WP PWIE SPF monitoring meeting: VR (UU & KTH)

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Tasks to be performed [2026]:
Production of B:W:N:O layers with co-deposited deuterium, followed by pre-characterisation and post-mortem analysis after exposure in TOMAS plasmas (VR).

Deliverables [2026]:
D007 - Assessment of deuterium removal from ion-implanted mixed tungsten–boron layers following exposure to TOMAS wall-conditioning plasmas (VR).

Samples

Layer description (100-150 nm):

W+B	W+B+D	W+N	W+O
W + B (high B content)	W + B (high B content) with D	W + N (high N content)	W + O
W + B (low B content)	W + B (low B content) with D	W + N (low N content)	Clean W sample (control)

Objectives:

To study tungsten mixed layers (including B, N, O, and D) under *IC plasma exposure*:

- Investigate **impurity removal**
- Investigate **surface modifications**, including the formation of W-enriched surface layers after plasma exposure
- Assess the impact of *plasma parameters* on **cleaning rates**, including *D removal*.

Strategy:

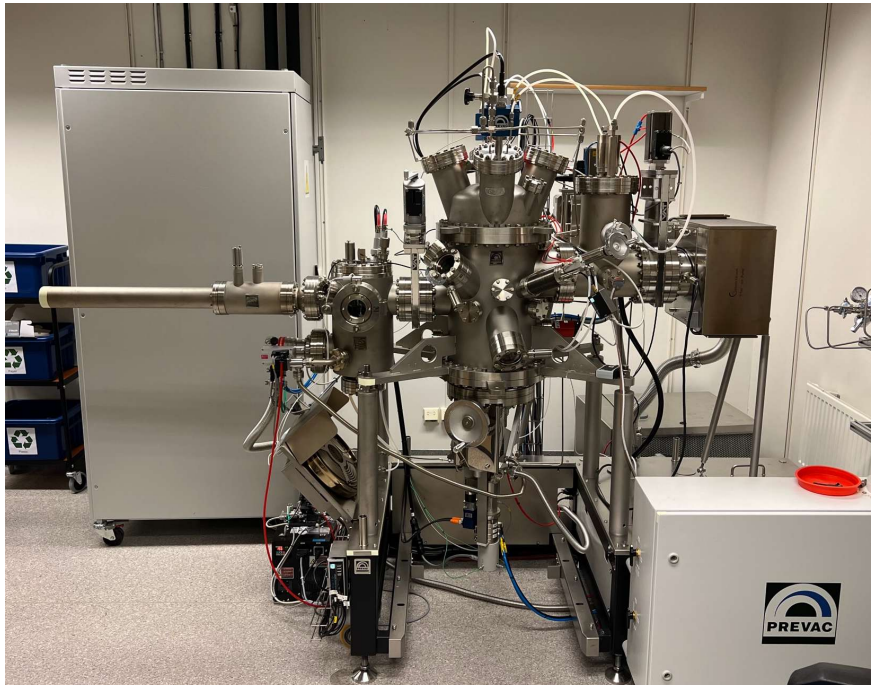
Samples will be characterized by IBA before and after exposure, and control samples will be prepared to account for possible *aging effects*.

For **deuterium-containing boron deposits**, the results will be directly compared with laboratory studies of *D removal by in-situ annealing*.

