SP B.4 – Be Reference Layers Production in Support of PWI Studies / Coating Facility Update: B Containing Layers and Dust Production Capabilities

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EPPA

ELEMENTARY PROCESSES IN PLASMA AND APPLICATIONS GROUP

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Outline

Be-based coatings with pre-defined properties

Set-ups development and tuning

Production of Be reference coatings Nov 2021-June 2023

Sample analysis – XRD TDS and SEM at IAP

- IBA at RBI, XRD at NCSRD, TDS an JSI, etc..

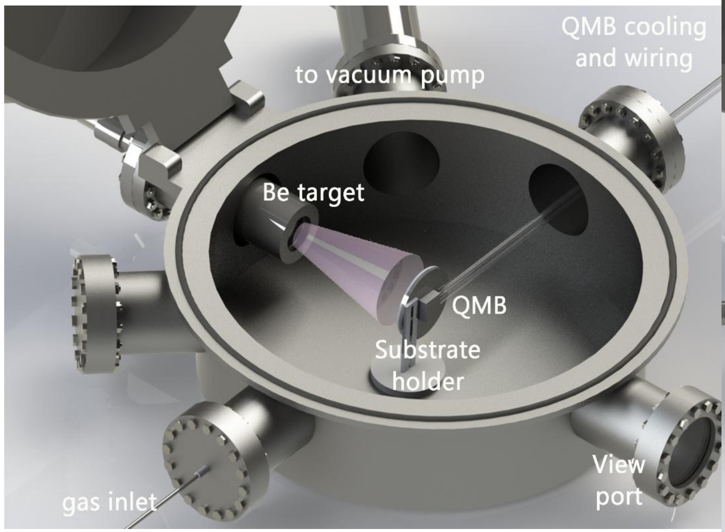
From Be/D to B/D and T experiments - BeHF upgrade to T facility

Boron coatings capabilities – with some preliminary results

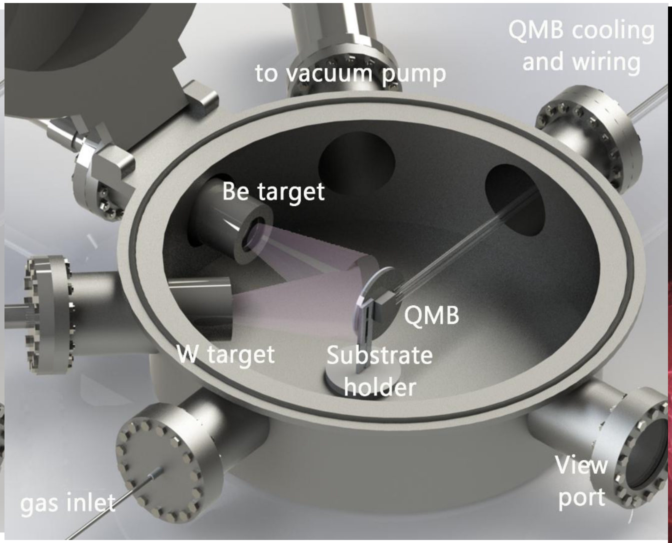
Other experimental capabilities

Future collaborations and plans

Be-based coatings with pre-defined properties



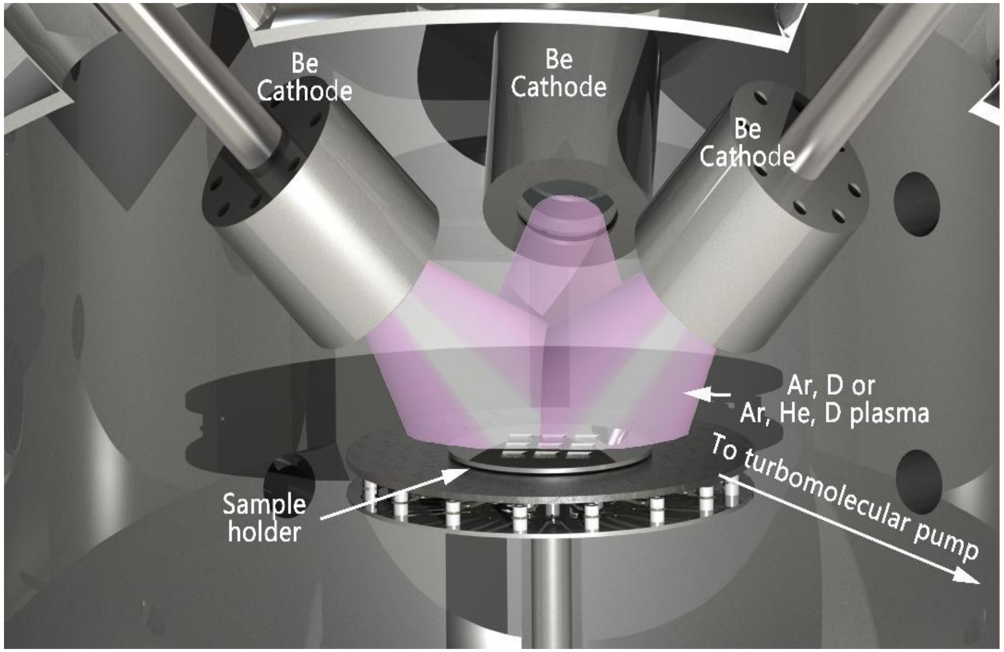
Schematic description of the coating system used for Be-D (Ne, N, He) layer deposition



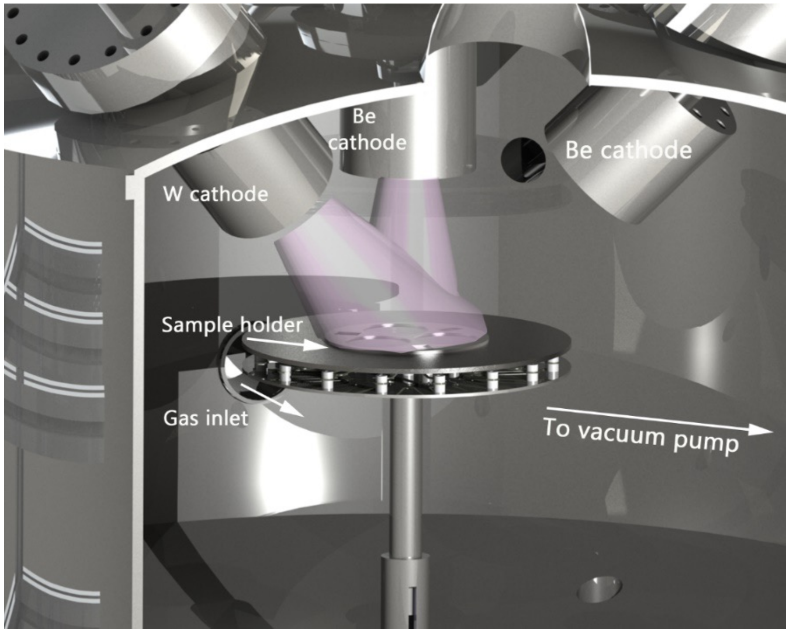
Deposition system used for obtaining Be(-W)-D/H/etc layers

Ignited W and Be MS Plasmas under D/Ar atmophere

Be-based coatings with pre-defined properties

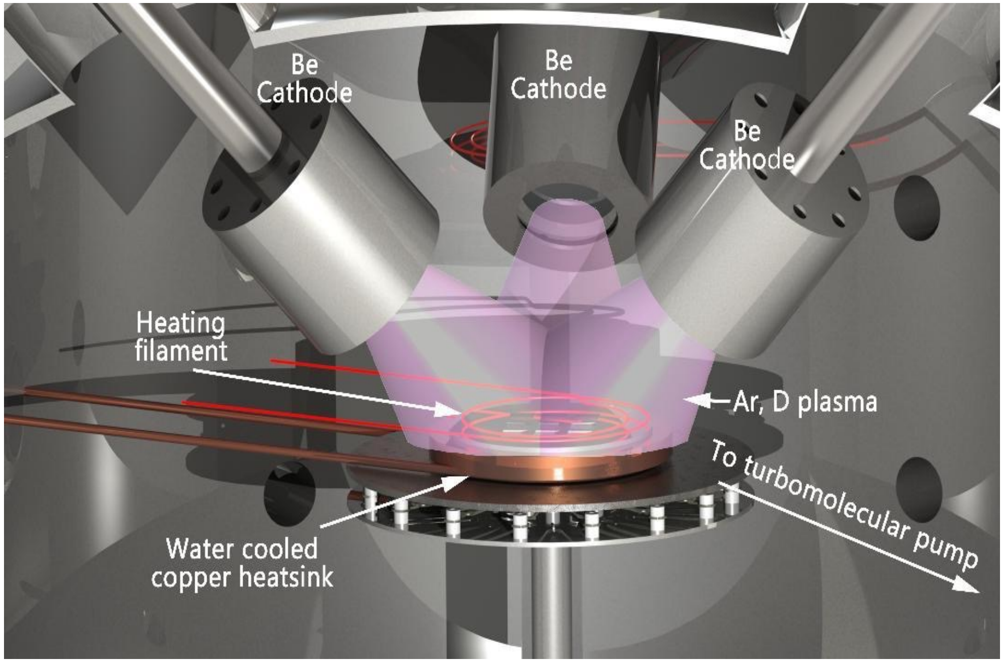


Schematic description of the coating system used for Be-D (H, O)) layer deposition

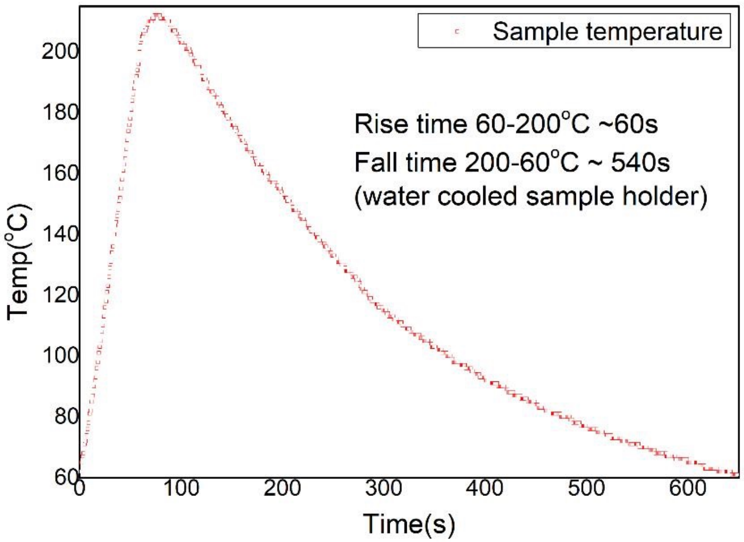


Deposition system used for obtaining Be(-C, W, etc.)-D/H/O/etc layers

Upgraded Be coating set-up for JET-like Pulses
Be-D/Be-H sample production for the EUROFusion Project



Schematic description of the coating system used for Be-D/Be-H (4:1 at ratio) layer deposition

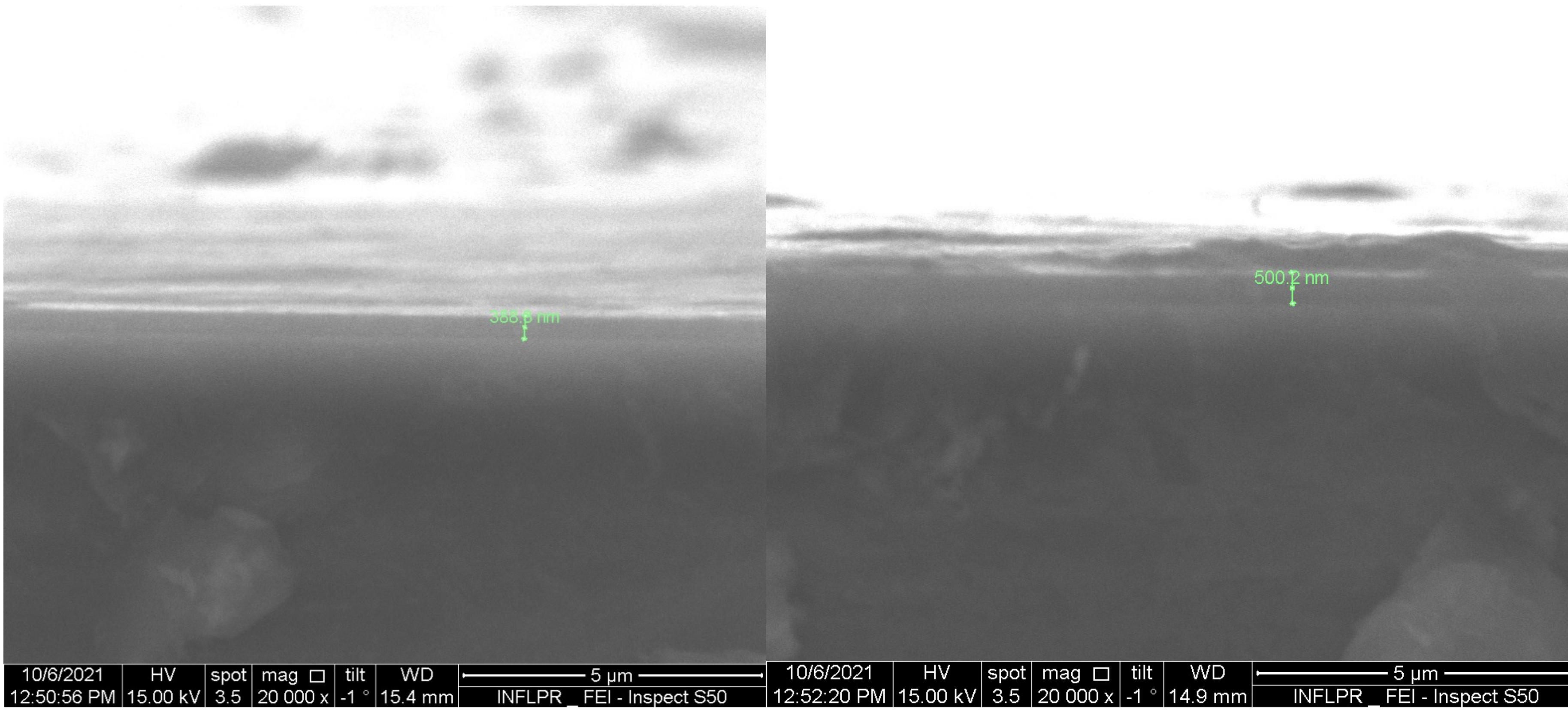


Heat ramp during the coating for a JET Like pulse simulation

Sample requirements under the SPB4 Production of Be containing coatings : 2021-2023

1. **Nov. 2021**: Be with D or H ~20%, 5 microns thick – 110 samples in total, thermally treated
2. **Nov 2021**: Be 20 microns layer, no gas,;, R.T. and 200 C during deposition: 12 Samples
3. **Feb 2022**: Be+O+D (5, 10 and 20 D at%) – 16 samples
4. **Iune 2022**: Be+D (10 D at%) 4 different temperatures: - 44 samples
5. **July 2023:** Be O D and Be O H, ~20%, 5 microns thick – 192 samples in total, thermally treated

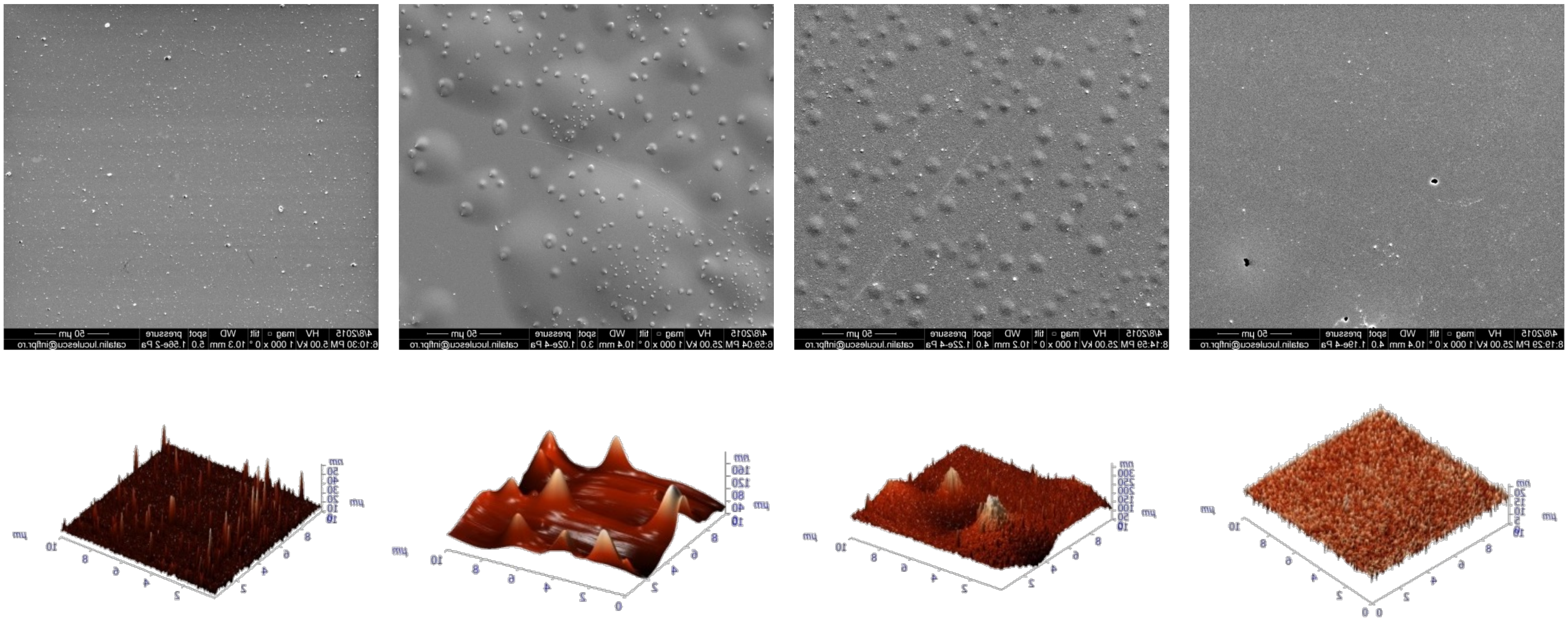
Production of Be-based coatings - pre-characterization of the samples



