EUROfusion

WP PWIE: SP B reporting 2022 / SP B plans for 2023

SPL B: Antti Hakola

VTT

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Introduction to SP B

- SP B deals with **experimental erosion, deposition, and material migration** investigations, in linear devices and laboratories as well as in EUROfusion toroidal devices
- Emphasis put on **post-exposure analyses (and pre-characterization)** besides the experiments
  - ✓ **NB!** In toroidal devices experiments primarily under other EUROfusion WPs (WP TE, WP W7X)

- The SP B work in **2022 was a direct continuation of the research themes introduced in 2021** – essentially a two-year program with small adaptations upon transition from 2021 to 2022
  - ✓ Details of individual tasks refined in a series of kick-off meetings (separately for each activity area) in March 2022
  - ✓ Task monitoring via email in July and September
- Emphasis put on defining deliverables to address **broader entities rather than manage a number of scattered tasks**
  - ✓ Comparative erosion experiments on the involved linear devices
  - ✓ Extracting material-migration pathways on AUG, WEST, and W7-X tiles and samples
  - ✓ Round-robin studies of produced reference coatings
- In addition, **thematic meetings** organized in smaller subgroups
  - ✓ Conclusions on the analysis campaign of WEST C3 marker samples – jointly with CEA
  - ✓ Role of surface roughness in sputtering/erosion – jointly with SP D
  - ✓ Brainstorming events on sample production, sample exposures and dust investigations
- All material of the past meetings available in INDICO, see https://indico.euro-fusion.org/category/325/

PWIE 2022: SP B

Work Package / Project Leader	WP PWIE
PL	Sebastijan Brezinsek
PSO	Alexandra de Schepper, Michael Reinhart

DPL for ADC:
Giuseppe Calabro

Sub-Work Package	PM	SP A	SP B	SP C	SP D	SP E	SP X	ADC	PEX
Title	Project Management	Particle & Heat Loads Studies	Experiments on erosion, deposition and material migration	Retention & Release	PSI & SOL Modelling	JET PSI	Plasma characterization, laser-based diagnostic development, and wall conditioning	Advanced Divertor Solutions for Power Exhaust in DEMO	PEX Upgrade JULE-PSI / JUDITH-3
Sub-Project Leader	Sebastijan Brezinsek	Jan W. Coenen	Antti Hakola	Klaus Schmid	Andreas Kirschner	Jari Likonen	Hennie van der Meiden	Giuseppe Calabro	
Activity Title		Synergistic Load Studies of Plasma-Facing Materials for ITER & DEMO	Physics of erosion and deposition	Transport of Hydrogen through the first wall of fusion devices	Plasma Boundary Modelling	Coordination activity, sample distribution, sample preparation, contact for JET DTE2 samples	Atomic and molecular processes in attached/detached plasma and sheath	Modelling of advanced divertor configurations for DEMO and PEX solutions	
Activity Title		High Particle Fluence Exposures of Plasma-Facing Components for ITER	Material migration in toroidal devices	Modelling of Hydrogen Transport properties in the first wall	Production of Atomic/Molecular and Surface Data	Comparison of hydrogenic retention quantification by different techniques and fuel removal assessment	Optimization of laser-based surface analysis diagnostics	Experimental assessment of PEX solutions and modelling interpretation	
Activity Title		Advanced Materials under thermo-mechanical and plasma loads	Characterization of plasma-exposed materials	Influence of He, high-flux D and impurities on Hydrogen retention and transport	Impurity Migration Modelling	Post-mortem analysis of PFC and other objects in JET	Characterisation and optimisation of TOMAS wall conditioning plasmas	Engineering boundary conditions related to DTT as ADC test-bed	
Activity Title		High Temperature performance of Armour Materials: Recrystallization and Melting	Reference coatings for ITER and DEMO	Influence of n-damage on Hydrogen retention and transport	Neutral Particles Modelling			Engineering boundary conditions related to DEMO ADC solutions	

SP B Milestones 2022

Relevant Work Package Milestones for SP B extracted from WP PWIE PMP 2022

WM31	SP B	Effective sputtering yields and erosion rates of W model systems with varying impact angles, morphologies, and surface structures at varying plasma conditions available (ITER+DEMO)	31.12.2022
WM32	SP B	Erosion and re-deposition patterns on selected marker samples and plasma-facing components, extracted from ASDEX Upgrade (2019-2021), WEST (C4, C5), and W7-X (OP1.2B) elucidated (ITER+DEMO)	31.12.2022
WM33	SP B	Be- and W-based reference coatings produced with composition, fuel content, and structure similar to those of typical co-deposited layers in tokamaks (ASDEX Upgrade, WEST, JET) (ITER+DEMO)	31.12.2022
WM34	SP B	Post-mortem analysis of material samples and components exposed to medium and high flux operation campaigns 2021/2022 in MAGNUM-PSI and PSI-2 performed.	31.12.2022

Main reasons for delays:

(i) Unavailibity of MAGNUM-PSI and slow start of GyM

(ii) Lengthy process for defining specifications of samples and their exposure in linear facilities

(iii) No new WEST samples

SP B Deliverables 2022

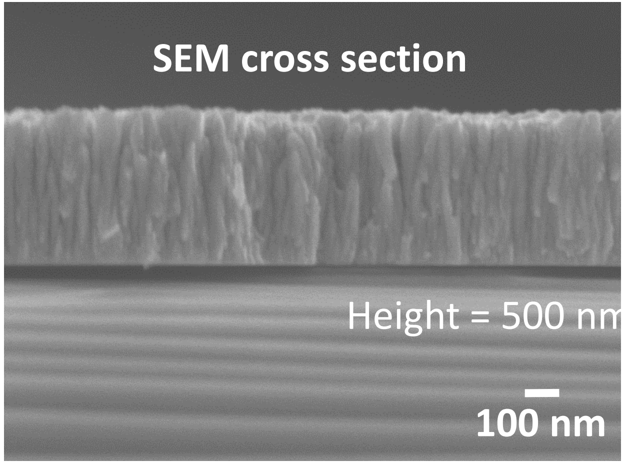
Activity	Deliverable ID(s)	Title
SP B.1	D001, D007 (2021 transfer)	Erosion rates of W model systems and composition and structure of re-deposited layers in MAGNUM-PSI at varying plasma conditions (DIFFER)
SP B.1	D002	Effective sputtering yields of W model systems with varying morphologies in pure and mixed plasmas in GyM and by hypervelocity dust impacts (ENEA)
SP B.1	D003	Erosion rates and angular distribution of W model systems with varying morphologies as well as composition and structure of re-deposited layers in PSI-2 at varying plasma conditions (FZJ)
SP B.1	D004, D006	Effective sputtering yields of W model systems with varying morphologies and structures, including angular distributions of sputtered particles, and re-deposited W layers following exposure to controlled D and impurity ion beams (ÖAW, VR)
SP B.1	D005, D008 (2021 transfer)	Size distribution and composition of Be and W dust formed during air and water leaks (IAP)
SP B.2	D001	Erosion, re-deposition, and fuel-retention patterns on selected WEST PFUs after C3, C4, and C5 campaigns (CEA)
SP B.2	D002, D003	Balance between gross and net erosion of plasma-facing materials, including components with different surface roughness and morphology, in controlled L- and H-mode plasma experiments (JSI, VTT)
SP B.2	D004, D005, D006, D007, D008, D009, D010, D11 (2021 transfer IPPLM)	Characterization of marker samples and coatings from selected plasma experiments on AUG, WEST, and/or W7-X with conclusions (FZJ, MPG, VR, IPPLM, RBI)
SP B.3	D001	Database on ageing, erosion, and fuel-retention behavior of selected WEST PFUs (CEA)
SP B.3	D002, D003, D004, D005, D006, D007, D008, D009 (2021 transfer IPPLM)	Characterization of selected AUG, WEST and/or W7-X wall tiles and plasma-exposed reference samples (FZJ, IPPLM, IST, IAP, MPG, NCSRD, VTT)
SP B.4	D001	W-based coatings with pre-defined properties (incl. SEM, AFM, TDS characterization) produced for analyses and plasma experiments (ENEA)
SP B.4	D002, D009 (2021 transfer)	Be and W-based coatings with pre-defined properties (incl. SEM, XRD, GDOES, TDS characterization) produced for analyses and plasma experiments (IAP)
SP B.4	D003, D004, D005, D006, D007, D008	Characterization of selected Be and/or W reference samples (CEA, CIEMAT, IST, JSI, RBI, VTT)

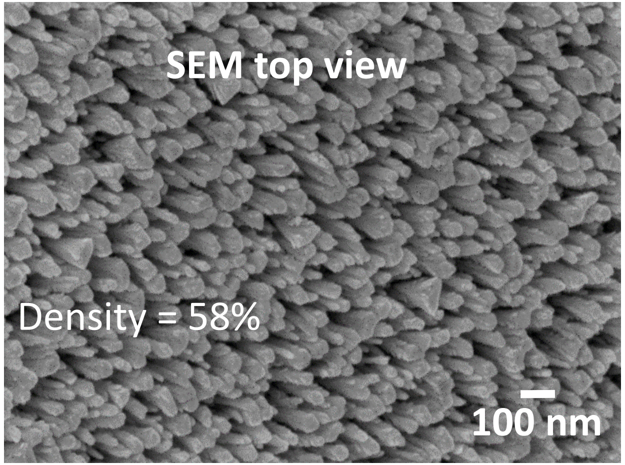
SP B.1 – Physics of erosion and deposition – selected results from 2022

SPB.1: Effective sputtering yields of W model systems and re-deposits in lab conditions

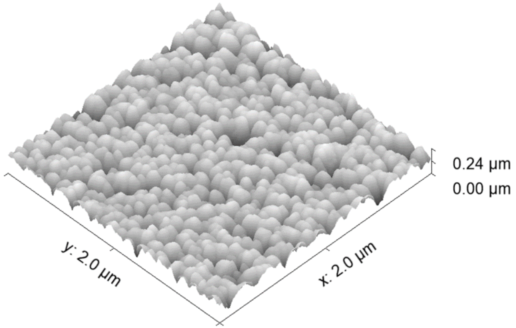
Key goals for the 2022 task:

- Further investigate influence of **varying morphologies and structures on W sputtering yields**
- Cooperation with UPM: created oriented **W nanocolumnar structure (NCW)** on QCM samples
- QCM experiments with these W samples using Ar and D ion bombardment at TU Wien
- Comparison to results of SPRAY (compare TU Wien SP-D task 2022) and cooperation with Uni Helsinki for MD





AFM top view



Deliverable: *PWIE.SPB.1.T002.D004, D006*
Status: *in progress (to be completed by 31.12.2022)*
Facilities: *5 days accelerator (VR) – status unclear*

Human Resources: *5 + 3 = 8 PM*
Involved RU: *ÖAW, VR*
Linked WP or TSVV: *WP ENR-MAT.01.VR, SP D.2.T002*

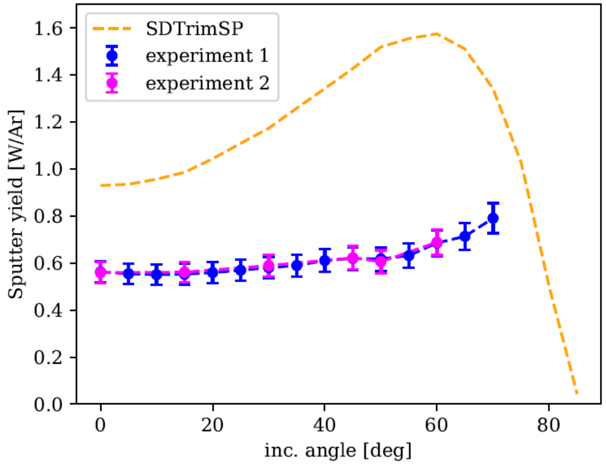
C. Cupak et al. ÖAW, D. Primetzhofer et al. VR

SPB.1: Effective sputtering yields of W model systems and re-deposits in lab conditions

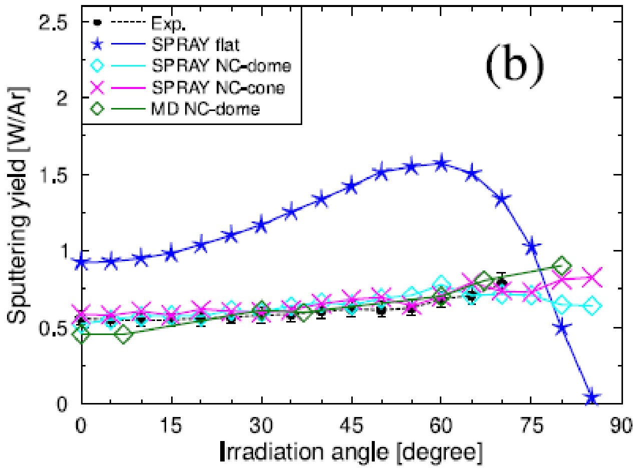
[1] https://doi.org/10.1103/PhysRevMaterials.6.075402

- NCW samples investigated by QCM under **2-keV Ar irradiation, variable incidence angle**
- Low fluence to ensure negligible surface erosion

QCM 1keV Ar^+ on NCW



QCM vs. Simulations 1keV Ar^+



- Ar^+ investigation finished, **see [1] for results**
- D^+ irradiations are ongoing → **no delays expected**

Outlook:
Use SPRAY to identify best possible NCW parameters (height and density)

✓ much reduced sputtering yield (compared to flat W)
✓ dependence on inc. angle decreased

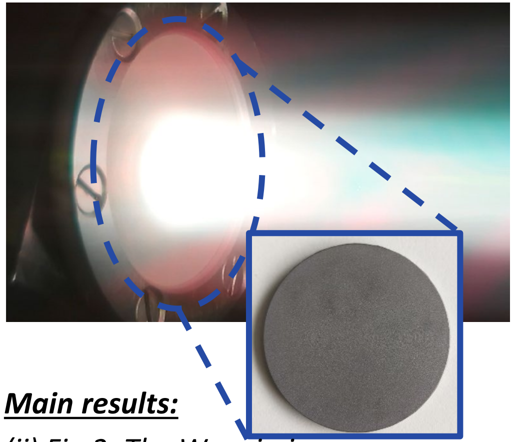
✓ Exp. trend could be reproduced by SPRAY and MD codes (SP-D task)
✓ Geometry effects + redeposition are main cause for sputter yield change