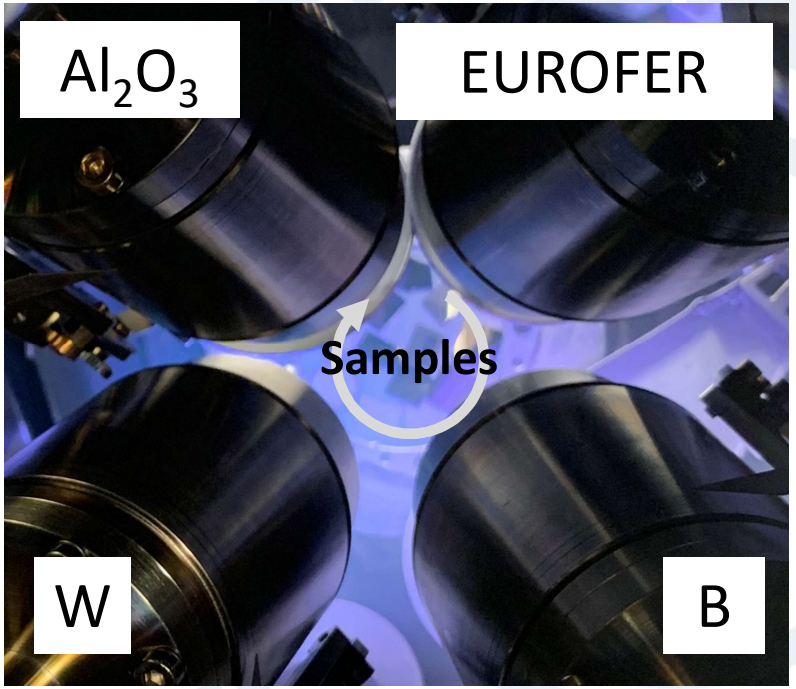
In progress: sample preparation and characterization for TOMAS experiment (November 2026).

Samples Preparation and Characterization

Samples in preparation by magnetron sputtering (UU):



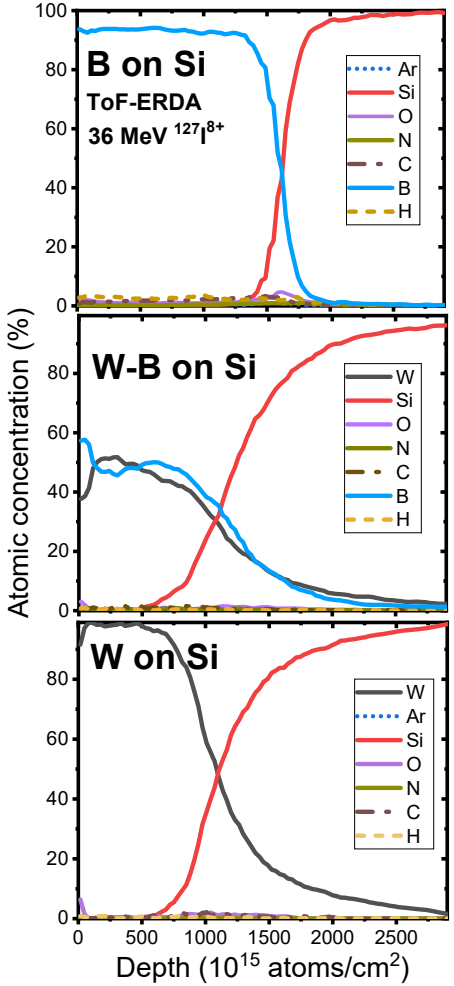
Prevac sputtering machine:
4 Magnetrons (2 DC and 2 RF).
Deposition in Ar and Ar + (D_2/N_2/O_2) mixed plasmas.
Base pressure < 10^{-7} mbar.
Annealing capability during deposition (up to 1000°C).
E. Pitthan et al. Nucl. Mater. Energy. 34 (2023)



