Optical emission spectroscopy, mass spectrometry and spectroscopic ellipsometry measurements of the erosion of Ar/H_2 plasma-facing carbon surfaces

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PMP
PLASMA & MATERIALS PROCESSING

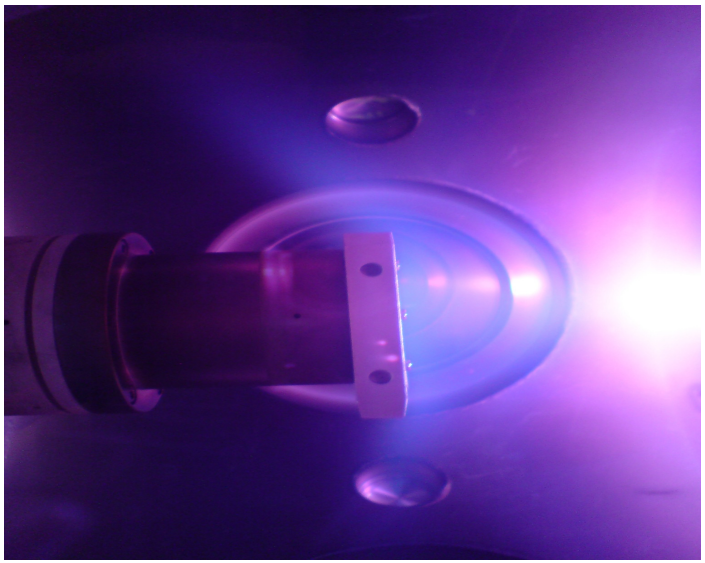
FOM

Motivation

General activity of the group:
plasmas – surfaces interactions
(deposition of thin layers, etching)

Particular activity (R. Engeln, D. C. Schram):

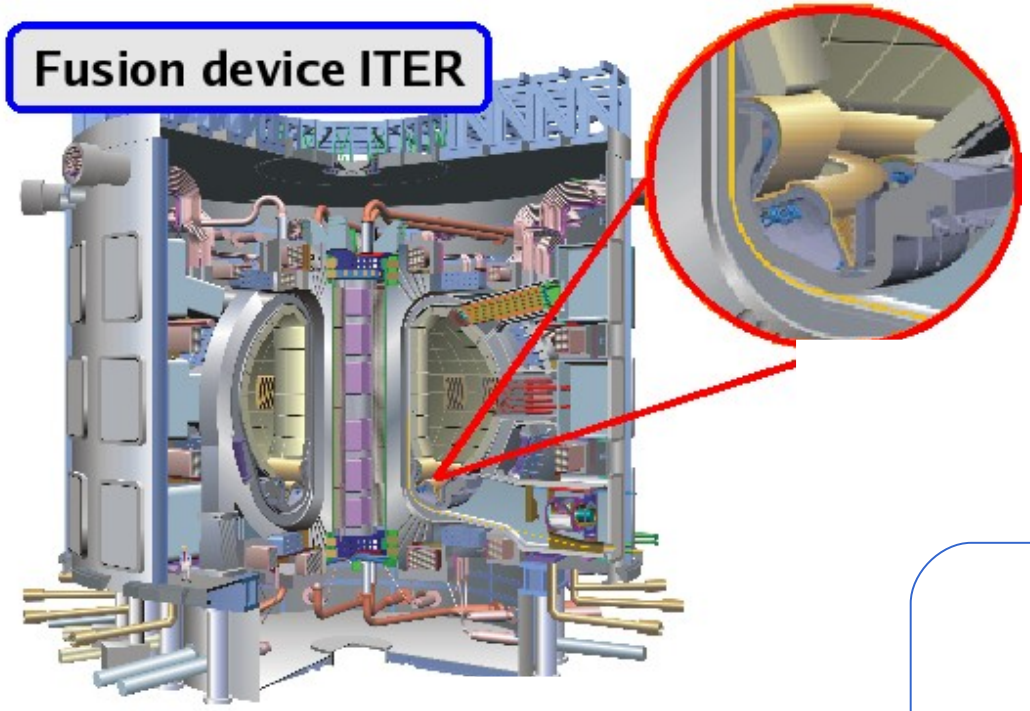
- Characterization of an expanding thermal plasma (H_2)
- Plasma H_2 – surfaces interactions



Application:

plasma H_2 – carbon interactions

Motivation



Possible material for ITER divertor:

Carbon Fiber Composite (CFC)