Deliverable: *PWIE.SPB.1.T002.D004, D006*
Status: *in progress (to be completed by 31.12.2022)*
Facilities: *5 days accelerator (VR) – status unclear*

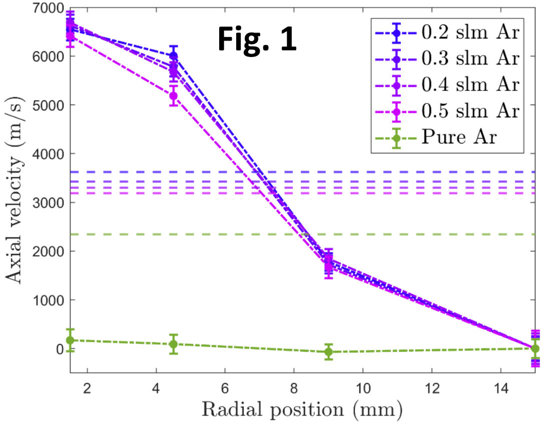
Human Resources: *5 + 3 = 8 PM*
Involved RU: *ÖAW, VR*
Linked WP or TSVV: *WP ENR-MAT.01.VR, SP D.2.T002*

C. Cupak et al. ÖAW, D. Primetzhofer et al. VR

SPB.1: Entrainment of argon impurities in Magnum-PSI

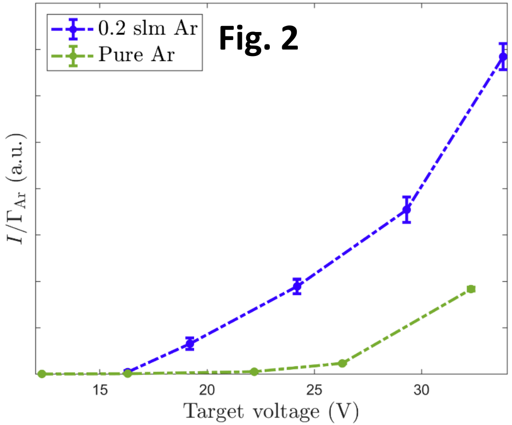


- Rough W samples exposed to (i) **H plasmas w/ Ar** and (ii) **pure Ar plasmas.**
- At ITER divertor-like high-density, low-temperature plasma conditions, the high ion-ion coulomb collisionality causes impurity entrainment: **impurities are accelerated by the plasma flow.**
- The extent to which entrainment occurs is determined from:
  - ✓ The **axial velocity** of the impurities, measured from the doppler shift of Ar emission
  - ✓ The **impact energy** of the impurities, estimated from line emission of eroded W



Main results:

(i) Fig 1: The axial velocity of seeded Ar ***exceeds the Ar sound speed*** *(dashed straight lines) and the pure Ar plasma velocity.*



Main results:

(ii) Fig 2: The W emission per argon influx (I/Γ_{Ar}) starts to increase at lower target voltages for the seeded plasma, indicating a ***larger impact energy for seeded Ar impurities****.*

Deliverable: *PWIE.SPB.1.T002.D001+D007*
Status: *in progress (to be completed by 31.12.2022)*
Facilities: *5 + 4 days MAGNUM-PSI, 0 + 1 days accelerator – will be used fully*

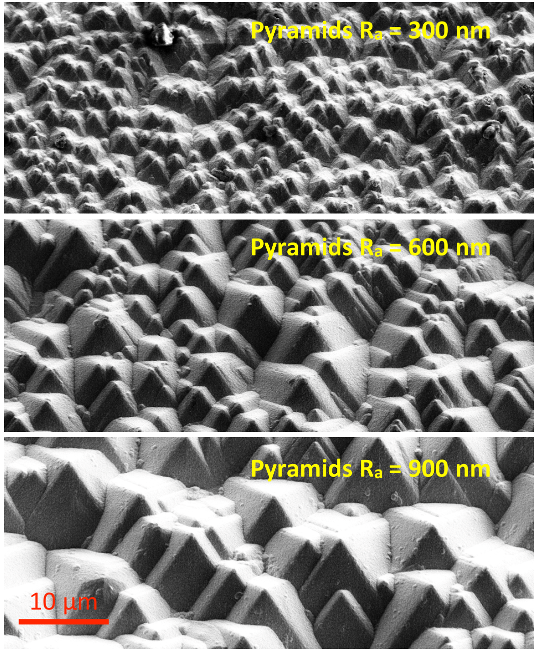
Human Resources: *4 + 4 PM*
Involved RU: *DIFFER*
Linked WP or TSVV: *None*

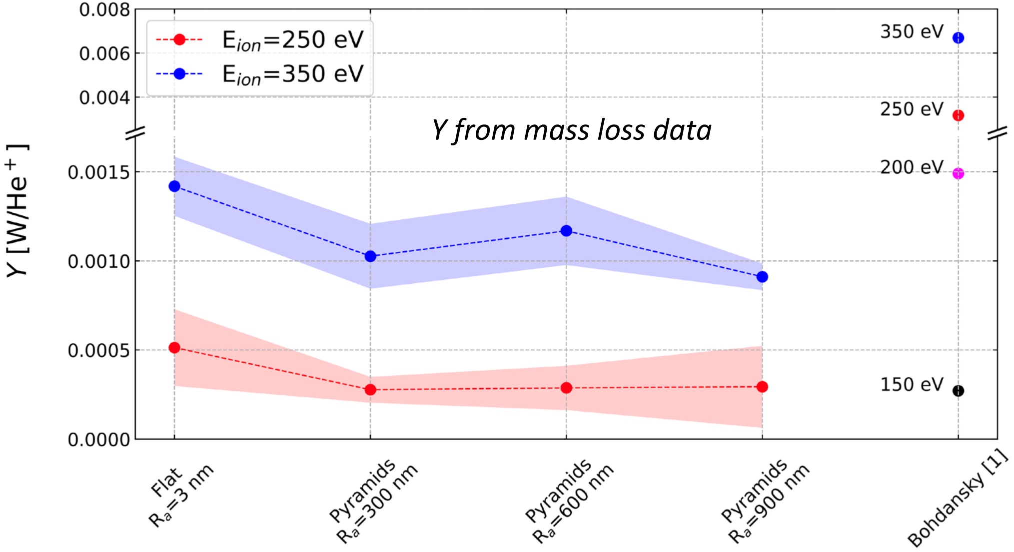
M. Cornelissen et al. DIFFER

SPB.1: Role of roughness in sputtering of W by GyM He plasma

- Exposure of W/Si samples: **6 He^+ energies @ 4.0×10^{24} He^+ m^{-2}**

He^+ energy [eV]	30	80	150	200	250	350





- **No erosion** for **E_{ion} ≤ 200 eV**
- $Y_{W/Si} \ll Y_{Bohdansky}$ → similar to other experiments [1] → due to **He atoms on a surface to shield W lattice atoms** and reduce their sputtering probability?

[1] R. P. Doerner, Scr. Mater. 143 (2018) 137-141

Deliverable: *PWIE.SPB.1.T002.D002*
Status: *in progress (to be completed by 31.12.2022)*
Facilities: *20 days GyM – will be used fully*

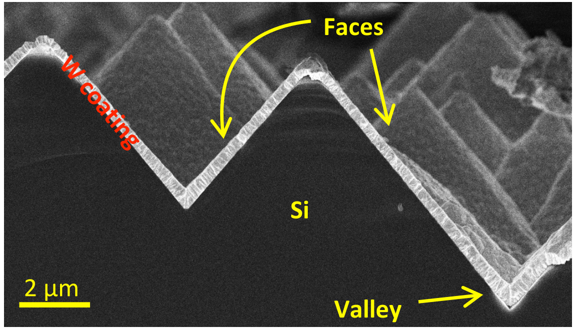
Human Resources: *4 PM*
Involved RU: *ENEA*
Linked WP or TSVV: *SP D.1.T002, SP D.3.T002*

A. Uccello et al. ENEA

SPB.1: Role of roughness in sputtering of W by GyM He plasma

Erosion data also from SEM cs images:
statistical analysis of W coating thickness loss (*Δs*)

Preliminary results

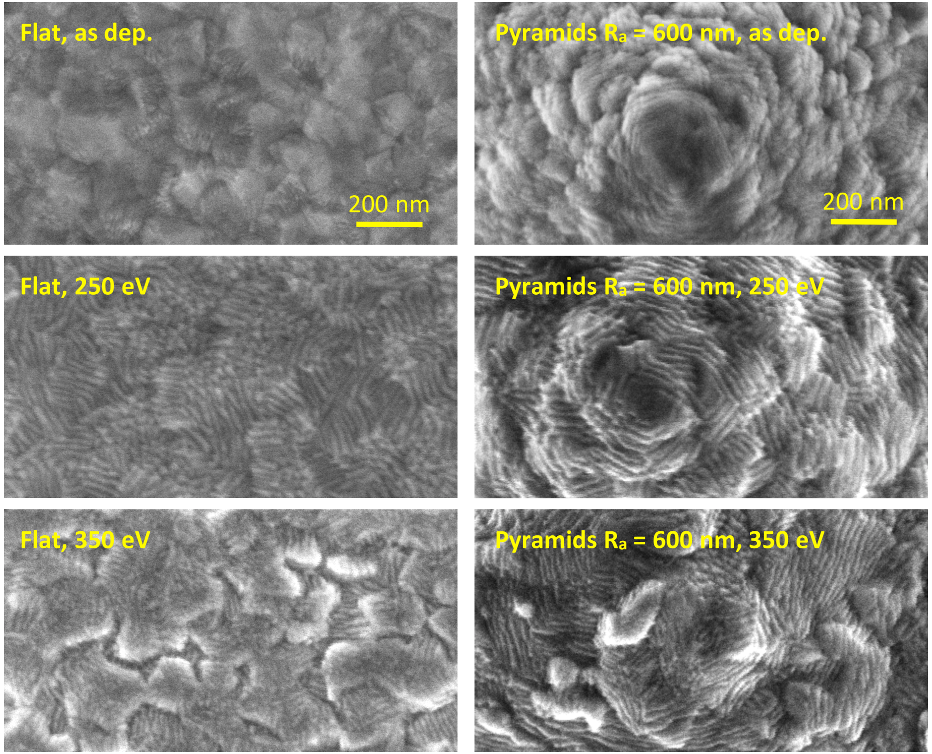


350 eV	Flat	Pyr. R_a = 900 nm	
		Faces	Valleys
$\overline{\Delta s}$ [nm]	60.7	49.4	34.6
$\sigma_{\Delta s}$ [nm]	17.0	29.9	35.9

- $\Delta s_{Flat} > \Delta s_{Pyramids}$, in agreement with Δm data
- $\Delta s_{Pyr.,Faces} > \Delta s_{Pyr.,Valleys}$ → deposition from faces in valleys?

Outlook:
Exposure of W/Graphite (different R_a) + W_{bulk} samples

Ripple-like nanostructures after exposures at $E_{ion} \geq 250$ eV



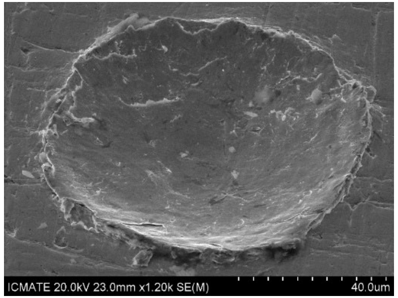
Deliverable: *PWIE.SPB.1.T002.D002*
Status: *in progress (to be completed by 31.12.2022)*
Facilities: *20 days GyM – will be used fully*

Human Resources: *4 PM*
Involved RU: *ENEA*
Linked WP or TSVV: *SP D.1.T002, SP D.3.T002*

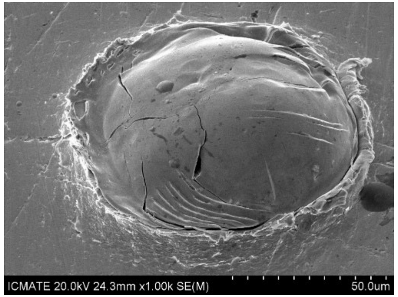
A. Uccello et al. ENEA

SPB.1: Surface erosion by hypervelocity W dust impacts

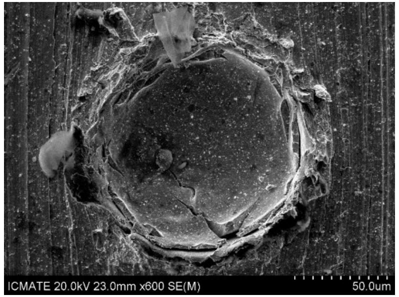
- Monodisperse W spherical dust has been shot on W samples at v_i impact velocity: $580 \le v_i$ [m/s] ≤ 3190 → three regimes of impacts identified.



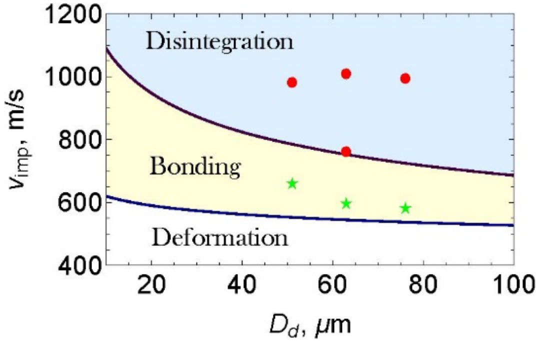
Deformation regime, 200 ÷ 600 m/s → shallow crater formation.



Bonding or cold spray regime, 600 ÷ 1000 m/s → sticking of dust on target.



Partial disintegration regime, 1÷ 4 km/s → material splash ejection and fragmentation.



- Empirical damage laws extracted from experimental data & found **critical erosion and bonding velocities** → results presented at SOFT 2022
- Excavated volume material estimated for single impacts.

