IPPLM activities in 2024: Electron microscopy and nanoindentation of JET PFCs – plans

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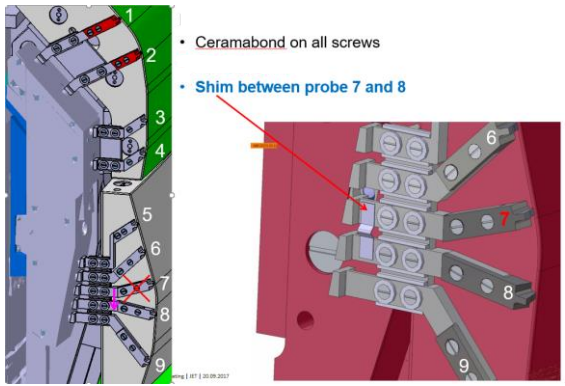
SPE analyses in 2024

All work scheduled for 2023 has been completed.

SPE3_D003: Electron microscopy (SEM, TEM, FIB) and nanoindentation of JET plasma facing components_ 2 PM

Langmuir probes 16IN probes 5, 7,8, 9, Tile 3 (removed in 2015)



The Langmuir probes study will include: (i) microscopic observations of the probes' surfaces along with studies of the chemical composition of the surfaces, (ii) studies of the dust on the probes (e.g., Be splashes), (iii) nanomechanical examinations of the sub-surface zone of the probes, both of the base and the tip, (iv) FIB cross-sections to determine grain size (to confirm possible recrystallization).
The overall objective of this work is twofold: (i) to determine by nanoindentation the changes in mechanical properties of W components after long-term exposure in JET-ILW and (ii) to determine possible damage caused by plasma-wall interaction.

The procedure described in work by M. Spychalski et al., „Tungsten Langmuir probes from JET-with the ITER-Like Wall: Assessment of mechanical properties by nano-indentation", Phys. Scr. 96 (2021) 124072.

The proposed action

- 2023 analyses: Bulk W-lamellae examinations (stack B: B2, B12, B13, B17, B23, B24 – ILW3 & ILW1+2+3)
  - W_154; 155; 161; 162; 168; 169; 175; 176; 182; 183; 189; 190 – to FZJ for LIDS and metallography
  - W_185; 192 – 1st to HR for D-NRA; 2nd to IAP for TDS
  - W_157; 164 – to IPPLM for microstructure analysis
  - W_186; 187 – to UoL for TDS and Total combustion
  - W_160; 167; 174; 181; 188; 195 to VTT for SIMS analysis

Examinations of lamellae from Stack B are part of a larger research project, which also involves several associations.

WUT 2023 work included:

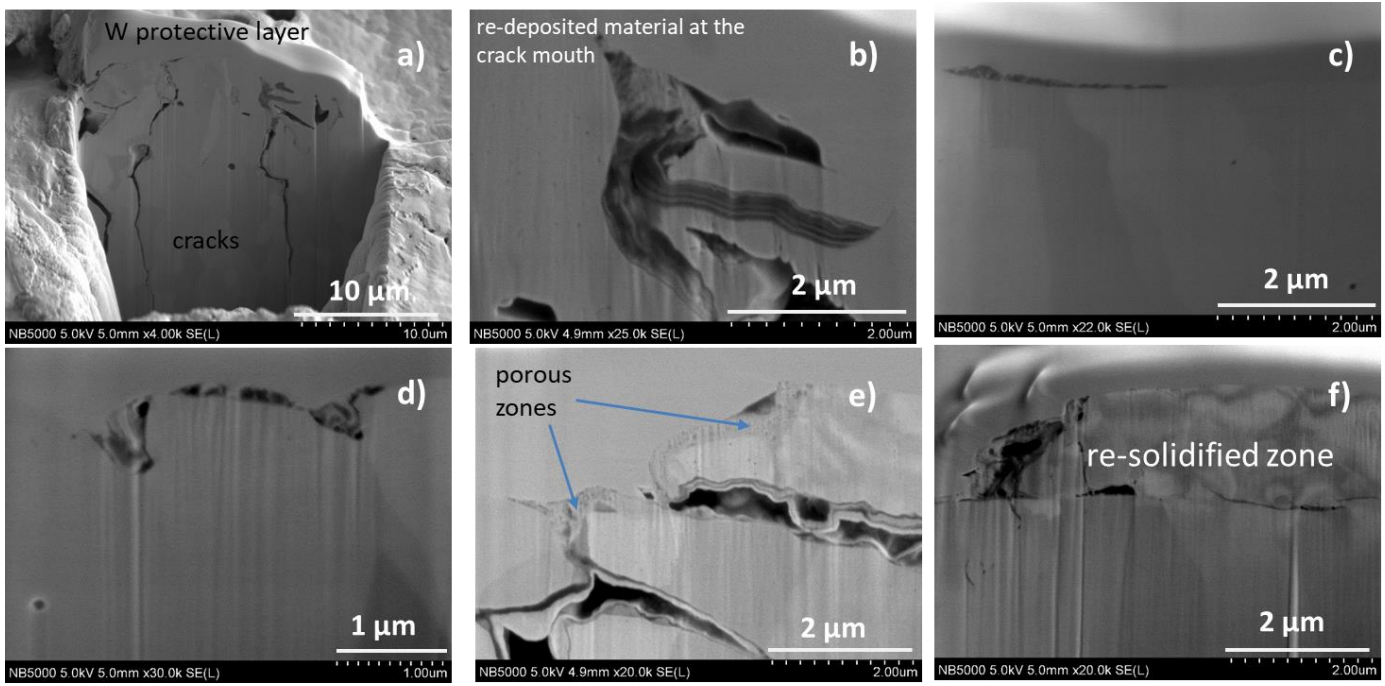
✓ *Microscopic observations of the surface, EDX analysis of the surface, and dust particles were carried out.*

✓ *To characterize the near-surface zone, a total of 14 FIB cross-sections were made in areas with three characteristic morphologies: a) in surface depressions, b) in convex, potentially re-melted areas, and c) through cracks.*

✓ *Two thin foils were cut out from the lamella 164 for microscopic observation.*

A proposal to consider preparing an article summarizing the results obtained for the lamellae from stack B.

Observations of the sub-surface zone of B lamellae on FIB cross-sections



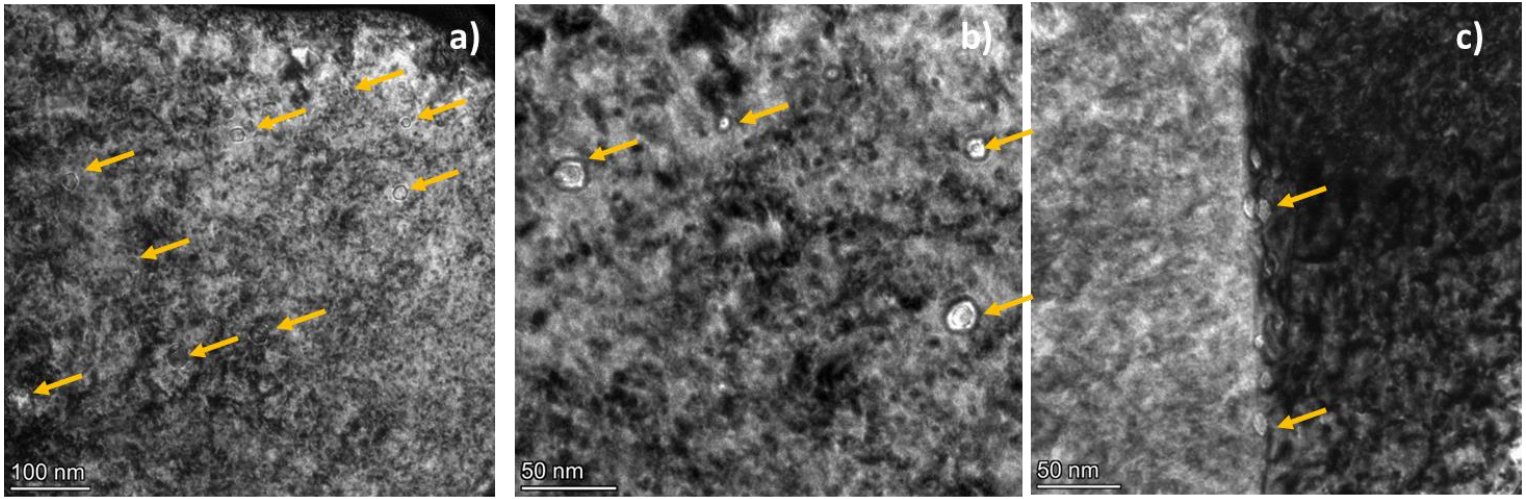
SEM images of FIB cross-section cut in areas with three characteristic morphologies:

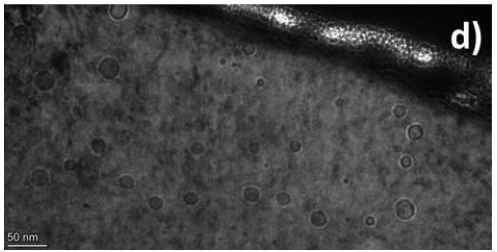
(i) in surface depressions,
(ii) in convex, potentially re-melted areas, and
(iii) through cracks.

✓ *Redeposition is observed inside the cracks, locally in the cavities, and on edges (shadowed areas).*

✓ *In these areas, we observe material with a different, porous, or stratified structure, sometimes, with traces of re-melting. EDX point measurements confirm higher levels of O and C, locally also N, Ni, and Fe in these areas.*

TEM studies of the subsurface zone of B lamellae bubbles





TEM images of bubbles present in the subsurface zone of 164 lamella.

The bubbles (10-30 nm in diameter) populate the region over 500 nm in depth. They are also present at the grain boundaries. Their size and distribution are consistent with what Tokitani observed at not-exposed lamella (Phys. Scr. T171 014010). Those bubbles are considered to be formed during the manufacturing process.

TEM studies of the subsurface zone of B lamellae re-deposits

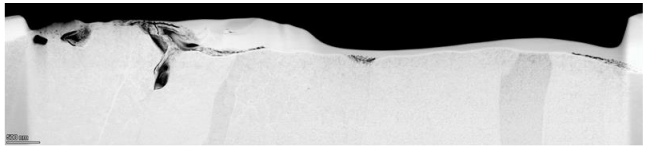


Fig. 1. STEM images of thin foil cut out from lamella 164.

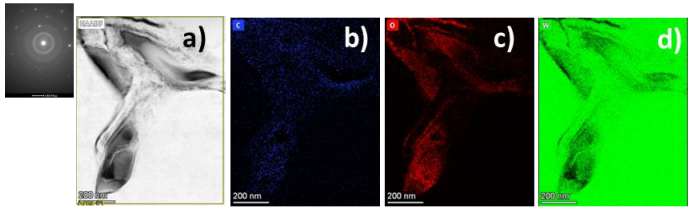


Fig. 2. STEM image of redeposit present in the crack mouth and mapping of O, C, and W inside re-deposit.

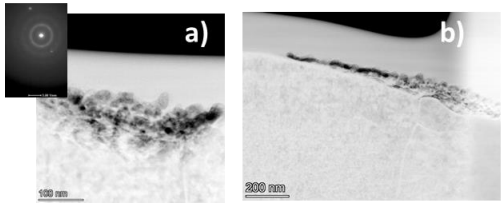


Fig.3. STEM image of granular redeposit present in the surface cavities.

- ✓ *Two areas with granular re-deposit were found. Both are in depressions present on the surface. Thickness 130 and 100 nm, respectively. Both have an amorphic structure and are characterized by increased C and O content.*
- ✓ *The extraneous material of irregular shape present on and below the surface of the lamella has most likely been deposited at the mouth of the crack. This zone is heterogeneous, partly porous, and partly stratified, of amorphous structure. It is characterized by increased C and O content.*