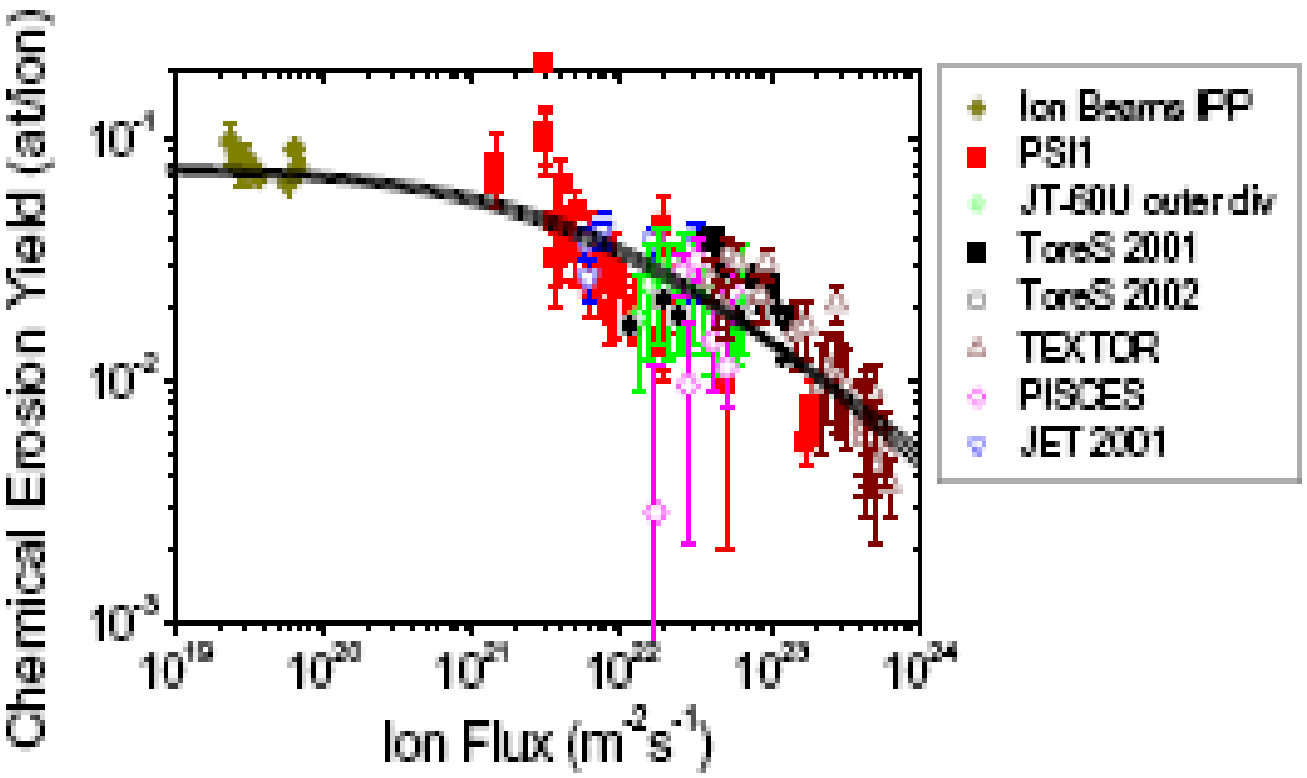
ITER divertor hits by:

1-10 eV ions

10^{24} $m^{-2}.s^{-1}$ particle flux

Carbon erosion by hydrogen

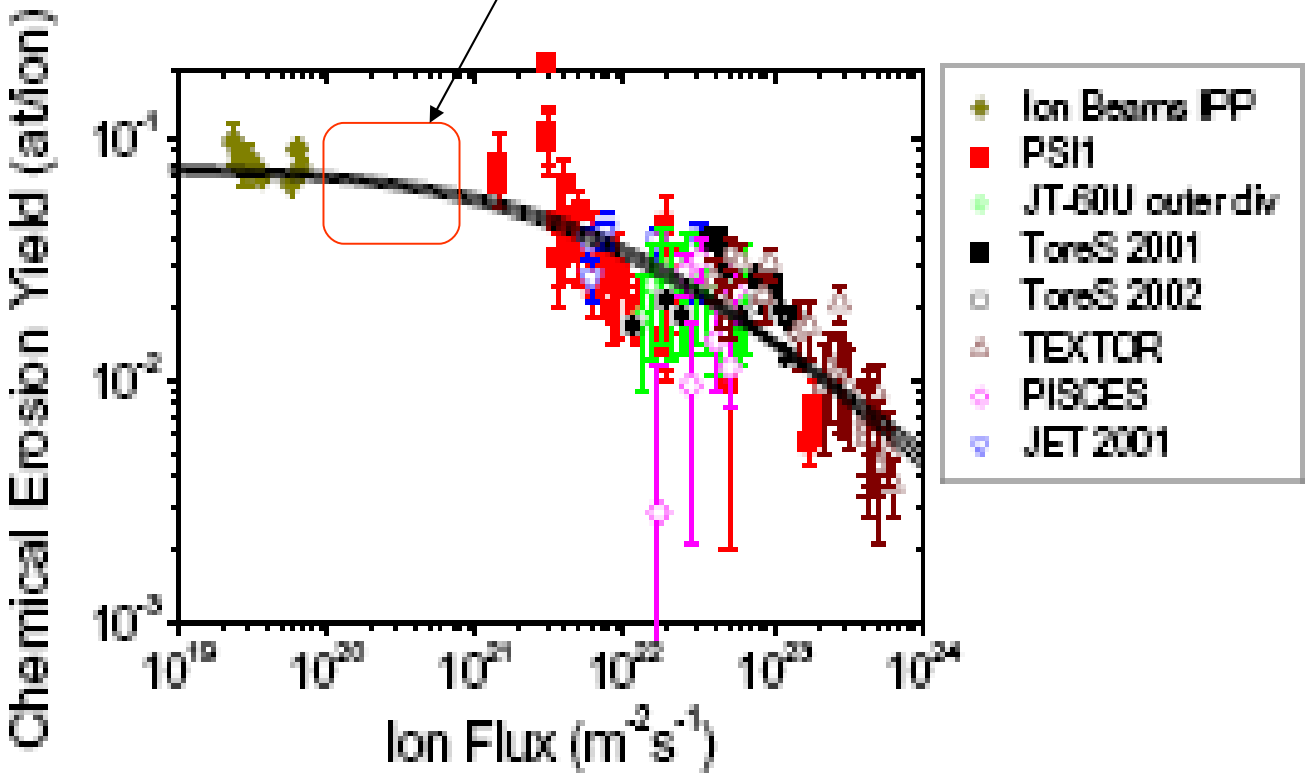
Motivation



J. Roth *et al*, *J. of Nucl. Mater.* **337-339**, 970-974 (2005).

Motivation

No measurements in the transition between constant and decreasing erosion yield

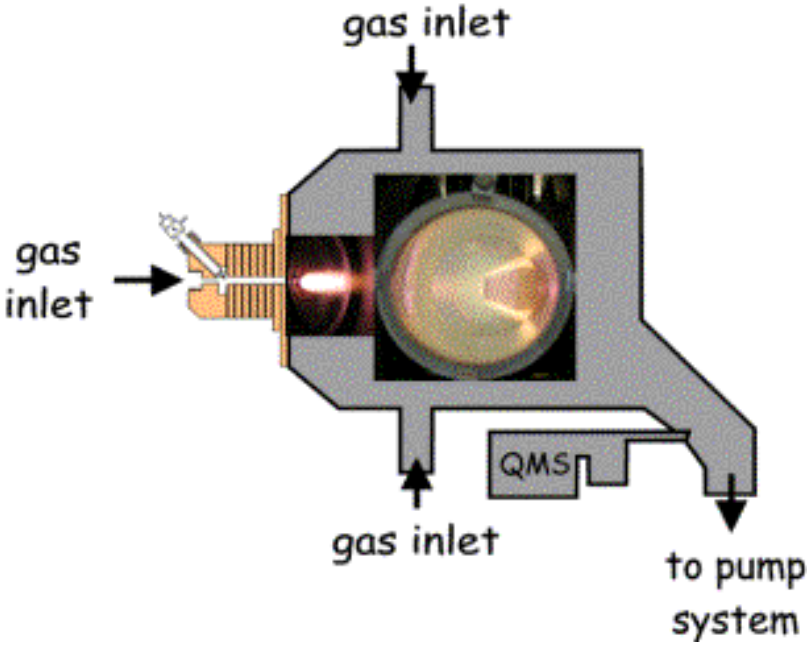


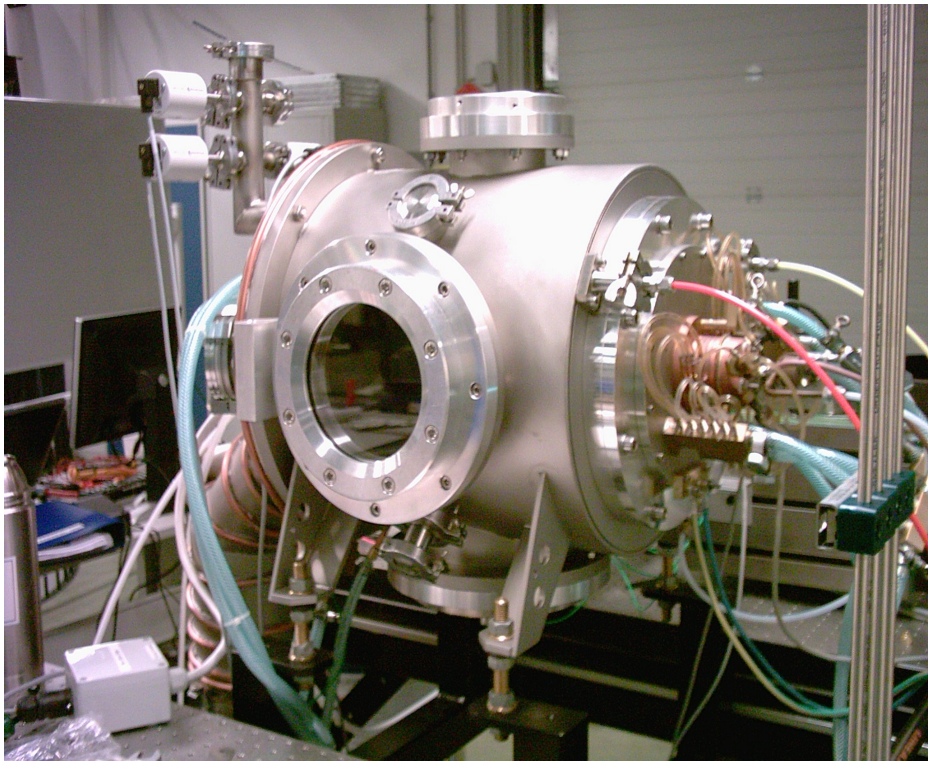
J. Roth *et al*, *J. of Nucl. Mater.* **337-339**, 970-974 (2005).