Deliverable: *PWIE.SPB.1.T002.D002*
Status: *in progress (this part completed)*
Facilities: *None*

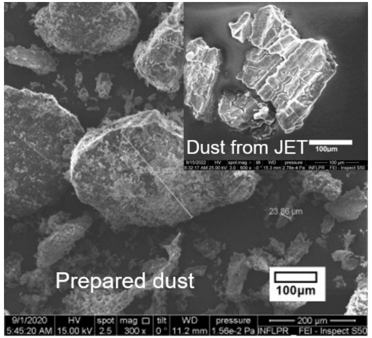
Human Resources: *4 PM*
Involved RU: *ENEA*
Linked WP or TSVV: *None (for this part)*

M. De Angeli et al. ENEA

SPB.1: Be and W dust formed during air and water leaks

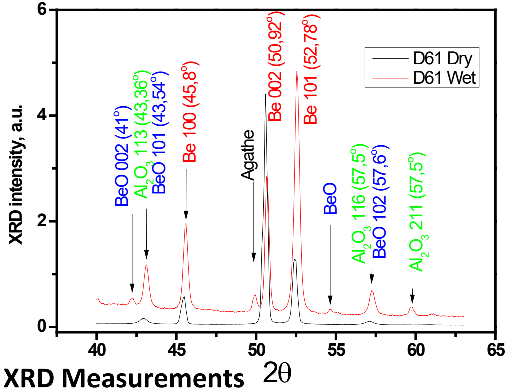
1. **Be dust generation in air and water environment** using alumina ball milling
2. **Particle size and morphology** determined using SEM microscopy
3. **Preferred crystal orientation** analyzed using XRD
4. **Thermal outgassing** using TDS, identified molecules: O_2, N_2, H_2O, BeO, Be_3N_2, $Be(OH)_2$

Outlook:
Parametric scans (incl. gas inclusions) for understanding physics of Be dust production



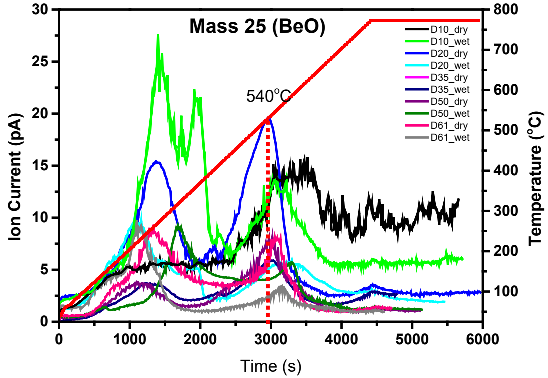
Particle size and morphology:

- 30-500 µm particles prepared & collected by sieving
- Rough surfaces for dust particles → **similarities to dust from JET**



XRD Measurements

- Shifts to small angles due to **tensile stress** in the Be polycrystalline structure.
- BeO diffraction present for samples prepared in wet conditions



TDS analysis of samples:

- More BeO, H_2O, N_2, $Be(OH)_2$ and less Be, O_2 and Be_3N_2 at wet conditions → water present in Be dust as pure H_2O, oxygen to form BeO and (OH) to form $Be(OH)_2$

Deliverable: *PWIE.SPB.1.T002.D005+D008*
Status: *completed*
Facilities: *None*

Human Resources: *2 + 2 PM*
Involved RU: *IAP*
Linked WP or TSVV: *WP ENR-MAT.01.IAP*

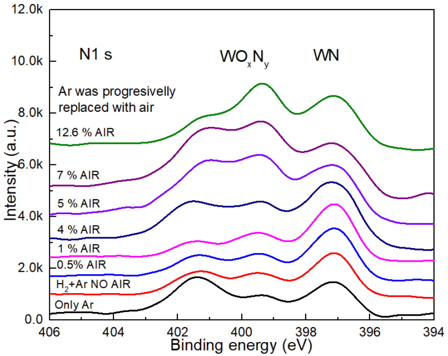
C. Lungu, T. Acsente et al. IAP

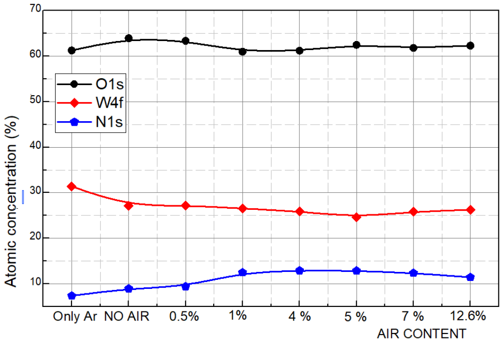
SPB.1: Be and W dust formed during air and water leaks

A) Synthesis of W dust in the presence of air leaks

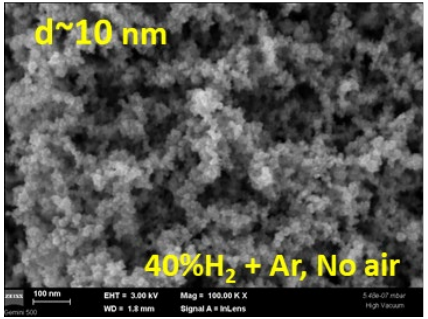
- Evaluation of the W dust synthesis rate presented in the previous review meeting
- Completed in 2022: dust morphology analysis by SEM & chemical composition by XPS
- Results presented in SOFT 2022

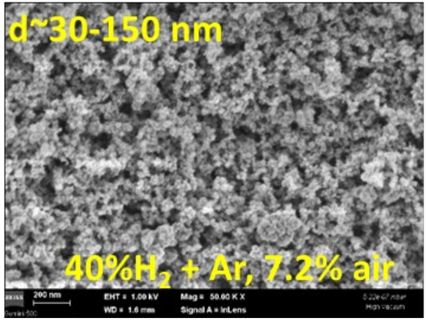
Outlook:
Parametric scans (incl. gas inclusions) for understanding physics of W dust production





Air leaks in discharges (+ H_2) leads to formation of oxides and nitrides





Agglomeration of W dust increases with larger air contents

B) Synthesis of W dust in the presence of H_2O leaks

- Samples prepared and their investigation (SEM, XPS) is in progress (will be finished this year)

Deliverable: *PWIE.SPB.1.T002.D005+D008*
Status: *completed*
Facilities: *None*

Human Resources: *2 + 2 PM*
Involved RU: *IAP*
Linked WP or TSVV: *WP ENR-MAT.01.IAP*

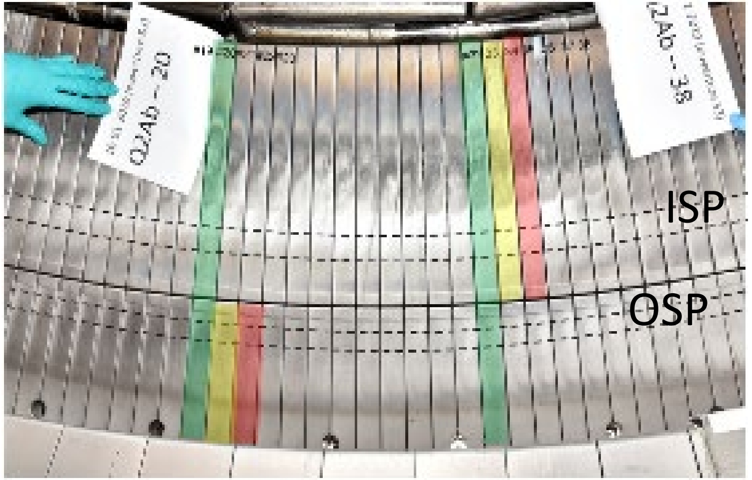
C. Lungu, T. Acsente et al. IAP

SP B.2 – Material migration in toroidal devices - selected results from 2022
SP B.3 – Characterization of plasma-exposed materials – selected results from 2022

SPB.2 & SPB.3: Erosion and deposition patterns on WEST PFUs removed after C3 and C4 campaigns

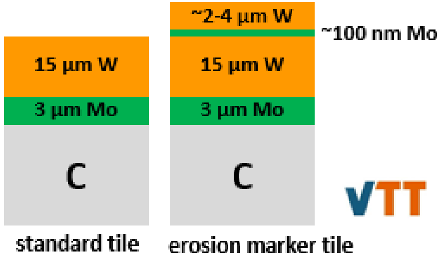
Recently reported in I. Jõgi et al., SOFT 2022 conference

- **Goal #1**: Determine and compare erosion, (re-)deposition, and fuel retention patterns on C3, C4, and C5 marker Plasma Facing Units (PFUs) → joint exercise between 11 Research Units under SP B.2, SP B.3(,and SP X.2)



Status of the work (as of early October)

- Full-tile analyses (MPG)
  - ✓ completed for C3 and C4 marker PFUs
  - ✓ ongoing for C5 marker PFUs (completed by the end of 2022)
- Core samples (VTT) and their analyses
  - ✓ completed for C3 marker PFUs
  - ✓ ongoing for C4 marker PFUs (completed by the end of 2022)
  - ✓ scheduled for C5 marker PFUs in early 2023
  - ✓ scheduled for additional standard tiles (for TOF-ERDA) in late 2022



Deliverables: *PWIE.SPB.2.T002.D001, D007, D008, D009, D010, D011*
PWIE.SPB.3.T002.D001, D003, D004, D005, D006, D007, D008, D009
Status: *almost completed* Facilities: ~20 days accel. (IST, JSI, MPG, NCSRD, RBI, VR, VTT)

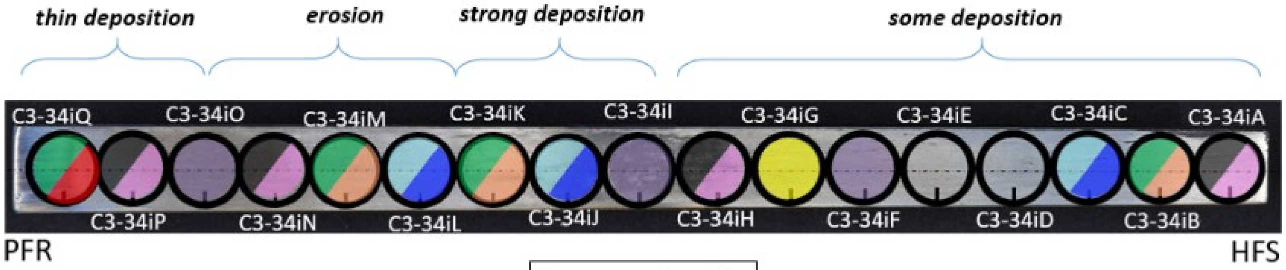
Human Resources: *~20 PM*
Involved RU: *CEA, IAP, IPPLM, IST, JSI, MPG, NCSRD, RBI, UT, VR, VTT*
Linked WP or TSVV: *WP TE*

Coordinators: E. Bernard, M. Diez (CEA)

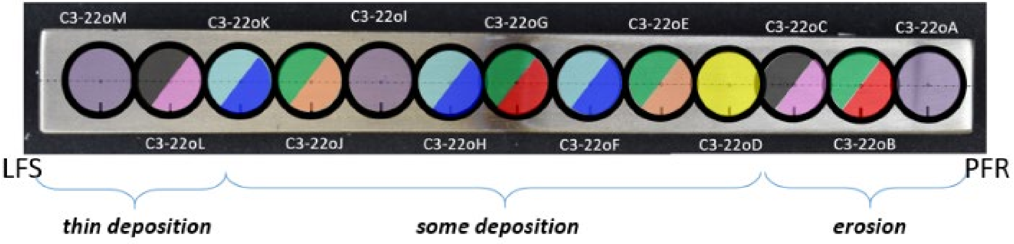
SPB.2 & SPB.3: Erosion and deposition patterns on WEST PFUs removed after C3 and C4 campaigns

Recently reported in I. Jõgi et al., SOFT 2022 conference

Distribution matrix of C3 and C4 core samples



inner marker tile



outer marker tile

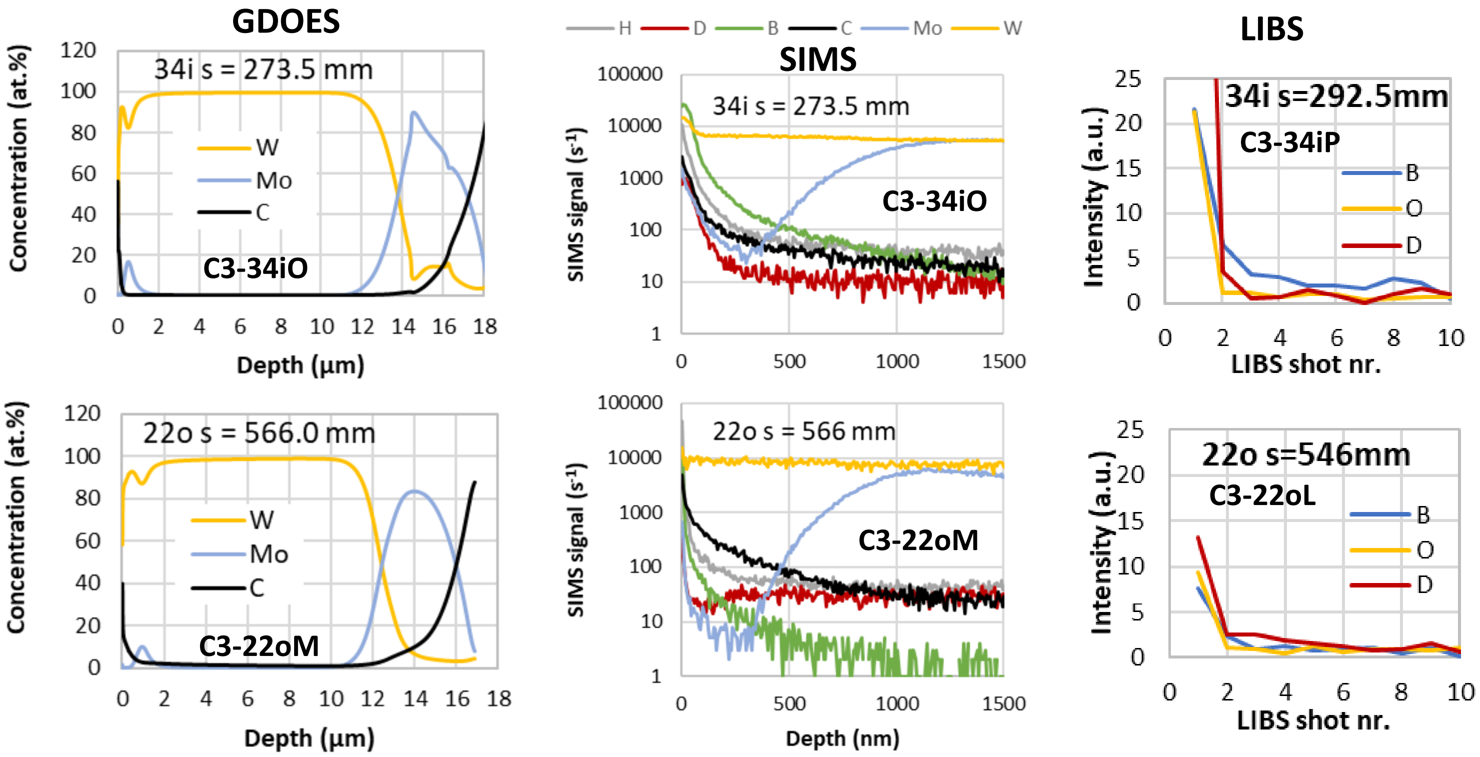
- JSI, Slovenia: µNRA for D content
- UT, Estonia: LIBS for depth-profile analysis of the deposits
- NCSRD, Greece: NRA for D content
- VTT, Finland: SIMS for depth-profiled analysis of the deposits
- RBI, Croatia: ERDA for deposits content analysis
- IAP, Romania: GDOES for erosion measurement
- IST, Portugal: ion beam analysis of the deposits
- VR, Sweden: depth-profiled analysis of the deposits
- IPPLM, Poland: microscopy

