SP B.1 ENEA activities in 2021: Effective sputtering yields of W model systems in GyM - plans and capabilities

A. Uccello,
on behalf of A. Cremona, F. Ghezzi, M. Pedroni, G. Alberti, D. Dellasega, M. Passoni

Beneficiary: ENEA
Linked Third Parties: ISTP-CNR Milano and Politecnico di Milano

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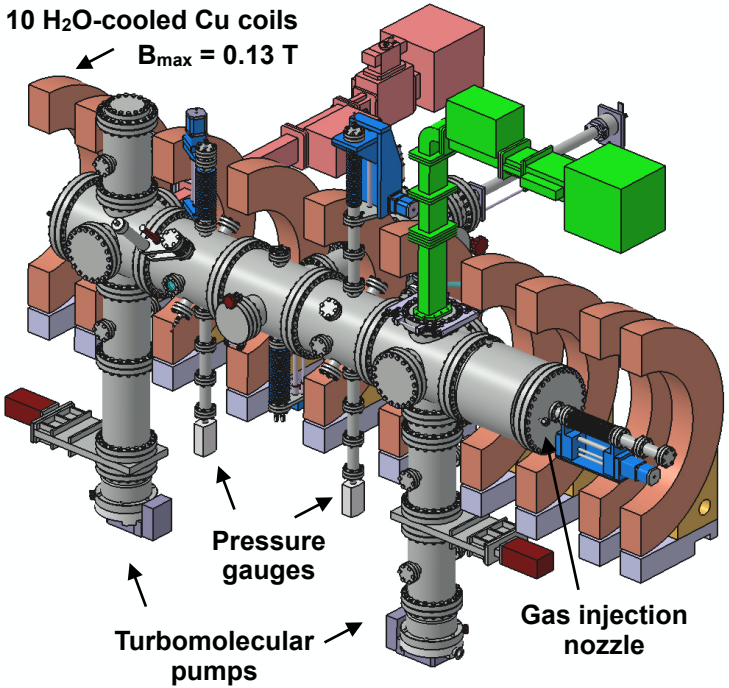
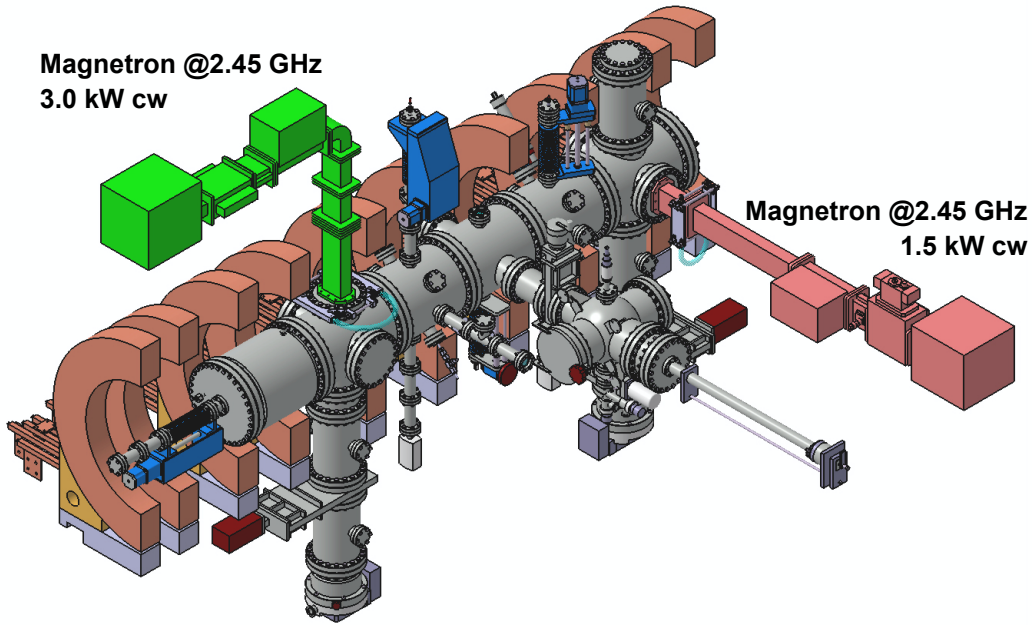
GyM linear plasma device @ ISTP-CNR Milano