Outline

- **Motivation**
  - Several works about interaction plasma-surfaces in the group
  - Importance of the effect of hydrogen on carbon in ITER
- **Experimental setup**
  - Using different kinds of diagnostics to get more informations about the different processes
- **Results**
  - Optical Emission Spectroscopy (OES)
  - Mass Spectrometry
  - Ex-situ Spectroscopic Ellipsometry (SE)
- **Summary**

Experimental setup





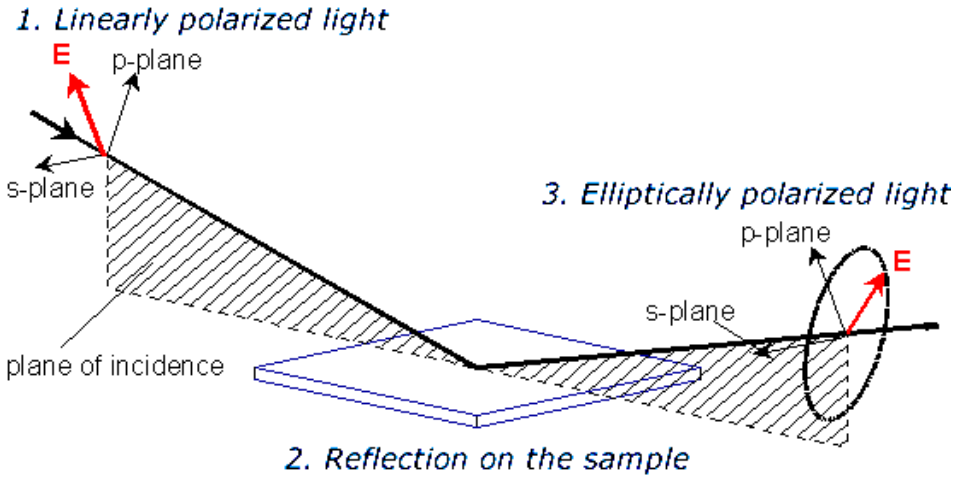
- Ar/H_2 plasma (45 scc/s Ar; 10 scc/s H_2)
- I = 50 A
- T_{sample} = 293 K

Experimental setup

Different diagnostics:

- Optical Emission spectroscopy
- Mass spectrometry
- Ex-situ Spectroscopic Ellipsometry

Principle of SE



Measurement of the change in the light polarization state upon reflection on a sample:

$$\rho = \frac{r^p}{r^s} = \tan\Psi\, e^{i\Delta}$$

Ψ and Δ can be related to the complex refractive index $\tilde{n}$ and therefore used to obtain the dielectric constants ε_1 and ε_2 (n and k)

Experimental setup

Transition pure Ar - Ar/H_2 plasma

Results: carbon erosion by argon ions

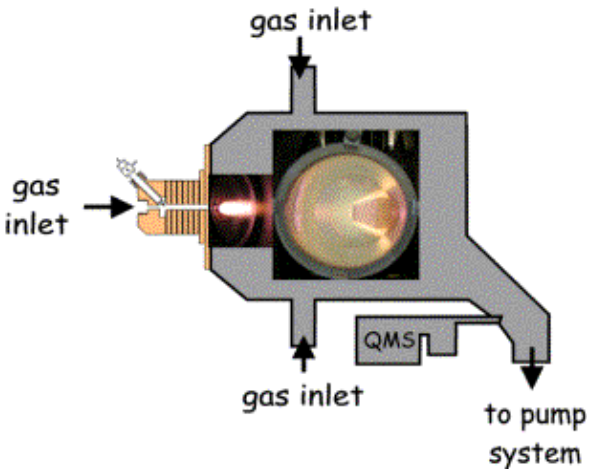
- Measurements done with Ar/H_2 plasma
- Possibility to control hydrogen ions flux with Ar/H_2 mixture
- Effect of Ar ions on carbon samples?

