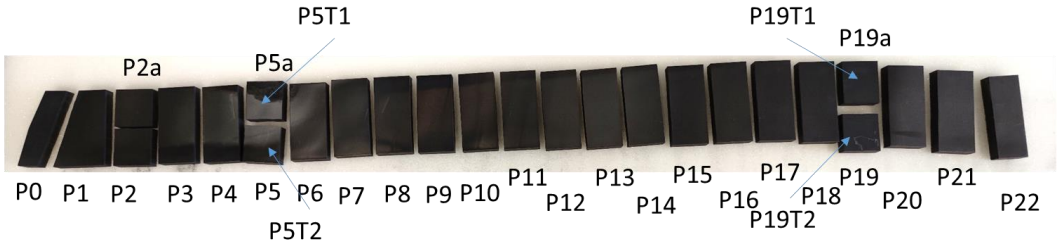
- ✓ *Erosion zones follow largely the strike lines on the horizontal target (HT). The width of the erosion zone is relatively broad.*
- ✓ *Net deposition occurs next to the inner HT strike line position.*
- ✓ *The erosion-deposition pattern observed is in good agreement with the one found on the marker horizontal target element TM2h6,*
- ✓ *Surface profilometry measurements (at 3 magnifications) completed,*



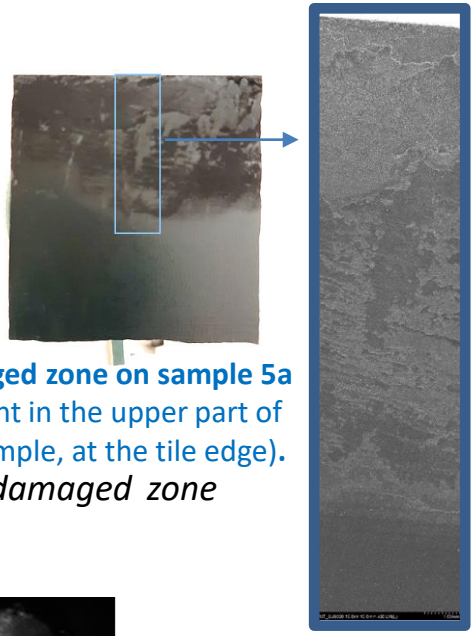
Changes in surface roughness along the length of the tile.

E. Fortuna-Zalesna et al., Erosion and redeposition pattern on the W7-X graphite test divertor unit tile, Fus. Eng. and Des. 191 (2023) 113589

W7X samples - *tile HM19TM400hTE1*



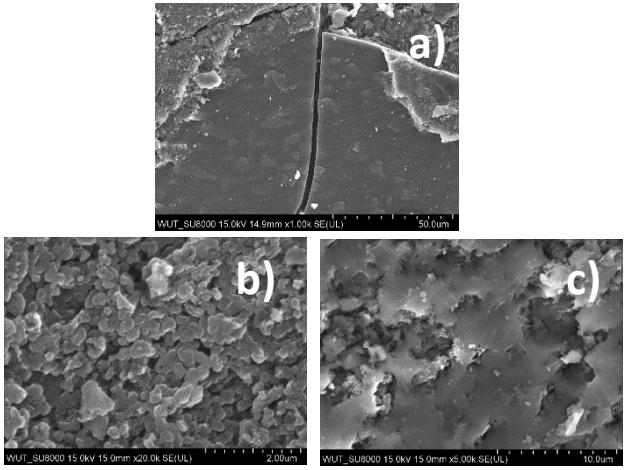
Note: damaged zone in samples designated as 4, 5 and 6 (result of an overloading experiment)



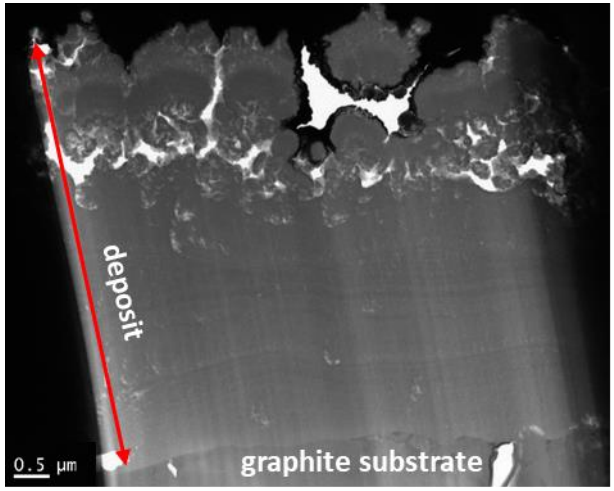
Damaged zone on sample 5a (present in the upper part of the sample, at the tile edge).