SEM images for Be co-depositions on Si substrate – thickness calibration

Production of Be-based coatings - pre-characterization of the samples

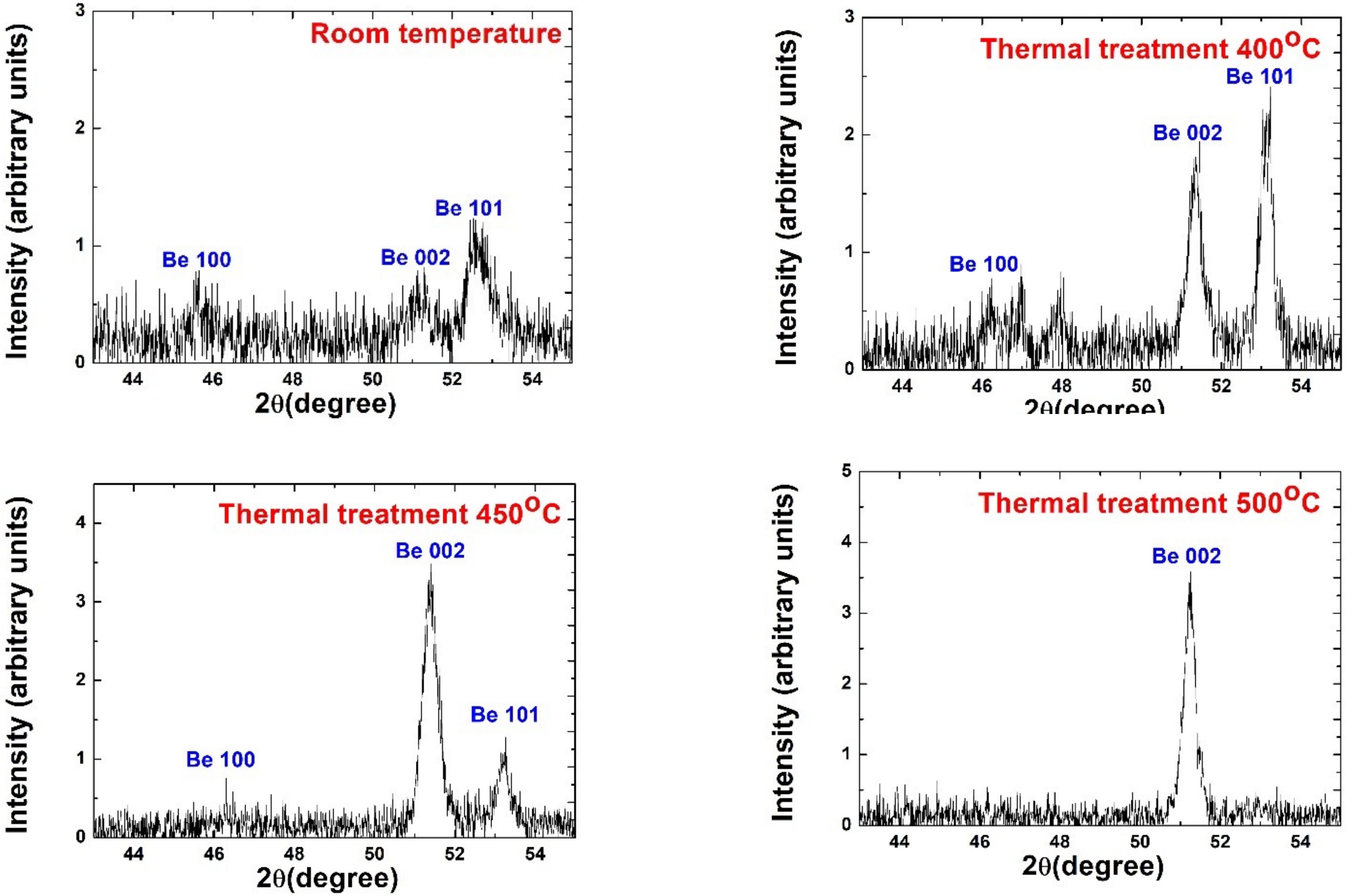
Be-D | W-D | Be-W-D | Be-W-D-N



SEM and AFM 3D images for
Be-D, W-D, Be-W-D and Be-W-D-N

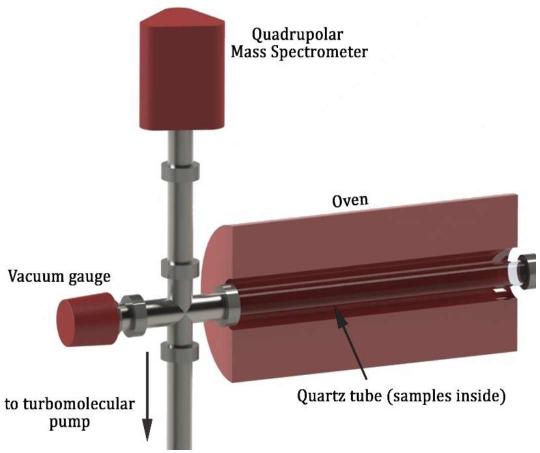
Production of Be-based coatings - pre-characterization of the samples

XRD Measurements

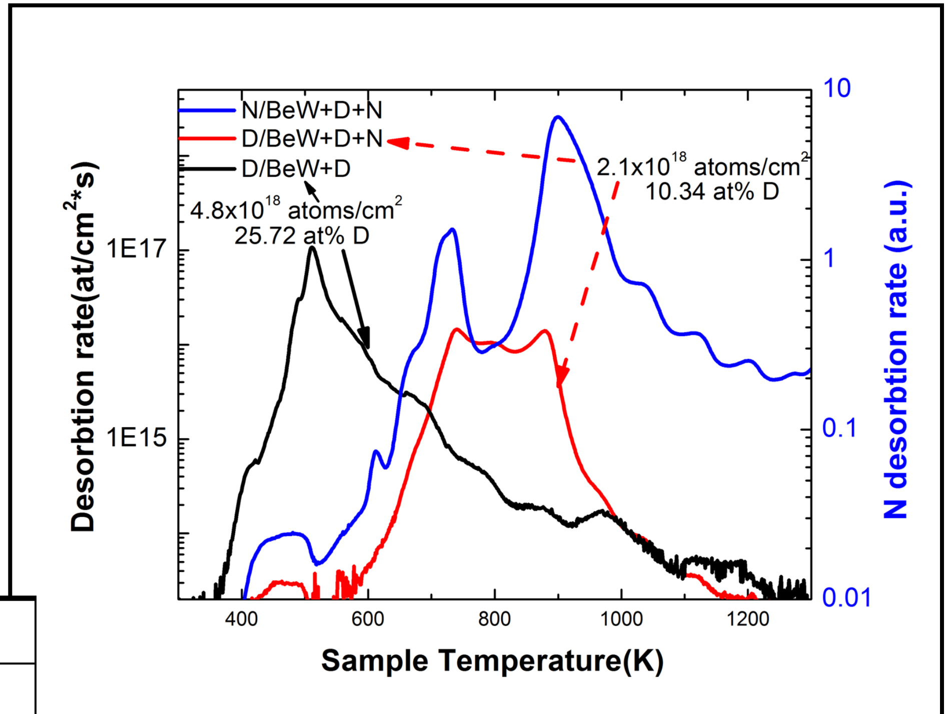


Production of Be-based coatings - pre-characterization of the samples

TDS Measurements



Experimental setup for TDS measurements



D release measured using TDS		
Sample	**D** **10^{17} cm^{-2}**	**D** **(%)**
W + D/Si	1.82	9.20
BeW + D/Si	1.39	3.93
BeW + D + N/Si	2.88	6.00
BeW + D/Mo	477	25.72
BeW + D + N/Mo	213	10.34

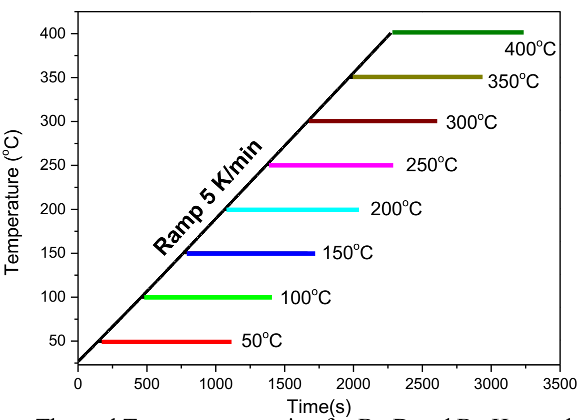
D and N release measured using TDS of mixed Be-W-D and Be-W-D-N films deposited on silicon

SPB 4: Production of reference coatings 2021-2022:

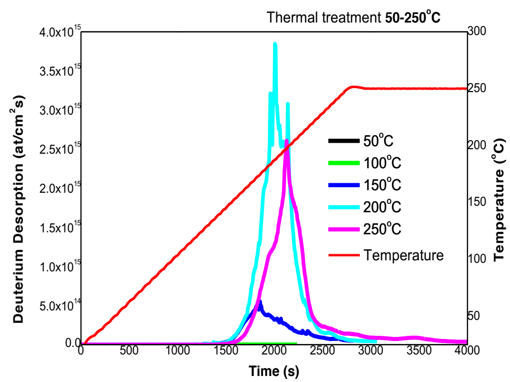
Be-based reference coatings:

- Be with D and H ~20%, 5 microns thick – 110 samples in total, thermally treated
- Be 20 microns layer, no gas; R.T. and 200 C during deposition: 12 Samples

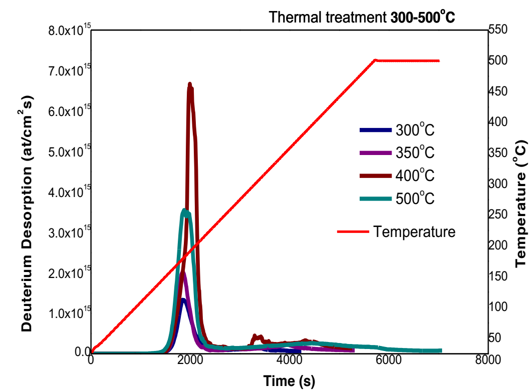
Thermal treatment and TDS Results:



Thermal Treatment operation for Be-D and Be-H sample



Deuterium release from Be-D layers on W substrates



Deuterium release from Be-D layers on tungsten substrates

XRD, TDS, SEM measurements were performed in order to have preliminary information on samples structure and morphology.

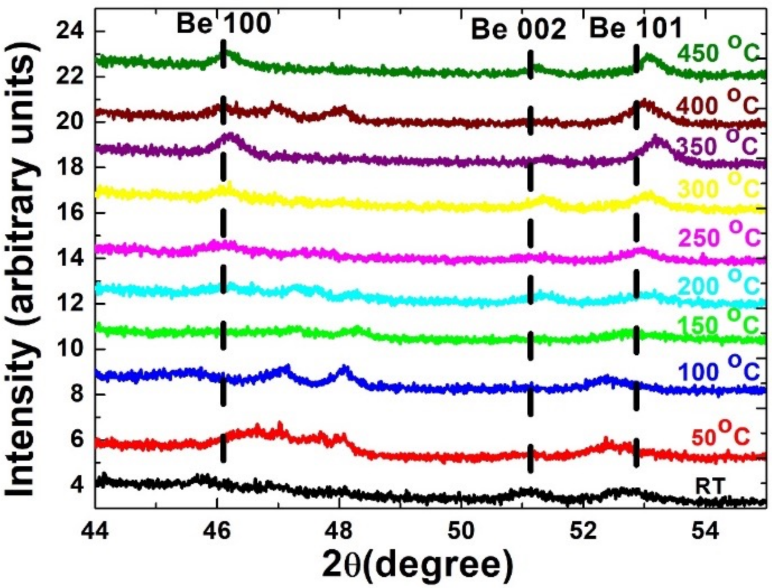
1. **Nov. 2021** :Be with D or H ~20%, 5 microns thick – 110 samples in total, thermally treated
2. **Nov 2021**: Be 20 microns layer, no gas,;, R.T. and 200 C during deposition: 12 samples
3. **Feb 2022**: Be+O+D (5, 10 and 20 D at%) – 16 samples
4. **Iune 2022**: Be+D (10 D at%) 4 different temperatures: - 44 samples.

All the samples were shipped, analysis finished.

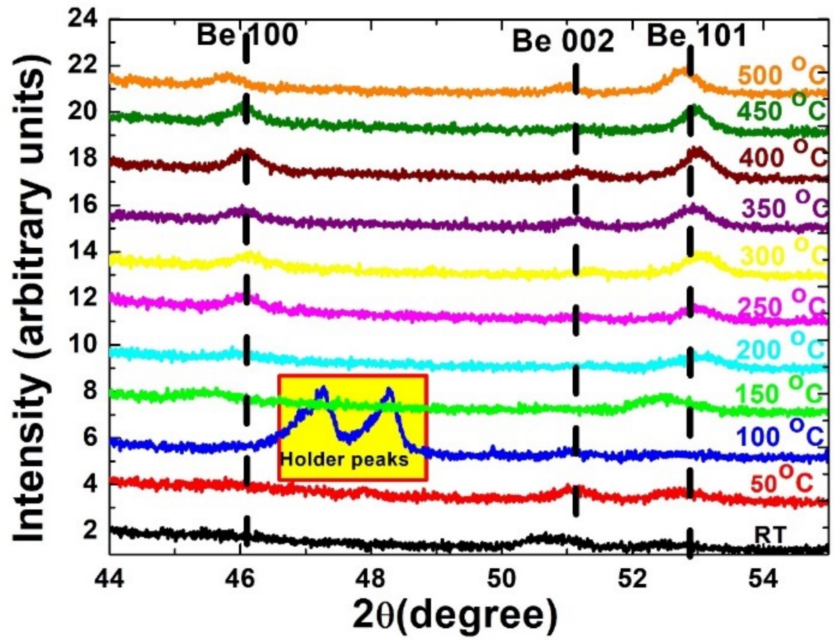
SPB 4: Production of Be reference coatings:

Be with D and H ~20%, 5 microns thick – 110 samples in total, thermally treated

XRD *measurements*



Be-D diffraction curves

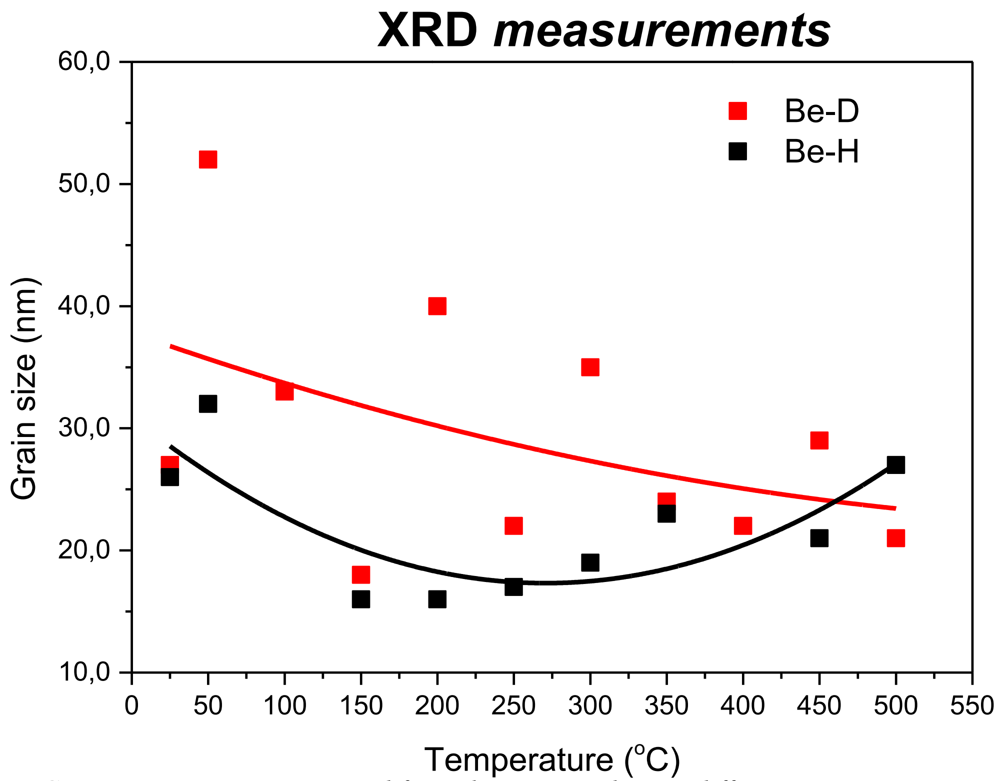


Be-H diffraction curves

- Shift (0.4°) of the 101 peak -> higher angles for T. T. samples > 300°C. =>Tensile stress
- Source of the tensile stress => coating process, released during the T. T..
- Grainsize: 18 to 52 nm with a decrease with T. T. temperature increase. Exception at 50 °C for Be-D sample.
- Corroborates with Raman measurements

SPB 4: Production of Be reference coatings:

Be with D and H ~20%, 5 microns thick – 110 samples in total, thermally treated



Grain size variation extracted from the Be-D and Be-H diffraction curves

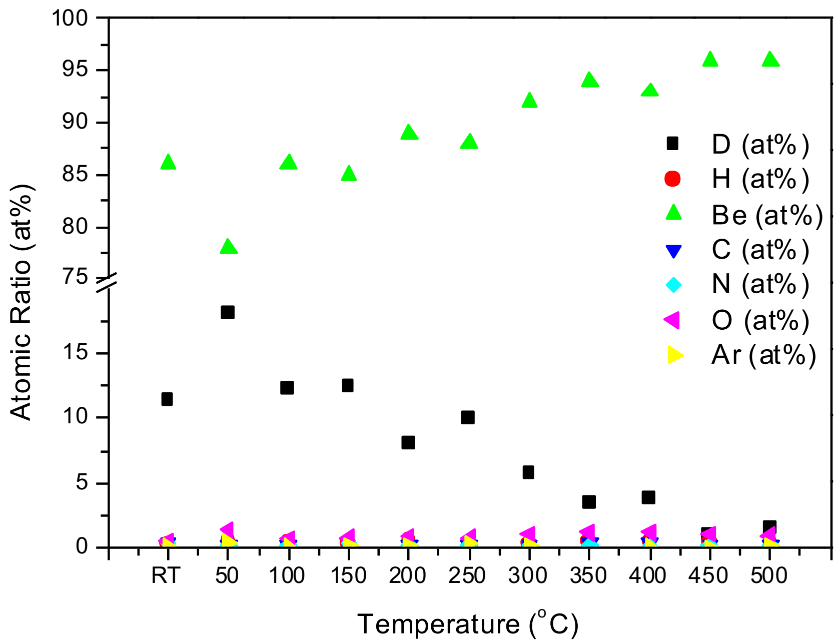
- Shift (0.4°) of the 101 peak -> higher angles for T. T. samples > 300°C. =>Tensile stress
- Source of the tensile stress => coating process, released during the T. T..
- Grainsize: 18 to 52 nm with a decrease with T. T. temperature increase. Exception at 50 °C for Be-D sample.
- Corroborates with Raman measurements done