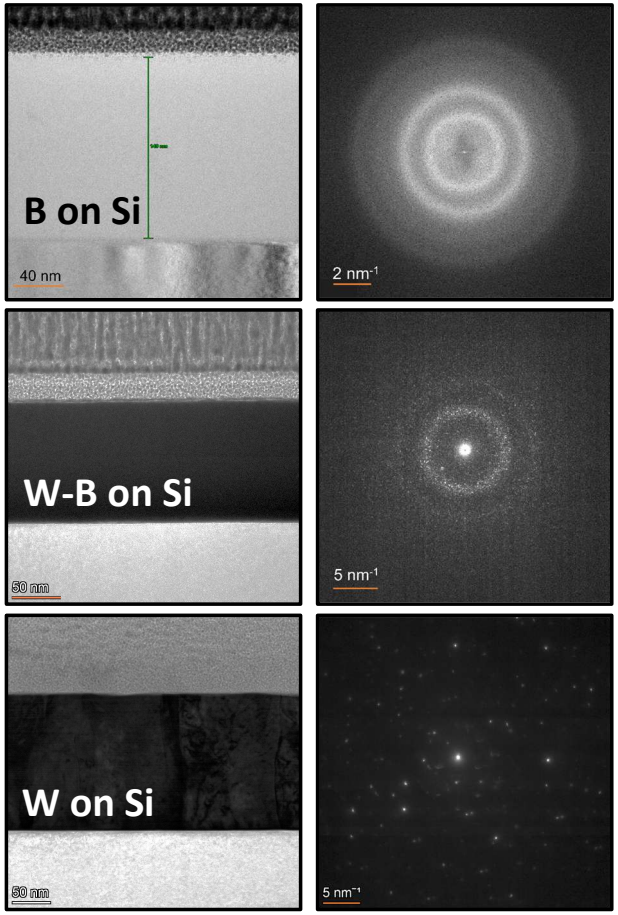
Simultaneous deposition of W and B under controlled atmospheres and deposition conditions.
D. N. Gautam et al. Nuclear Materials and Energy (2025) 45.
D. N. Gautam et al. Nuclear Materials and Energy (2025) 46.

Characterization of W-B layers (D. Gautam et al., 2025):

Composition (IBA):

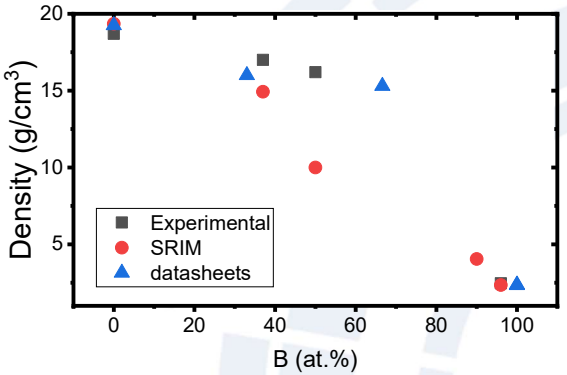


STEM images and *e*-diffraction:



W-B mixtures: amorphous-like

Experimental Density (IBA + TEM):



Experimental densities are comparable to values reported in the literature.

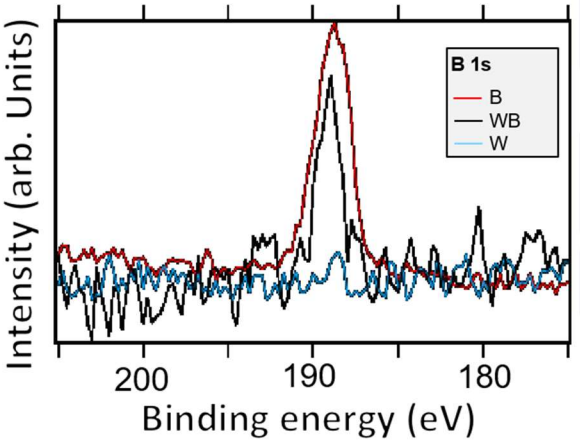
SRIM-based extrapolations underestimate the measured densities.

Chemical environment (HAXPES):

Ga Kα (Bulk sensitive)
Photon energy 9252 eV

A similar boron chemical environment is observed in both pure B and W-B layers.

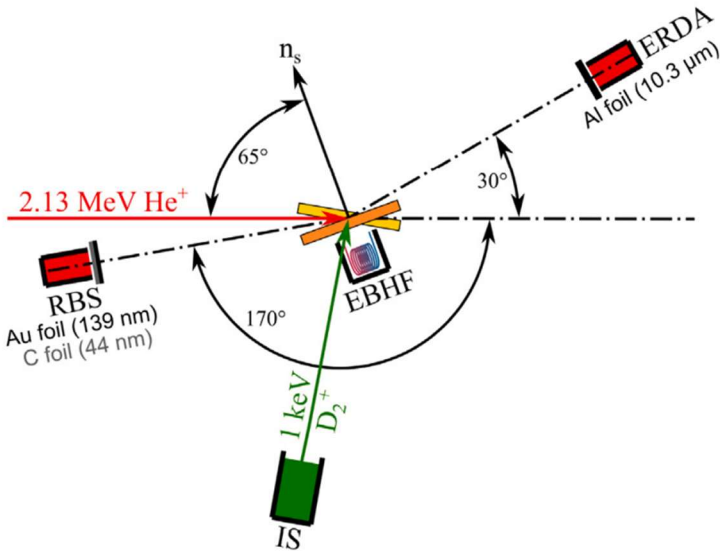
No B oxide in B sample.