Deliverables: *PWIE.SPB.2.T002.D001, D007, D008, D009, D010, D011*
PWIE.SPB.3.T002.D001, D003, D004, D005, D006, D007, D008, D009
Status: *almost completed* Facilities: ~20 days accel. (IST, JSI, MPG, NCSRD, RBI, VR, VTT)

Human Resources: *~20 PM*
Involved RU: *CEA, IAP, IPPLM, IST, JSI, MPG, NCSRD, RBI, UT, VR, VTT*
Linked WP or TSVV: *WP TE*

Coordinators: E. Bernard, M. Diez (CEA)

SPB.2 & SPB.3: Erosion and deposition patterns on WEST PFUs removed after C3 and C4 campaigns



- Comparison made between GDOES, SIMS, and LIBS for the depth profiles of different elements on selected C3 samples
- LIBS also proven to be a **working tool for determining composition of deposited layers**

Deliverables: *PWIE.SPB.2.T002.D001, D007, D008, D009, D010, D011*
PWIE.SPB.3.T002.D001, D003, D004, D005, D006, D007, D008, D009
Status: *almost completed* Facilities: ~20 days accel. (IST, JSI, MPG, NCSRD, RBI, VR, VTT)

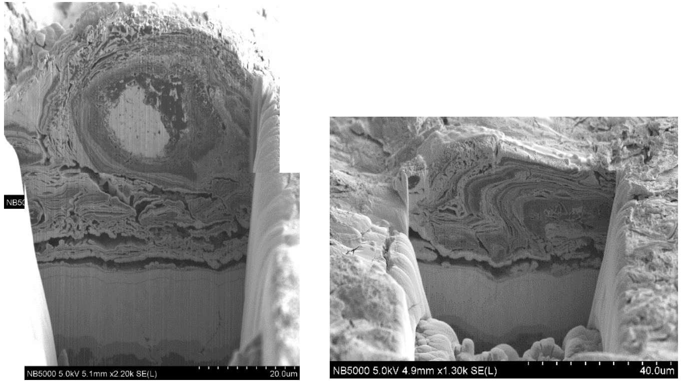
Human Resources: ~*20 PM*
Involved RU: *CEA, IAP, IPPLM, IST, JSI, MPG, NCSRD, RBI, UT, VR, VTT*
Linked WP or TSVV: *WP TE*

I. Jõgi (UT, SP X.2), A. Hakola (VTT), E. Grigore (IAP)

SPB.2 & SPB.3: Erosion and deposition patterns on WEST PFUs removed after C3 and C4 campaigns

- Examples of microscopy studies of samples from the inner divertor after the C4 campaign
- **Thick deposits (>50 μm) with a complex structure** observed
- Some deposits **contain sheets/flakes, distributed inhomogeneously** which further contain spherical/elongated elements and stratified structures; directional bands rich in W visible on top
- EDS measurements indicate increased signals for B, O, C and Cu

SEM images of the deposit morphology, sample J.



SEM images of the deposit and marker layer cross-sections, sample J.

Deliverables: *PWIE.SPB.2.T002.D001, D007, D008, D009, D010, D011*
PWIE.SPB.3.T002.D001, D003, D004, D005, D006, D007, D008, D009
Status: *almost completed* Facilities: ~20 days accel. (IST, JSI, MPG, NCSRD, RBI, VR, VTT)

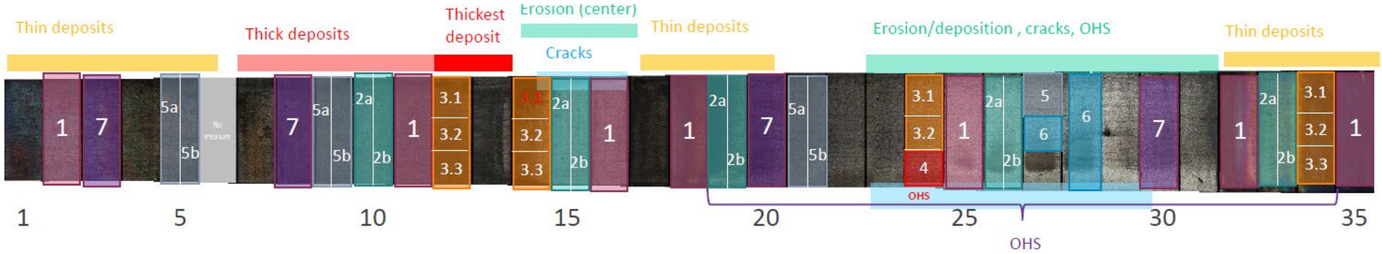
Human Resources: *~20 PM*
Involved RU: *CEA, IAP, IPPLM, IST, JSI, MPG, NCSRD, RBI, UT, VR, VTT*
Linked WP or TSVV: *WP TE*

E. Fortuna et al. (IPPLM)

SPB.2 & SPB.3: Erosion and deposition patterns on WEST PFUs removed after C3 and C4 campaigns

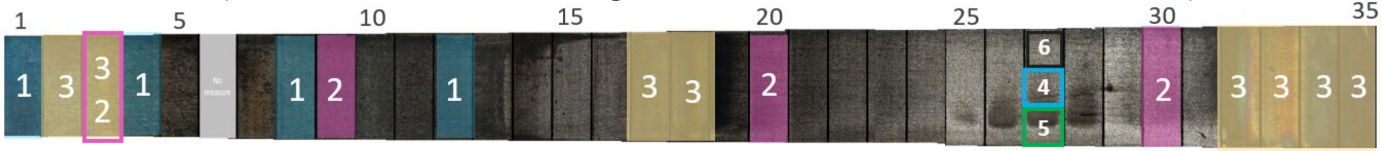
M. Diez et al., PSI 2022; P. Reilhac et al. SOFT 2022

- **Goal #2:** Repeat the exercise for selected ITER-like PFUs removed after WEST Phase I operations



1: CEA, UT, VTT
2: CEA, IAP, IPPLM, RBI, VR
3: CEA, FZJ, JSI
4: CEA
5: IST, NCSRD, VR
6, 7: outside EF

- **Status in the end of 2022:** numbered monoblocks extracted and sent for analyses, the rest require more effort (foreseen in 2023 – cutting machine to arrive in December 2022)



Full PFU: IPP MPG (impurities profile)
1,2 : outside EF
3: PIIM (thin films)
4: IUSTI (thermal diffusivity)
5: FZJ (cracks metallography)
6: Mines St Etienne (W microstructure)

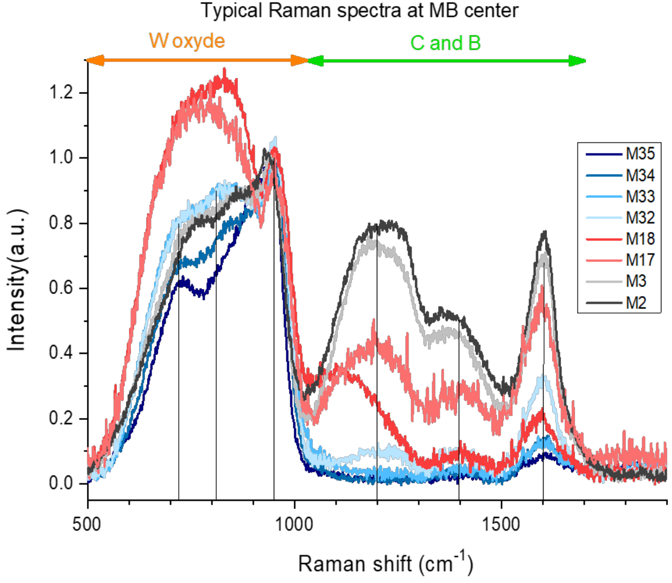
Deliverables: *PWIE.SPB.2.T002.D001, D004, D007, D008, D009, D010*
PWIE.SPB.3.T002.D001, D002, D003, D004, D005, D006, D007, D008
Status: *delayed* Facilities: ~20 days accel. (IST, JSI, MPG, NCSRD, RBI, VR, VTT)

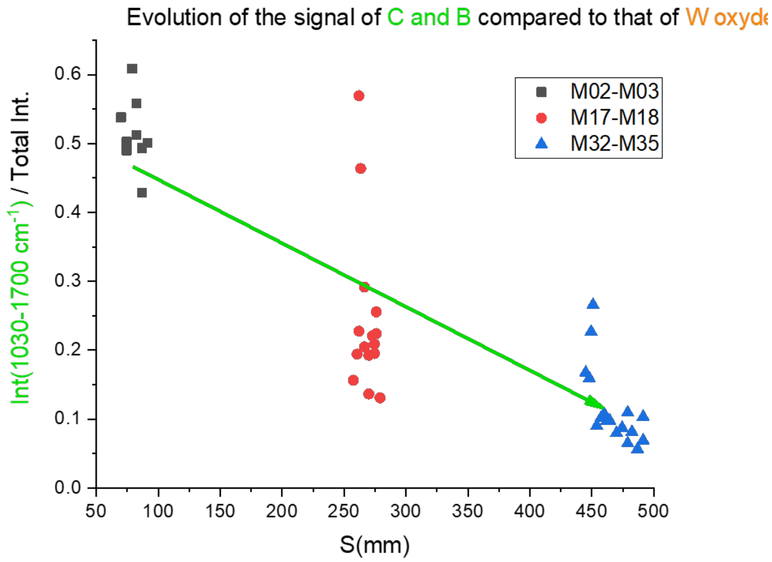
Human Resources: *~20 PM*
Involved RU: *CEA, IAP, IPPLM, IST, JSI, MPG, NCSRD, RBI, UT, VR, VTT*
Linked WP or TSVV: *WP TE*

Coordinators: E. Bernard, M. Diez (CEA)

SPB.2 & SPB.3: Erosion and deposition patterns on WEST PFUs removed after C3 and C4 campaigns

- Non-destructive analyses of thin colored deposits using Raman and SEM-EDX along the radial direction ongoing





- **Thin deposits contain more C and B on the inner side**
- Raman detects mainly WO_3 for the MBs 33-35 on the outer side

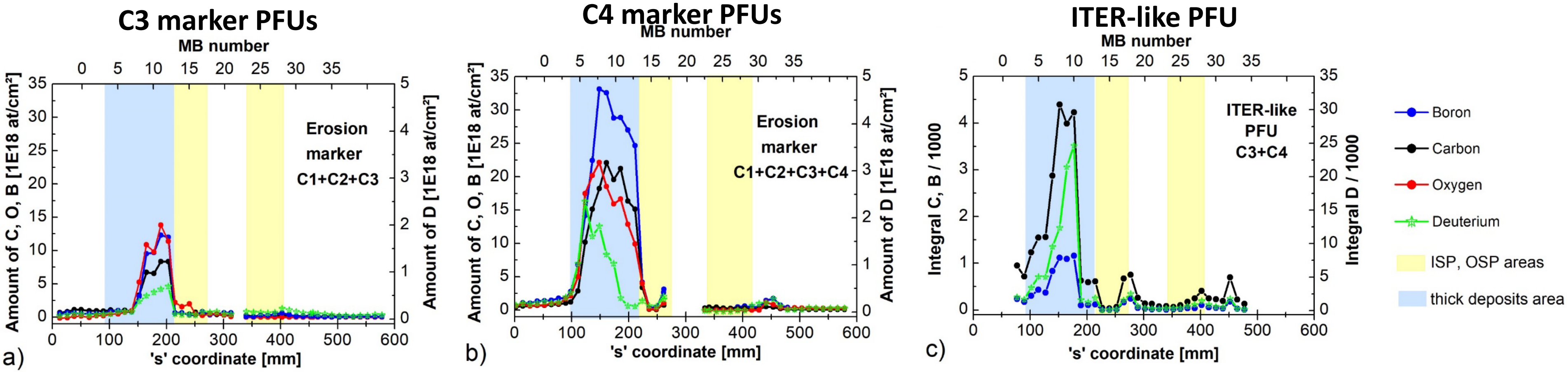
Deliverables: *PWIE.SPB.2.T002.D001, D004, D007, D008, D009, D010*
PWIE.SPB.3.T002.D001, D002, D003, D004, D005, D006, D007, D008
Status: *delayed* Facilities: ~20 days accel. (IST, JSI, MPG, NCSRD, RBI, VR, VTT)

Human Resources: *~20 PM*
Involved RU: *CEA, IAP, IPPLM, IST, JSI, MPG, NCSRD, RBI, UT, VR, VTT*
Linked WP or TSVV: *WP TE*

C. Martin et al. (CEA)

SPB.2 & SPB.3: Erosion and deposition patterns on WEST PFUs removed after C3 and C4 campaigns

- First comparisons made between C3 and C4 marker PFUs as well as ITER-like PFUs – based on ion-beam data
- Light elements detected on the PFC surfaces: B (63 h of boronization), C (lower divertor substrate), O (oxidation during plasma exposure or air exposure), as well as D
- Level of light impurities **increases by three times from C3 to C4** marker PFUs
- **Dominant impurities** in C3 marker PFU: B+O; in C4 marker PFU: B; in ITER-like PFU: C+D