SPB 4: Production of Be reference coatings:

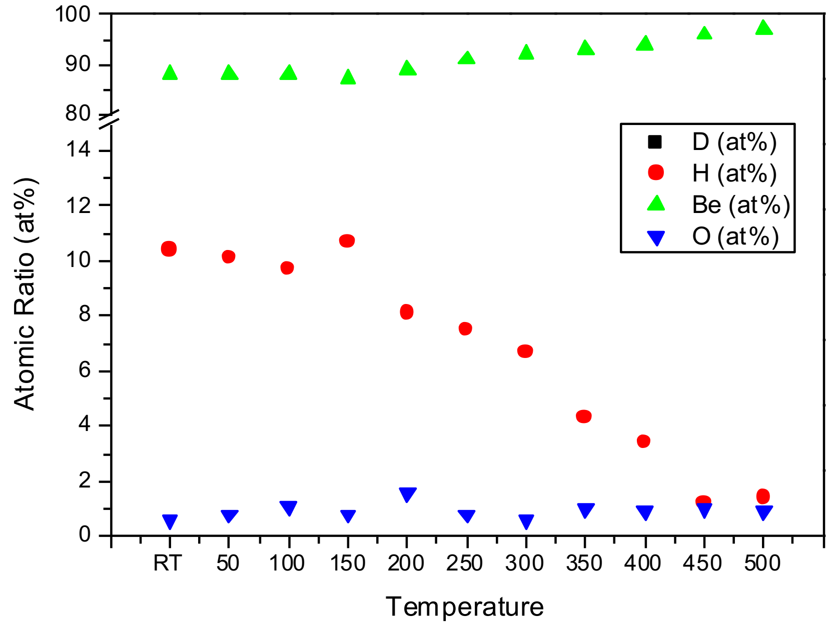
Be with D and H ~20%, 5 microns thick – 110 samples in total, thermally treated

HIERDA measurements

Performed at RBI (Many thanks to Iva Bogdabovici)



Be-D diffraction curves an depth profiles fom HIERDA



Be-H depth profiles from HIERDA

- D or H ratio drop with the T. T. temperature
- Oxygen below 1 %
- ~10 % H isotope at room temperature
- No other impurities => High quality confirmation of the coatings

SPB 4: Production of Be reference coatings:

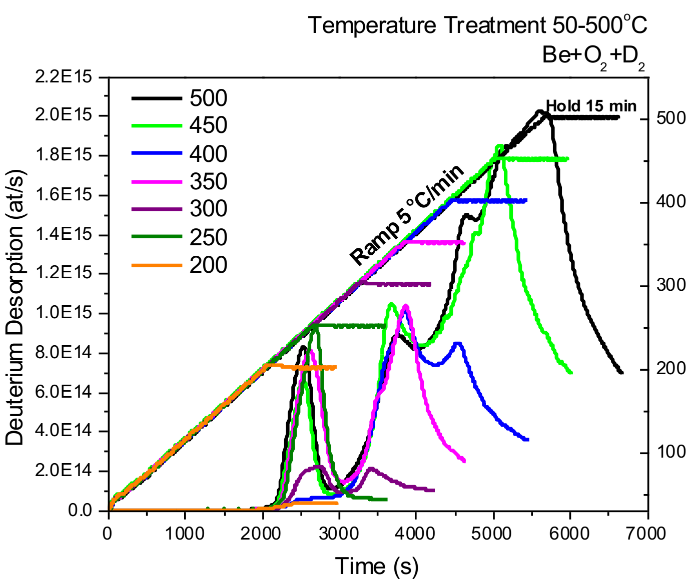
Samples produced in 2023

1. May 2022: Be+O+H – 186 samples; **May 2022**: Be+O+D - 186 samples

2. June 2023 – Thermal treatment up to 500°C, 50°C step, 15 minutes hold

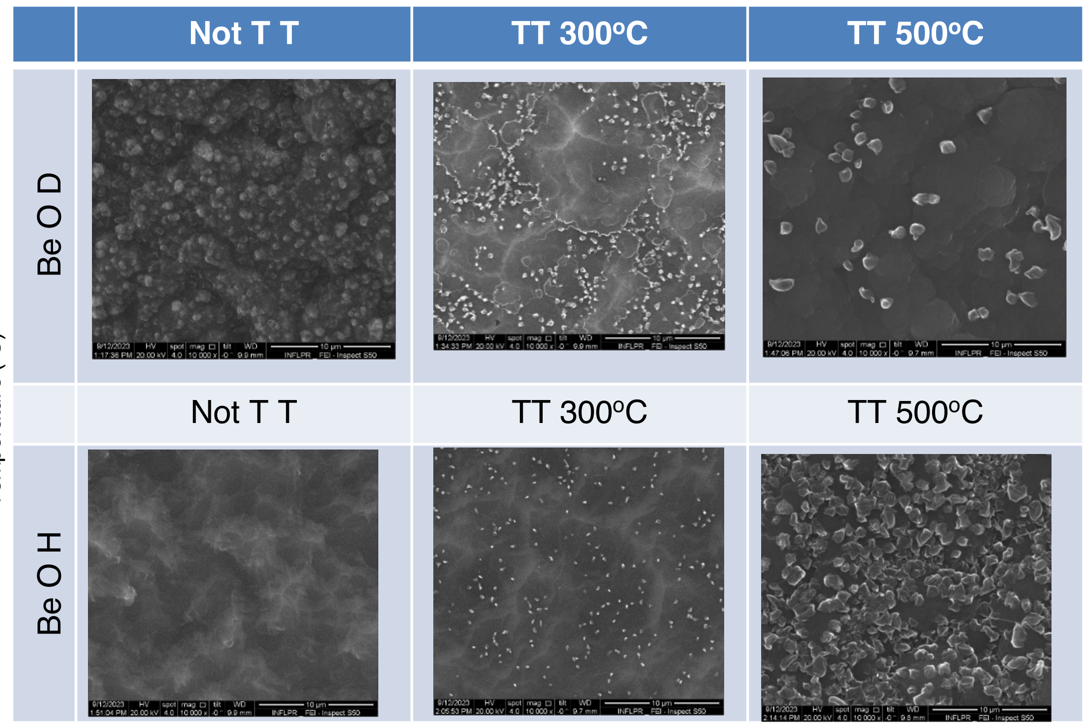
XRD, TDS, SEM measurements were performed in order to have preliminary information on samples structure and morphology.

Thermal treatment and TDS during the treatment



Thermal Treatment operation for Be-O- D samples

SEM images aquired after the thermal treatment

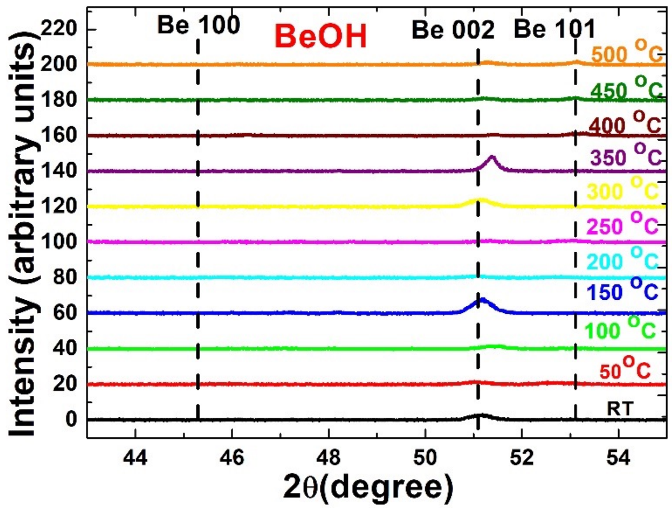


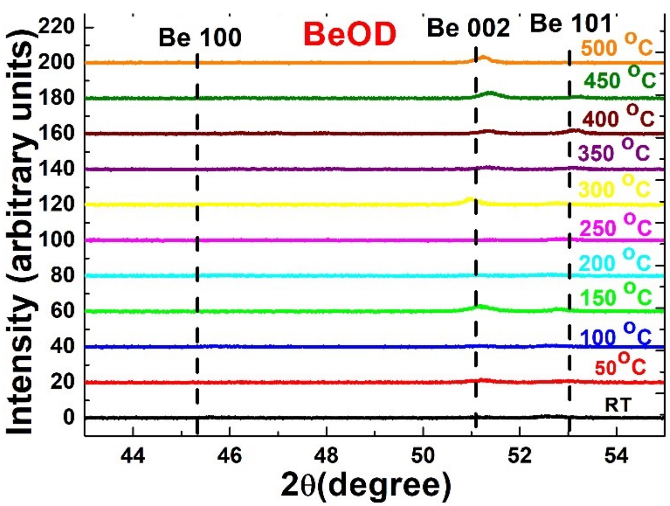
Grain formation starts at 250°C. More intense for H containing BeO layers

SPB 4: Production of Be reference coatings:

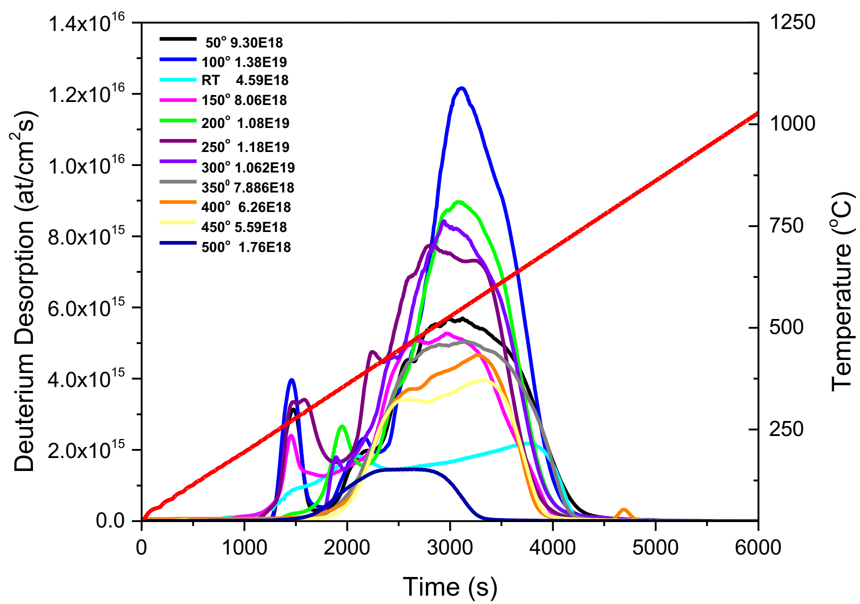
XRD and TDS results

XRD was performed an all types of samples an presented below.





TDS measurements finished



XRD and TDS data are available and interpreted.

A comparison betwen no O containing samples from 2022 and the ones just produced **is necessary** and will be performed.

Summary of Be containing reference samples production

Samples requirements for PWIE SP B 4 and production status:

1. **Nov. 2021**: Be with D or H ~20%, 5 microns thick – 110 samples in total, thermally treated
2. **Nov 2021**: Be 20 microns layer, no gas,;, R.T. and 200 C during deposition: 12 Samples
3. **Feb 2022**: Be+O+D (5, 10 and 20 D at%) – 16 samples
4. **Iune 2022**: Be+D (10 D at%) 4 different temperatures: - 44 samples
5. **July 2023:** Be O D and Be O H, ~20%, 5 microns thick – 192 samples in total, thermally treated

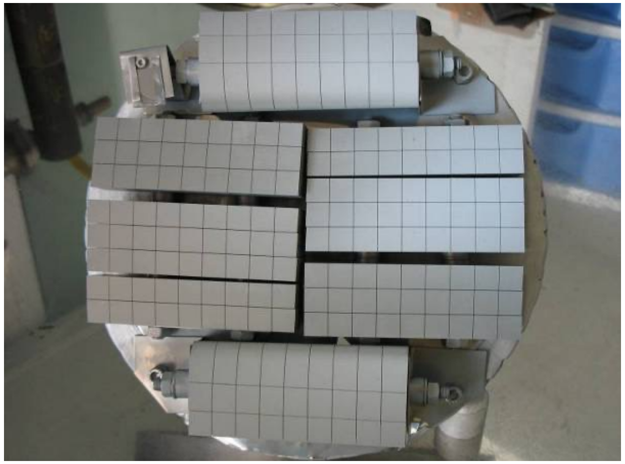
Pre-characterization before sample delivery:

XRD, TDS, SEM measurements were performed in order to have preliminary information on samples structure and morphology.
Alongside with IBA and Raman – measurements certified the samples high quality

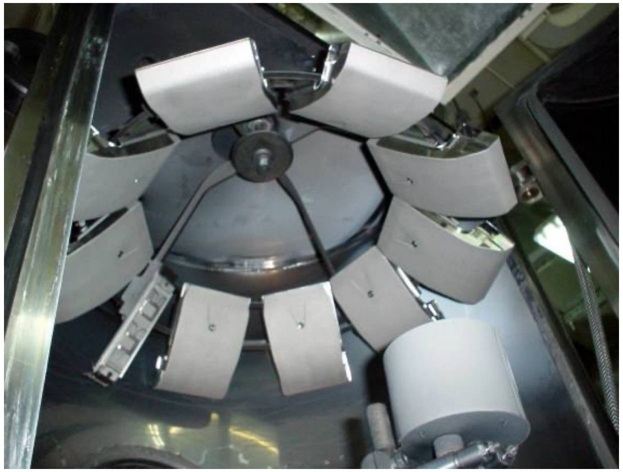
Consistent database on D retention and release for Be containing co-deposited layers

We need to include results on 2023 samples : thermal treated O containing BeD and BeH layers. We are collecting data.
Discussions are underway to resolve some results discrepancies.

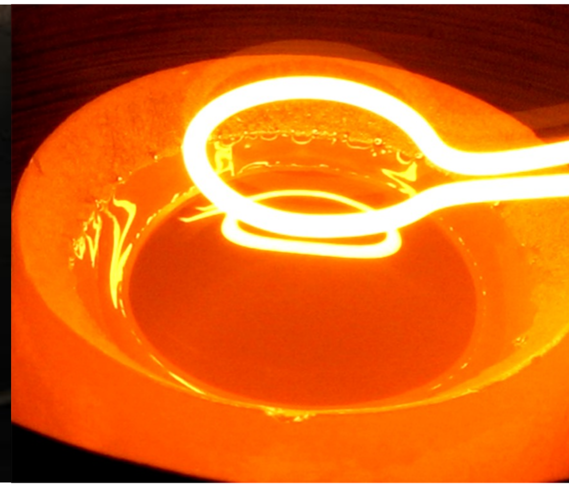
From Be/D to B/D and T experiments

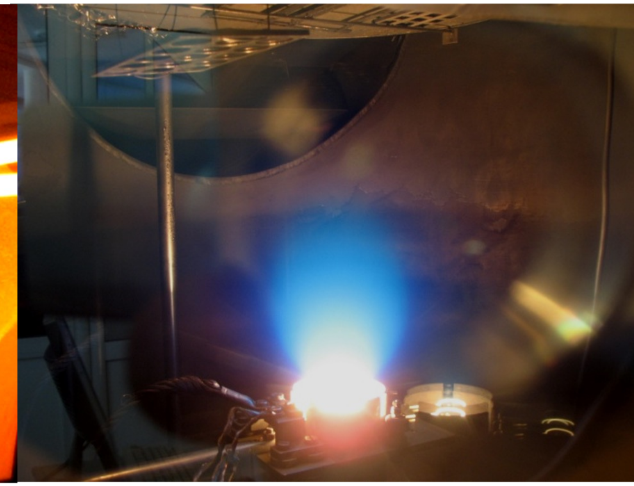


EPPA



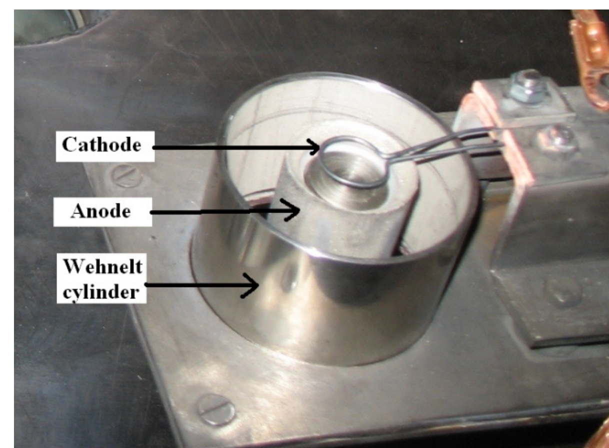
From Be/D to B/D and T experiments



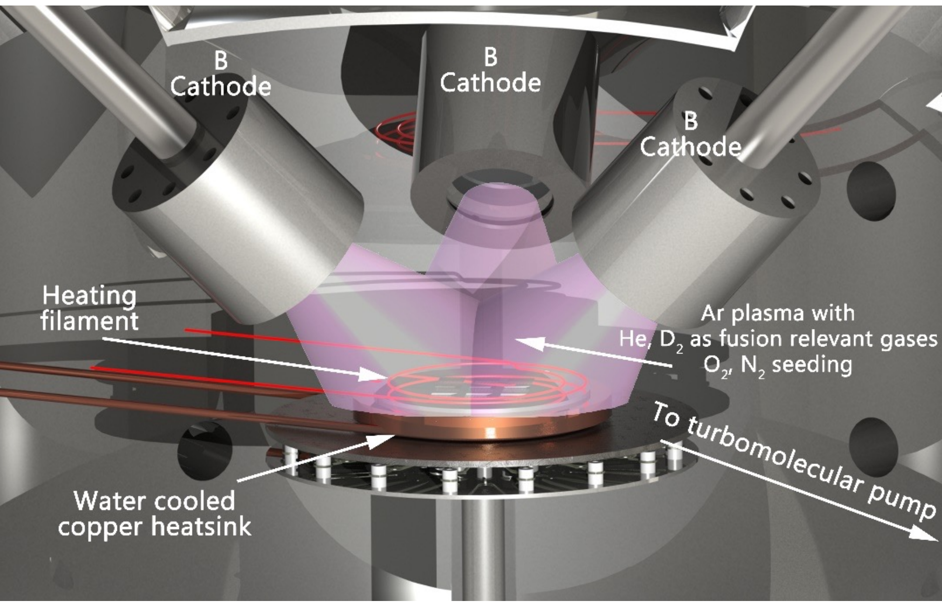


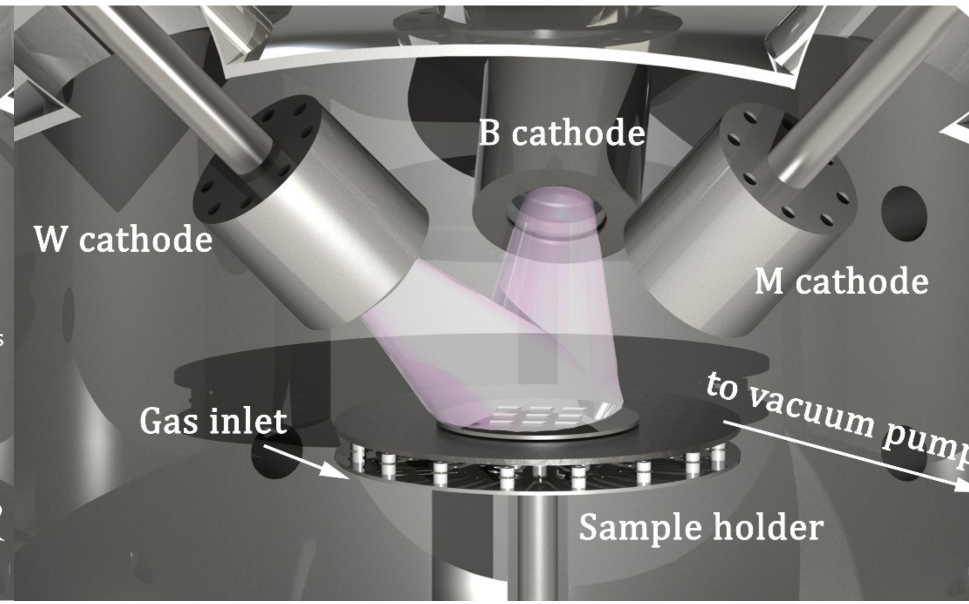
Boron coatings were succesfully performed in the past (2009). Pure 50 microns layers