Deuterium Retention in W-B layers (D. Gautam 2025):

Deuterium retention in sputter-deposited W-B layers:

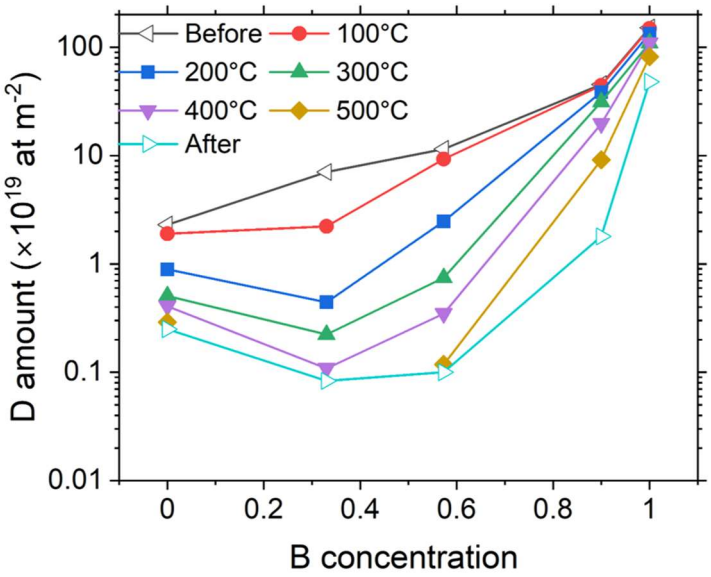
- In-situ implantation (500 eV/D).
- Ion beam analysis during annealing.



M. Fellinger et al. Nucl. Mater. Energy (2025)

D retention as a function of composition and temperature

- *Pure boron:* highest D retention and temperature stability.
- *W-B mixtures:* greater D release during annealing than pure W.



A. Hakola et al. (submitted for publication)

Ongoing work focuses on comparison with deuterium incorporated during deposition.

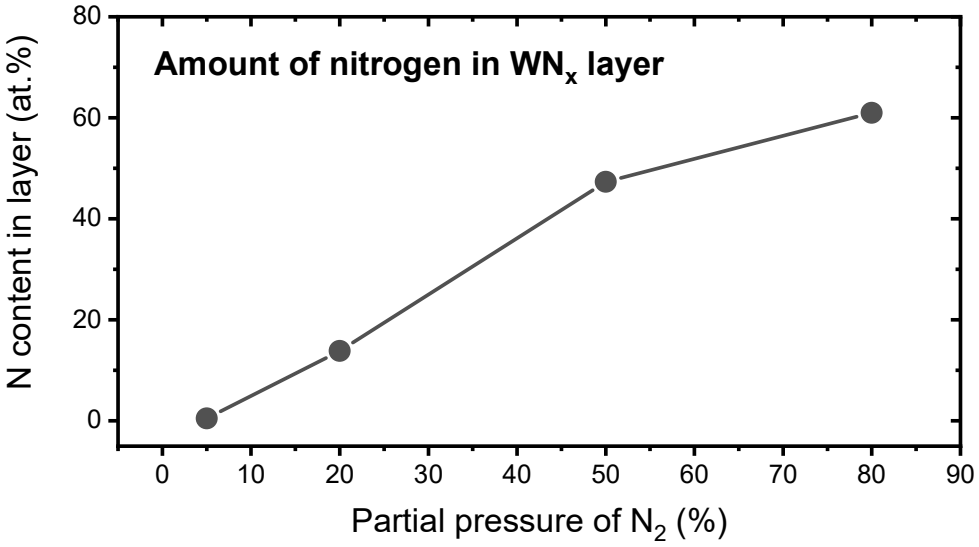
Similar samples will be exposed to TOMAS for comparison in D removal.