Deliverables: *PWIE.SPB.2.T002.D001, D004, D007, D008, D009, D010*
PWIE.SPB.3.T002.D001, D002, D003, D004, D005, D006, D007, D008
Status: *delayed* Facilities: ~20 days accel. (IST, JSI, MPG, NCSRD, RBI, VR, VTT)

Human Resources: ~*20 PM*
Involved RU: *CEA, IAP, IPPLM, IST, JSI, MPG, NCSRD, RBI, UT, VR, VTT*
Linked WP or TSVV: *WP TE*

M. Diez et al. (CEA), M. Balden et al. (MPG)

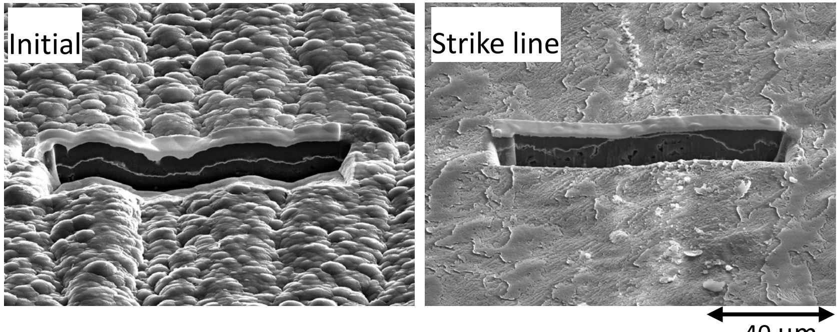
SPB.2 & SPB.3: Characterization of TDUs removed from W7-X after the OP1.2B campaign

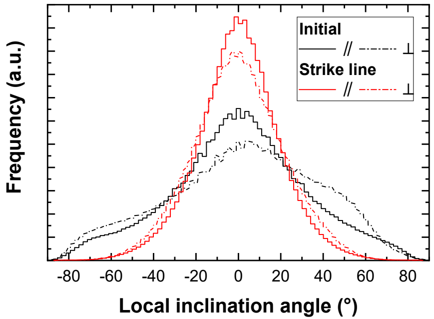
- Work concentrated on the analyses of different Test Divertor Units (TDUs) and other samples
  - ✓ **marker TDUs for erosion/deposition and surface-roughening studies during OP1.2B**

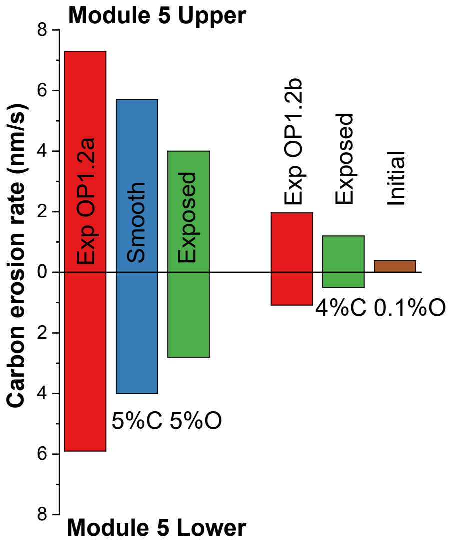
Outlook:
Erosion studies in OP2 using midplane manipulator

Main results

- Plasma exposure **smoothens the surface and creates specific surface patterns**
- Simulated and experimental erosion rates in **OP1.2A and OP1.2B agree within a factor of 2**; surface roughness plays a strong role
- Reduced erosion from OP1.2A to OP1.2B due to **smaller O concentration** (boronizations) → erosion in OP1.2B dominated by H







Deliverables: *PWIE.SPB.2.T002.D004, D006, D008, D009, D011*
PWIE.SPB.3.T002.D002, D003, D006
Status: *completed* Facilities: ~15 days accelerator (FZJ, MPG, VR, VTT)

Human Resources: ~*10 PM*
Involved RU: *FZJ, IPPLM, MPG, VR, VTT*
Linked WP or TSVV: *WP W7X*

M. Mayer et al. (MPG)

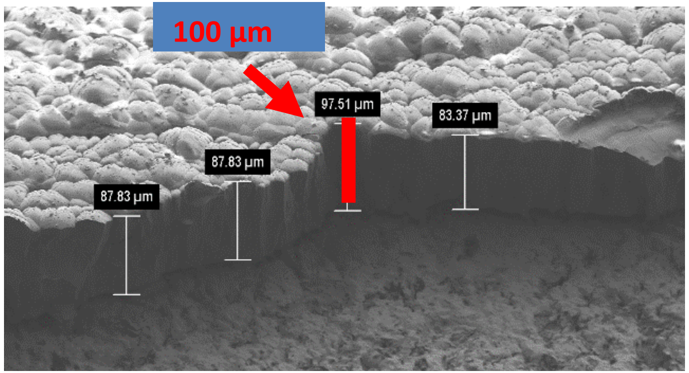
SPB.2 & SPB.3: Characterization of TDUs removed from W7-X after the OP1.2B campaign

- Work concentrated on the analyses of different Test Divertor Units (TDUs) and other samples
  - ✓ selected TDUs/samples for determining deposition of impurities (incl. ^{13}C and various metals) and surface modification patterns

20 TDU target elements (TE) extracted for ^{13}C analyses, using the reaction $^{13}C(d,p_0)^{14}C$

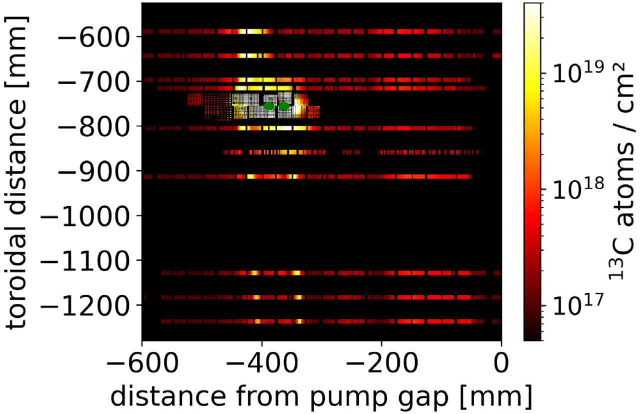
Main results

- High ^{13}C deposition around injection holes: **>10^{20} atoms cm^{-2} in 10 cm perimeter**
- Vicinity shows saturated regions (white), thickness > 6 µm (up to 100 µm by SEM)



SEM image of a delaminated layer ~1 mm apart from one injection hole

2D ^{13}C deposition on HM39TM200h+300h



Deliverables: *PWIE.SPB.2.T002.D004, D006, D008, D009, D011*
PWIE.SPB.3.T002.D002, D003, D006
Status: *completed* Facilities: ~15 days accelerator (FZJ, MPG, VR, VTT)

Human Resources: *~10 PM*
Involved RU: *FZJ, IPPLM, MPG, VR, VTT*
Linked WP or TSVV: *WP W7X*

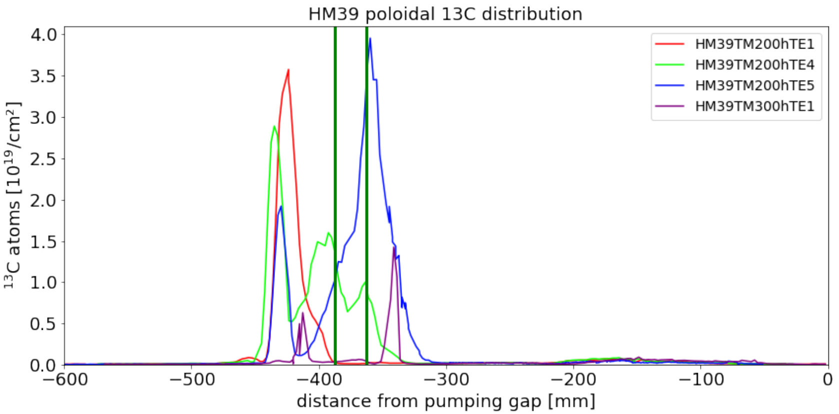
M. Racinski et al. (FZJ)

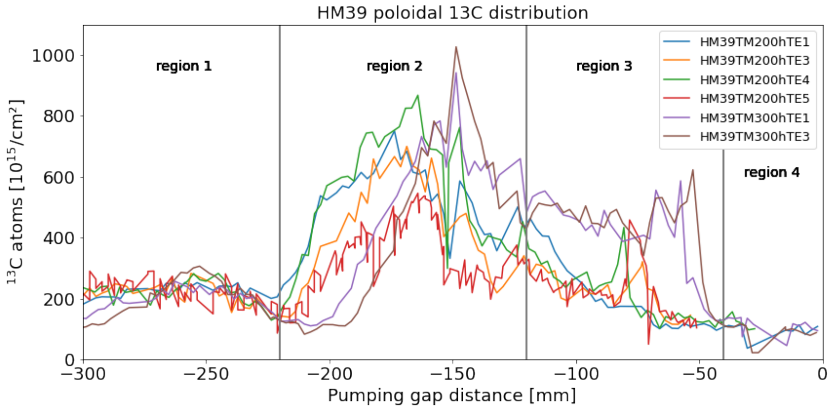
SPB.2 & SPB.3: Characterization of TDUs removed from W7-X after the OP1.2B campaign

- Work concentrated on the analyses of different Test Divertor Units (TDUs) and other samples
  - ✓ selected TDUs/samples for determining deposition of impurities (incl. ^{13}C and various metals) and surface modification patterns

Main results

- Direction to TM100h (top side): 1 peak, shifted away from the pumping gap
- Direction to TM300h (bottom side): splitting into 2 peaks
- Secondary peak along the strike line (-80-(-250 mm)): low deposition but regular pattern across the TE (nm range)





Deliverables: *PWIE.SPB.2.T002.D004, D006, D008, D009, D011*
PWIE.SPB.3.T002.D002, D003, D006
Status: *completed* Facilities: ~15 days accelerator (FZJ, MPG, VR, VTT)

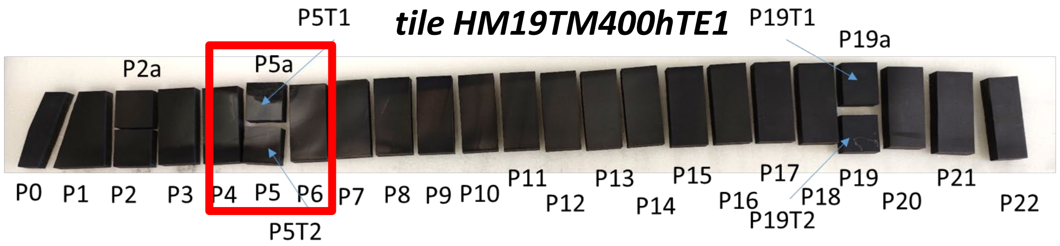
Human Resources: *~10 PM*
Involved RU: *FZJ, IPPLM, MPG, VR, VTT*
Linked WP or TSVV: *WP W7X*

M. Racinski et al. (FZJ)

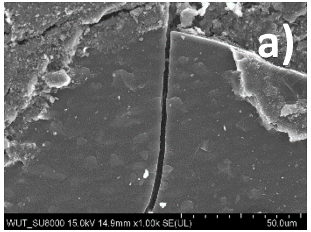
SPB.2 & SPB.3: Characterization of TDUs removed from W7-X after the OP1.2B campaign

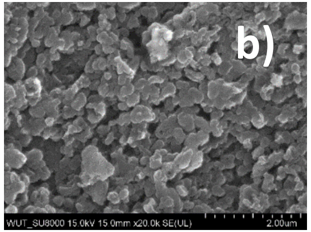
- Work concentrated on the analyses of different Test Divertor Units (TDUs) and other samples
  - ✓ **SEM/TEM/EDS observations of TDUs with damaged zones**

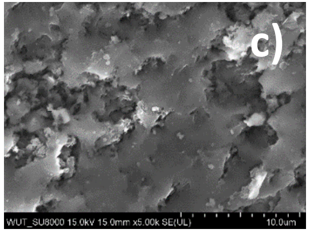
tile HM19TM400hTE1



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

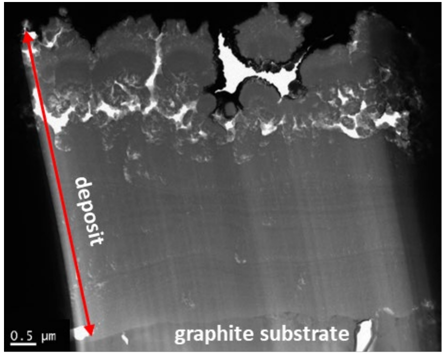






Damaged zone on sample 5a

TEM image of the damaged zone. *Thick layer of re-deposited material revealed.*



Deliverables: *PWIE.SPB.2.T002.D004, D006, D008, D009, D011*
PWIE.SPB.3.T002.D002, D003, D006
Status: *completed* Facilities: ~15 days accelerator (FZJ, MPG, VR, VTT)

Human Resources: *~10 PM*
Involved RU: *FZJ, IPPLM, MPG, VR, VTT*
Linked WP or TSVV: *WP W7X*

E. Fortuna et al. (IPPLM)

SPB.2 & SPB.3: Analysis of AUG samples

A. Hakola et al. (VTT), M. Balden and K. Krieger et al. (MPG), M. Racinski et al. (FZJ), I. Bogdanovic Radovic et al. (RBI), S. Markelj and M. Kelemen et al. (JSI)

	Priority 2022	Sub-task	Coordination / samples	SEM / EDX / FIB / OM – pre	RBS / NRA - pre	DIM-experiment	SEM / EDX / FIB / OM - post	RBS / NRA - post	Evaluation	Other institutions	Status	Publication
New sub tasks	1	AUG He-campaign-2022 (WP-TE)	yes	done	done	scheduled 19.07.2022	ongoing	waiting	waiting	ongoing	ongoing	pending
	2	AUG depo-cracks	No	no	no	campaign integrated	done	no	done	no	finished	PSI 2022 in reviewing
Continuation of sub-task from 2021	3	Melting (Ir, Nb, bridging)	yes yes	done	no	Apr 2021 5.7. 2022	done ongoing	no	done ongoing	no	finished ongoing	PSI 2022 in reviewing
	4	Au-marker (net/gross erosion)	2020	done	done	9.7. 2020	done	done	done	ongoing	finished	PSI 2022 in reviewing
	5	Roughness (erosion)	2020	done	no	9.7. 2020	done	done	done	ongoing	finished	PSI 2022 in reviewing
	6	B-dropper (2nd - MEM)	yes	done	done	8.6. 2021	done	done	done	no	finished	PSI 2022 in reviewing
	7	Gap load (2nd - rev/co-field)	Yes	done	done	18.3.2021	done	no	done	done	finished	Ongoing pinboard
	8	IR-rel. tile	Yes	no	no	Mar 2021	done	no	done	no	ongoing	no
	9	Arc inserts	no	no	no	campaign integrated	done	no	done	no	ongoing	finished