5 microns more realistic maximum thickness target
Suitable for large coating surfaces (up to 600mm diameter.



From Be/D to B/D and T experiments





Schematic description of the coating system used for ***B****-D (H, O)) layer deposition*

Deposition system used for obtaining ***B*** *(-C, W, etc.)-D/H/O/etc layers*

Prospects for studying B layers – Preliminary results

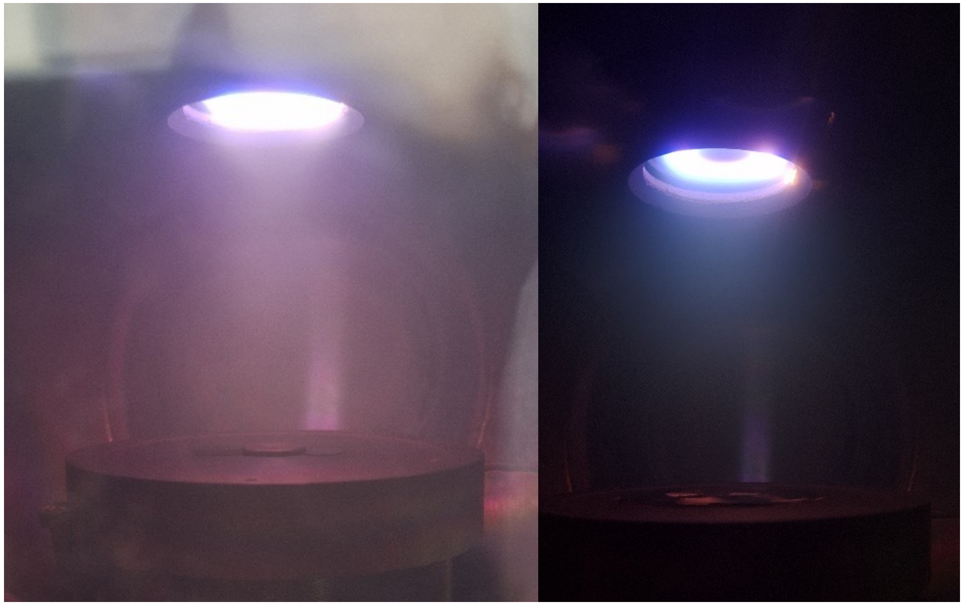
Deuterium release behavior from B-D layers in varying working conditions

Sample Preparation

- Boron target
- Ar+D_2 mixt gas
- Magnetron sputtering in radio frequency mode
- Desired thickness of 500 nm
- Working parameter varied:
  - Pressure
  - Gas flow
  - Substrates temperature
  - BIAS voltage applied on substrates

RF MS plasma

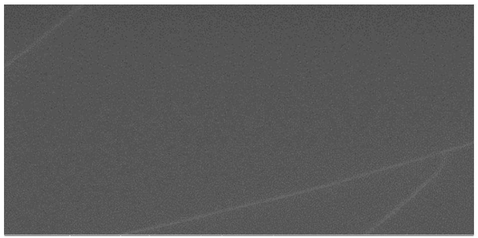
HiPIMS plasma



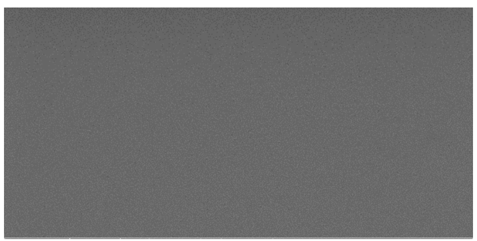
Deuterium release behavior from B-D layers in varying working conditions

SEM Measurements

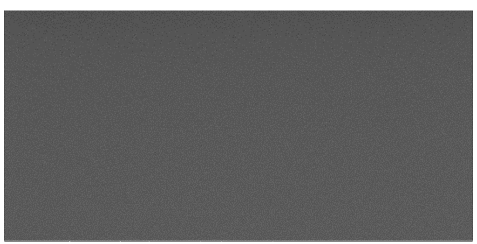
- **Deuterium flux variation:**



a. Ar:D=5:1

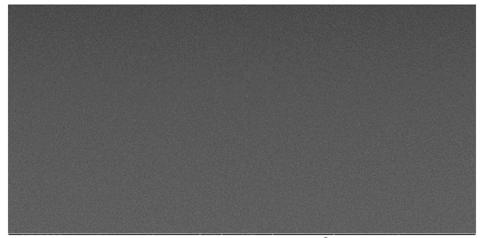


b. Ar:D=2:1

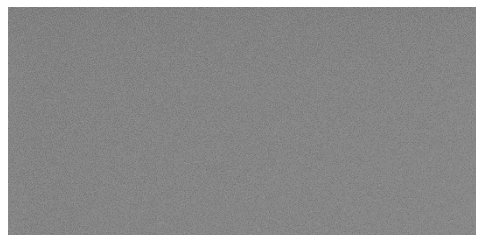


c. Ar:D=1:1

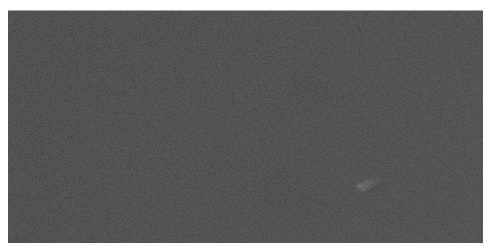
- **Pressure variation:**



a. $8*10^{-3}$mbar

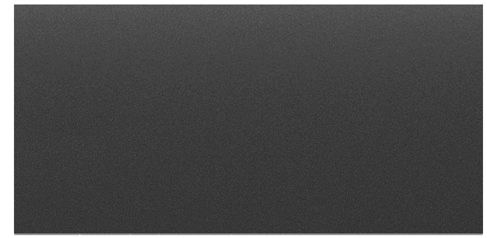


b. $3*10^{-2}$mbar

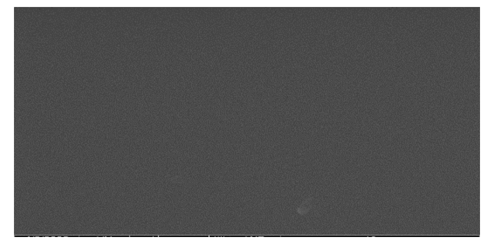


c. $8*10^{-2}$mbar

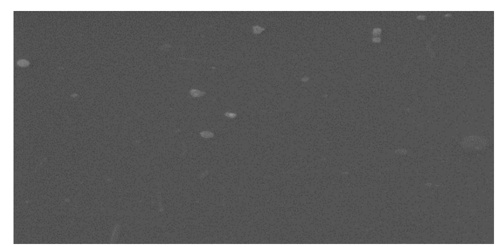
- **BIAS applied on substrates variation:**



a. 30V



b. 60V

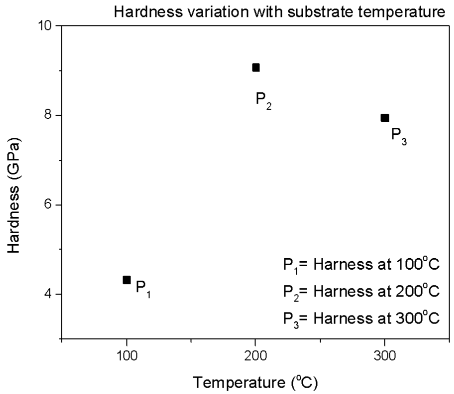


c. 100V

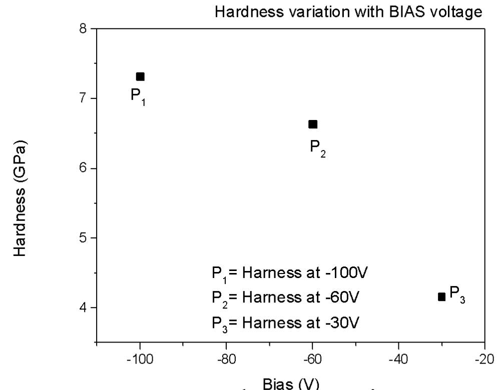
Prospects for studying B layers – Preliminary results

Deuterium release behavior from B-D layers in varying working conditions

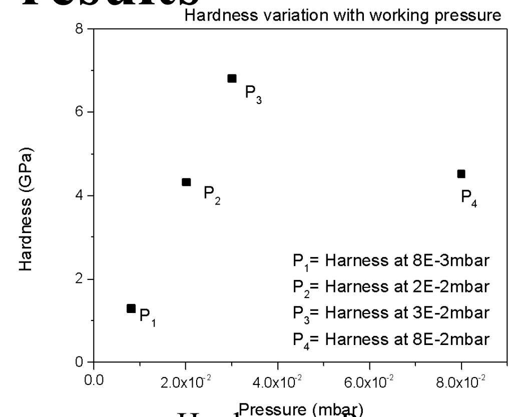
Nanoindentation and TDS results



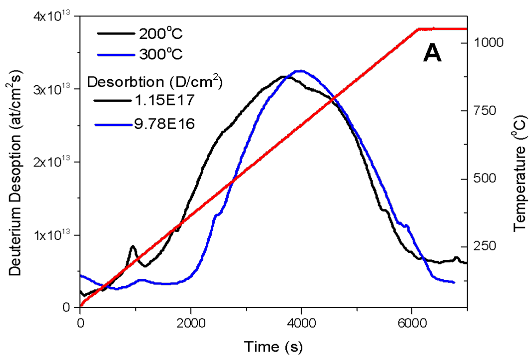
Hardness vs Temperature

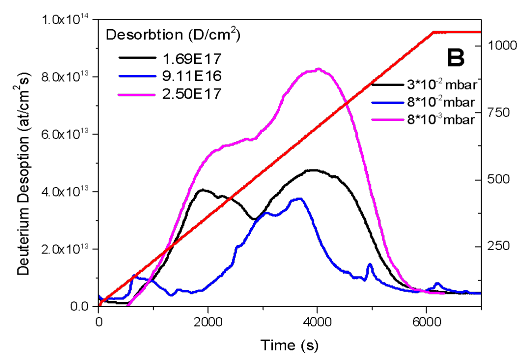


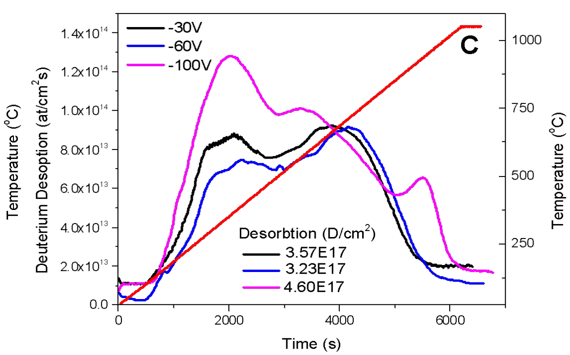
Hardness vs Bias



Hardness vs Pressure







- We performed the study on 500nm B-D co-deposited layers by RF - MS.
- SEM images shows that the sample surface is free of roughness.
- Hardness is affected by the deposition condition. The highest value (9GPa) was obtained at the temperature of 200°C.
- TDS measurements determined a strong relationship between deposition conditions and the total amount of deuterium released from the samples.

Prospects for studying B layers – Preliminary results

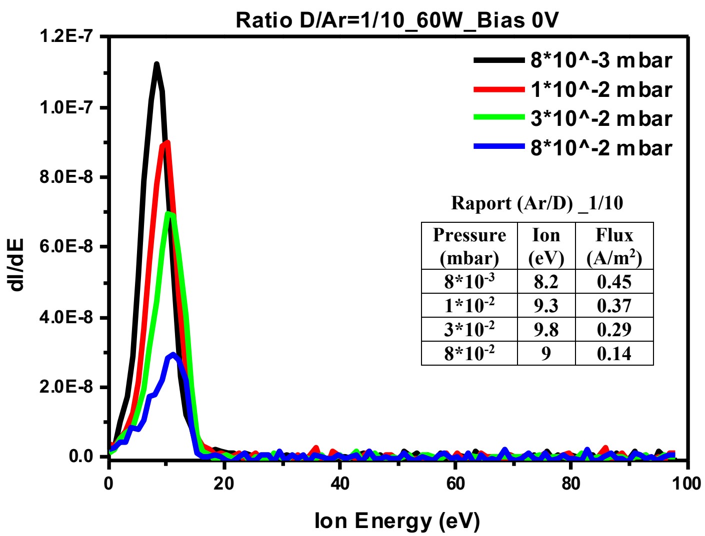
Deuterium release behavior from B-D layers in varying working conditions

Deuterium trapped inside the samples during the coating process

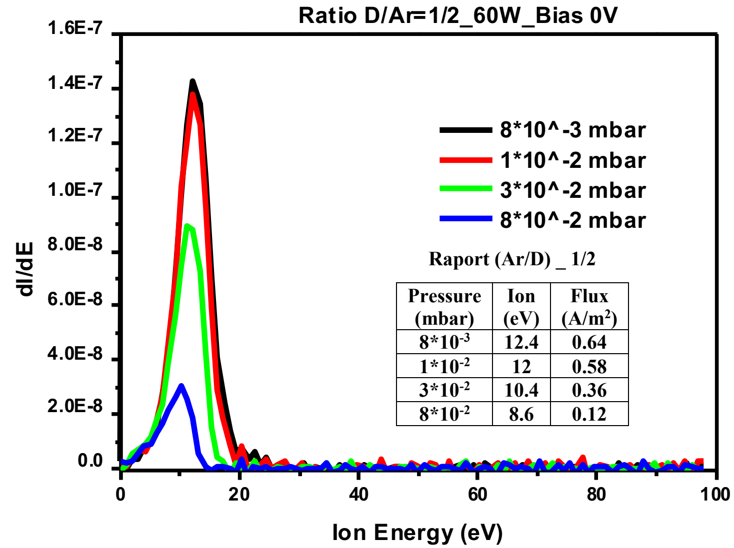
Deposition Conditions	D_2:Ar (ratio)	Pressure (mbar)	Temperature (°C)	Bias (V)	D ratio normate la dimensiune cross
D_2:Ar (ratio)	1:10	$1x10^{-2}$	Room Temperature	0V	4,1%
	1:5				-
	1:2				4,76%
	1:1				**8,59%**
Pressure (mbar)	1:1	$8x10^{-3}$	Room Temperature	0V	3%
		$3x10^{-2}$			4%
		$8x10^{-2}$			**1,4%**
Temperature (°C)	1:1	$1x10^{-2}$	200°C	0V	1,74%
			300°C		1,8%
Bias (V)	1:1	$1x10^{-2}$	Room Temperature	-30V	3,88%
				-60V	4,94%
				-100V	6,61%

Ion energy measurements for B-Ar-D MS plasma

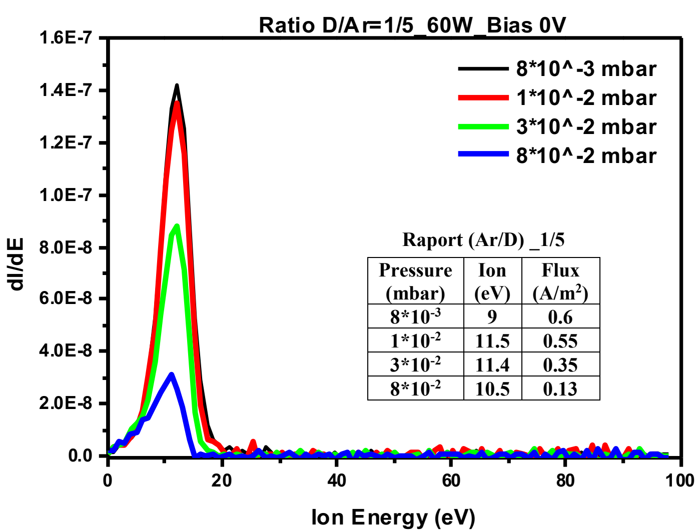
B+Ar+D, P=60W, D:Ar=from 1/10 to 1/1, pressure varried



