QUANTIFICATION OF SPUTTERED MOLYBDENUM INSIDE A RIT TO ASSESS GRID EROSION AT DIFFERENT MODES OF OPERATION

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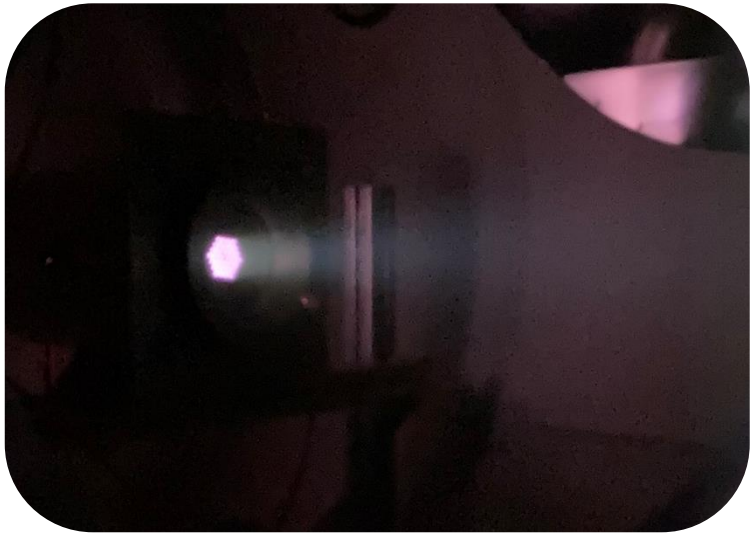
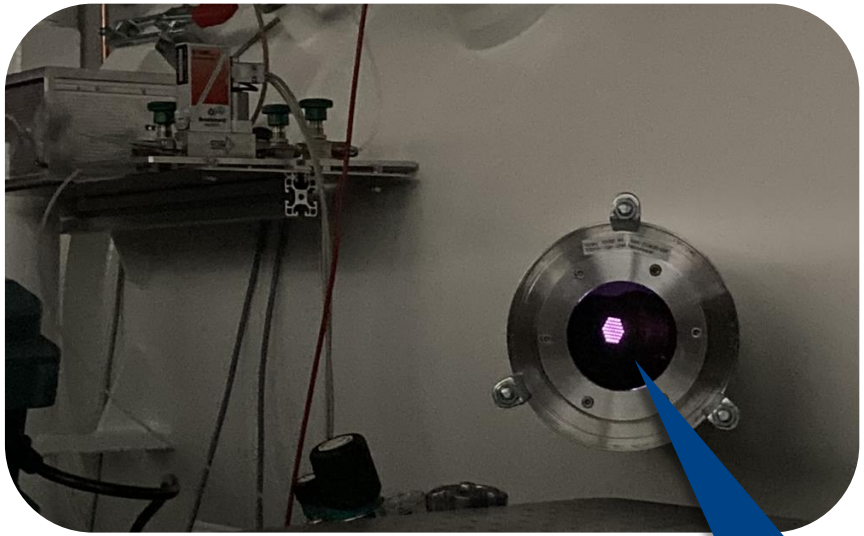
Justus-Liebig-University Giessen

Mühlleithen, 15.03.2024

01 INTRODUCTION
RADIO-FREQUENCY ION THRUSTER (RIT)



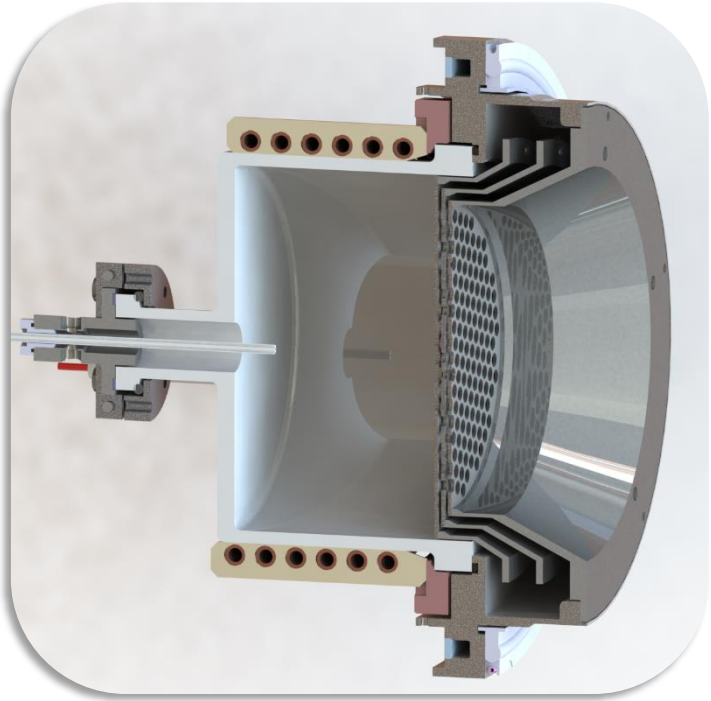


RIT-10 from JLU Giessen
operating with Xenon in the “Idefix” vacuum facility

View along the
optical axis

01 INTRODUCTION
RADIO-FREQUENCY ION THRUSTER (RIT)

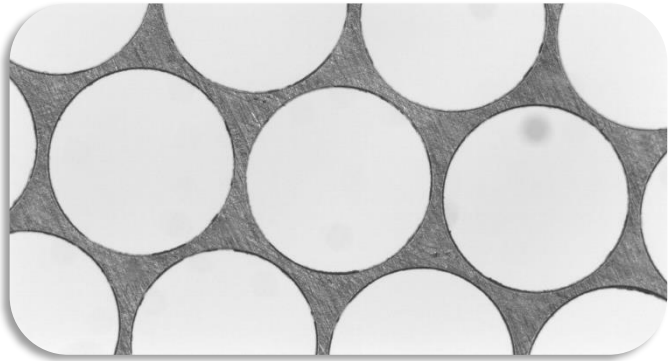
Important components of the RIT	
Gas inlet	Invasive plasma diagnostics can be mounted through the gas inlet in a central position
Coil	An alternating electromagnetic field is generated when connected to the radio frequency generator (RFG)
Plasma vessel	The material consists of a non-conductive and heat-resistant glass.
Grid system	A 3-grid system is used. The screen grid is made of Molybdenum.

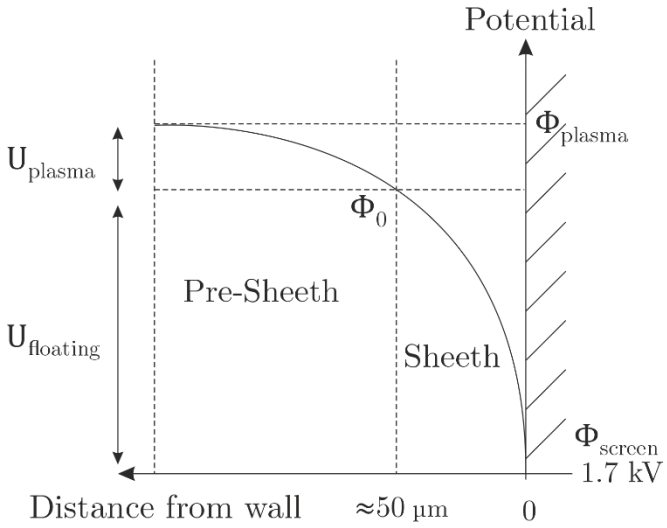


Schematic view of the *RIT-10* from JLU Giessen

02 MOTIVATION
SCREEN SPUTTERING

- Ions from the bulk plasma are accelerated towards every surface in contact with the plasma.
- For high efficiency modes of operation this potential can reach critical values.