Vacuum vessel	Stainless steel (SS): L = 2.11 m, Ø = 25 cm (optional: SS liner with W coating)
Pumping system	2 turbopumps: p_{base} = 1E-8 mbar, p_{work} < 1E-3 mbar
Working gas	H_2, D_2, N_2, He, Ar, He+NH_3 and mixtures





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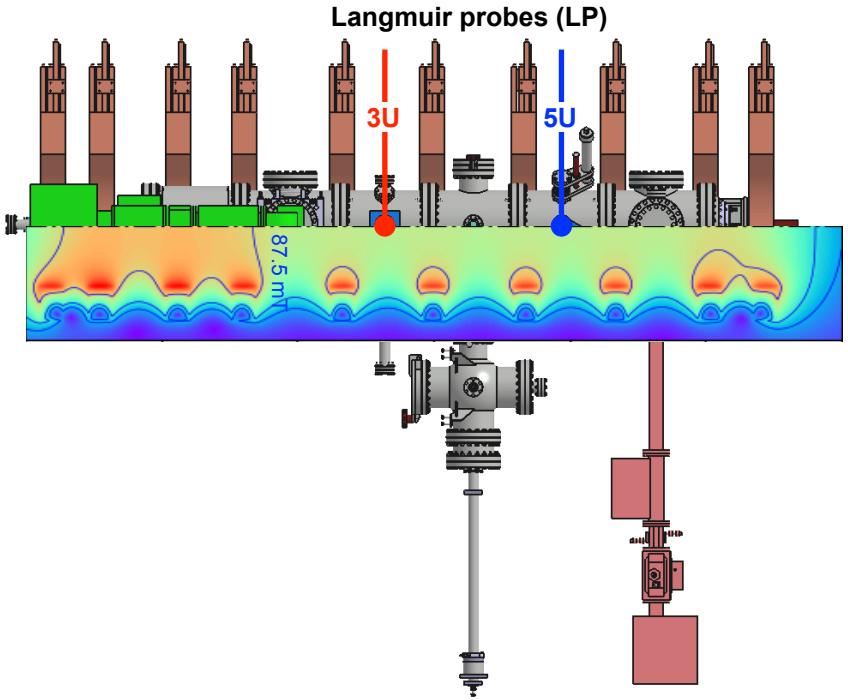
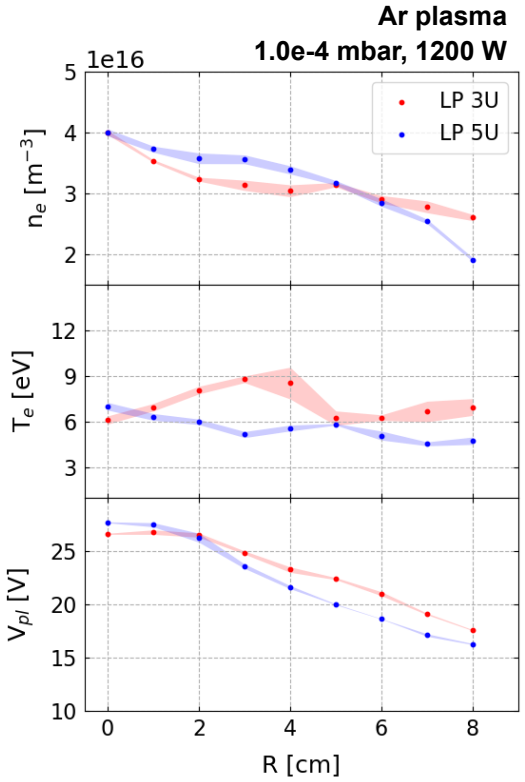