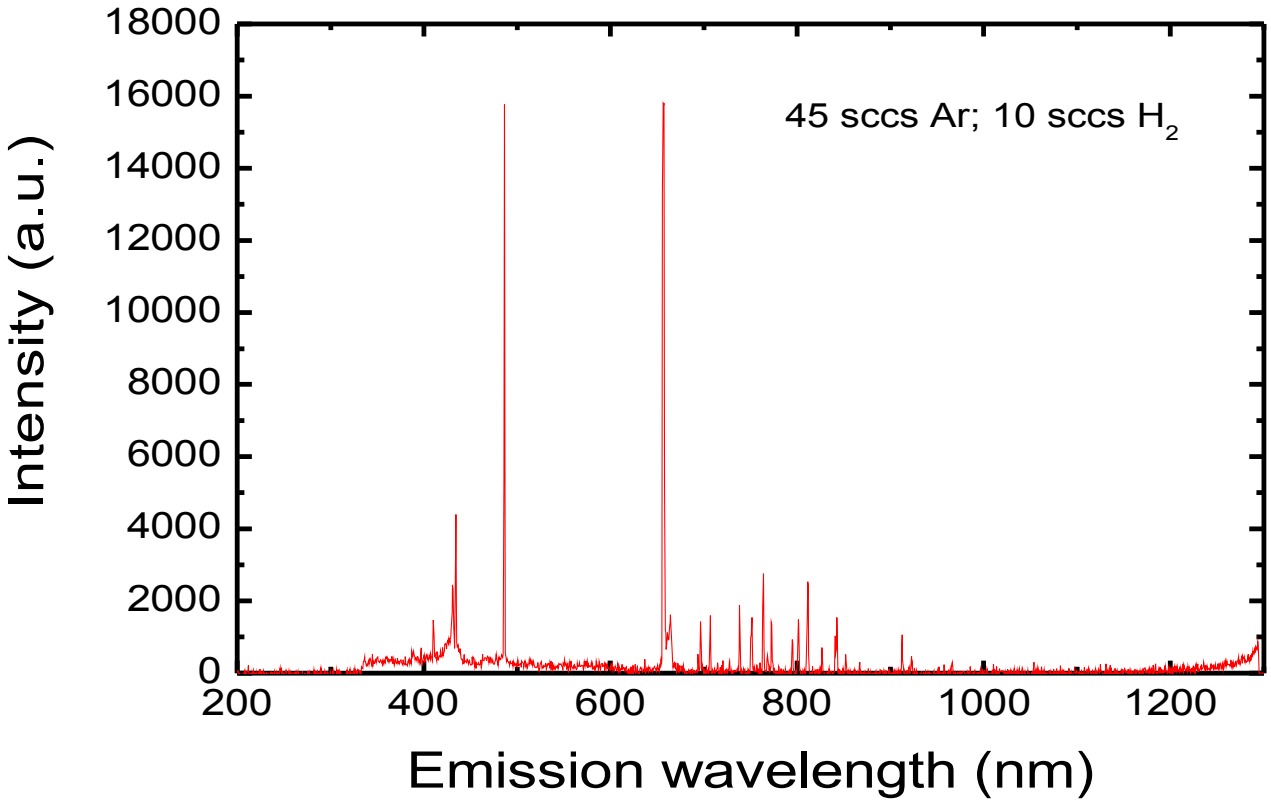
- Carbon samples exposed to a pure argon plasma
- Ex-situ SE on samples before and after exposure

Erosion rates by argon ions:

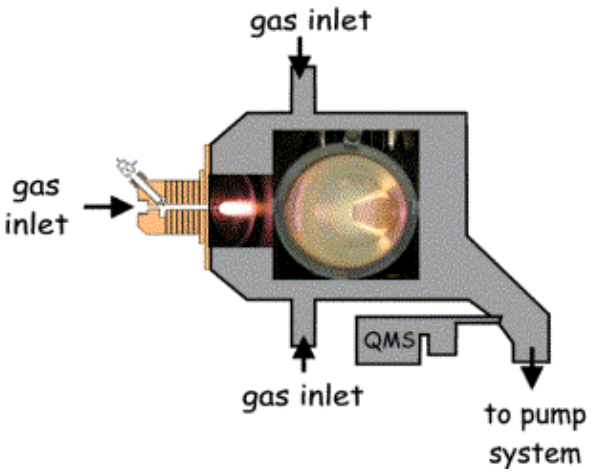
- 0.14 nm/s

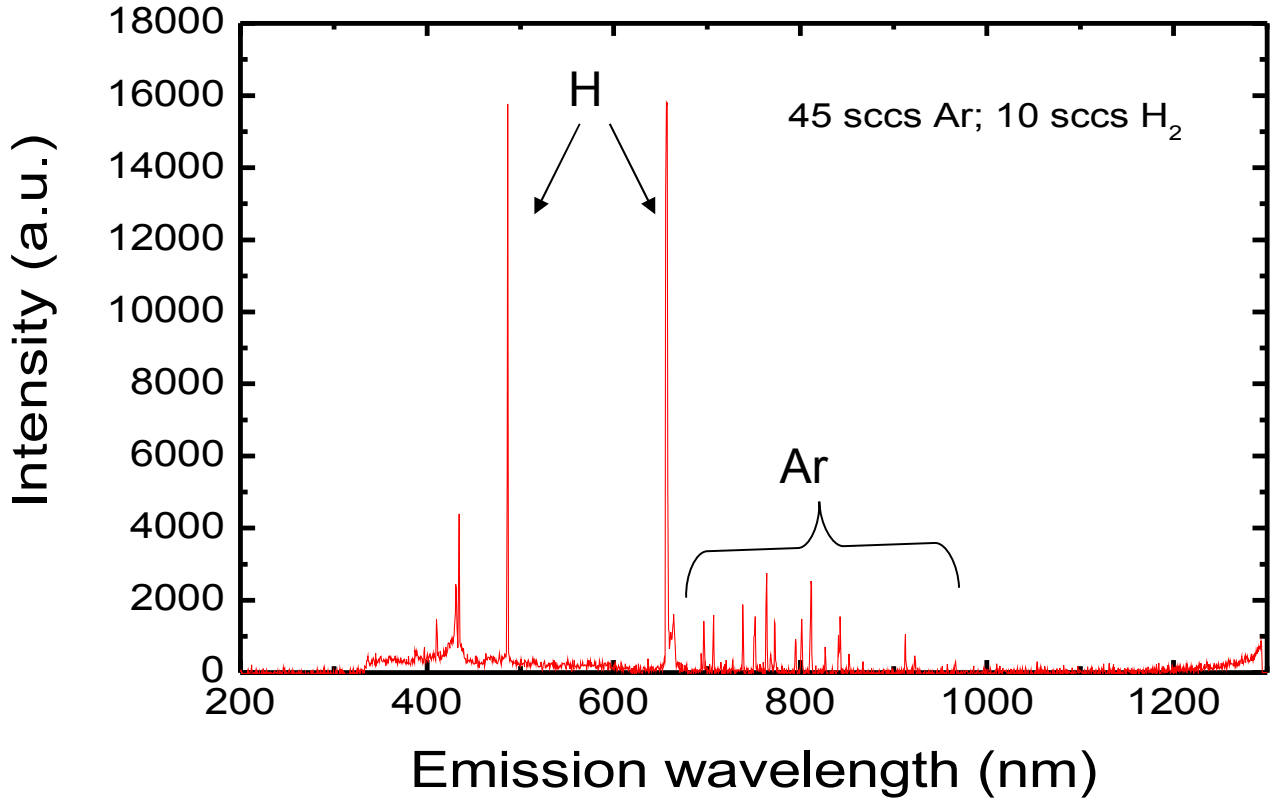
Results: OES


gas inlet
gas
inlet
QMS
gas inlet
to pump
system

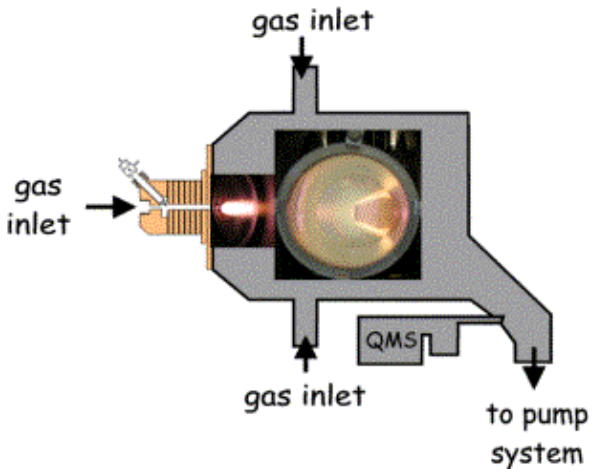

45 sccs Ar; 10 sccs H2
Intensity (a.u.)
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
200
400
600
800
1000
1200
Emission wavelength (nm)