Characterization of W-N and W-O Layers:

Mixture of W + N_2:

S. Zandren and N. Rågåker, Bachelor project 2026 KTH.

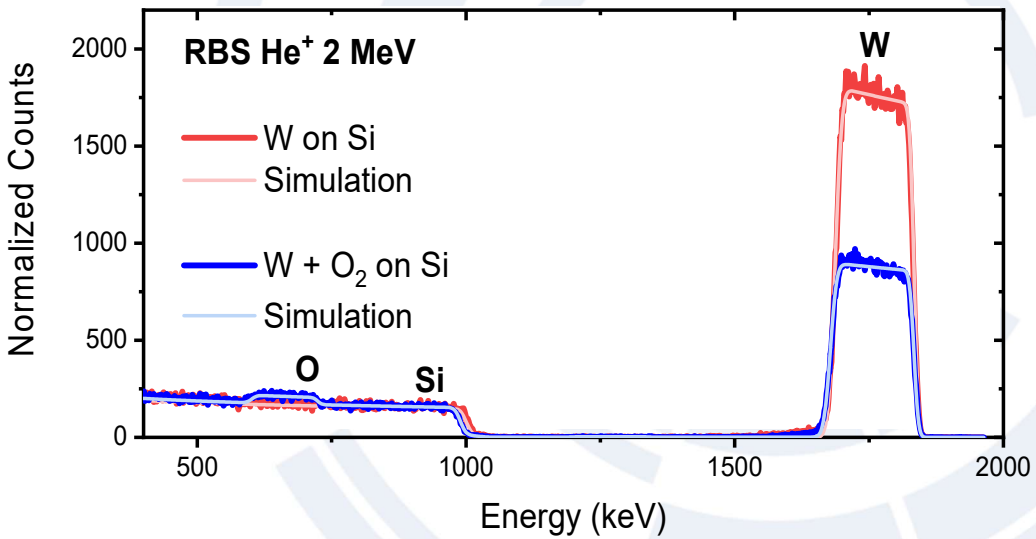
- Study of Potential Impurities on Fusion Reactor Walls.
- The nitrogen content in W films can be controlled.



Mixture of W + O_2:

P. Karlsson, Mater project 2026 UU.

- Study of Potential Impurities on Fusion Reactor Walls.
- WO_3 formation over the investigated O_2 flux range.



Similar samples will be exposed to TOMAS

Exposure conditions

Planned plasma exposure conditions:

IC frequency, MHz	Magnetic field, A*	RF power, kW	Gas pressure, mbar	Gas	Duration, min*	Duty cycle, s	Comment
45	1600	~ 5	~$7*10^{-4}$	H	10	4/10.9	Short hydrogen exposure
45	1600	~ 5	~$7*10^{-4}$	H	30	4/10.9	Longer hydrogen exposure
		~ 5	~$7*10^{-4}$	He	10	4/10.9	Similar power and duration as H exposure
		~ 5	~$7*10^{-4}$	He	30	4/10,9	Longer version of He exposure

Exposure parameters were selected to enable direct comparison with previous TOMAS experiments.
If experimental time is limited, priority should be given to the long-duration H and He exposures.

Planned diagnostics:

- Monitoring of sample temperatures.
- Comparison of particle fluxes using a Retarding Field Analyzer (RFA) or Neutral Particle Analyzer (NPA) (Possibly through comparison with previous discharges performed under identical operating conditions)
- Monitoring of the gas phase using a residual gas analyzer (optional).

Samples are prepared on ~1 × 1 cm Si substrates, allowing the use of either the standard TOMAS sample holder or an in-house masking system.

Summary

Status and next steps:

- Sample deposition ongoing.
- IBA characterization planned/completed for this year.
- TOMAS exposure scheduled for November 2026.
- Post-exposure IBA.
- Comparison with annealing experiments.