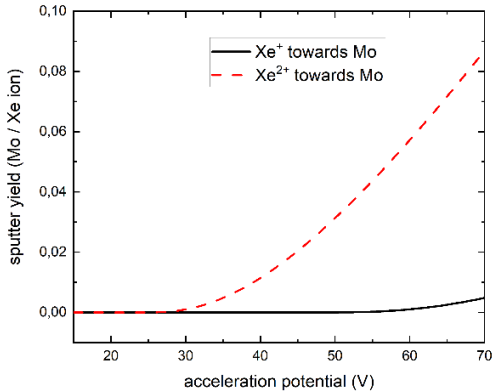


Microscopic Observations of the Screen grid of a ***RIT-10*** from JLU Giessen

Screen Grid	
Position	Inner position in direct contact with the plasma
Voltage	1 kV – 2 kV
Erosion Type	Screen grid sputtering

02 MOTIVATION
SCREEN SPUTTERING

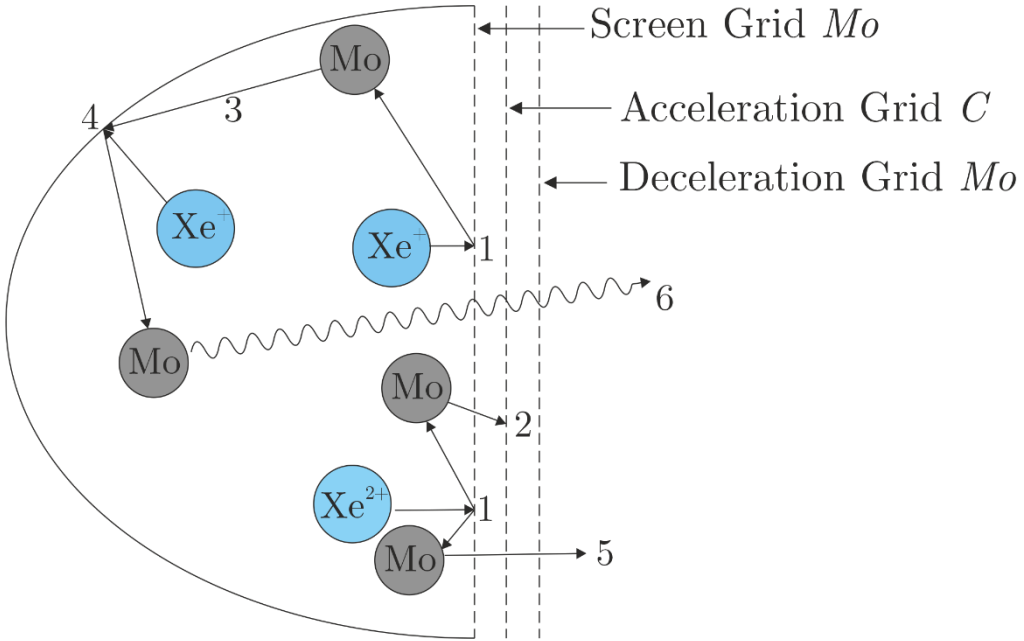
- At these energies, doubly charged xenon ions can sputter Molybdenum from the screen grid material.
- Thin metal films on the inside of the plasma vessel increase power consumption due to eddy current losses.



Exemplary picture of the *RIT-10* glass vessel completely coated with Molybdenum.
Here an additional negative bias voltage was applied to the Mo grid.

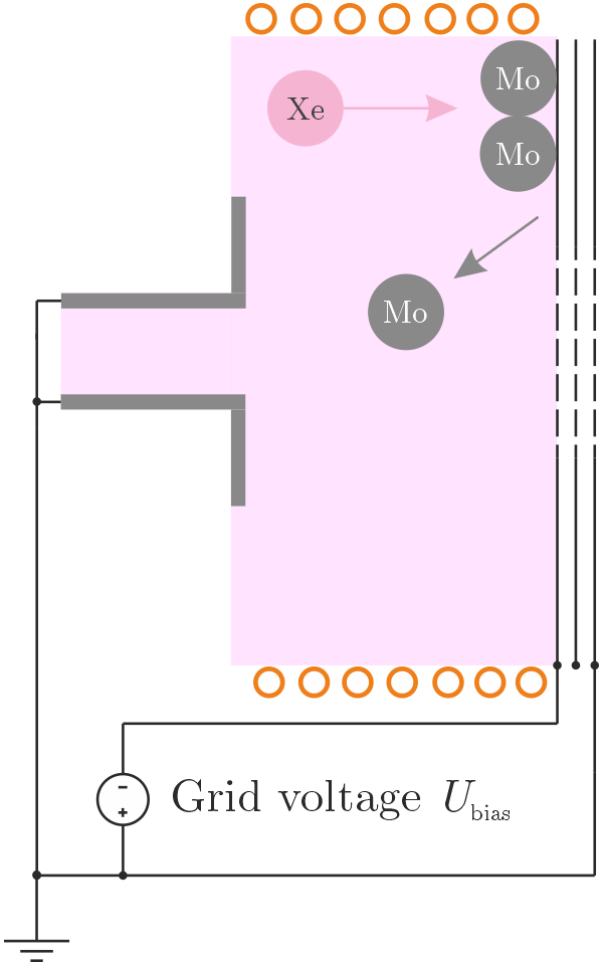
03 EXPERIMENTAL SETUP
POSSIBLE PROCESSES OF MO EROSION

Process overview	
1.	Screen grid sputtering
2.	Deposition on the grid system
3.	Deposition inside the plasma vessel
4.	Deposition abrasion by ion impact
5.	Exit chamber
6.	Emission of light, used for spectral analysis



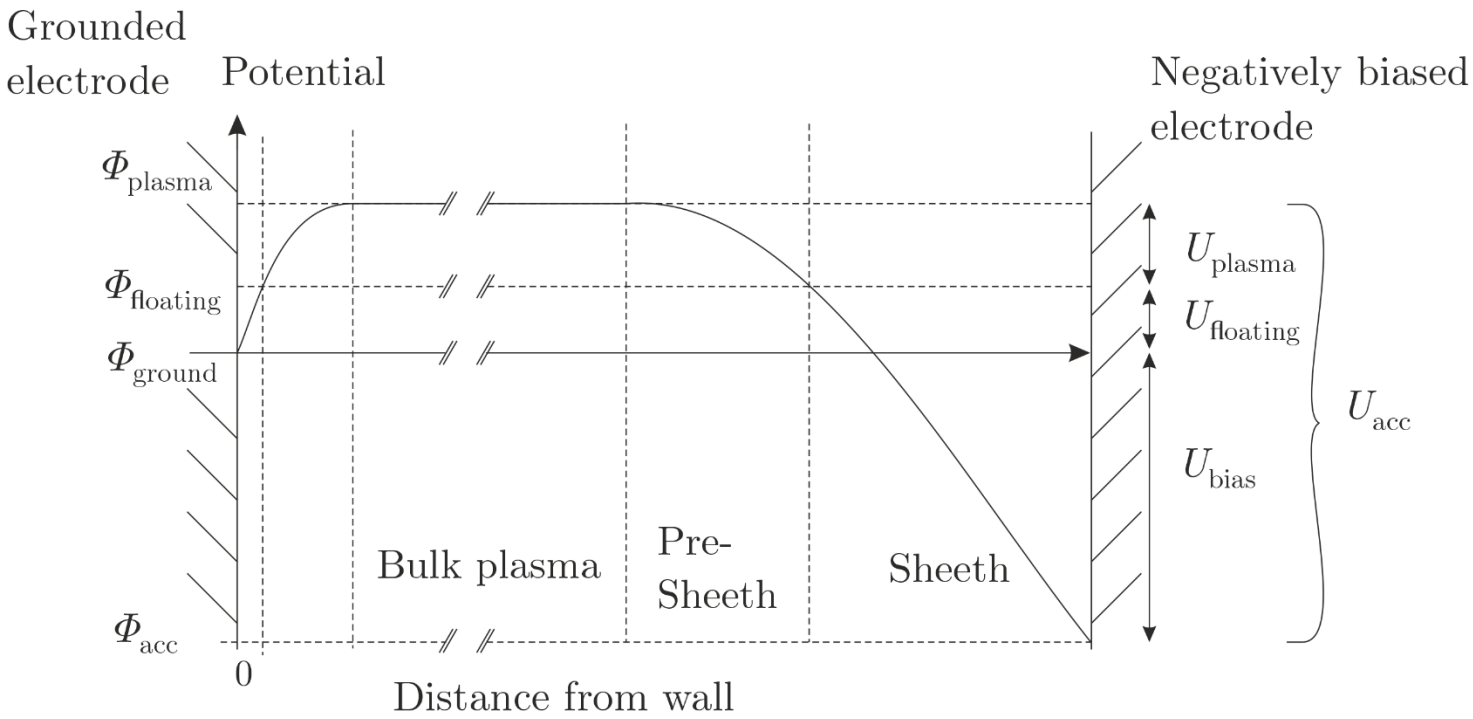
03 EXPERIMENTAL SETUP
ARTIFICIAL SCREEN SPUTTERING