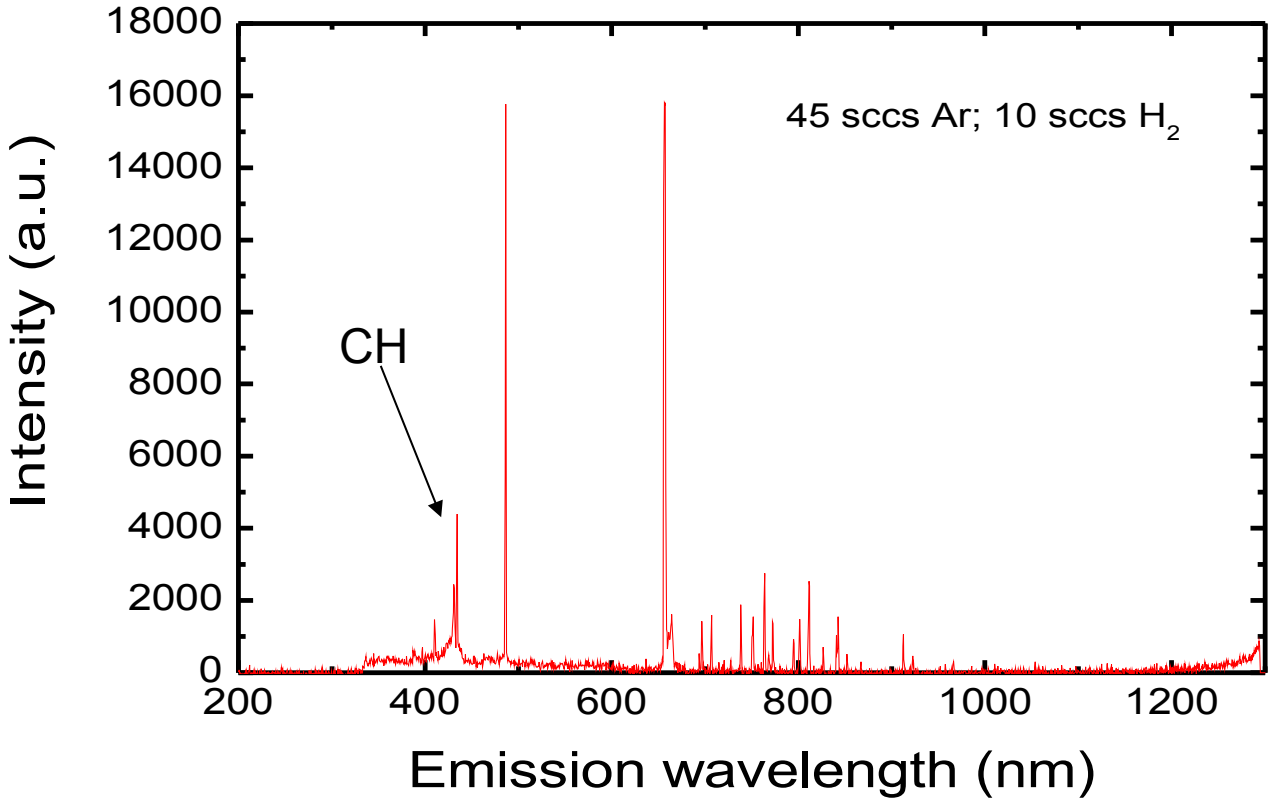
Results: OES


gas inlet
gas inlet
QMS
gas inlet
to pump system

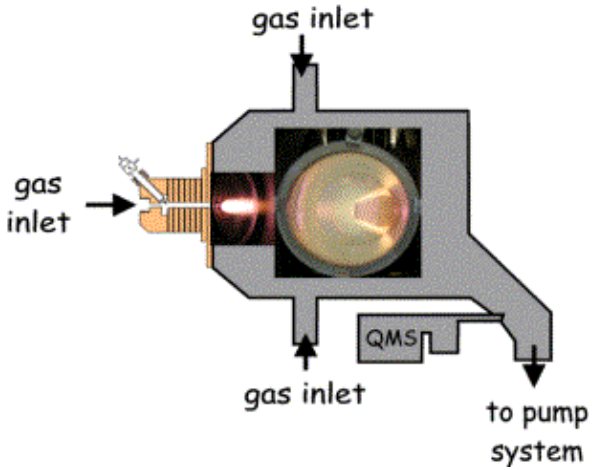

H
45 sccs Ar; 10 sccs H2
Ar
Intensity (a.u.)
Emission wavelength (nm)
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
200
400
600
800
1000
1200