Source	ECRH
B [T]	up to 0.13
n_e [m^{-3}]	up to 10^{17}
T_e [eV]	3-15
T_i [eV]	<0.1
Γ [ions $m^{-2}s^{-1}$]	up to 10^{21}
Φ_{max} [ions m^{-2}]	10^{25} (7 h)
Incident ion energy [eV]	20-400
t_{pulse} [s]	Steady state
$Ø_{plasma}$ [cm]	20



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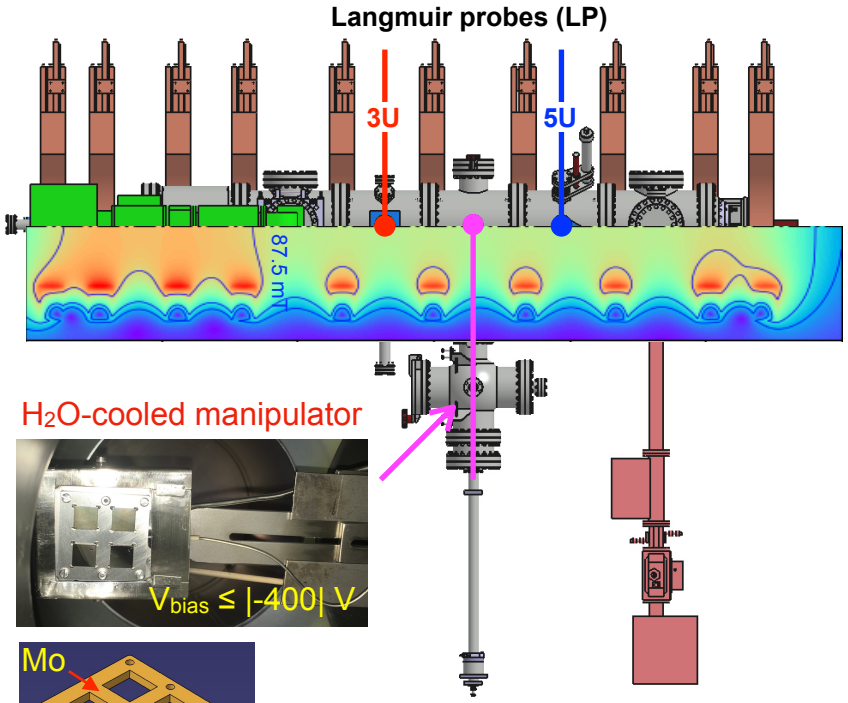

Sample geometry
Eurofusion standard
square slab l = 12 mm - 0.2 mm and s ≤ 3 mm

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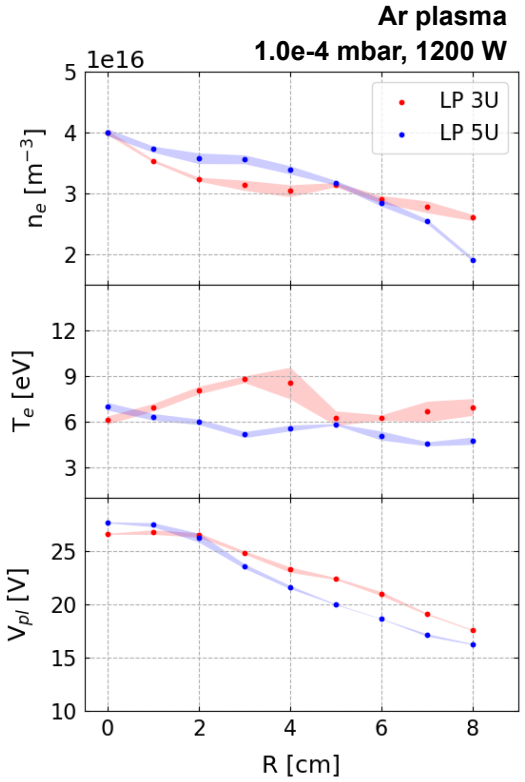
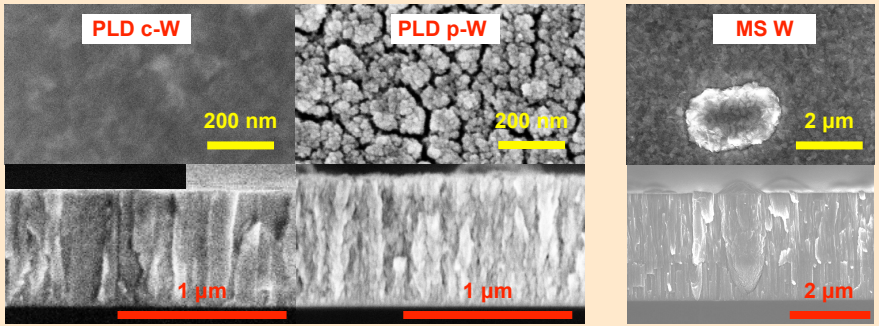