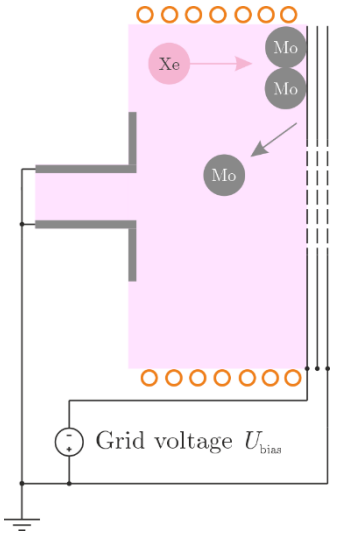
- To erode Molybdenum plasmas with low plasma potential a negative bias voltage is applied to the screen grid.
- To quantify the amount of eroded Molybdenum the weight of the grid is measured before and after a given erosion duration of 4 to 24 h.
- During this measurement optical emission (OE) spectra are taken periodically.



03 EXPERIMENTAL SETUP
ACCELERATION VOLTAGE

$$U_{\text{acc}} = U_{\text{plasma}} + U_{\text{floating}} + |U_{\text{bias}}|$$

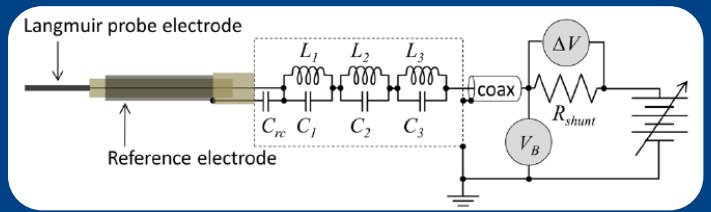


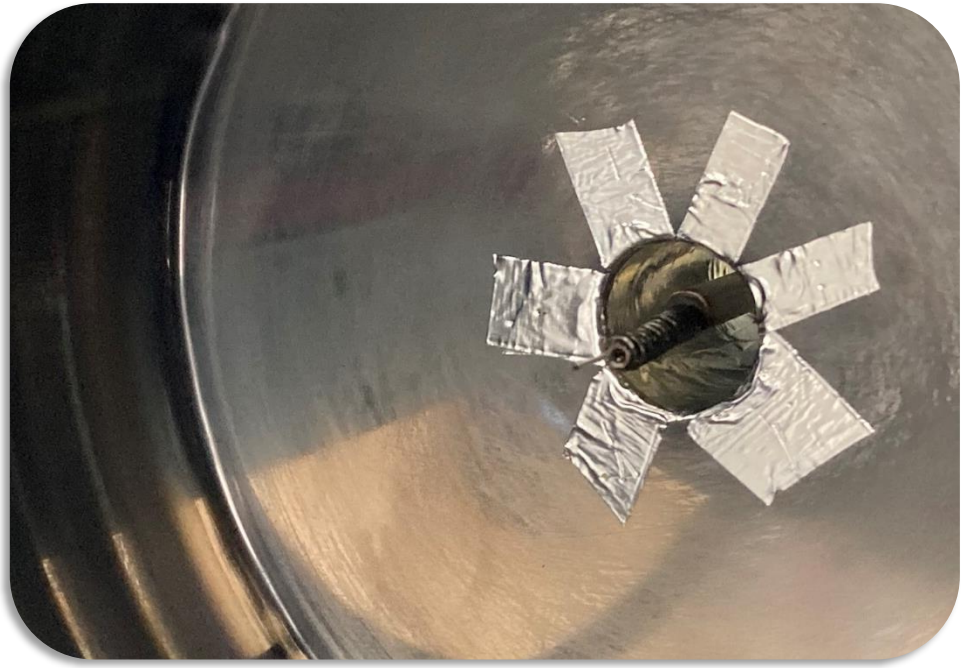


03 EXPERIMENTAL SETUP
DETERMINATION OF THE PLASMA POTENTIAL

- To gain information about the plasma potential for the different modes of Mo erosion a Langmuir single probe is used
- Ref: Recommended Practice for Use of Langmuir Probes in Electric Propulsion Testing

Robert B. Lobbia et al. 2017, journal of propulsion and power, Fig. 13

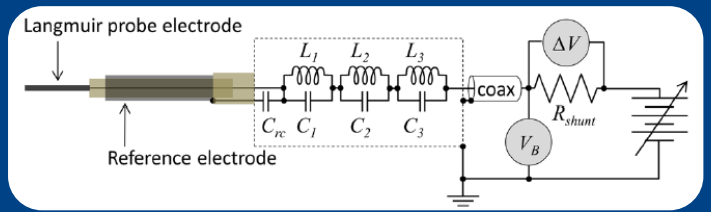


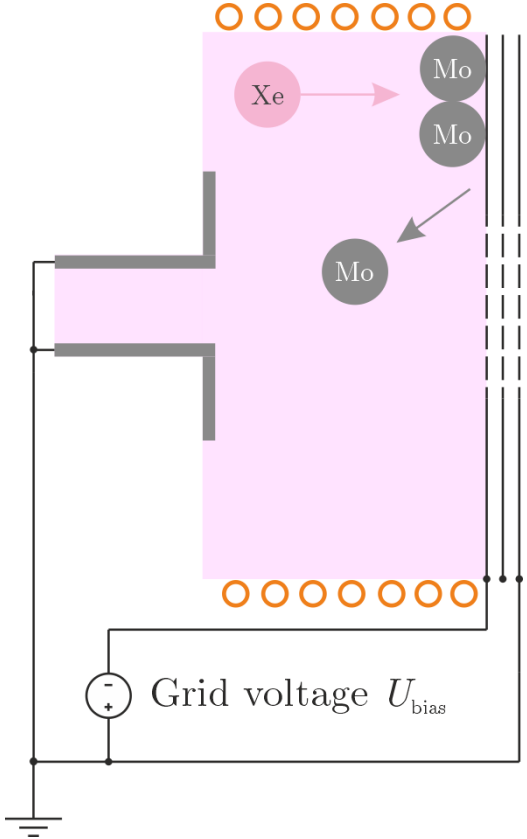


03 EXPERIMENTAL SETUP
DETERMINATION OF THE PLASMA POTENTIAL

- Two chokes are used to provide a high impedance for the RFG frequency at $f_{\mathrm{RFG}} = 1.5\ \mathrm{MHz}$ and its second harmonic
- With the source measure unit, the voltage is applied, and the current measured for $I_{\mathrm{max}} = 100\ \mathrm{mA}$