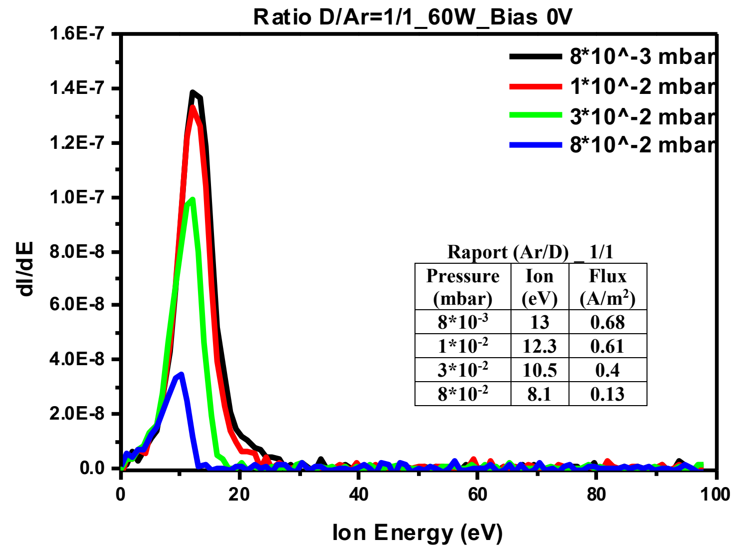
Pressure (mbar)	Ion (eV)	Flux (A/m^2)
$8*10^{-3}$	8.2	0.45
$1*10^{-2}$	9.3	0.37
$3*10^{-2}$	9.8	0.29
$8*10^{-2}$	9	0.14



Pressure (mbar)	Ion (eV)	Flux (A/m^2)
$8*10^{-3}$	12.4	0.64
$1*10^{-2}$	12	0.58
$3*10^{-2}$	10.4	0.36
$8*10^{-2}$	8.6	0.12



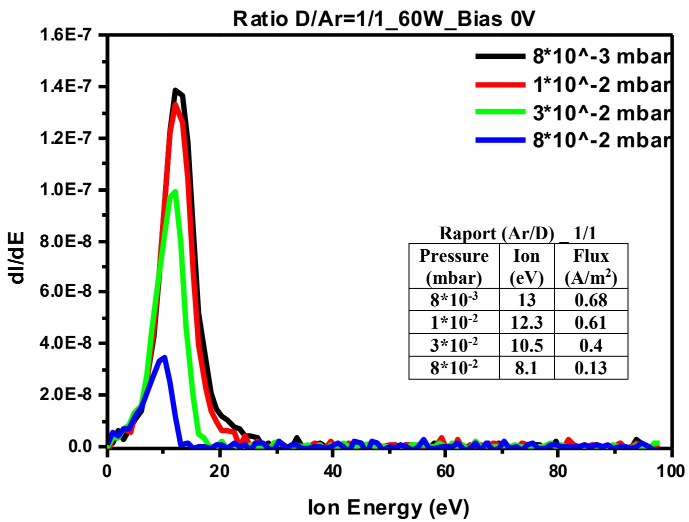
Pressure (mbar)	Ion (eV)	Flux (A/m^2)
$8*10^{-3}$	9	0.6
$1*10^{-2}$	11.5	0.55
$3*10^{-2}$	11.4	0.35
$8*10^{-2}$	10.5	0.13

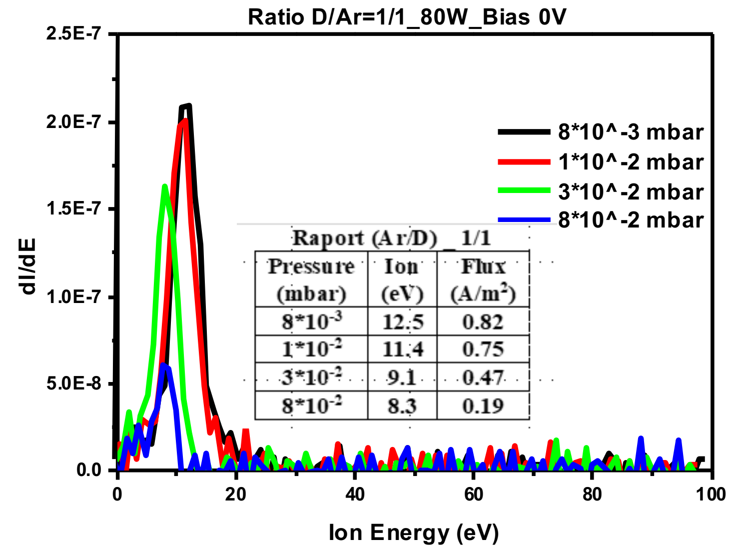


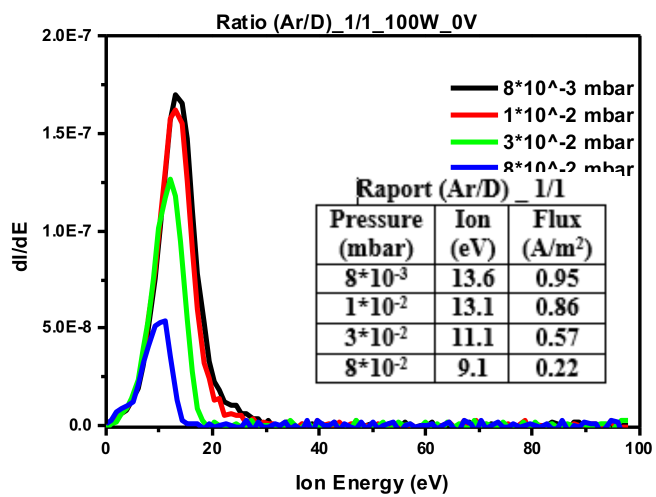
Pressure (mbar)	Ion (eV)	Flux (A/m^2)
$8*10^{-3}$	13	0.68
$1*10^{-2}$	12.3	0.61
$3*10^{-2}$	10.5	0.4
$8*10^{-2}$	8.1	0.13

Ion energy measurements for B-Ar-D MS plasma

B+Ar+D, P=30, 60, 100 W, D:Ar=from 1/10 to 1/1, pressure varried

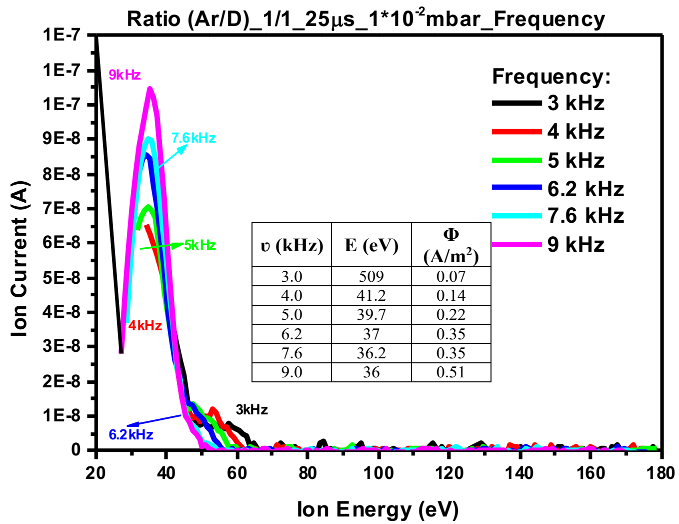




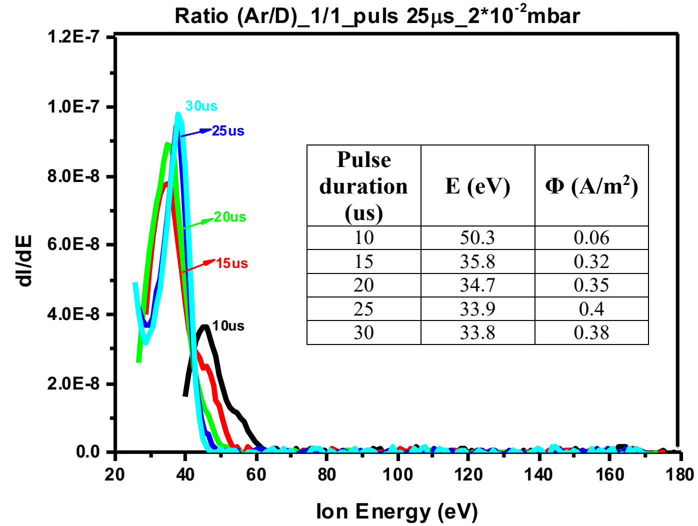


Ion energy measurements for B-Ar-D MS plasma

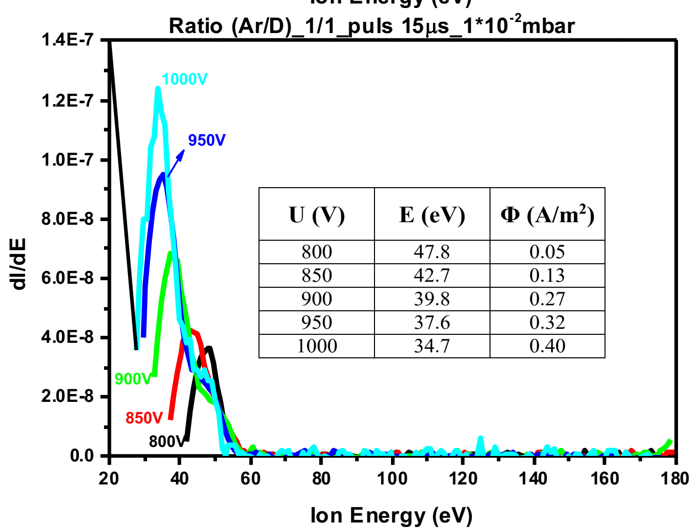
B+Ar+D, Ar/D: 1/1, HiPIMS MP, Frequency varried



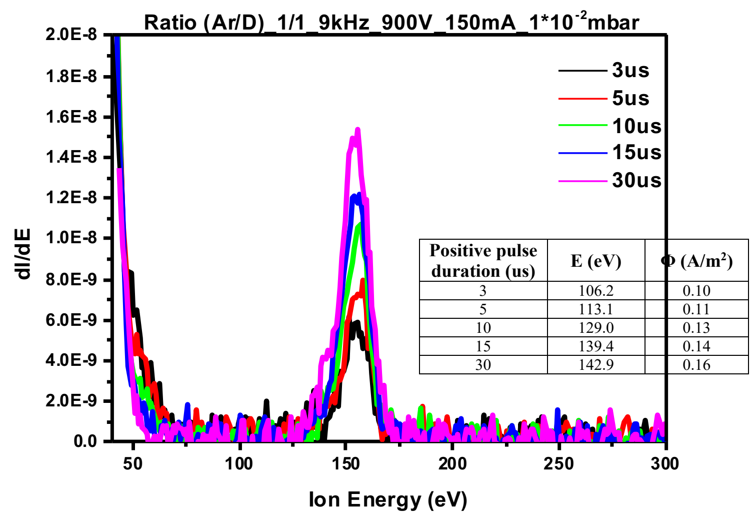
υ (kHz)	E (eV)	Φ (A/m^2)
3.0	509	0.07
4.0	41.2	0.14
5.0	39.7	0.22
6.2	37	0.35
7.6	36.2	0.35
9.0	36	0.51



Pulse duration (us)	E (eV)	Φ (A/m^2)
10	50.3	0.06
15	35.8	0.32
20	34.7	0.35
25	33.9	0.4
30	33.8	0.38



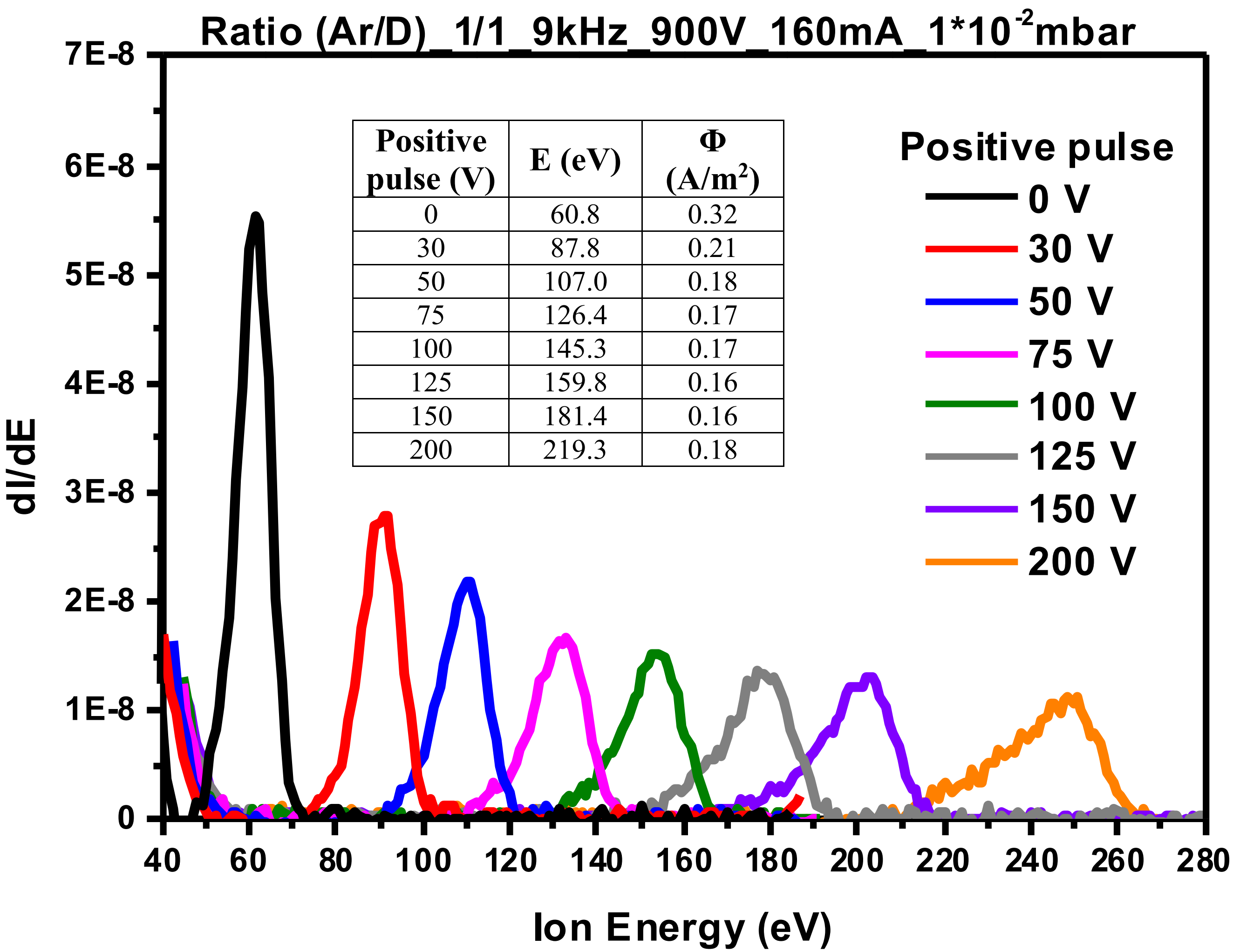
U (V)	E (eV)	Φ (A/m^2)
800	47.8	0.05
850	42.7	0.13
900	39.8	0.27
950	37.6	0.32
1000	34.7	0.40



Positive pulse duration (us)	E (eV)	Φ (A/m^2)
3	106.2	0.10
5	113.1	0.11
10	129.0	0.13
15	139.4	0.14
30	142.9	0.16

Ion energy measurements for B-Ar-D MS plasma

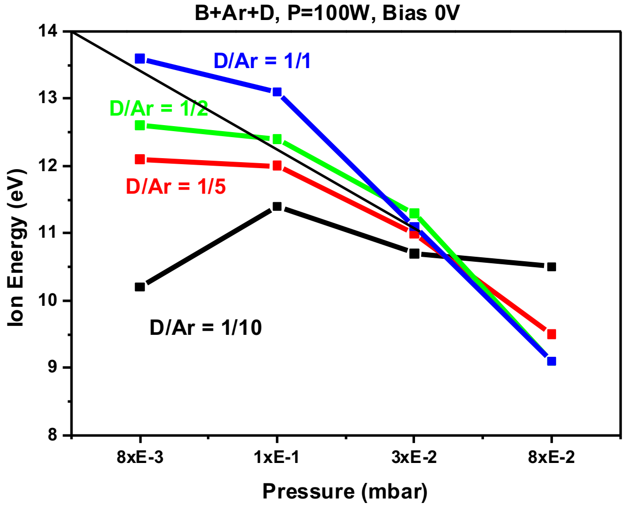
B+Ar+D, Ar/D: 1/1, p=1xE-2, HiPIMS BP, Positive pulse varried

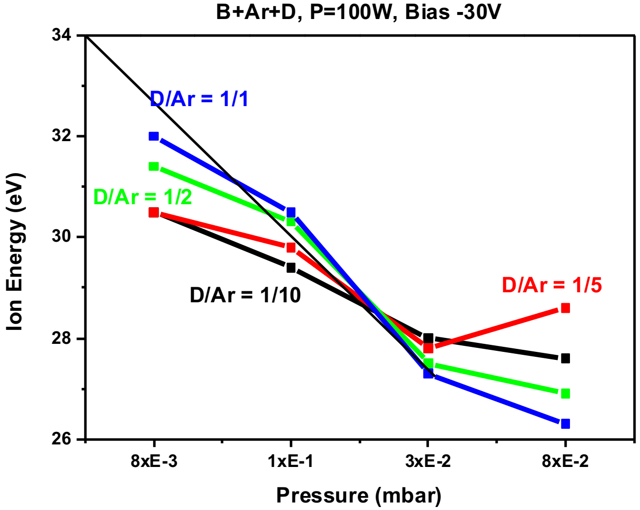


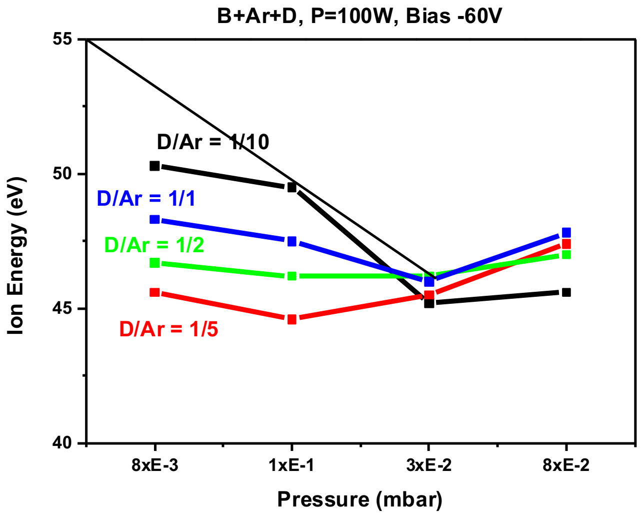
Positive pulse (V)	E (eV)	Φ (A/m^2)
0	60.8	0.32
30	87.8	0.21
50	107.0	0.18
75	126.4	0.17
100	145.3	0.17
125	159.8	0.16
150	181.4	0.16
200	219.3	0.18