D2: Effective sputtering yields of W model systems with varying morphologies in pure and mixed plasmas in GyM

Role of **morphology** in sputtering process

What we can do in Milan → Production of:

- ITER- and DEMO-relevant W coatings
  with columnar and porous morphologies
  by pulsed laser deposition (PLD) @ ENEA-Polimi
- W coatings by magnetron sputtering @ ENEA-ISTP



SEM by G. Angella
CNR-ICMATE Milano

- W-graphene heterostructure (from 2022?)
  L. Laguardia project TBD during SP B.4 KoM

Role of **roughness** in sputtering process

What we can do in Milan → Production of:

- Rough graphite substrates
  by plasma etching
  R_a → 110, 280, 600 nm
  @ ENEA-ISTP

[A. Eksaeva, et al., Phys. Scr. **T171**(2020)014057]

- Regular pyramidal structures
  on silicon by plasma etching
  @ ENEA-ISTP
  TBD during SP B.4 KoM

SEM by S. Pietralunga
IFN-CNR; CNST@Polimi, IIT

Followed by deposition of

- ITER- and DEMO-relevant W coatings
  by PLD and magnetron sputtering
  @ ENEA-Polimi + ENEA-ISTP

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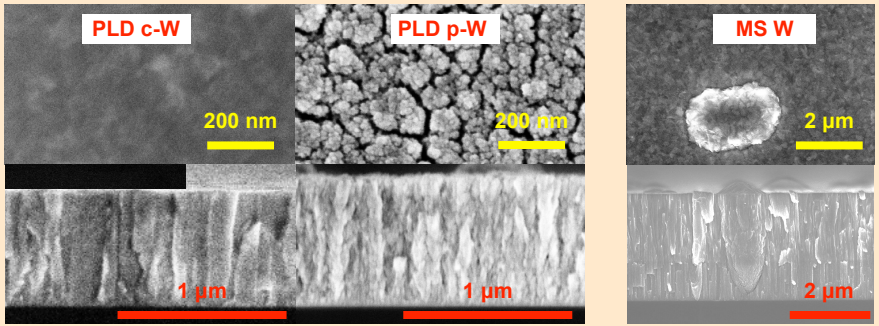

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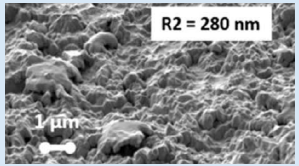

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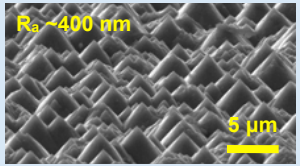