Work in progress:

- ✓ *SEM/EDS observations of all samples completed. Description in progress.*
- ✓ *TEM examinations of the material structure in the damaged zone and outside the damaged zone completed (sample 5).*
- ✓ *Distinct differences in the surface morphology between Tiles 1 and 2.*

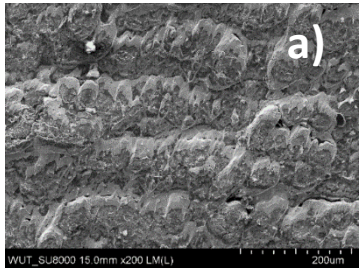


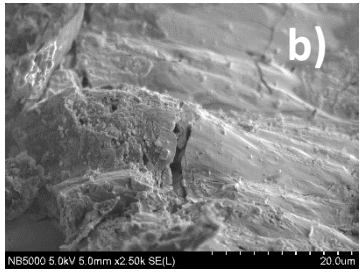
Typical surface morphologies present in the damaged zone: (i) granular and (ii) flake-like. *Re-deposited material of layered and granular structure present.*

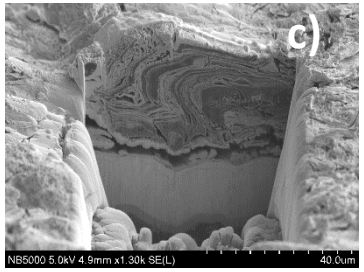


TEM image of deposit present in the damaged zone of sample 5. *A thick layer of redeposited material was revealed.*