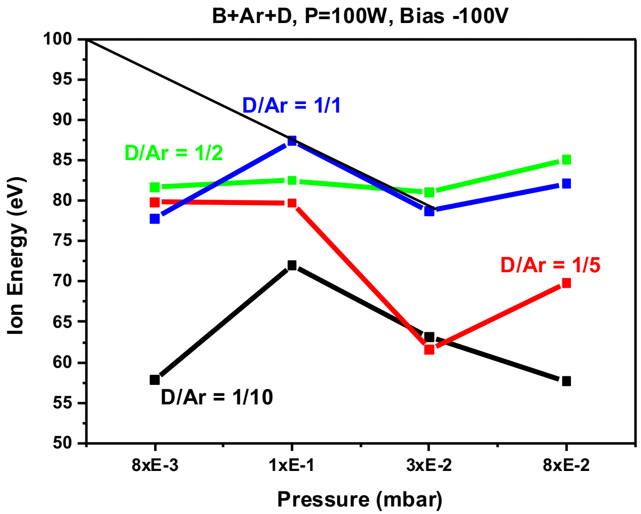
Ion energy measurements for B-Ar-D MS plasma

RF B+Ar+D plasma , P=100W

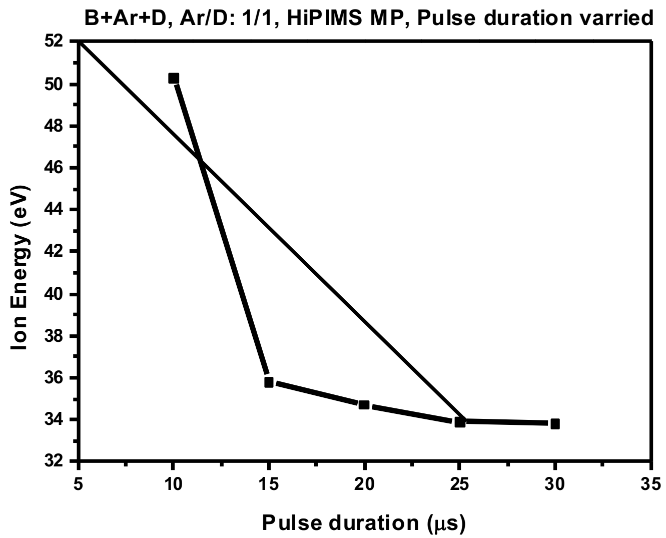


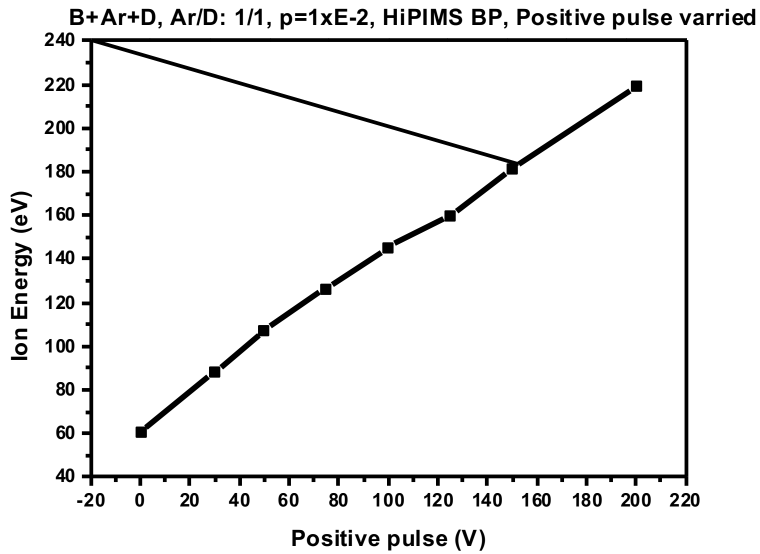


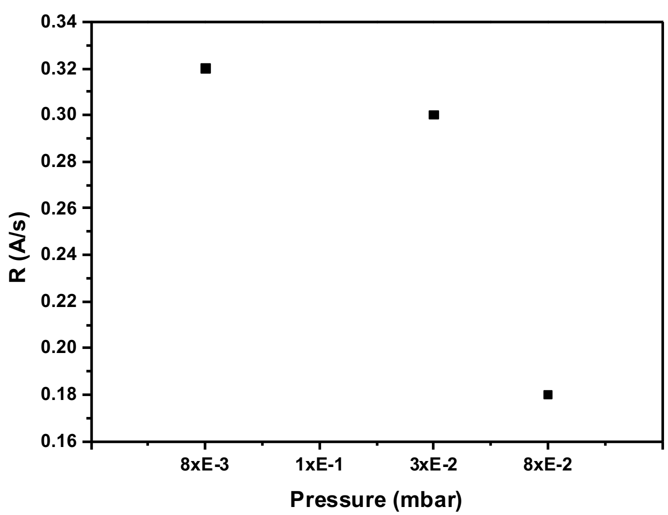


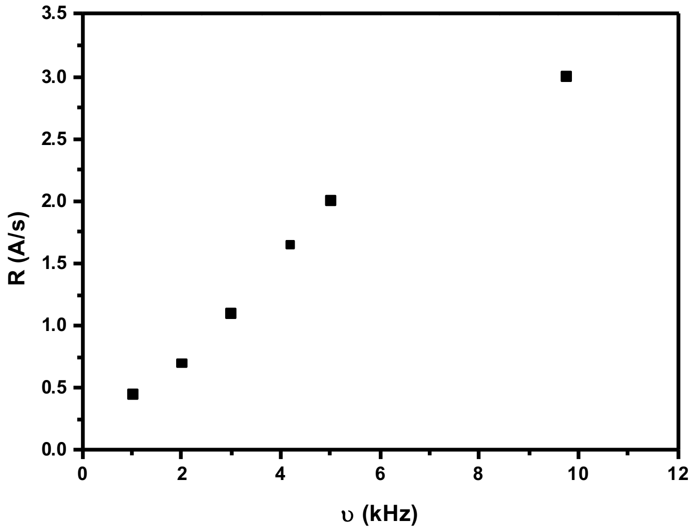


Ion energy and deposition rate measurements for B-Ar-D MS plasma









Prospects for studying B layers – PLANS for 2024

Workplan for production of B layers

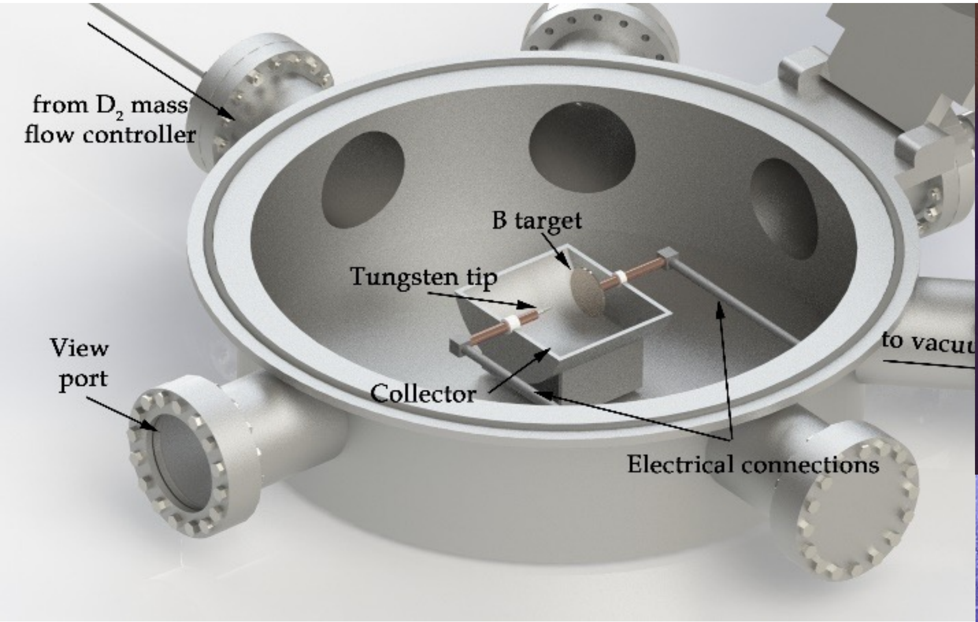
- ✓ Repeat the exercise performed with CEA in 2022 and 2023:
  - **2024:** BD and BH with high H and D content (more than 10%), thermally treated from 50 to 500°C
  - **2025:** Oxygen addition to the same set of samples
- ✓ Samples for permeation studies under SP C as follows:
  - **2024:** different thickness samples 500 to 5000 nm, pure B
  - **2025:** gaseous inclusions of the types of samples
- ✓ For micromechanical measurements and water exposure to check the delamination behavior of B surface layers exposed to boiling water
  - **2024:** B-coated W substrates, 12×15×1 mm^3, 5 μm, dense and porous
  - **2025:** boron with D 10 % of 10×10×1 mm^3 samples
- ✓ **Additionally**: B+W (pure and D doped) composite coatings for re-deposition studies
- ✓ Analysis of the produced coatings using **SEM, TDS, XRD, Sputtered XPS and nanoindentation**

Deliverables:

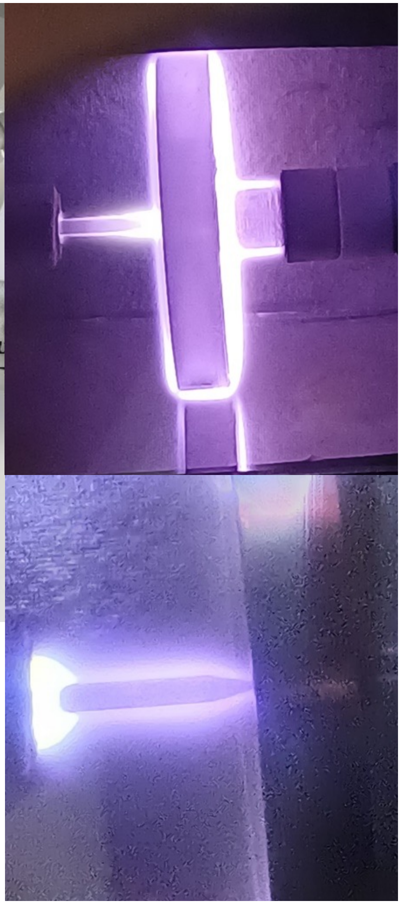
Database of **B** containing deposited layers; **D/B ratio** versus plasma conditions. **Fuel removal efficiency** assessment on boron containing layers.

Samples to be produced for any other experiments suggested by laboratories.

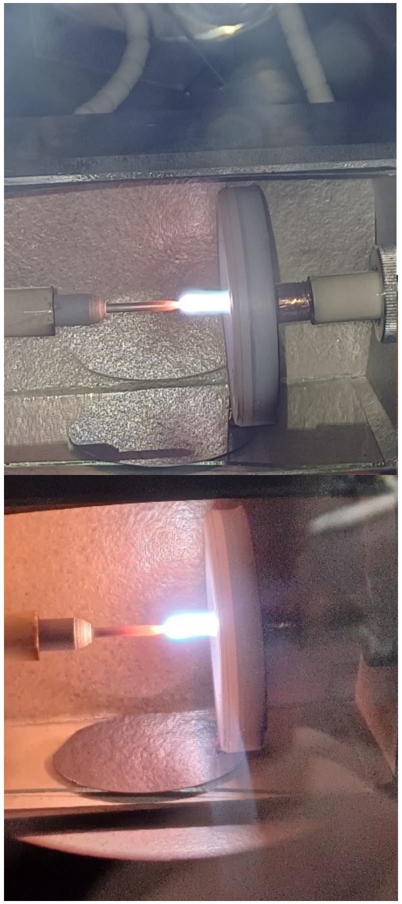
SPB 4: Production of B samples for lab experiments



Glow discharge

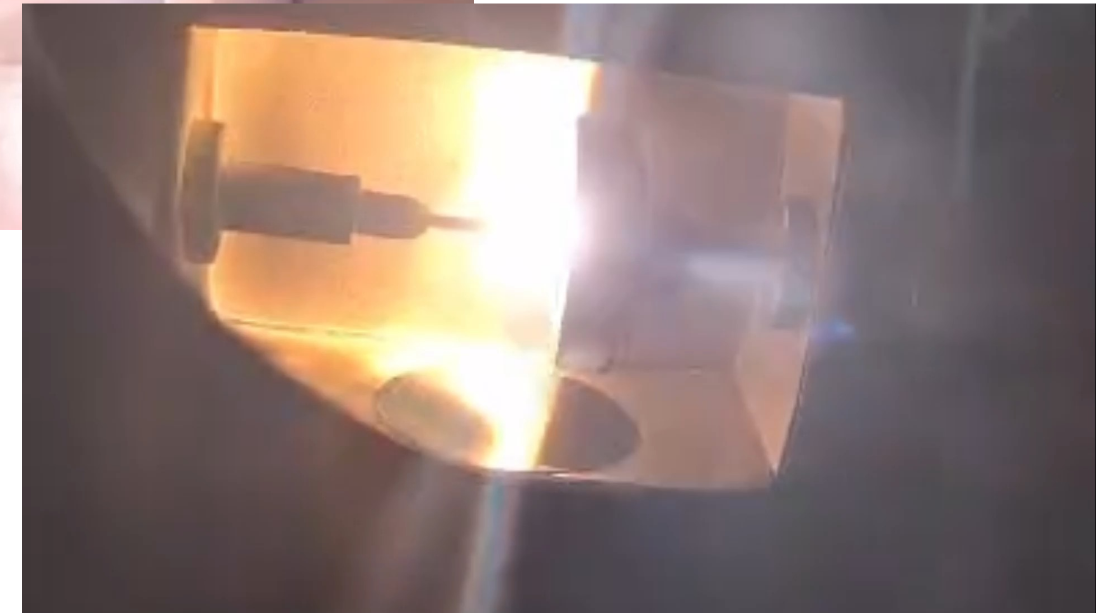


Aching discharge



Apparatus: a DC / pulsed reactor working in deuterium or H2/D2 mixture gas. Addition of water and air will be performed.
An arc discharge was ignited between a 1 inch B plate and a W tip.

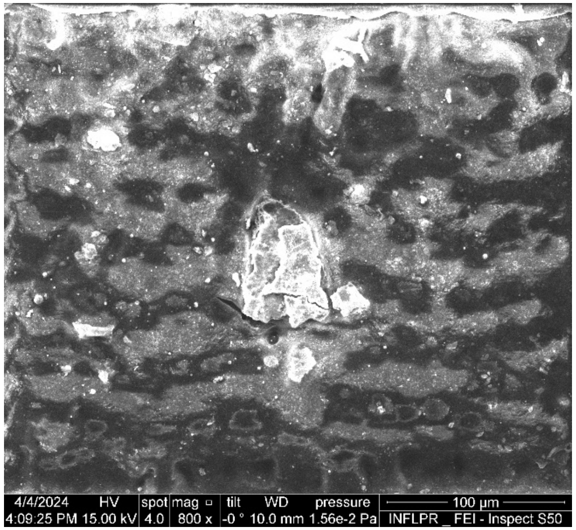
Arching – No B collected

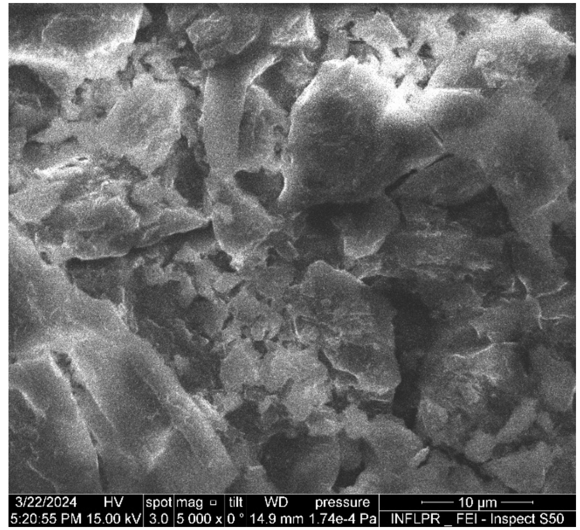


Arching – B collected
See the droplets

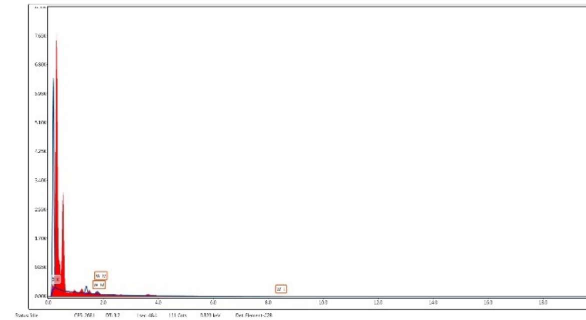
SPB 4: Production of B samples for lab experiments