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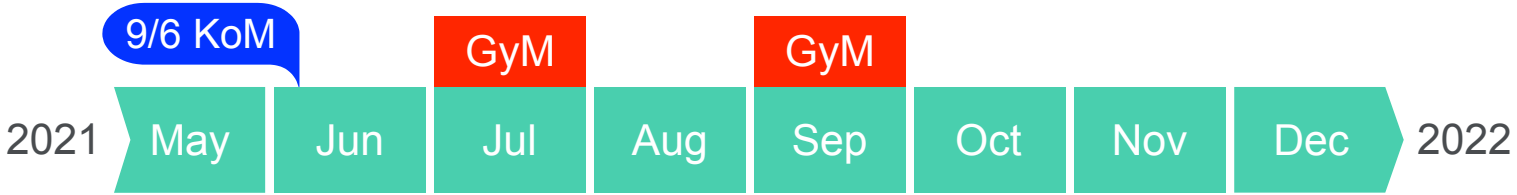
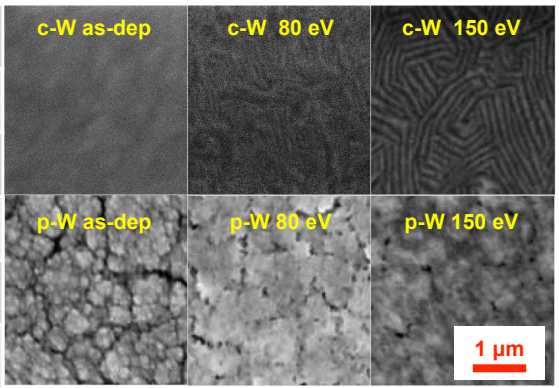


Exposure of W model systems to helium plasma of GyM changing He^+ E_{kin} (i.e. V_{bias}) and/or fluence → **Why He?**

- Investigation of morphology evolution of W model systems after **deuterium** plasma exposure in GyM ✓
  [M. Sala, et al., NME, **24**(2020)100779]
- Literature → He plasma - W model systems interaction ✗
  - ➡ Preliminary experimental study of morphology evolution by using GyM
- Data from GyM He plasma exposures for benchmarking modelling efforts with SOLPS-ITER and ERO2.0 of ENEA-Polimi+ISTP under SP D

[M. Sala, et al., PPFC 62(2020)100779]
[E. Tonello, et al., NF **61**(2021)066036]
[G. Alberti, et al. NF **61**(2021)066039]

Plasma species	He
n_e [m^{-3}]	$6 \cdot 10^{16}$
T_e [eV]	7
Γ [ions $m^{-2}s^{-1}$]	$5 \cdot 10^{20}$
Φ_{max} [ions m^{-2}]	$7 \cdot 10^{24}$ (4 h)
He^+ E_{kin} [eV]	80 & 150