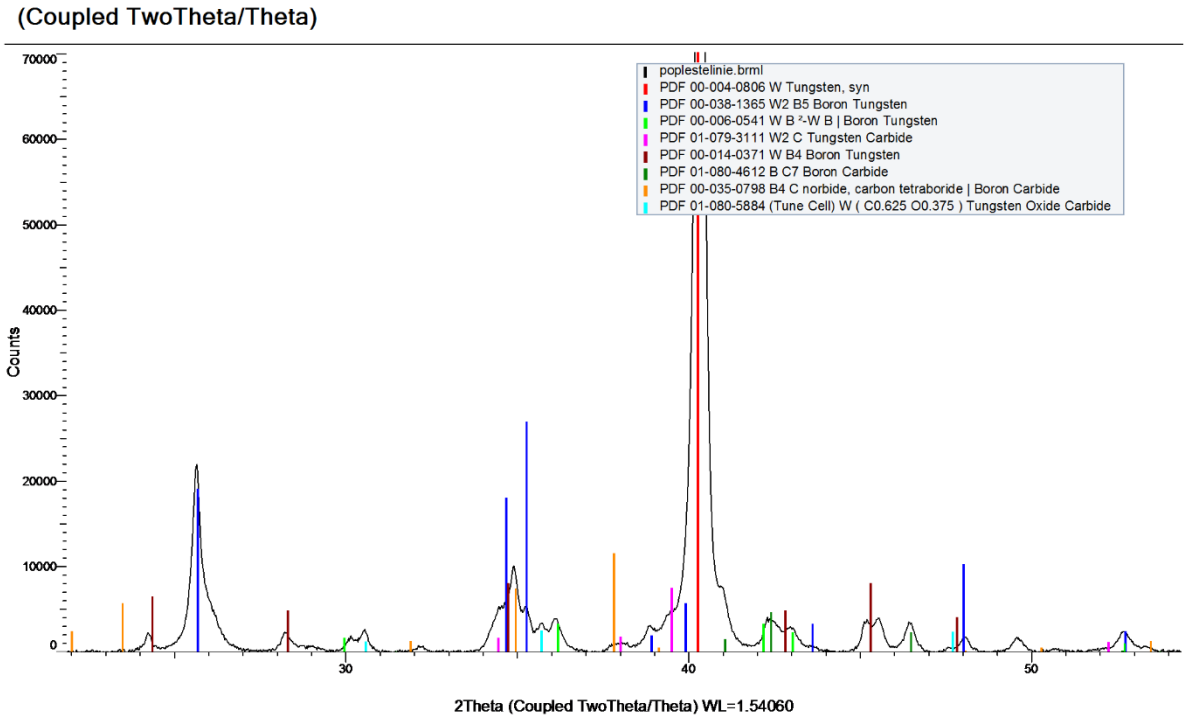
WEST samples







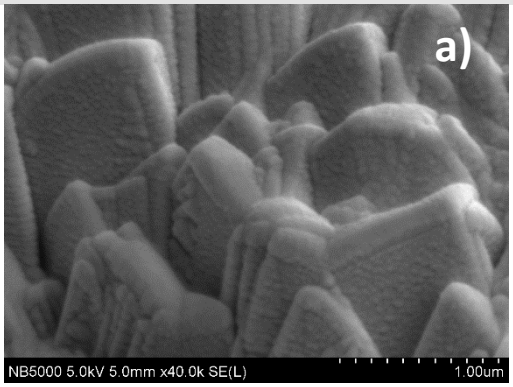
SEM images of the deposit morphology and internal structure, sample J, C4

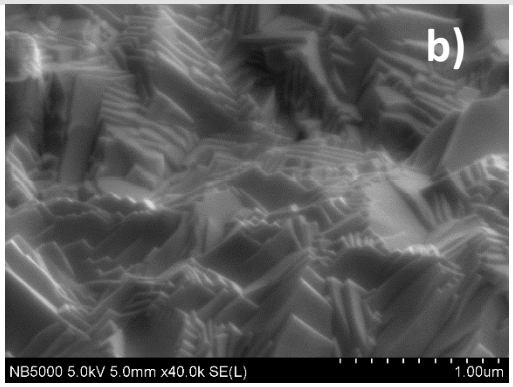


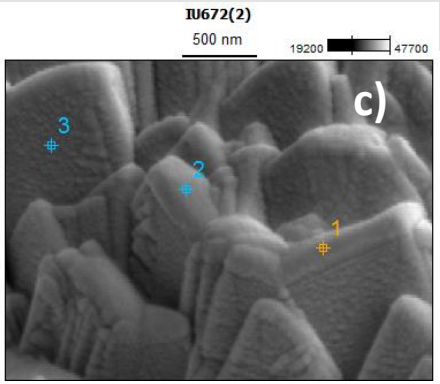
XRD pattern, sample J, C4.

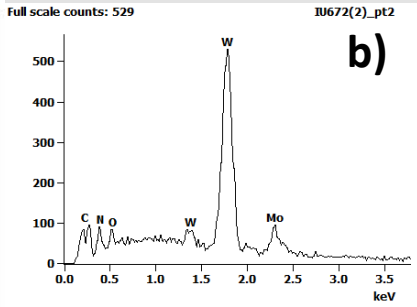
The main conclusion that can be drawn from the analysis of this spectrum is the presence of intermetallic phases from the W-B system, tungsten borides.

Reference coatings

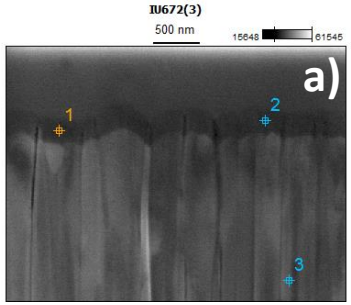


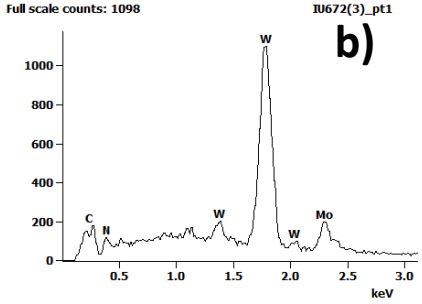






SEM images of the sample IU 672 morphology in the central spot region (a, c) and outside (b) together with the EDS spectrum from the re-deposited material (d). *Re-deposition from the electrode material found.*





SEM image of the sample IU 672 cross-section (a) together with the EDS spectrum from the surface layer (d), central spot. *Thin layer of re-deposited material found.*

- ✓ *Mo re-deposition in the central spot, present at the surface of the samples IU672 and EU2_30_3 after Magnum experiments. Surface morphology described.*

B3/4 deliverables and plans for 2023

Deliverables:

- B3: Microscopy investigations of selected AUG, WEST, W7-X, MAGNUM-PSI, PSI-2, and GyM samples
- B4: Microscopy investigations of selected Be and W reference samples

Plans for 2023:

- W7X samples: completion of examinations of the second tile, designated as HM19TM400hTE1
- New samples from WEST monoblocs and C4 and C5 campaigns (new samples to be delivered soon)
- Determine surface changes on selected AUG samples as well as on samples from GyM, PSI-2, and MAGNUM-PSI (no new samples so far)
- Surface analyses for selected Be and W reference samples (no new samples so far)