- See next slides & separate talk
- See PSI 2022 (V. Rohde et al.)
- See next slides
- See next slides
- Samples outside EUROfusion
- Discussed in previous report
- Discussed in previous report

Change since KoM

Change since Midterm reporting

Deliverables: *PWIE.SPB.2.T002.D002, D003, D004, D005, D010*
PWIE.SPB.3.T002.D002, D006, D008
Status: *completed* Facilities: ~13 days accelerator (JSI, MPG, RBI, VTT)

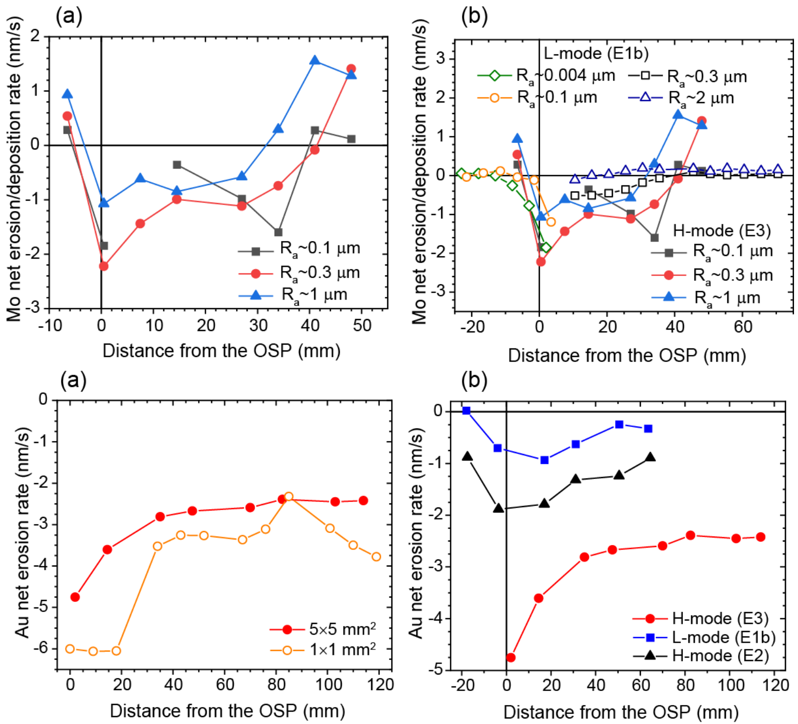
Human Resources: *~10 PM*
Involved RU: *FZJ, JSI, MPG, RBI, VTT*
Linked WP or TSVV: *WP TE*

SPB.2 & SPB.3: Analysis of AUG samples

A. Hakola et al. (VTT), M. Balden and K. Krieger et al. (MPG), M. Racinski et al. (FZJ), I. Bogdanovic Radovic et al. (RBI), S. Markelj and M. Kelemen et al. (JSI)

Items #4 and #5: Au marker samples and roughness samples – reported in PSI 2022

- Study net/gross erosion of Au and effect of roughness on erosion in H-mode
- Increasing surface roughness **reduces net erosion but less than in L-mode**
- Net-erosion rates in **H-mode 2-5 times higher than in L-mode**
- Exposure to H-mode conditions results in strong local variations in the poloidal and toroidal erosion/deposition profiles



Top: Poloidal net erosion/deposition profiles for different roughness samples
Bottom: Poloidal net erosion profiles (a) for the 5×5 mm² and 1×1 mm² Au marker spots in H-mode and (b) for the 5×5 mm² Au marker spots during different L- and H-mode experiments

Deliverables:	*PWIE.SPB.2.T002.D002, D003, D004, D005, D010*
	PWIE.SPB.3.T002.D002, D006, D008
Status: *completed* Facilities: ~13 days accelerator (JSI, MPG, RBI, VTT)	

Human Resources: *~10 PM*
Involved RU: *FZJ, JSI, MPG, RBI, VTT*
Linked WP or TSVV: *WP TE*

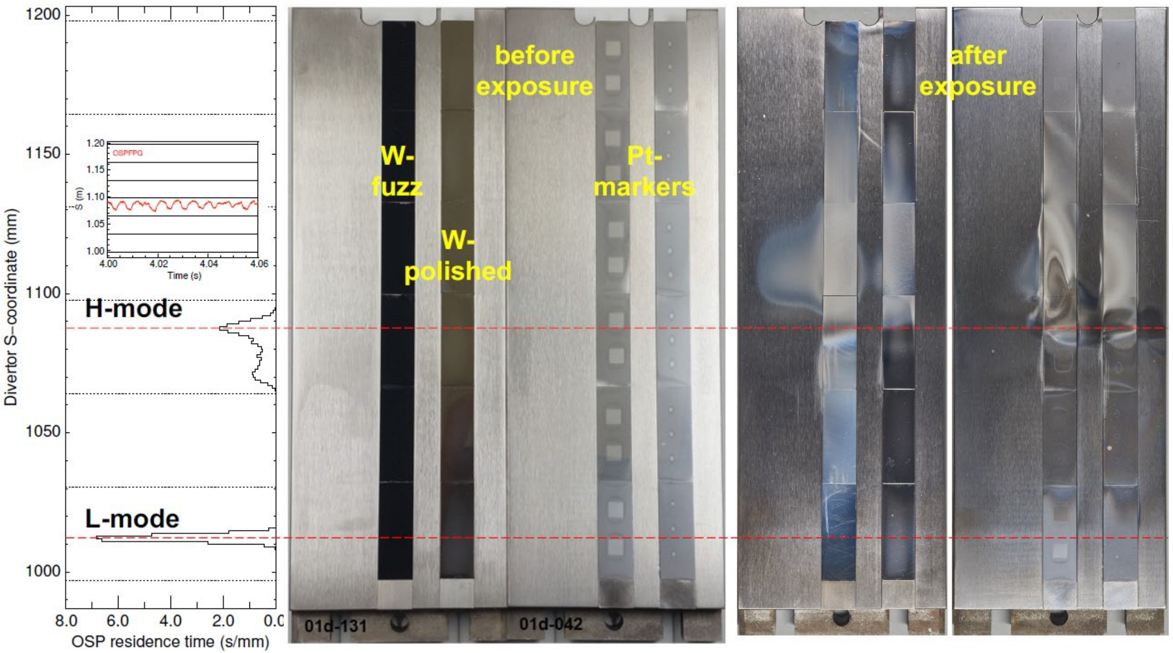
SPB.2 & SPB.3: Analysis of AUG samples

A. Hakola et al. (VTT), M. Balden and K. Krieger et al. (MPG), M. Racinski et al. (FZJ), I. Bogdanovic Radovic et al. (RBI), S. Markelj and M. Kelemen et al. (JSI)

Item #1: Exposure of samples to helium plasmas

- Exposure of samples with (i) W fuzz, (ii) bulk W, and (iii) Pt markers to L- and H-mode discharges
- Main goals to study formation & erosion of W fuzz and comparing erosion to results in D

Outlook:
Extensive analysis programme in 2023 for several labs involved → separate meeting for organization in early 2023



Deliverables: *PWIE.SPB.2.T002.D002, D003, D004, D005, D010*
PWIE.SPB.3.T002.D002, D006, D008
Status: *completed* Facilities: ~13 days accelerator (JSI, MPG, RBI, VTT)

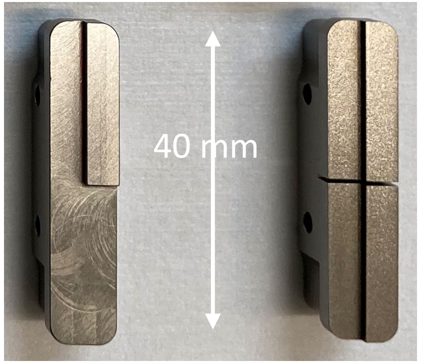
Human Resources: ~*10 PM*
Involved RU: *FZJ, JSI, MPG, RBI, VTT*
Linked WP or TSVV: *WP TE*

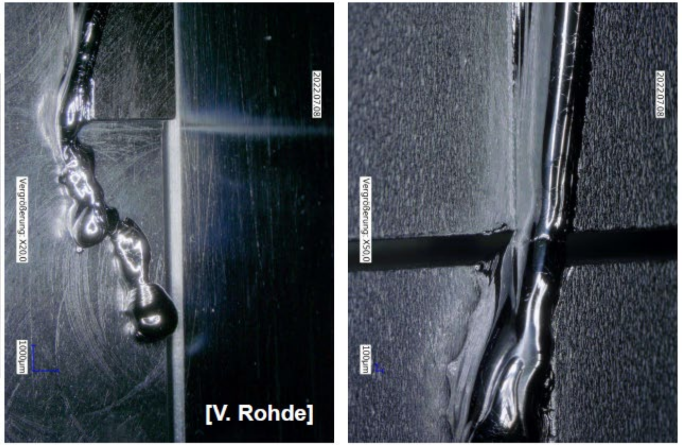
SPB.2 & SPB.3: Analysis of AUG samples

A. Hakola et al. (VTT), M. Balden and K. Krieger et al. (MPG), M. Racinski et al. (FZJ), I. Bogdanovic Radovic et al. (RBI), S. Markelj and M. Kelemen et al. (JSI)

Item #3: Continuation of melting studies

- Samples with leading edges and toroidal gaps exposed to H-mode plasmas in D to study free flow of spilled melt and possible bridging of the gap
- Melt motion across gaps as well as **spilling of the flow over the edges clearly demonstrated** → no melt penetrating into the gap!
- Data available for simulations with the MEMENTO code





Deliverables: *PWIE.SPB.2.T002.D002, D003, D004, D005, D010*
PWIE.SPB.3.T002.D002, D006, D008
Status: *completed* Facilities: ~13 days accelerator (JSI, MPG, RBI, VTT)

Human Resources: *~10 PM*
Involved RU: *FZJ, JSI, MPG, RBI, VTT*
Linked WP or TSVV: *WP TE*

K. Krieger et al. (MPG)

SP B.4 – Reference coatings for ITER and DEMO – selected results from 2022

SPB.4: Overview of activities

- SP B.4 deals with **production of W and Be reference samples according to agreed Master Excel** – latest update in September 2022 to come up with a manageable plan for the period 2021-2022
- Several RUs involved in **characterization of the produced reference layers as well as the outcomes of their exposure** into plasmas in linear machines (MAGNUM-PSI, PSI-2, GyM)

Excerpt from the Master File – this particular table contains 251 lines…

Research Unit	Specifications	Size (mm3)	Thickness (um)	Gas	Temperature (deg C)	Substrate	# of samples	To whom?	Comments	WP and SP	Produced by
ENEA-POLIMI	W-HiPIMS	PSI-2 geometry	>0,4		Nominal	graphite, polished	1	FZJ	FIB marking @ FZJ before PSI-2 experiments	SP B.1	06/2022
ENEA-POLIMI	W-HiPIMS	PSI-2 geometry	>0,4		Nominal	graphite, low roughness, Ra = 100 nm	1	FZJ	FIB marking @ FZJ before PSI-2 experiments	SP B.1	06/2022
ENEA-POLIMI	W-HiPIMS	PSI-2 geometry	>0,4		Nominal	graphite, medium roughness, Ra = 300 nm	1	FZJ	FIB marking @ FZJ before PSI-2 experiments	SP B.1	06/2022
ENEA-POLIMI	W-HiPIMS	PSI-2 geometry	>0,4		Nominal	graphite, polished	6	FZJ	PSI-2 experiments	SP B.1	06/2022
ENEA-POLIMI	W-HiPIMS	PSI-2 geometry	>0,4		Nominal	graphite, low roughness, Ra = 100 nm	6	FZJ	PSI-2 experiments	SP B.1	06/2022
ENEA-POLIMI	W-HiPIMS	PSI-2 geometry	>0,4		Nominal	graphite, medium roughness, Ra = 300 nm	6	FZJ	PSI-2 experiments	SP B.1	06/2022

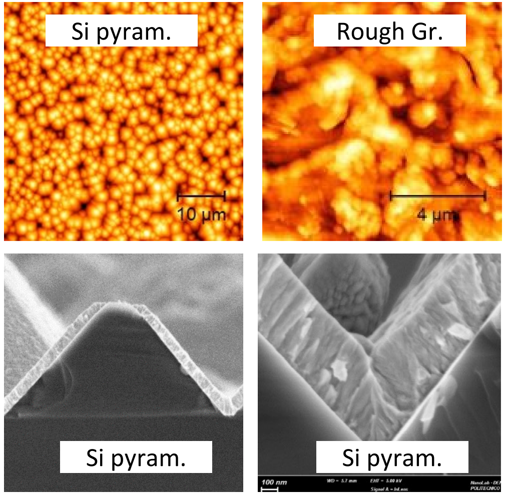
SPB.4: Production of W-based reference coatings

Main research areas in 2022:

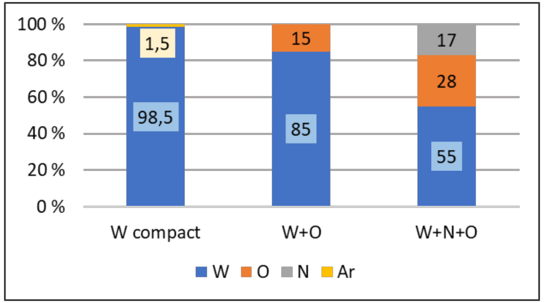
- W coatings on flat and rough surfaces, 500 nm thick (GyM, ÖAW) ~60 samples
  - ✓ substrate preparation by ISTP-CNR (chemical/plasma etching) + W deposition by HiPIMS
  - ✓ Flat and pyramidal-Si substrates as well as flat and rough graphite
- W coatings on Mo, 1 µm thick, for the LIBS studies ~100 samples
  - ✓ Compact W films (HiPIMS)
  - ✓ Amorphous-like W+O and W+N+O films, with varying O and N concentrations (PLD)