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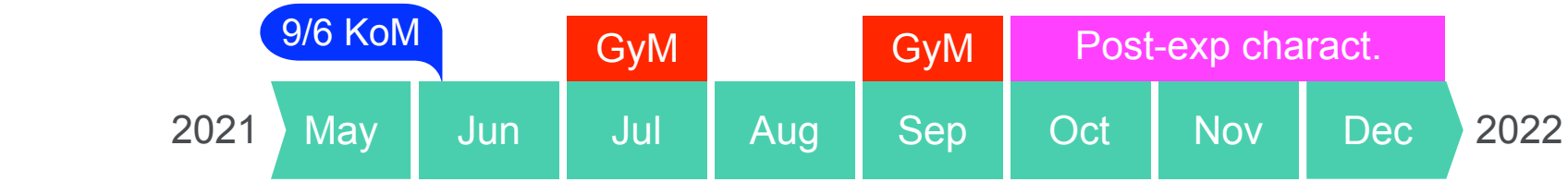
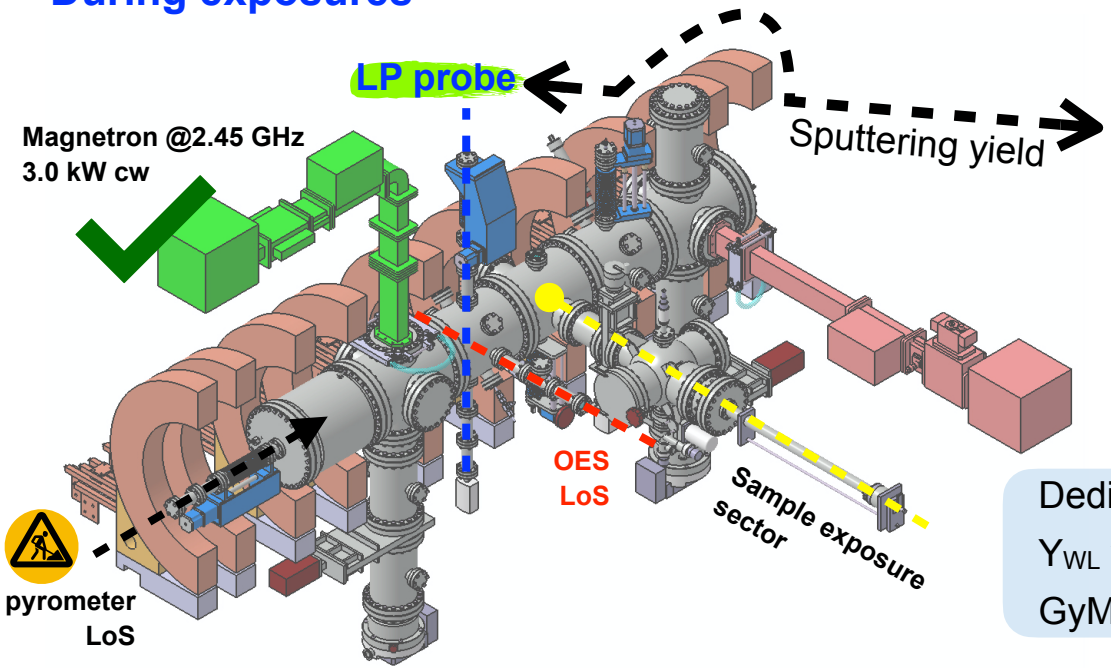


During exposures



Before and after exposures

In Milan

- Weighing → erosion
  by using balance @ ENEA-CNR-Mi
- SEM → morphology evolution
  @ ENEA-Polimi
- AFM → topography evolution
  @ ENEA-ISTP

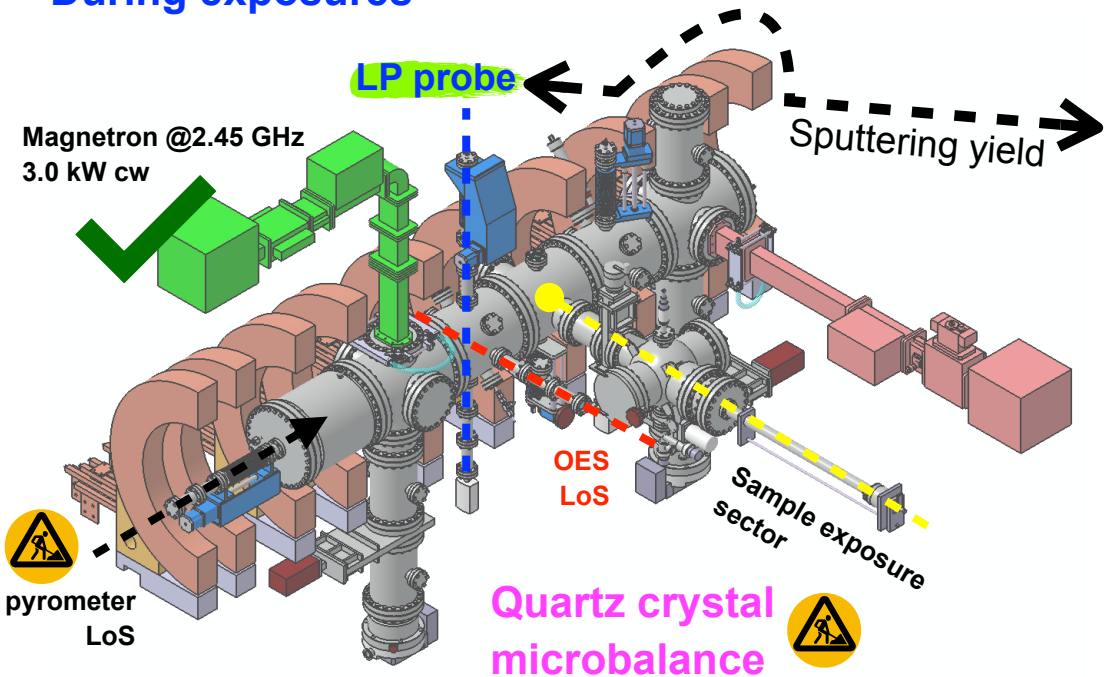
Dedicated exposures (one sample each), aim: Y_{WL} vs. Y_{OES} by using W S/XB data obtained with GyM in the frame of WP-PFC, SP 7.4