Robert B. Lobbia et al. 2017, journal of propulsion and power, Fig. 13





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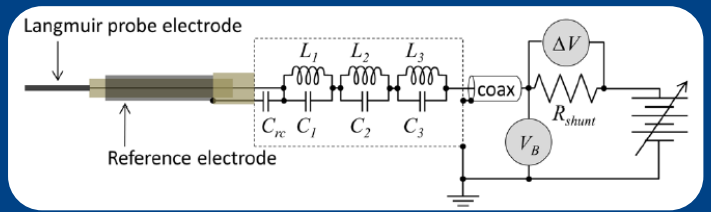
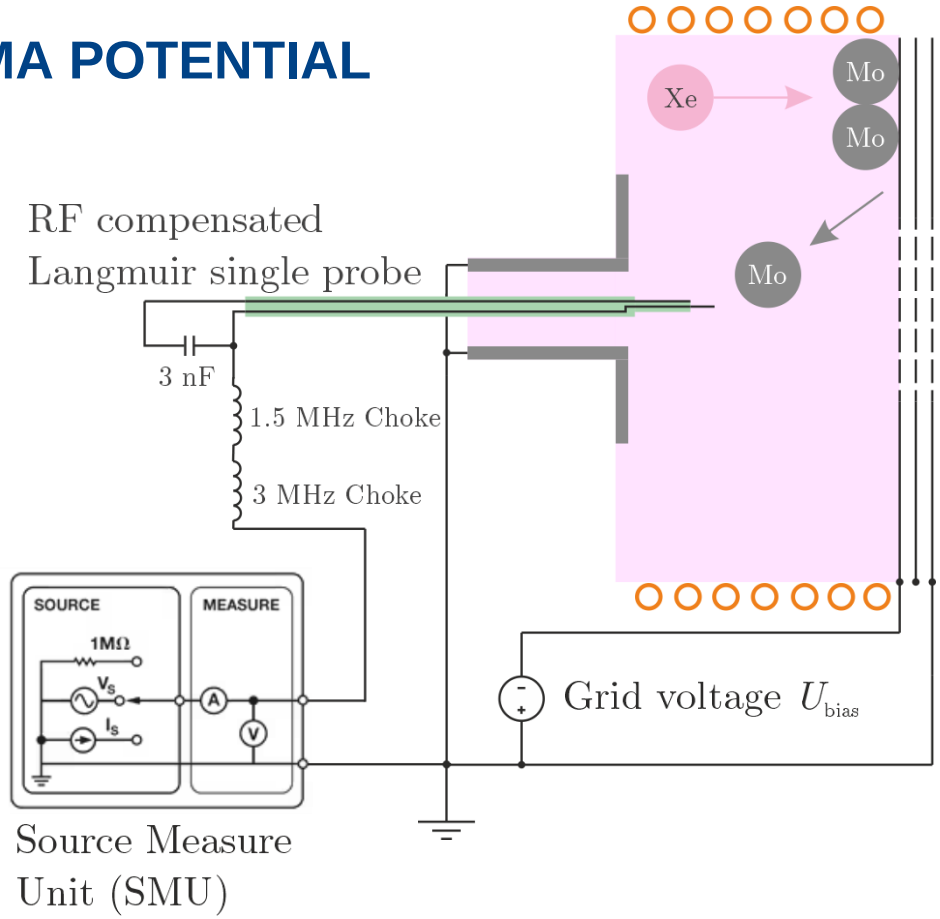
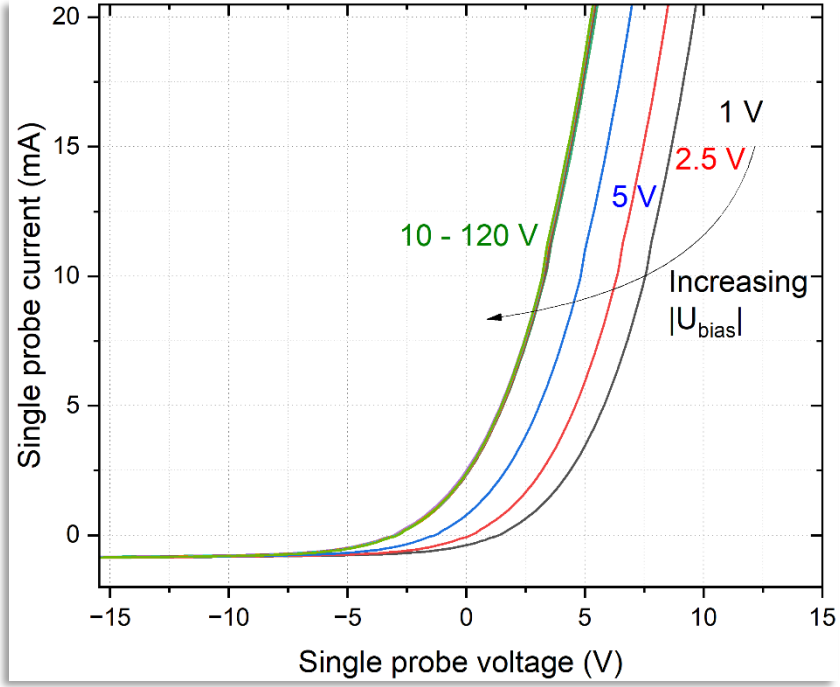
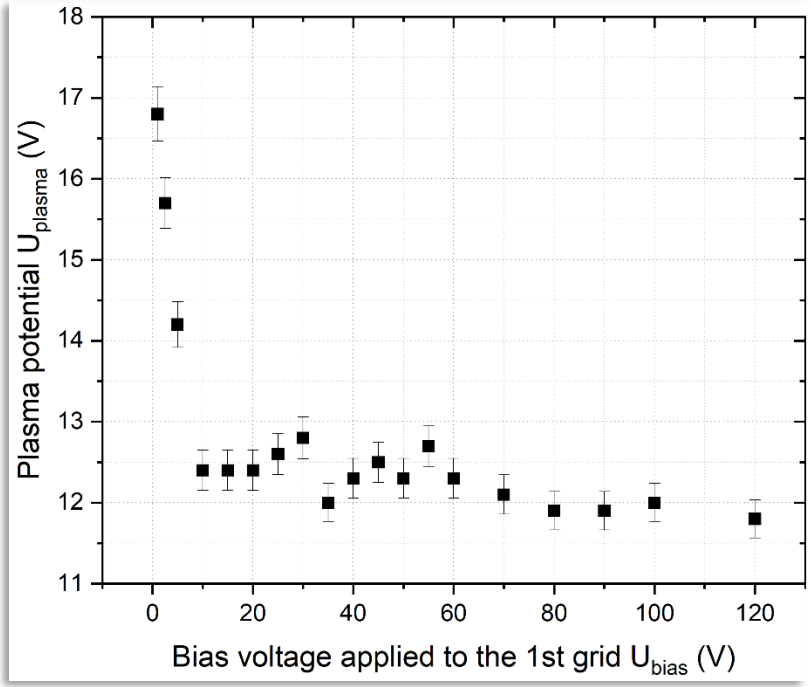