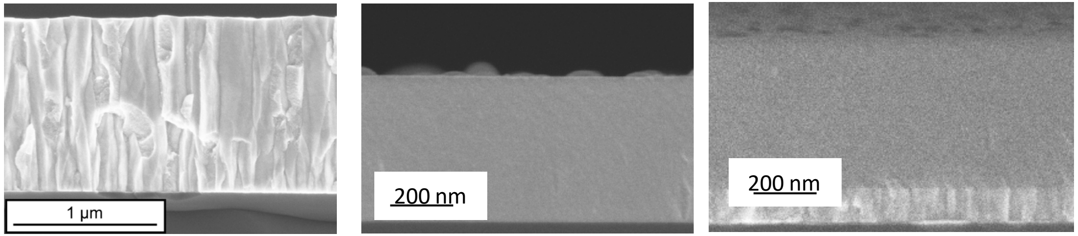
AFM

SEM



EDXS





W compact **W+O** **W+N+O**

Deliverable: *PWIE.SPB.4.T002.D001*
Status: *completed*
Facilities: None

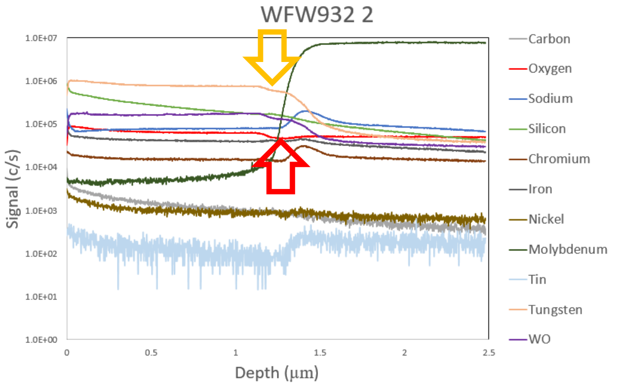
Human Resources: 3 *PM*
Involved RU: *ENEA*
Linked WP or TSVV: *SP X.2.T002, SP B.1.T002.D001-D003*

M. Passoni et al. (ENEA)

SPB.4: Production of W-based reference coatings

Main research areas in 2022:

- W coatings on flat and rough surfaces, 500 nm thick (GyM, ÖAW) ~60 samples
  - ✓ substrate preparation by ISTP-CNR (chemical/plasma etching) + W deposition by HiPIMS
  - ✓ Flat and pyramidal-Si substrates as well as flat and rough graphite
- W coatings on Mo, 1 µm thick, for the LIBS studies ~100 samples
  - ✓ Compact W films (HiPIMS)
  - ✓ Amorphous-like W+O and W+N+O films, with varying O and N concentrations (PLD)
  - ✓ SIMS of W+O films (CIEMAT) indicate transition from W+O at ~1.1 µm to a W layer (thickness ~0.2 µm); O variations between or across samples cannot be determined



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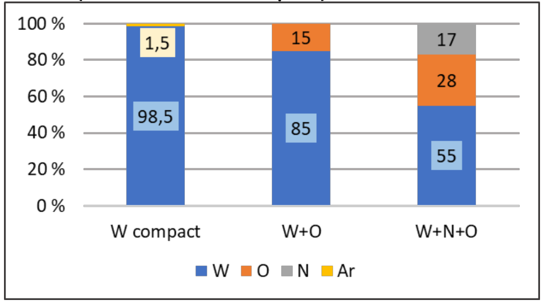
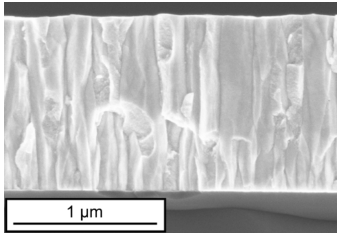
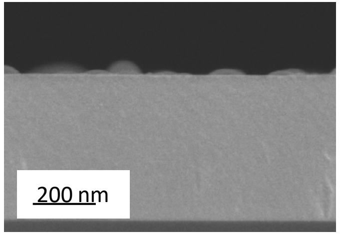
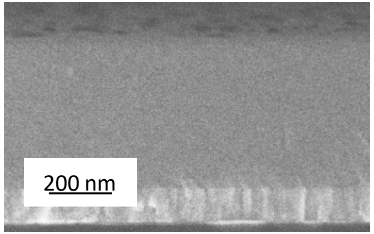




W compact



W+O



W+N+O

Deliverable: *PWIE.SPB.4.T002.D001, D004*
Status: *completed*
Facilities: None

Human Resources: 3 *PM + 3 PM*
Involved RU: *ENEA, CIEMAT*
Linked WP or TSVV: *SP X.2.T002, SP B.1.T002.D001-D003*

M. Passoni et al. (ENEA), D. Alegre et al. (CIEMAT)

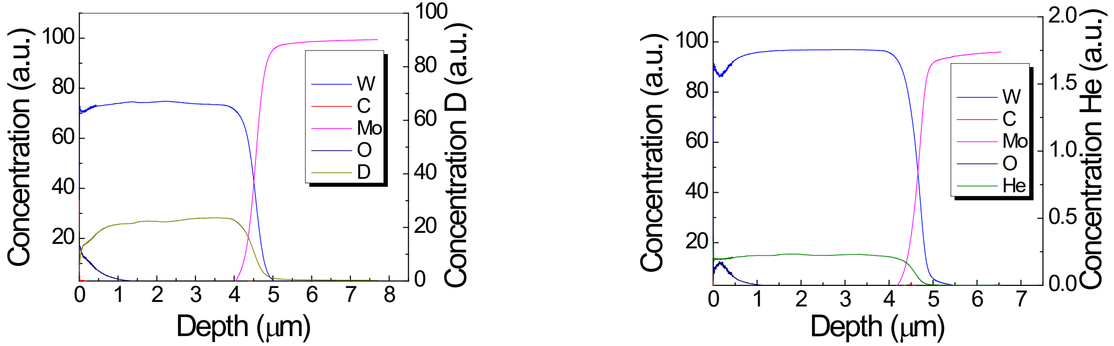
SPB.4: Production of Be- and W-based reference coatings

Main research areas in 2022:

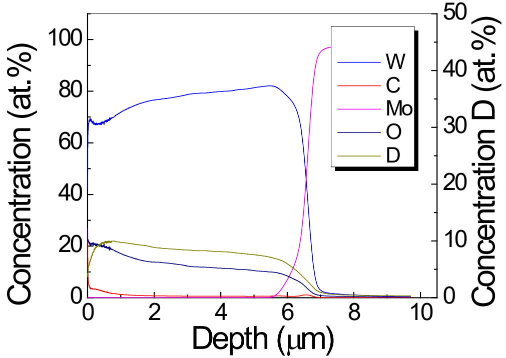
- **Production of W-based layers** – mainly for LIBS development and exposures in linear devices
  - ✓ W+He(5 at.%)+D(5 at.%); W+Ne (5 at.%); W+Ne(5 at.%)+D (5 at.%); W+O(5 at.%); W+O(5 at.%)+D(10 at.%)
  - ✓ Samples exhibit smooth and uniform profiles for the gases – however, Ne detection difficult
  - ✓ TOF-ERDA analysis in agreement with GDOES and used for calibrating the H/D/He concentrations

sample	H (at.%)	D (at.%)	He (at.%)	^{14}N (at.%)	^{16}O (at.%)	W (at.%)
W+He+D	1.7 ± 0.3	8.9 ± 1.4	18 ± 1	4.5 ± 0.6	4.4 ± 0.6	59 ± 4
	1.1 ± 0.2	11.2 ± 1.5	16.2 ± 1.5	4.7 ± 0.6	4.4 ± 0.6	61 ± 4

TOF-ERDA data for two W+He+D coatings



GDOES depth profiles for a W+He+D coating (left D profile, right He profile)



GDOES depth profiles for a W+O+D coating

Deliverable: *PWIE.SPB.4.T002.D002*
Status: *completed*
Facilities: None

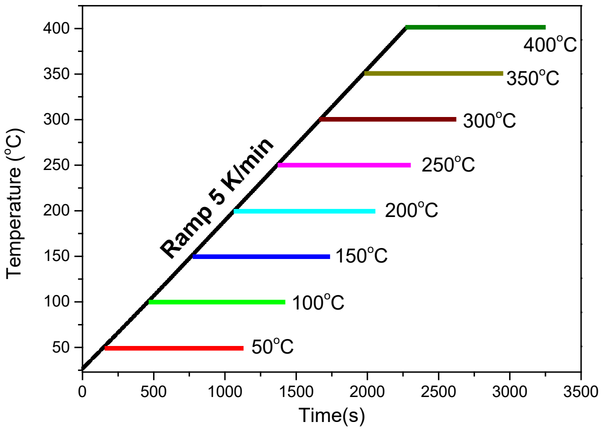
Human Resources: 9 *PM*
Involved RU: *IAP*
Linked WP or TSVV: *SP X.2.T002, SP B.1.T002.D001-D003*

E. Grigore et al. (IAP), I. Bogdanovic Radovic et al. (RBI)

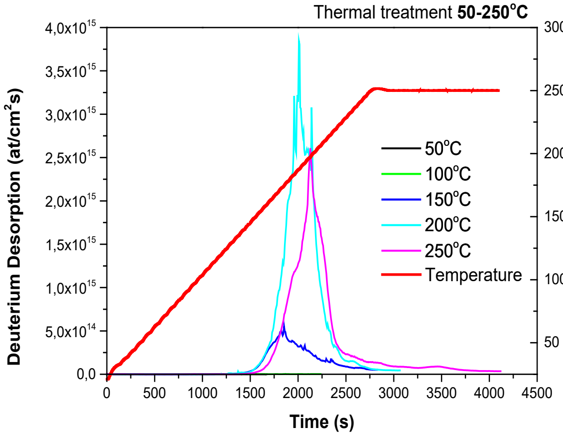
SPB.4: Production of Be- and W-based reference coatings

<u>Main research areas in 2022:</u>

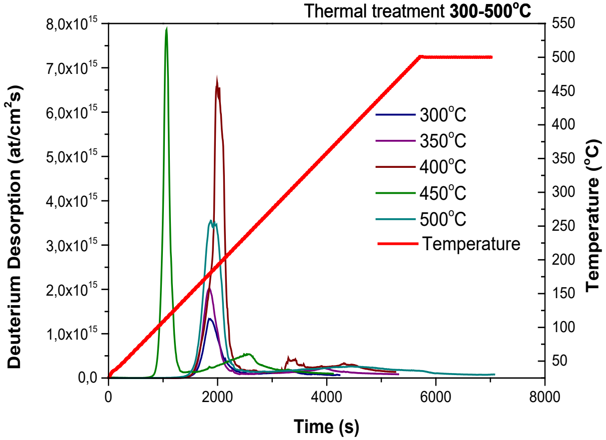
- **Production of Be-based layers** – for systematic parametric studies
  - ✓ **Be+O+D (5, 10 and 20 at.%) – 16 samples – and Be+D (5-10 at.%) at 4 different temperatures - 44 samples**
  - ✓ **Be with D or H (~20 at.%), 5 μm thick – 110 samples in total - thermally treated at different temperatures**
  - ✓ Clear differences in the D release patterns observed with the annealing temperature!



Thermal treatment scheme for Be-D and Be-H



D release from Be-D samples (on Si)



D release from Be-D samples (on W)

Deliverable: *PWIE.SPB.4.T002.D002*
Status: *completed*
Facilities: None

Human Resources: 9 *PM*
Involved RU: *IAP*
Linked WP or TSVV: *SP X.2.T002, SP B.1.T002.D001-D003*

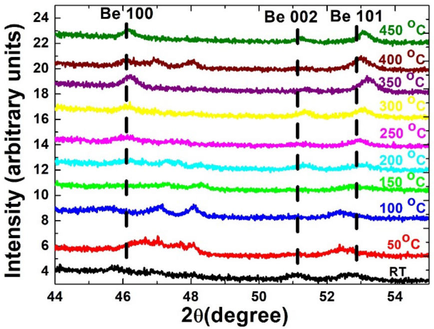
C. Porosnicu et al. (IAP), I. Bogdanovic Radovic (RBI)

SPB.4: Production of Be- and W-based reference coatings

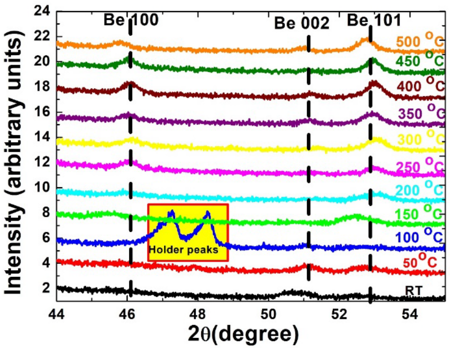
Main research areas in 2022:

- **Production of Be-based layers** – for systematic parametric studies
  - ✓ **Be with D or H (~20 at.%), 5 μm thick – 110 samples in total - thermally treated at different temperatures**

Be+D

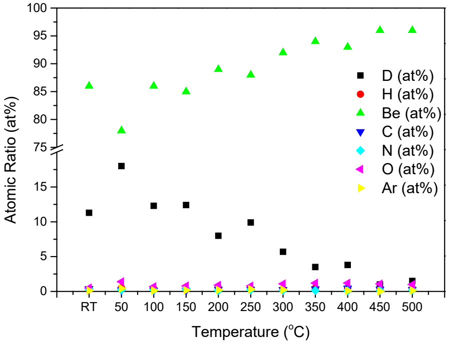


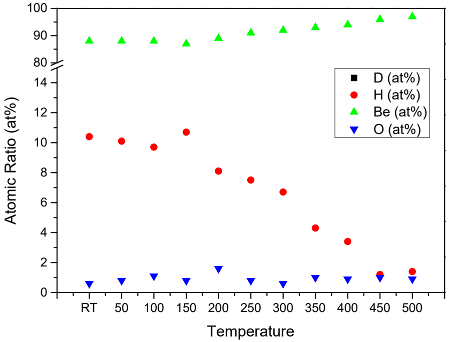
Be+H



Top: XRD results indicate

- Shift of the (1 0 1) peak at > 300°C due to tensile stress
- Grain size to decrease from 52 to 18 nm with the annealing temp.