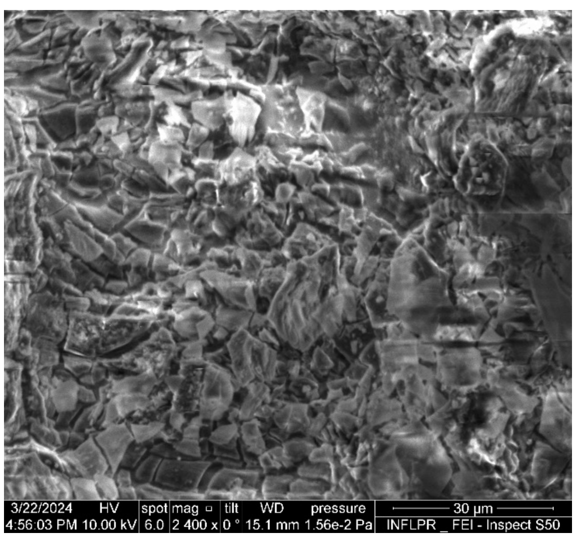
Boron particles produced by arching

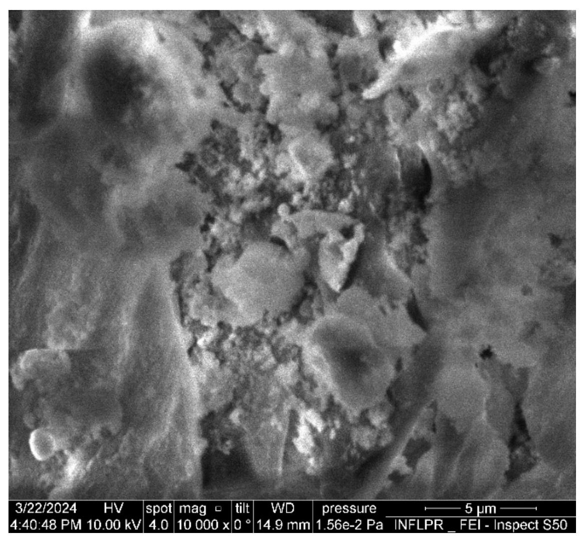




EDS shows W as the only “impurity” (W tip)







Several dimensions and shapes
Very large amount of B present
Parametric study in terms of productivity rate vs
pressure,
discharge parameters,
gasses used, etc.
will be performed in 2024

Workplan for dust

- ✓ Investigations of B dust production using the plasma-arc device
  - **2024:** systematic study on B dust particle formation and size with the arc parameters
    - Productivity rate vs. pressure, electric parameters, gasses used, etc.
  - **2025:** extend the studies to dust with gaseous addition (air leak and water vapors)
  - Characterization using SEM, TDS, XPS → **calling for XRD collaboration**
- ✓ Investigations of B/W mixed and pure W dust production using the plasma-arc device
  - **2024:** B/W mixture particle formation by usage of pure B or B/W composite coating on W substrate, as well as W dust production by plasma arching.
  - **2025:** extend the studies to dust with gaseous addition (D, He, etc, air leak and water vapors)
  - Characterization using SEM, TDS, XPS → **calling for XRD collaboration**

Prospects for studying B layers – our capabilities

Sample production capabilities

- TVA – up to 3 plasma sources, low gas amount intake – best for pure layers – 5-5000nm
- MS (DC, RF, HiPIMS, BP HiPIMS) – up to 7 magnetrons at once, up to 3 gasses intake - 5-5000nm
- Post coating plasma exposure – GD, Plasma torch, etc.
- T facility – experiments and sample handling from July 2024

Pure B, B/D, B/W/D, different gaseous adition, several parameters variation (T, P, ion energy, thickness, gas fluxes, discharge type)

Charactherisaton: SEM/EDS, XRD, XPS, TDS, T surface monitoring, nanoindentation, XPS

- LIBS/LIA QMS – first tryouts on B/D codeposits succesfull.
- Linear plasma device with in-situ LIBS – from late 2025

Sample preparation facility allready fully equiped for boron containing coatings. Tritium facility included inside the current BeHF can be used for boron. Preliminary data available for capability demonstration

Prospects for studying B layers capabilities – Proposal of an experimenta plan - Example and ideas

Typical pure B layers – 100nm or more

- characterisation and ready for implantation
- interphase study (B unstable at B-W interface)
- plasma torch exposed (various parameters)- TDS
- tritiation - TDS

Codeposited B-D layers

- different thicknesses, temperatures, pressures, plasma type etc,

Repeat the exercise with other more complicated systems (W, C, O, He, Ne, N intake)

Work plan has to be established by SP Leaders under SPB, SPC, SP D, SPX and SPF3 since the need of a *“database of artificial B layers for physics studies: stability, fuel content, and release”*

Collaboration with CEA

Etienne HODILLE

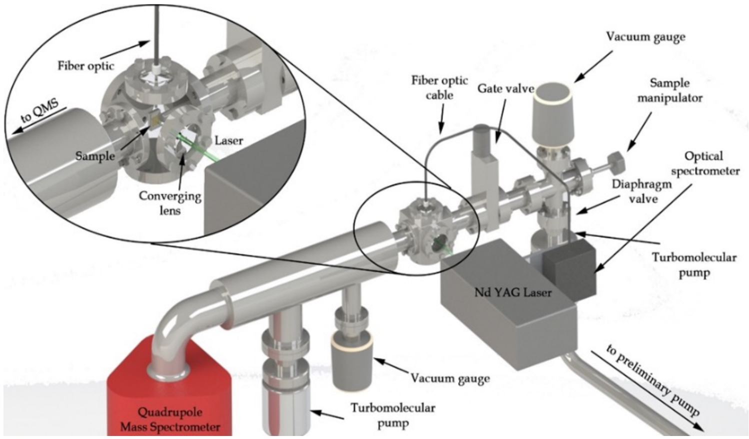
- Coroboration of TDS and diffusion reactions – MHIMS code – understand the D retention in B – PhD Student from Romania

SPB 4: Production of B samples for lab experiments

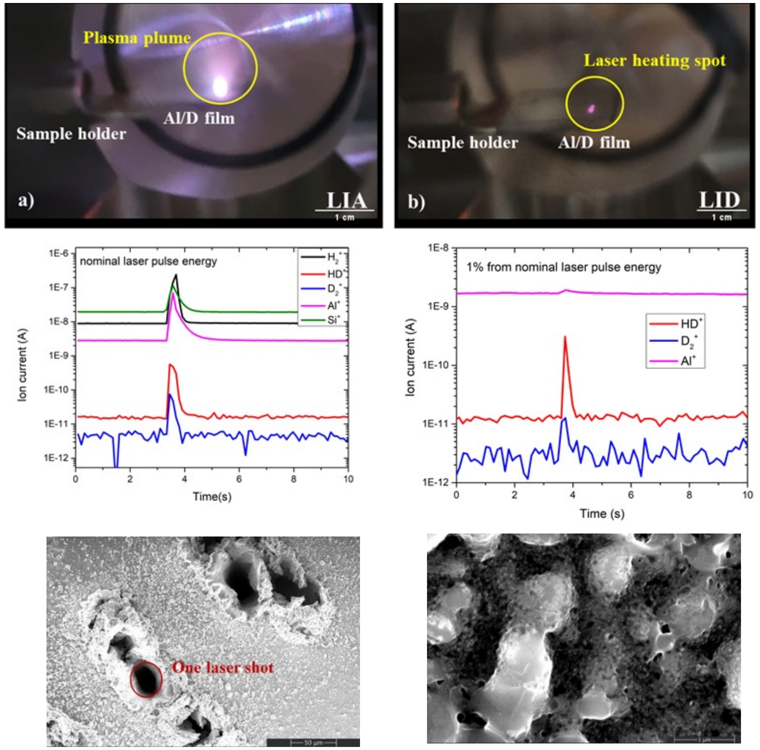
Other experimental capabilities

H isotopes release measurements LIBS, LIA-QMS and LID-QMS

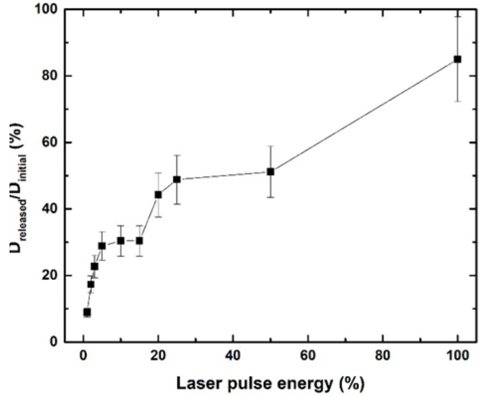
- Q-switched laser / 1 kHz / wavelengths of 1053 nm/ pulse duration:10 $\pm$ 3 ns, the nominal pulse energy - 350 µJ, and nominal laser fluence was around 84 × 10^{-4} J/cm^2.
- QMS and OES simultaneously measurements.
- LIA-QMS and LID-QMS calibration was performed for D_2
- Cross correlation between TDS and LIDS/LIBS



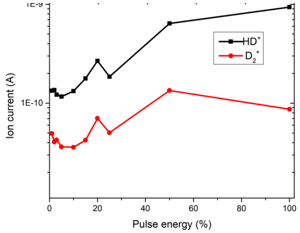
Experimental setup for LIA and LID analysis by QMS and OES.



a) LIA 100 % from nominal laser pulse energy.
b) LID 1 % from nominal laser pulse energy.



9 % efficiency for D release by LID process and
85 % efficiency for D release by LIA process considering that TDS has 100% efficiency



The HD^+ and D_2^+ ion currents dependence on laser pulse energy


Spectrochimica Acta Part B: Atomic Spectroscopy 208 (2023) 106774

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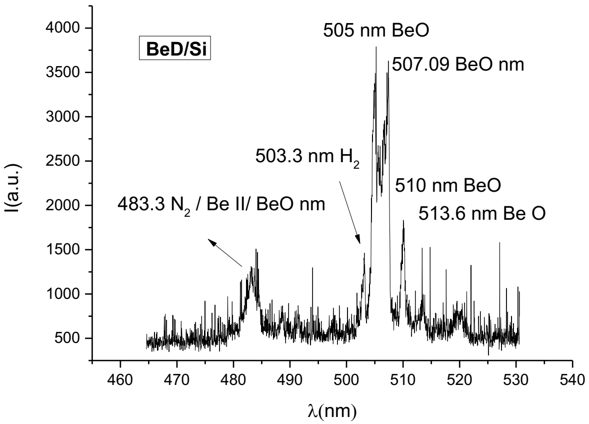
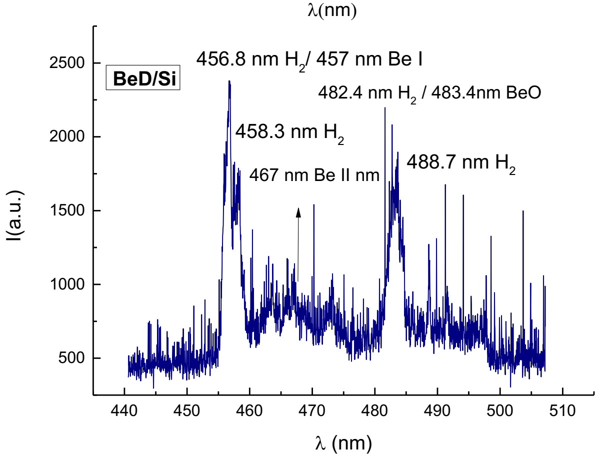
Considerations on hydrogen isotopes release from thin films by laser induced ablation and laser induced desorption techniques

Sasa-Alexandra Yehia-Alexe [a,b], Andreea Groza [a,*], Mihai Serbanescu [a], Maria Elena Zarif [a,c], Bogdan Bita [a,b], Paul Dinca [a], Bogdan Butoi [a], Cornel Staicu [a,b], Corneliu Porosnicu [a]

Other experimental capabilities

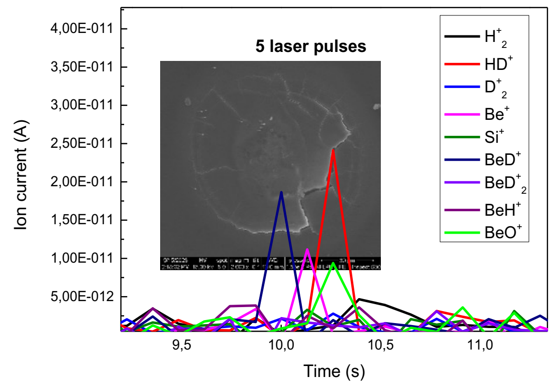
Preliminary results on deuterium release from BeD/Si layers by laser induced ablation/ desorption - QMS and OES techniques

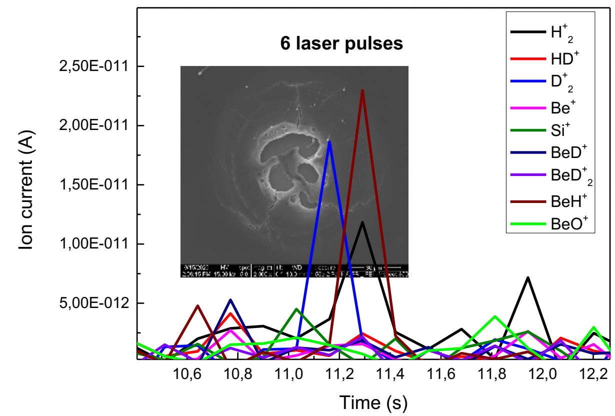


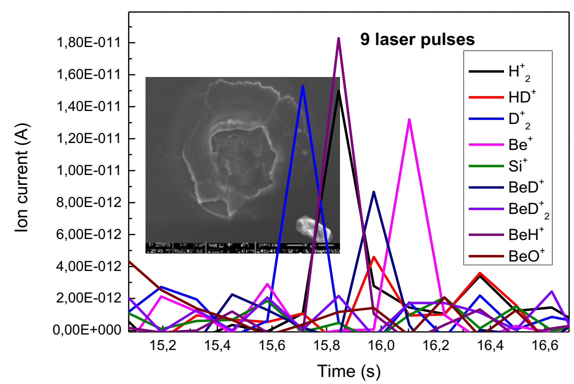


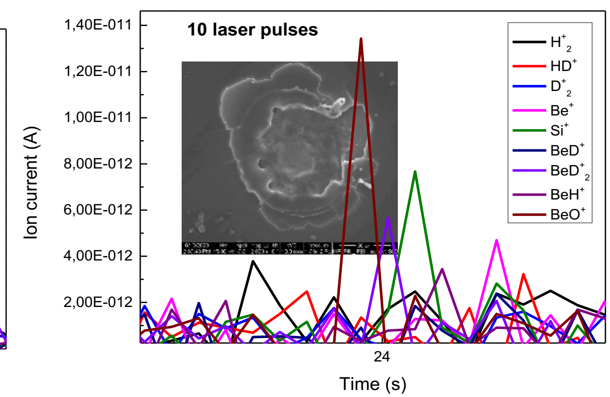
Evidence of BeO, BeH and H_2/D_2 optical emission bands during laser ablation of BeD/Si samples

Selectivity in the detection of components as function of number of laser pulses





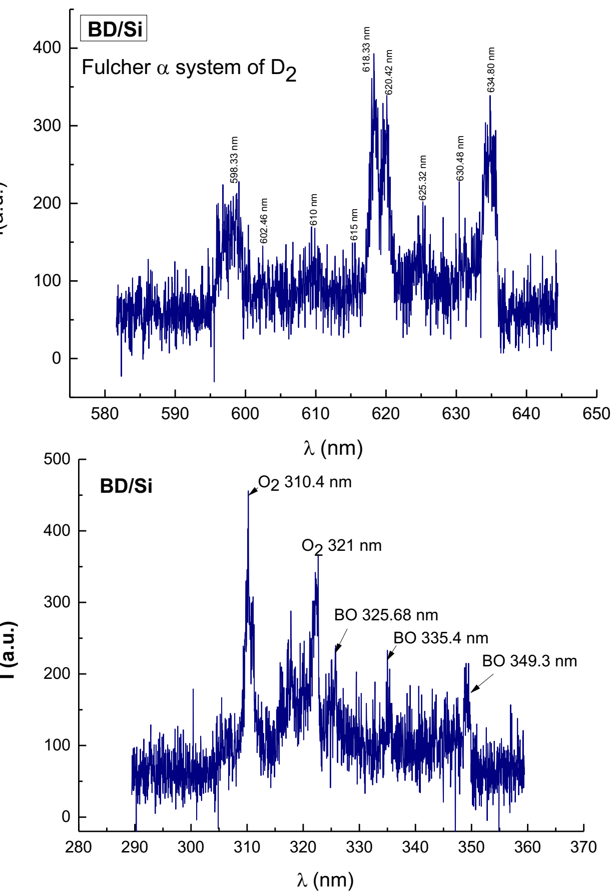




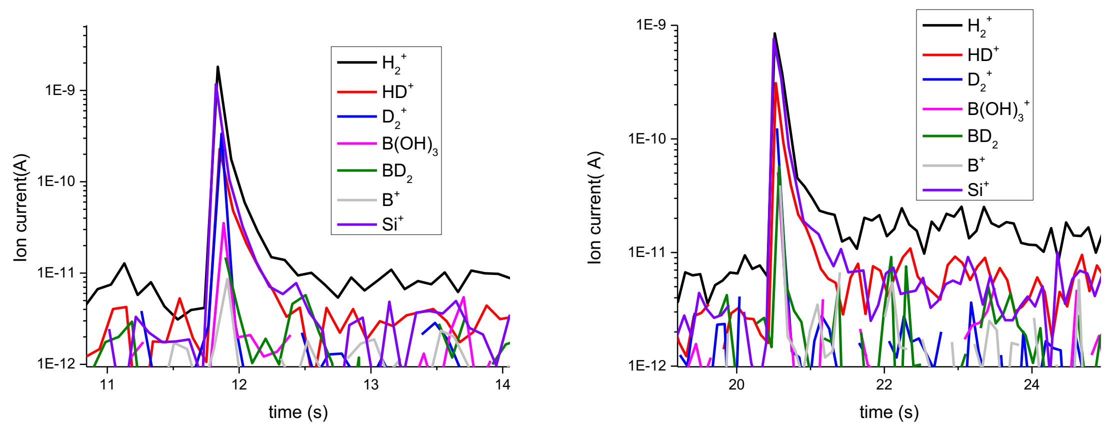
Mass spectral analysis of components produced by laser ablation and laser desorption of BeD/Si samples

Other experimental capabilities

Preliminary results for deuterium release from BD/Si layers by laser induced ablation/desorption – QMS and OES techniques



Evidence of BO and H_2/D_2 optical emission bands during laser ablation of BD/Si samples



Mass spectral analysis of components produced by laser ablation and laser desorption of BD/Si layers

From Be/D to B/D and T experiments

Coroboration of TDS and diffusion reactions – MHIMS code

Etienne HODILLE from CEA

Bulk model

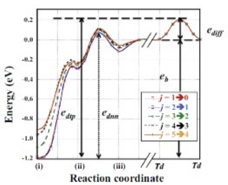
$$\frac{\partial c_m}{\partial t} = \nabla(D(T) \cdot \nabla c_m) - \Sigma_i \left(\frac{\partial c_{t,i}}{\partial t}\right) + S_{ext}(H,\ H^+)$$

$$\frac{\partial c_{t,i}}{\partial t} = -\nu_i(T) \cdot c_{t,i} + \nu_m(T) \cdot c_m \cdot (n_i - c_{t,i})$$

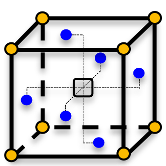
Surface

$$\frac{dc_{surf}}{dt} = \Gamma_{stick}(H_2, H) - 2\nu_{des}(T) c_{surf}^2 - \lambda \left.\frac{\partial c_m}{\partial t}\right|_{x=0}$$

N. Fernandez et al., Acta Mater. 94 (2015)
H in vac in W



V_1D_n	E_{dt}
V_1D_1	1.43 eV
V_1D_2	1.42 eV
V_1D_3	1.25 eV
V_1D_4	1.17 eV
V_1D_5	1.11 eV
V_1D_6	0.86 eV



QUESTION:
A Rate equation model for D desoption from Boron codeposited layer relevant for WEST and/or ITER?