04 PRELIMINARY RESULTS
SINGLE PROBE MEASUREMENTS

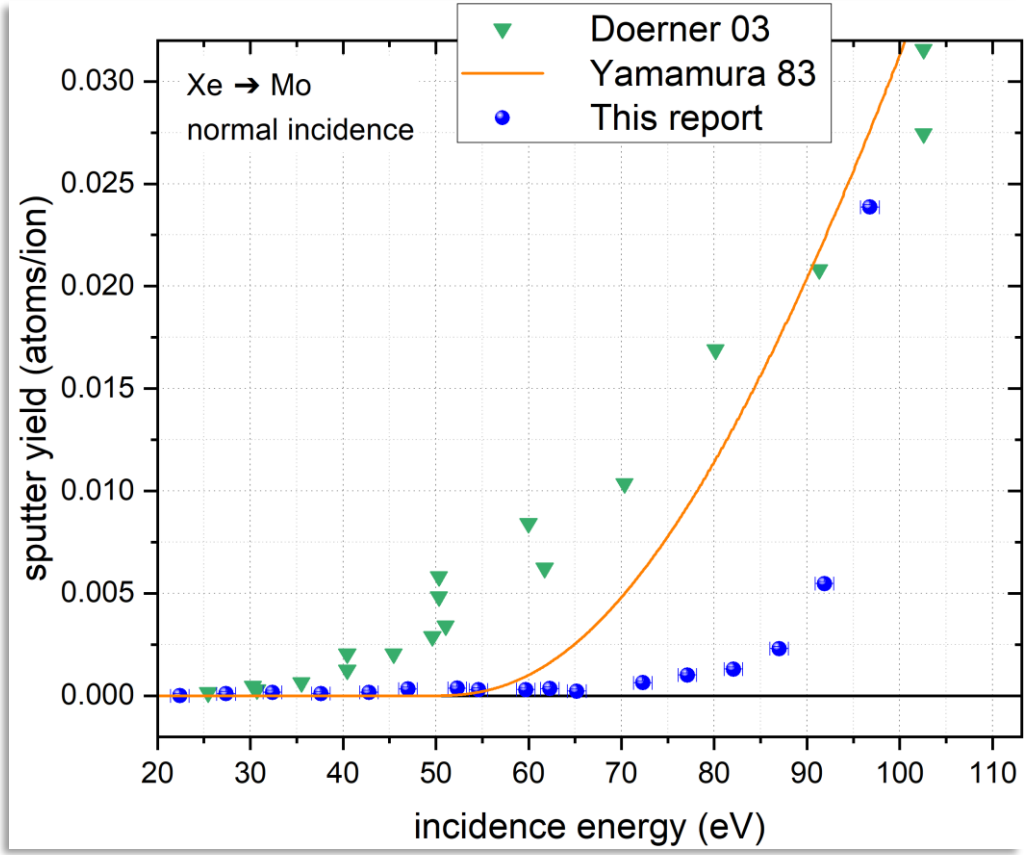
The plasma potential approaches a certain value of ≈ 12 V even for very high negative bias voltages.





04 PRELIMINARY RESULTS DERIVED SPUTTER YIELDS

- With this actual quantities of Mo can be measured
- By comparison with literature values, our measurement method is showing slight differences
- For higher energies Mo may deposit back onto the grid system
- For lower energies, some parts of the exposed surface may have a lower threshold



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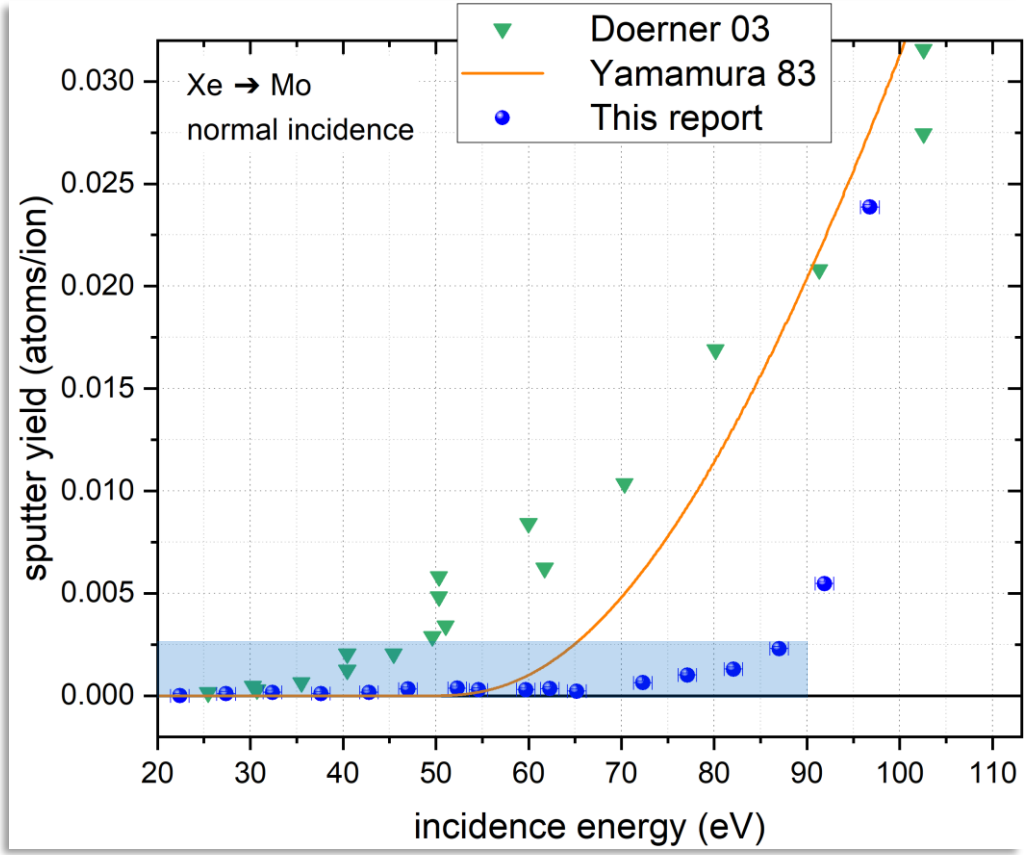

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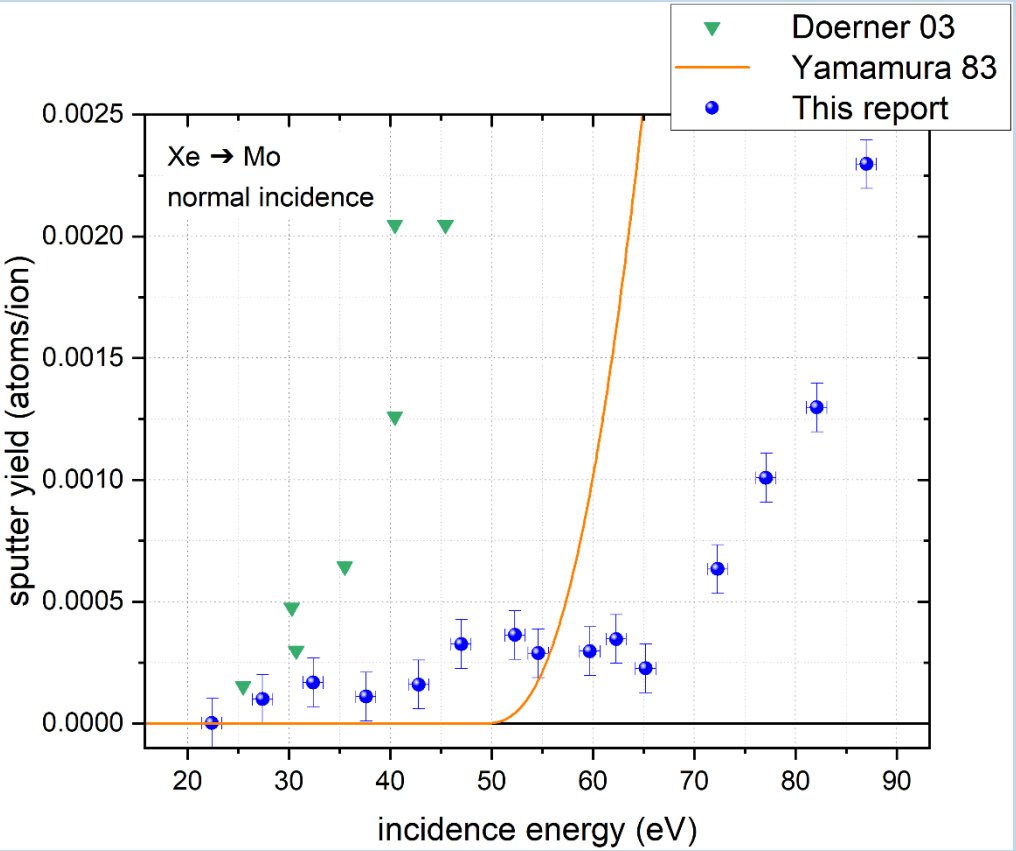
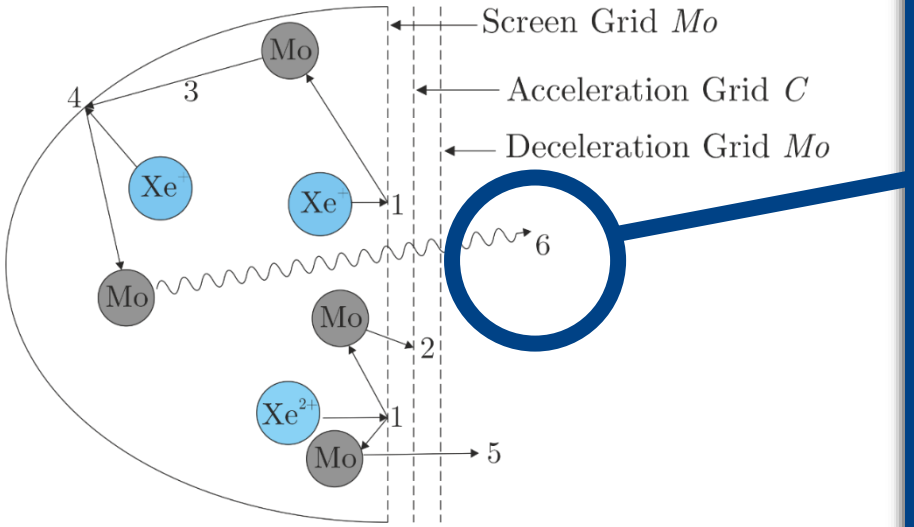