Bottom: TOF-ERDA results show

- D or H ratio to drop systematically with the annealing temperature
- Oxygen below 1 at. %, H levels stay at ~10 at.% at RT
- No other impurities → high quality of the coatings

Deliverable: *PWIE.SPB.4.T002.D002*
Status: *completed*
Facilities: None

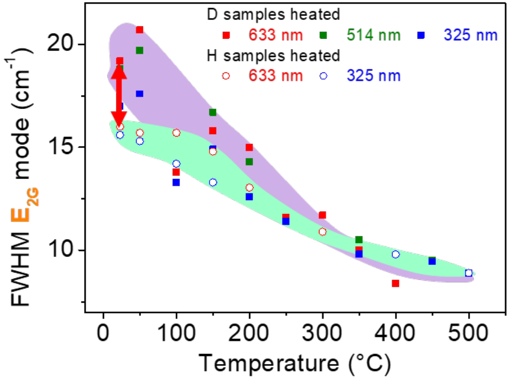
Human Resources: 9 *PM*
Involved RU: *IAP*
Linked WP or TSVV: *SP X.2.T002, SP B.1.T002.D001-D003*

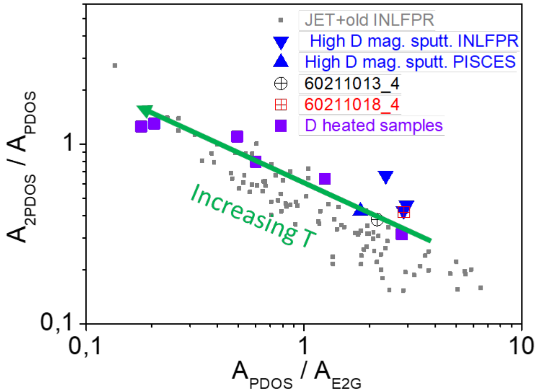
C. Porosnicu et al. (IAP), I. Bogdanovic Radovic (RBI)

SPB.4: Raman studies of Be+H/Be+D samples

- The produced Be+D and Be+H films analyzed using Raman spectroscopy
- The results for the FWHM of the main Raman peak indicate
  - ✓ **Less defects by heating**
  - ✓ Clear difference in H and D samples at T < 150°C
- The relevant A_{PDOS}/A_{E2G} and A_{2PDOS}/A_{PDOS} parameters evolve with heating
  - ✓ No correlation with grain size as obtained by XRD
  - ✓ **Defects most likely in crystallites in the bulk**
  - ✓ Similarities – but also some differences with the existing data

*"Old data" from C. Pardanaud et al. Physica Scripta **96** (2021) 124031*





Old data

Deliverable: *PWIE.SPB.4.T002.D003*
Status: *completed*
Facilities: None

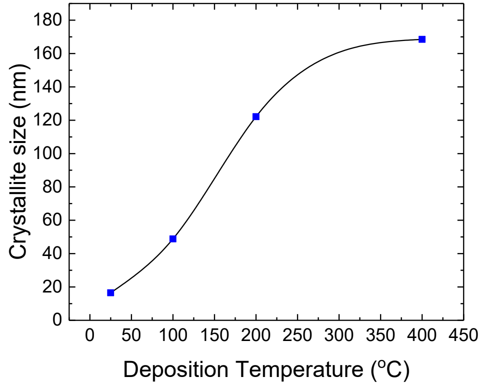
Human Resources: 2 *PM*
Involved RU: *CEA*
Linked WP or TSVV: *None*

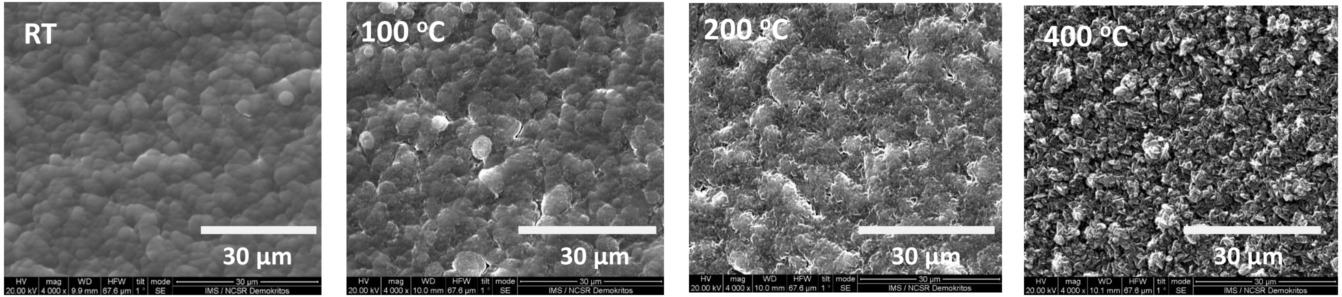
C. Pardanaud et al. (CEA)

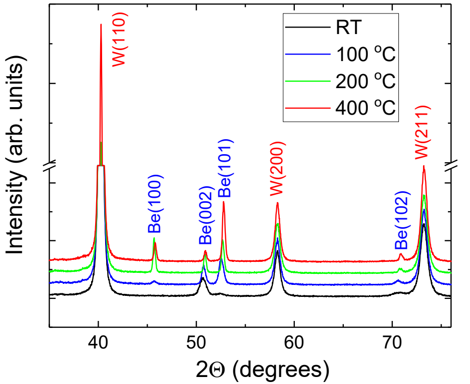
SPB.4: Characterization of Be+D samples produced at different temperatures – examples of results

Main research results in 2022:

- Characterization of the Be+D and Be+O+D (5-10 at.%) samples produced at 4 different temperatures – SEM, EDX, XRD, XPS
  - ✓ Be crystallizes at hexagonal P63/mmc space group
  - ✓ Increasing deposition temperature **increases both the roughness and the crystallite size** but decreases the lattice constant
  - ✓ Increasing deposition temperature also **changes the surface texture** and makes it more enhanced towards [100] and [101] directions







Deliverable: *PWIE.SPB.4.T002.D006; PWIE.SPB.3.T002.D007*
Status: *completed*
Facilities: None

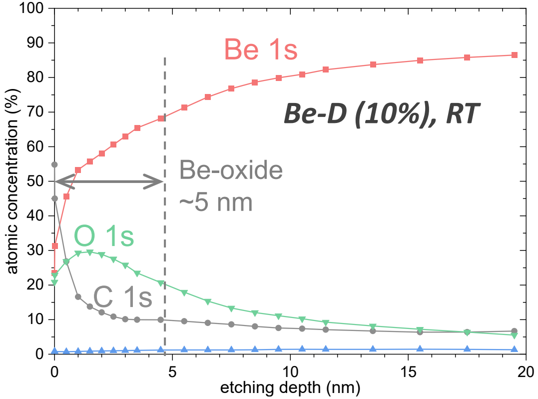
Human Resources: 4 PM + 3 PM
Involved RU: *JSI, NCSRD*
Linked WP or TSVV: *None*

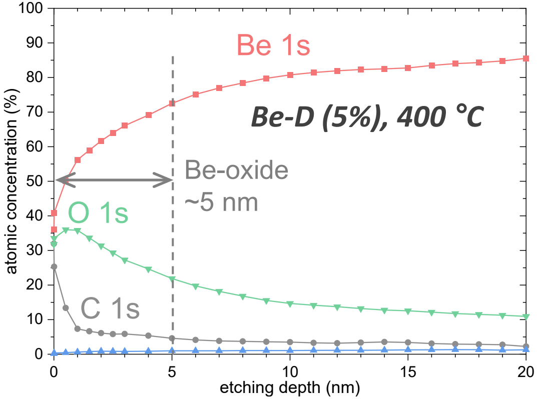
M. Panjan et al. (JSI), K. Mergia et al. (NCSRD)

SPB.4: Characterization of Be+D samples produced at different temperatures – examples of results

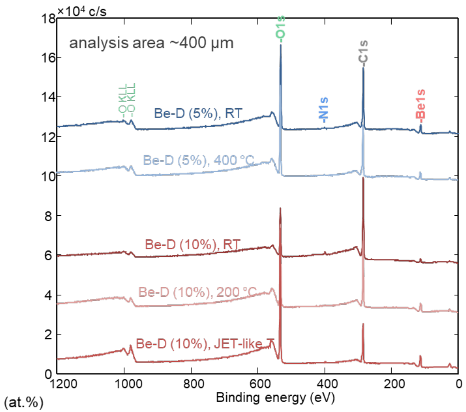
Main research results in 2022:

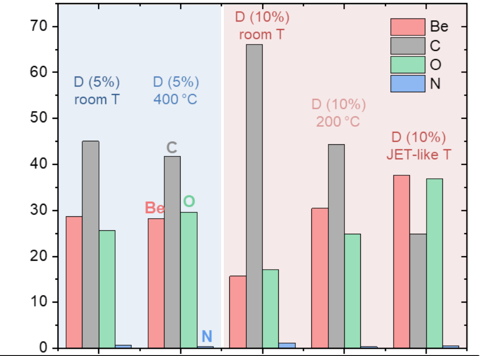
- Characterization of the Be+D and Be+O+D (5-10 at.%) samples produced at 4 different temperatures – SEM, EDX, XRD, XPS
  - ✓ The surface **depth profiles for the light elements, however, are quite similar**
  - ✓ Increased surface temperature seems also lead to **increased O and Be concentrations** on the surface (but only observed for one series of samples)
  - ✓ Generally: BeO thickness ~5 nm, N present as nitrides in subsurface region (1-2 at.%), C as contamination and as carbide in subsurface region (~3-6 at.%)





XPS survey spectra (C, O, Be, N)





Deliverable: *PWIE.SPB.4.T002.D006; PWIE.SPB.3.T002.D007*
Status: *completed*
Facilities: None

Human Resources: 4 PM + 3 PM
Involved RU: *JSI, NCSRD*
Linked WP or TSVV: *None*

M. Panjan et al. (JSI), K. Mergia et al. (NCSRD)

Planning for 2023

SP B Overview of 2023 R&D efforts

- Most of the tasks will be **continuation of the 2022 activities**, however, in some cases the scope will be refined
  - ✓ More emphasis on analysis of samples from the **AUG helium experiment** – compensated by reducing PMs dedicated to measurements of reference samples and those from W7-X and WEST (no new components)
  - ✓ More **coordinated efforts** for erosion/re-deposition studies in linear facilities and understanding the physics of dust production
  - ✓ Focus of the production of reference samples (SP B.4) moves more **towards the erosion experiments in SP B.1**
- Other changes in the list of research topics
  - ✓ Starting **survey of metallic dust production** in toroidal devices → pending for funding decision (SP B.3/SP B.1)
  - ✓ Assessing the **role of CX neutrals on erosion** → during AUG shutdown would be an “archeological exercise” in 2023
  - ✓ Inclusion of **LIBS as an analysis tool** under SP B.3 → may lead to shift of activities from SP X into SP B (in later years)
- Main classes of reference samples under SP B.4 in 2023
  - ✓ **W and W+O coatings** with well-defined compositions and morphologies for “comparative” PSI-2, MAGNUM-PSI, and GyM erosion experiments – including layers simulating re-deposited W
  - ✓ Limited number of **W-based samples for LIBS** development and calibration
  - ✓ Production of a series of **Be+O+D samples**, analogously to previous Be+D coatings, for assessing their relevance as co-deposits
  - ✓ Comparison of **implanted and co-deposited** Be+O+D and W+O+D layers

SP B Proposed milestones 2023

WMxx	SP B	Dependence of erosion rates on plasma flux and impurity composition available for W model systems and role of CX neutrals on sputtering in past experiments reported (ITER+DEMO)	31.12.2023
WMxx	SP B	Erosion and re-deposition patterns and characteristics of W nanostructures on marker samples originating from ASDEX Upgrade helium experiments determined (ITER+DEMO)	31.12.2023
WMxx	SP B	Marker samples and ITER-like plasma-facing units removed after the WEST C5 campaign characterized and comparison made between C3, C4, and C5 results (ITER+DEMO)	31.12.2023
WMxx	SP B	Fuel-containing Be+O and W+O samples produced, exposed in linear facilities, and characterized for their similarities to existing or expected layers in tokamaks (ASDEX Upgrade, WEST, JET) (ITER+DEMO)	31.12.2023

SP B Proposed deliverables 2023

Activity	Deliverable ID(s)	Title
SP B.1	D001	Erosion rates of W and W+O model systems in MAGNUM-PSI at varying fluxes, fluences, and impurity contents (DIFFER)
SP B.1	D002	Erosion rates of W and W+O model systems in GyM at varying fluxes, fluences, and impurity contents (ENEA)
SP B.1	D003	Erosion rates of W and W+O model systems in PSI-2 at varying fluxes, fluences, and impurity contents (FZJ)
SP B.1	D004, D006	Effective sputtering yields of nanostructured W model systems following exposure to controlled D and impurity ion beams (ÖAW, VR)
SP B.1	D005	Parametric dependencies of Be and W dust particles on their production mechanisms (IAP)
SP B.1	D006	Comparison of hypervelocity dust impacts on W and W+O model systems with data from tokamaks (ENEA)
SP B.2	D001	Erosion and deposition patterns on marker and ITER-like PFUs after WEST C5 campaign (CEA)
SP B.2	D002, D003, D004	Balance between gross and net erosion and qualification of W fuzz in AUG He plasmas (FZJ, VTT, MPG)
SP B.2	D005, D006	Erosion and deposition characteristics of manipulator samples from OP2 experiments in W7-X (FZJ, MPG)
SP B.3	D001	Database on ageing, erosion, and fuel-retention behavior of selected WEST PFUs (CEA)
SP B.3	D002, D003, D004, D005, D006, D007, D008, D009, D010	Characterization of selected AUG, WEST and/or W7-X wall tiles (FZJ, IAP, IPPLM, IST, JSI, MPG, NCSRD, RBI, VTT)
SP B.4	D001	W-based coatings with pre-defined properties produced for analyses and plasma experiments (ENEA)
SP B.4	D002	W-based coatings with pre-defined properties produced for analyses and plasma experiments (IAP)
	D003	Be-based coatings with pre-defined properties produced for analyses and plasma experiments (IAP)
SP B.4	D004, D005, D006, D007, D008, D009, D010	Characterization of selected Be and/or W reference samples (CEA, CIEMAT, IPPLM, IST, JSI, RBI, VTT)