D2: Effective sputtering yields of W model systems with varying morphologies in pure and mixed plasmas in GyM

Plans for 2022 and beyond

Exposure of W model systems to D+He plasma for different [x%D_2, (1-x)%He], changing He^+ E_{kin} or fluence
+ for set of values of ions E_{kin} or fluence, D plasma exp. followed by He plasma exp. and vice versa

During exposures



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- Weighing → erosion
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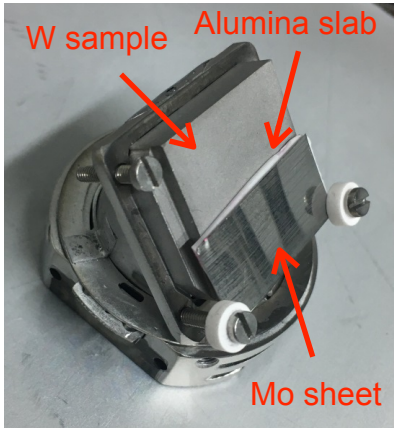
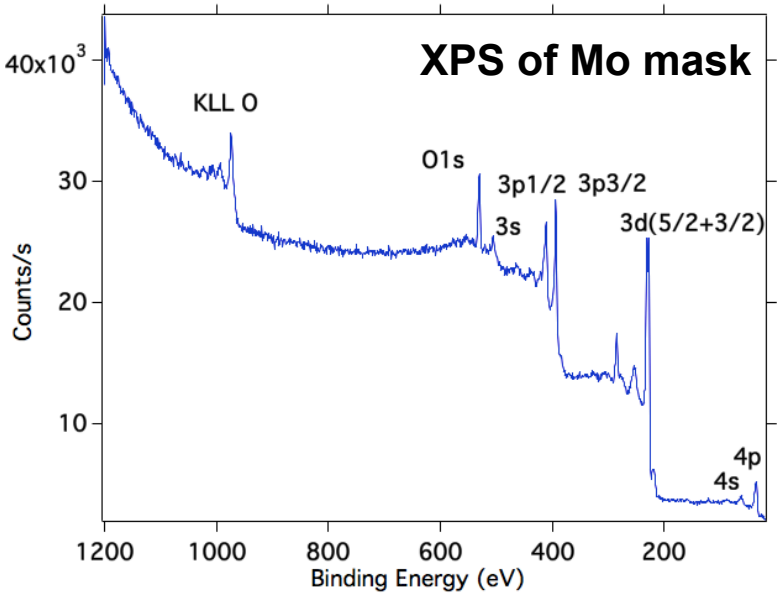
Same methodology

Thank you!

Evaluation of W re-deposition

- Exposure of W sample, partially masked with Mo sheet, to Ar plasma of GyM
- Sample biased to -400 V
- Mo sheet insulated from sample by alumina slab





- No traces of W
- O from impurities and oxidation of Mo mask

gross erosion (OES) ≅ net erosion (mass loss)