05 OPTICAL EMISSION SPECTROSCOPY (OES)



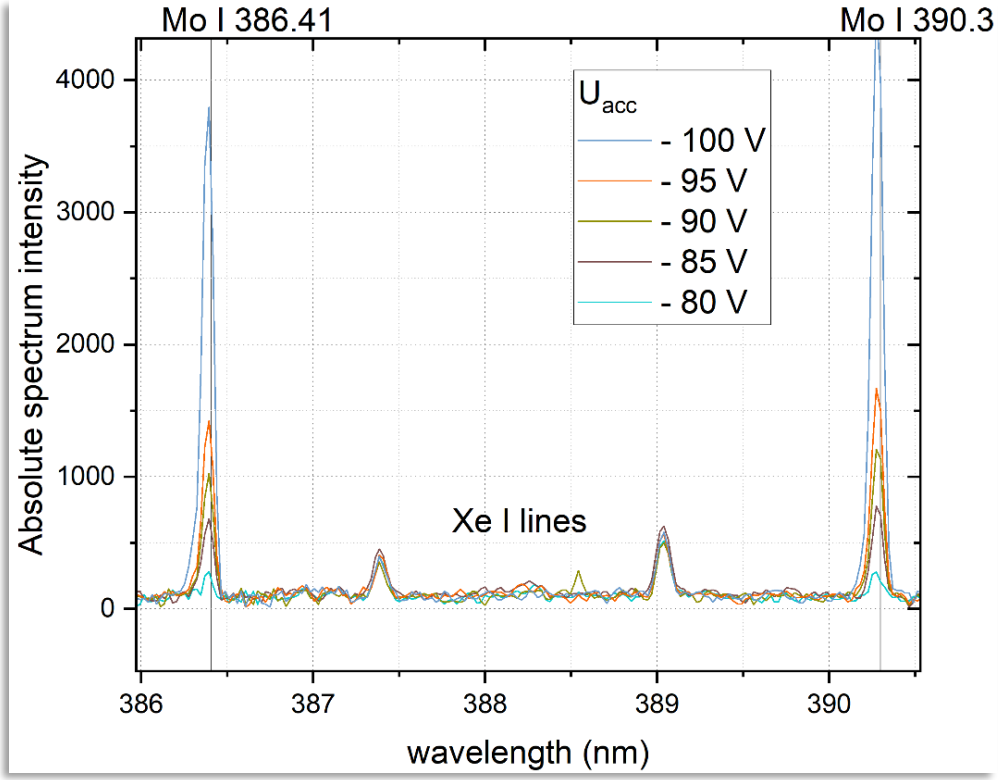
Optical Emission Spectroscopy (OES):

1. Focus the light from the thruster onto the input slit of a spectrometer using a lens system.

2. Identify Mo emission lines in the Xe background spectrum:
   - 379.80 nm / 386.41 nm / 390.30 nm

05 OPTICAL EMISSION SPECTROSCOPY (OES) EXEMPLARY SPECTRA

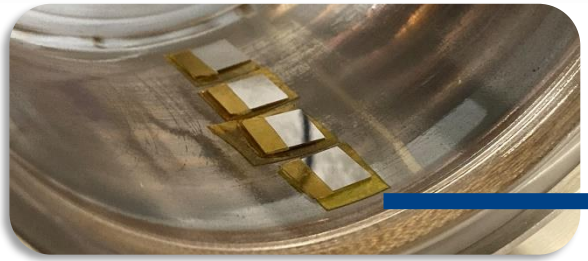
- Normalization to the 396.8 nm *Xe I* line of a defined spectrum.
- Dynamic changes and trends of the Mo intensity are observed.
- Determine the onset point where Molybdenum cannot be detected anymore.