Distance: cm-m; µm-mm; nm-µm; 1-10 nm; Cristal 10 Å

Density function theory DFT → **Molecular dynamics MD** → **Kinetic Monte Carlo OKMC** → **Diffusion-reaction Code MHIMS**

Activation energy of elementary processes

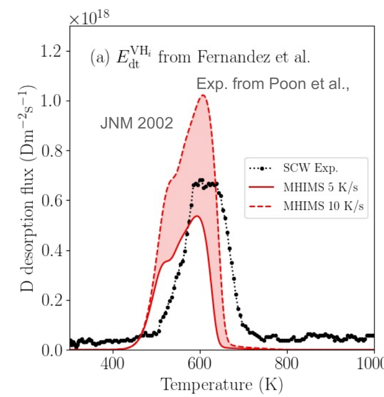
Creation of defects by neutrons

Evolution of defects created by neutrons

Diffusion-reaction Code MHIMS ⇄ **Conditions tokamak**

Desorption

Geometry
Plasma fluxes



Exemple of parametrisation of the model for W:

TDS with D detrapping from Mono-vacancies

Temps: Ground states Atomic vibration; Interatomic dynamics ps - ns; µs - minutes; Hours - days

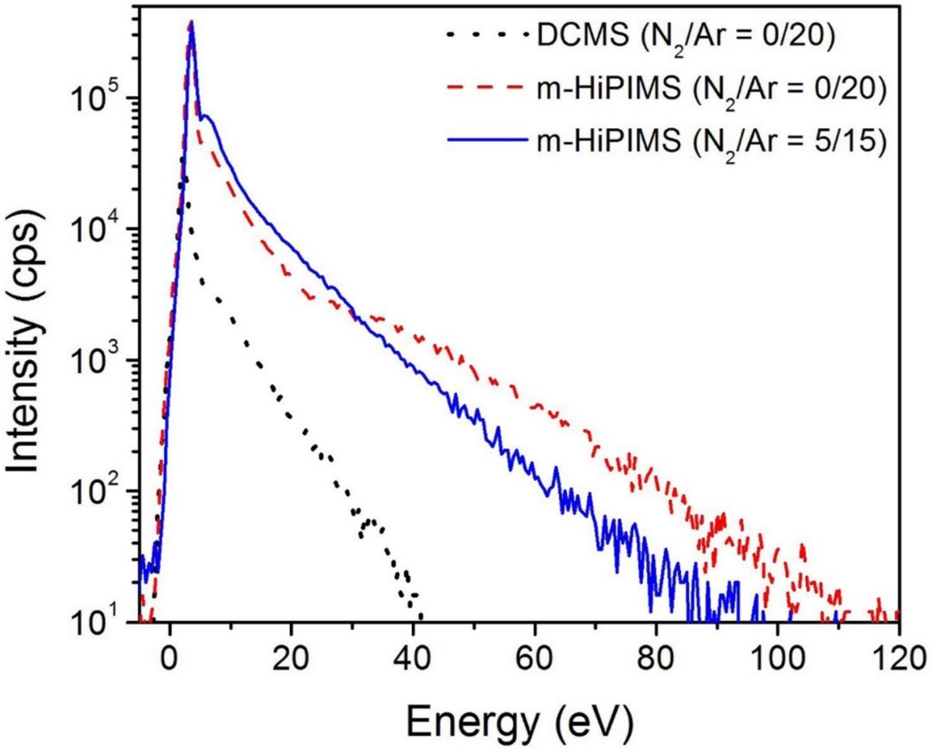
Magnetron sputtering plama regimes available

DCMS

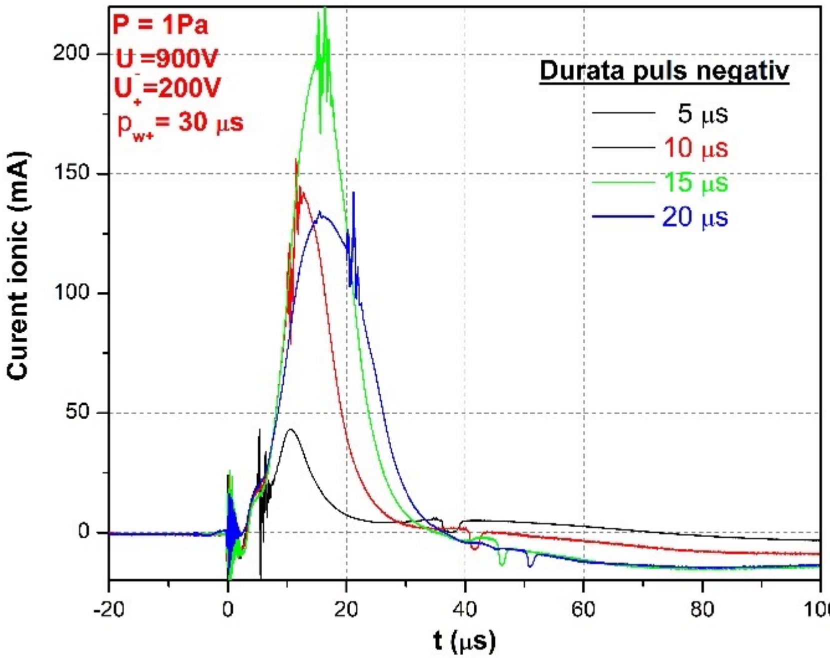
RF – 13.56MHz

sp-HiPIMS

BP-HiPIMS



Ion energy distribution function



Ion saturation current vs pulse lenght

Extra slides

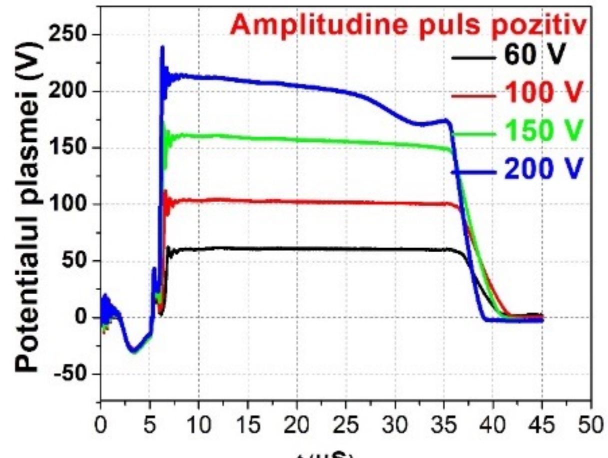
Plasma parameters – National funded PostDoc - Paul Dinca

Bipolar short pulse HiPIMS advantages – Measurements on Be/D and Be/D/N magnetrons

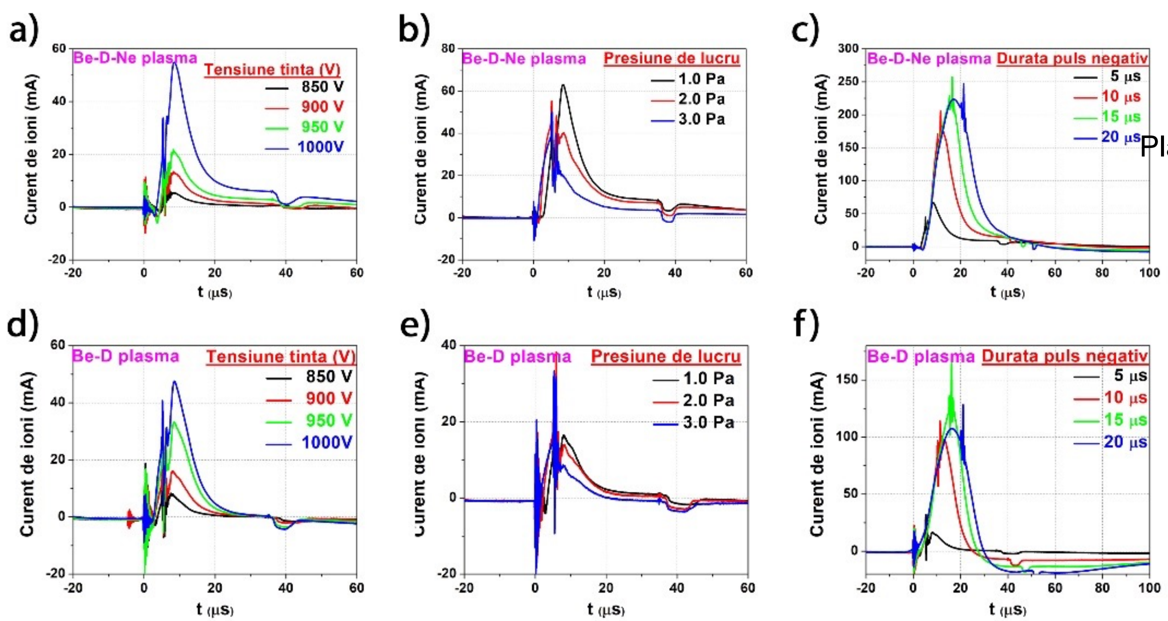
Magnetron sputtering plama regimes available

DCMS
RF – 13.56MHz

sp-HiPIMS
BP-HiPIMS



Plasma potential vs time for different positive pulses



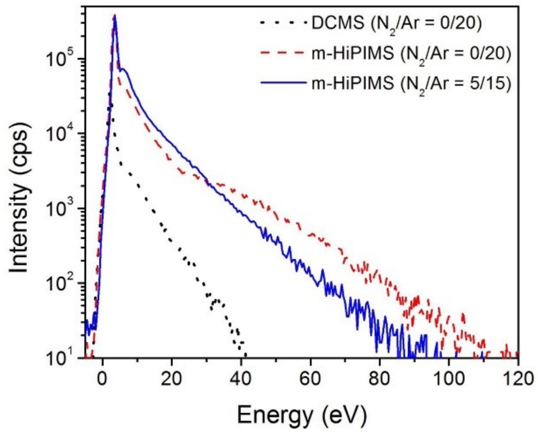
Ion current distribution for the Be/D and Be/D/N plasmas

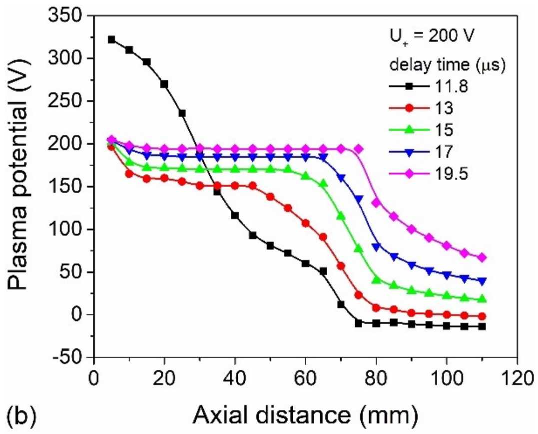
Extra slides

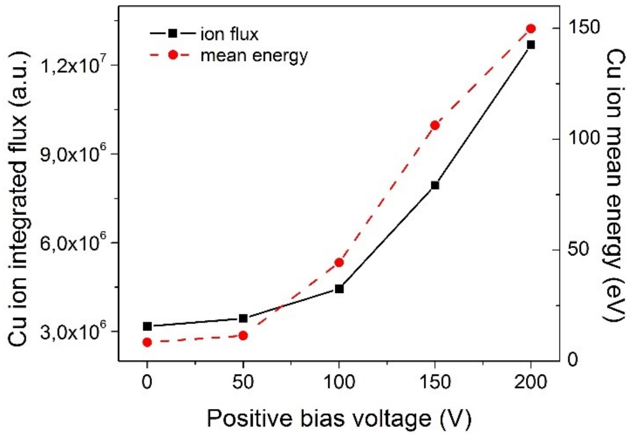
Bipolar short pulse HiPIMS advantages

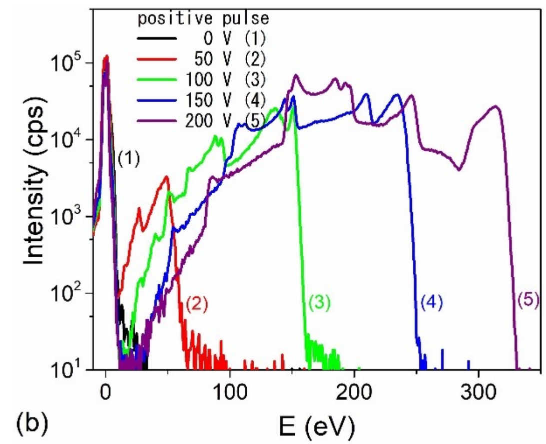
Magnetron sputtering plama regimes available

DCMS	sp-HiPIMS
RF – 13.56MHz	BP-HiPIMS







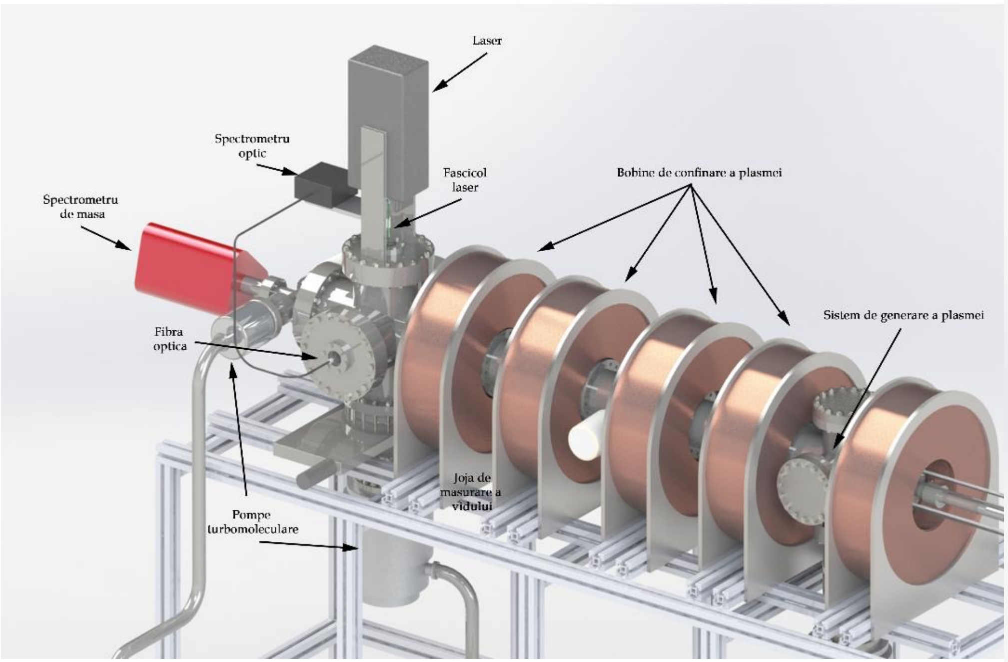


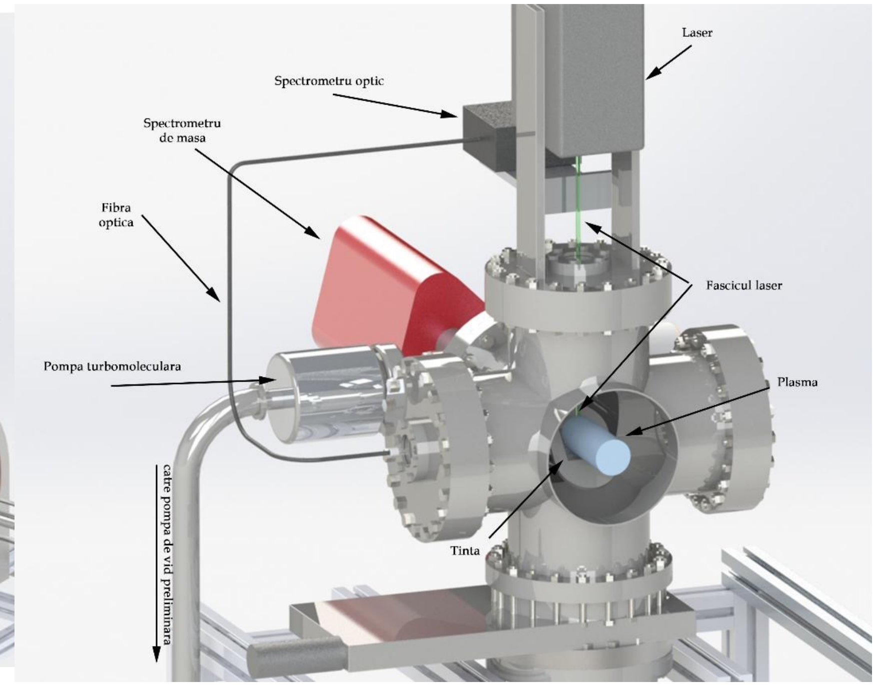
Data published in Surface and Coatings Technology, 359, 2019, 97

Ion energy distribution functions

Extra slides

Plasma linear device with insitu LIA/LID QMS and OES





Funding successfully acquired. Project starts in July 2024
Optimistic operation time: late 2025