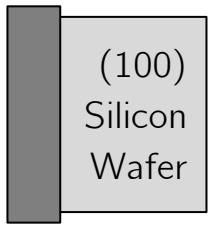


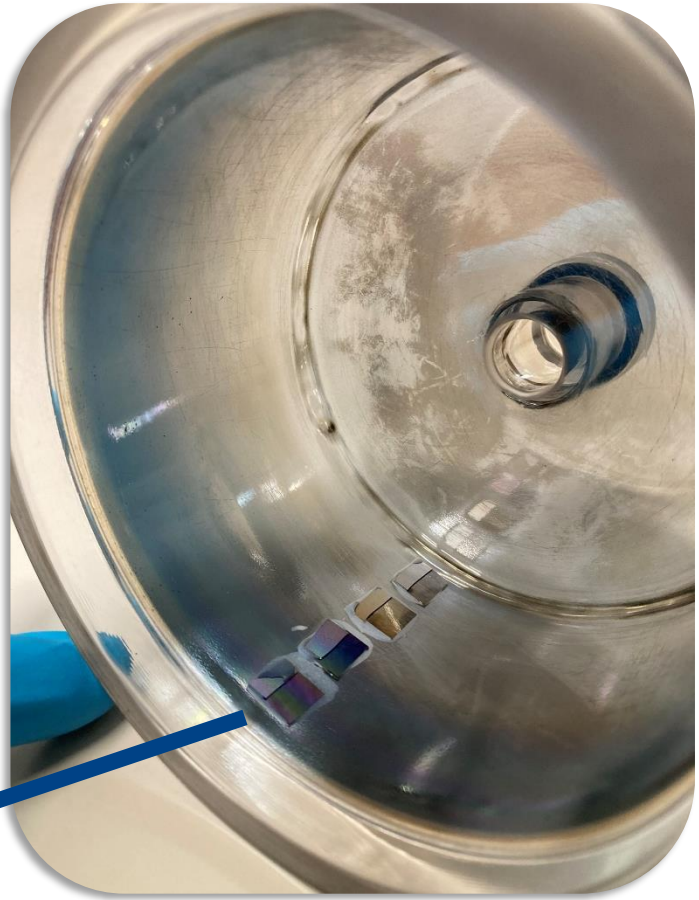
06 ANALYSIS OF WITNESS PLATES

Depth profile analysis of witness plates

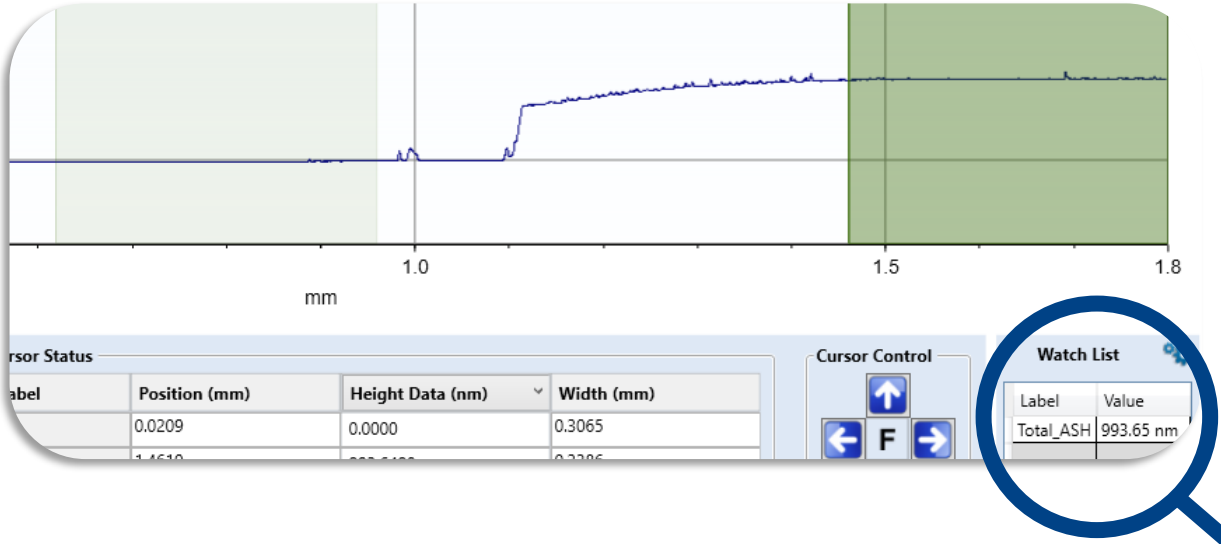
- Witness plates are placed inside the thruster to assess the deposited Mo.
- Samples are retrieved after being exposed to the plasma for a defined period of time at a given operating point

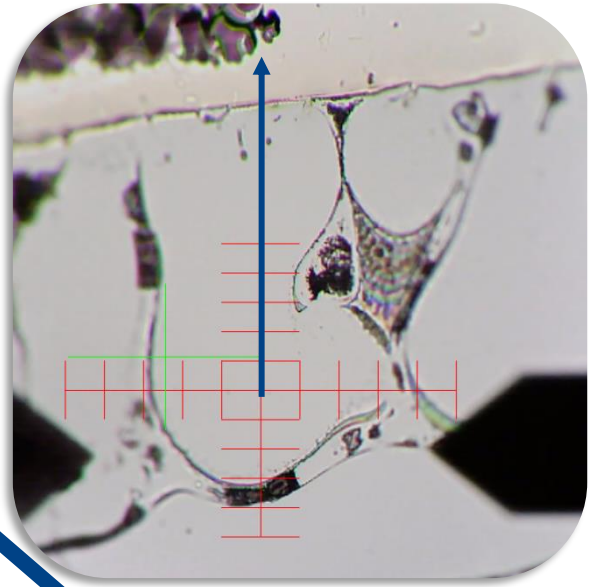






06 ANALYSIS OF WITNESS PLATES
PROFILOMETER MEASUREMENT



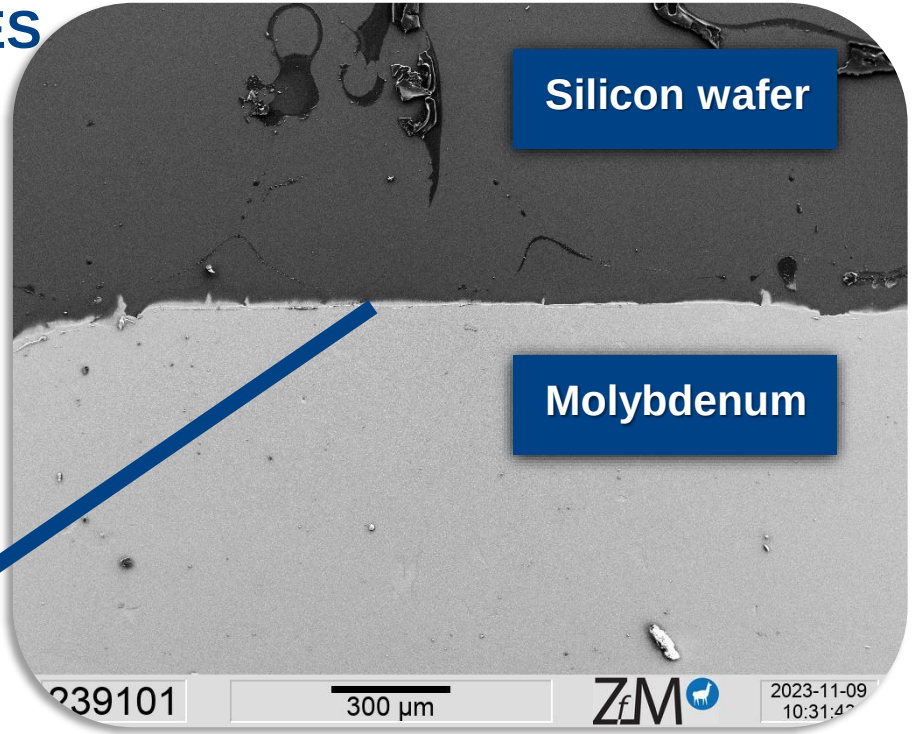


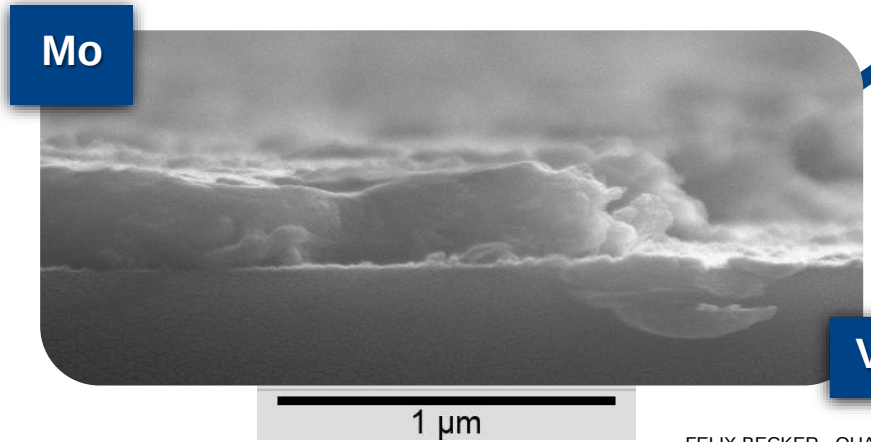
The layer thickness of the Molybdenum on the witness plates is measured with a profilometer for all positions.

993.65 nm Result for the Molybdenum layer thickness

06 ANALYSIS OF WITNESS PLATES
SEM ANALYSIS

- The morphology of the witness plates is analyzed with a scanning electron microscope (SEM).
- The layer can also be observed from the side (under 90° angle).



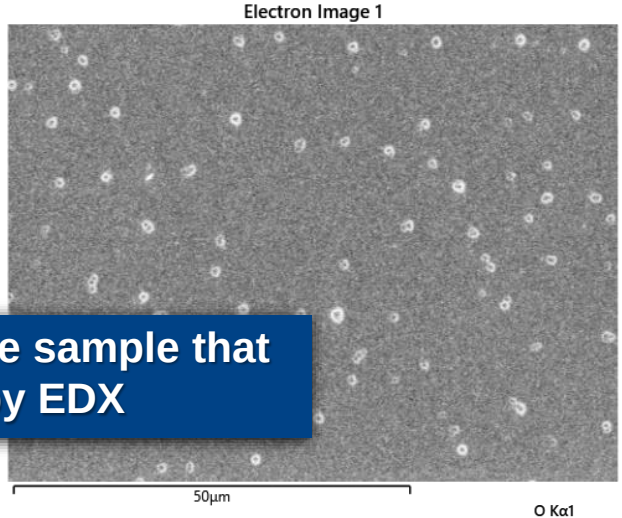


View under 90° angle

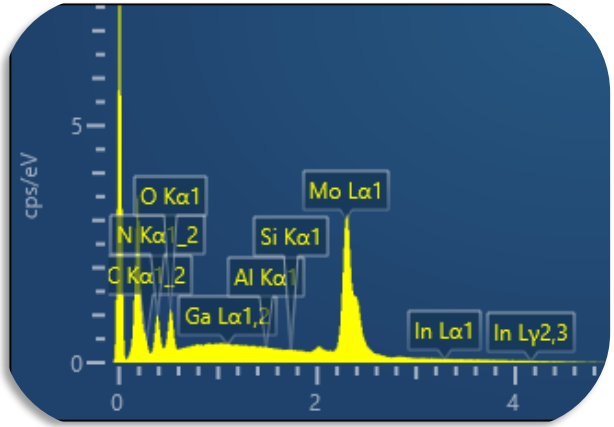
06 ANALYSIS OF WITNESS PLATES
EDX ANALYSIS

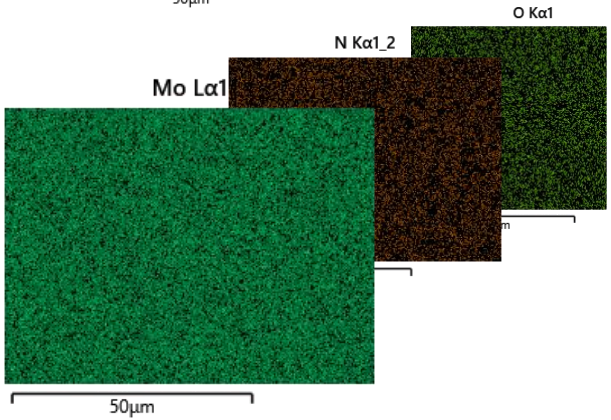
- In addition, the surface composition of the samples is analyzed by energy-dispersive X-ray spectroscopy (EDX).

Atomic species	Wt %	σ
Mo	**89.5**	**0.2**
N	6.0	0.1
O	3.2	0.1
C	1.2	0.1
Si	0.1	0.1
Al	0.1	0.1



Surface of the sample that is analyzed by EDX



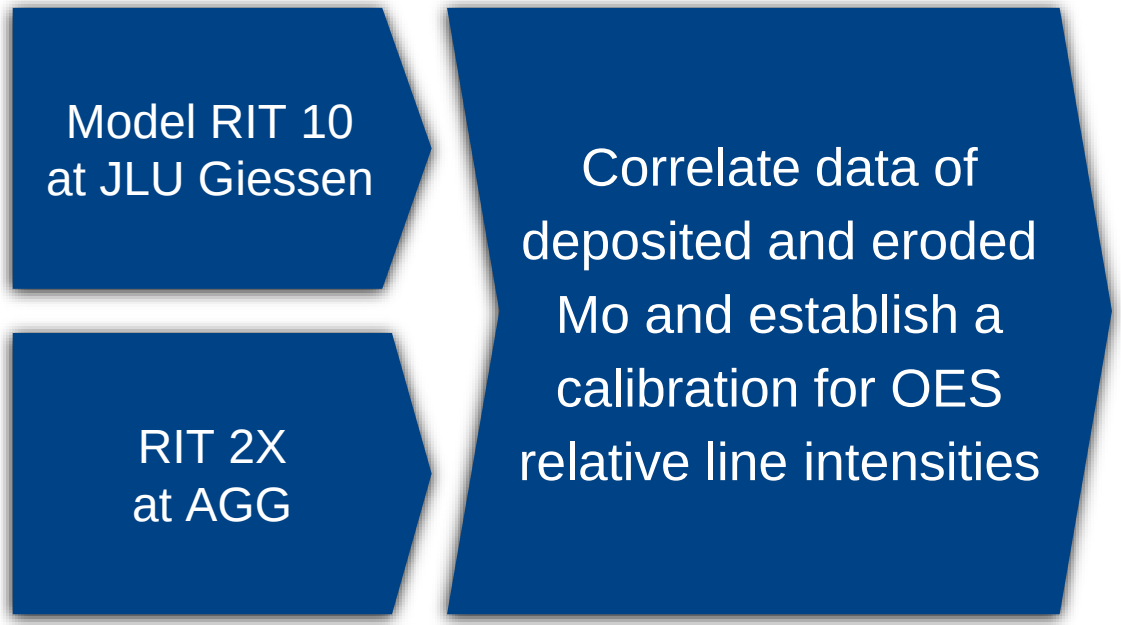


07 APPLICATION MAIN INCENTIVE

We aim to use results found with these measurements to detect and assess any traces of erosion for the ***RIT-2X*** when limit testing its maximum performance possibilities

RIT-2X from Ariane Group GmbH

08 OUTLOOK
FUTURE PLANS AND OBJECTIVES



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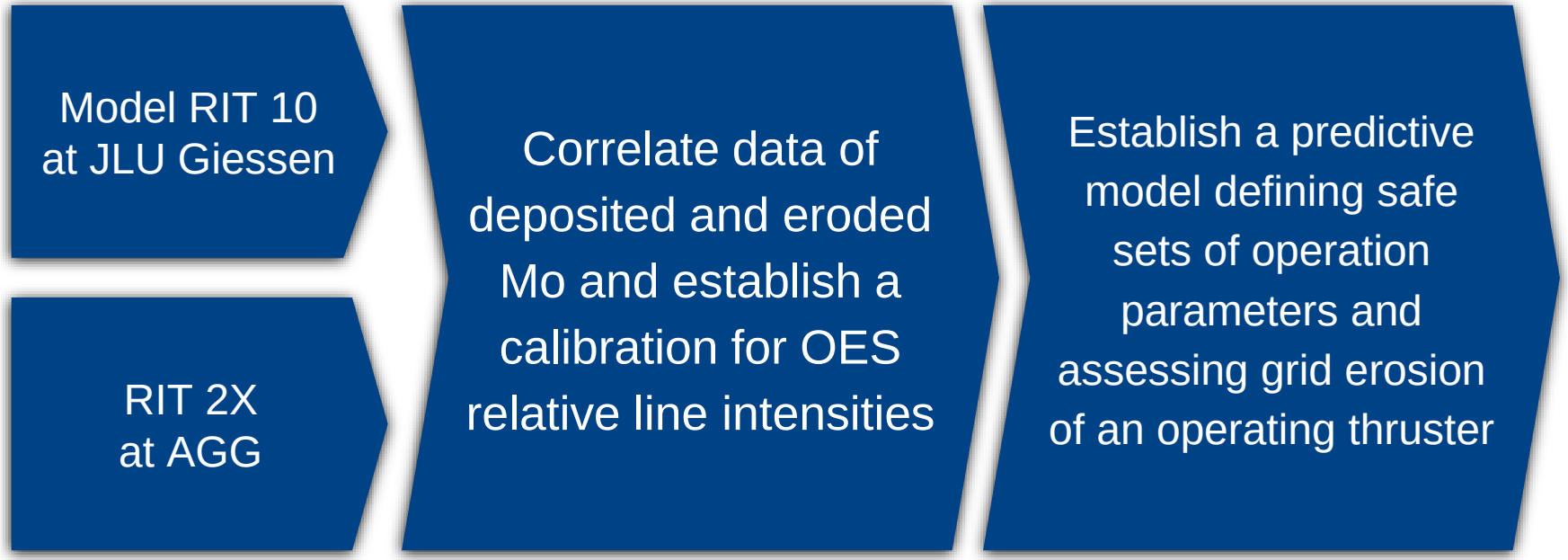

Thank you for your attention