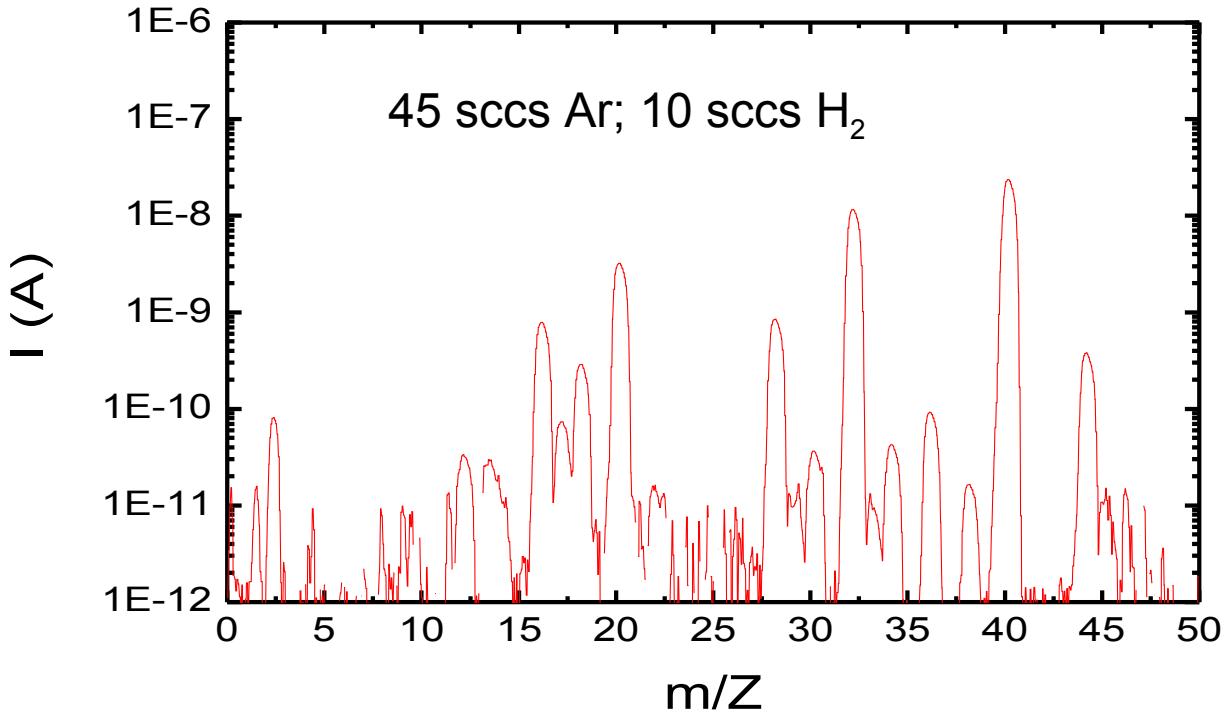
Results: OES


gas inlet
gas inlet
QMS
gas inlet
to pump system

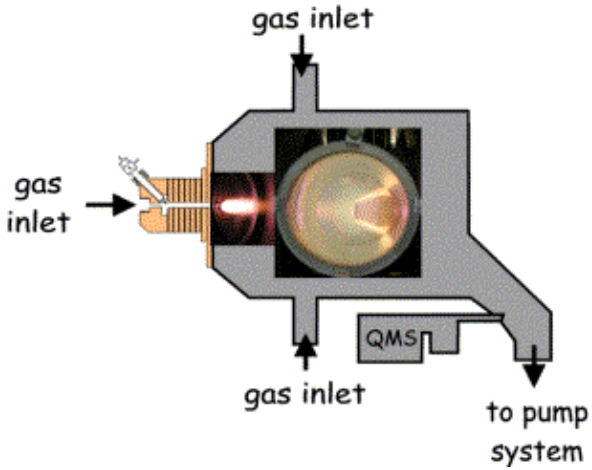

45 sccs Ar; 10 sccs H2
CH
Intensity (a.u.)
Emission wavelength (nm)
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
200
400
600
800
1000
1200

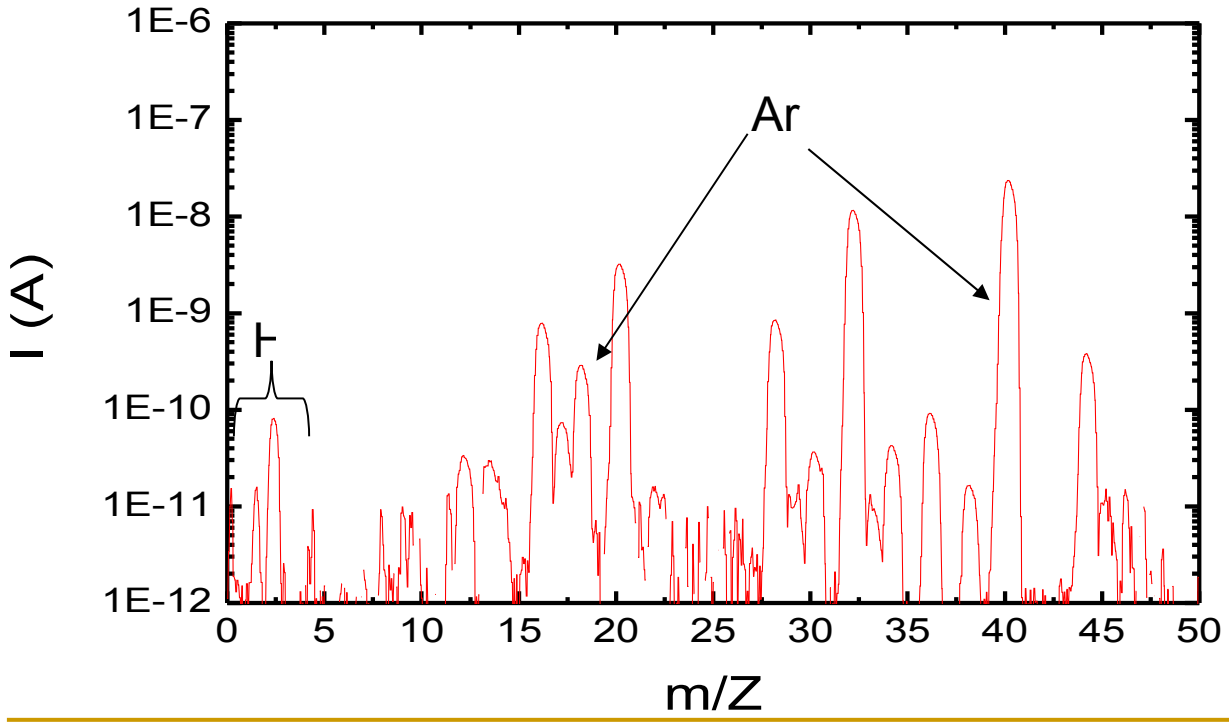
Results: mass spectrometry



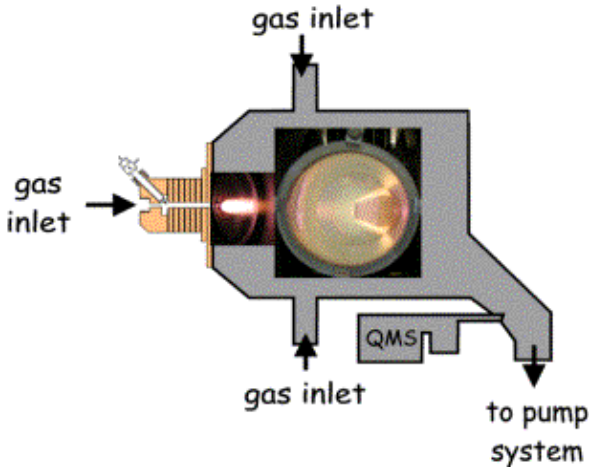


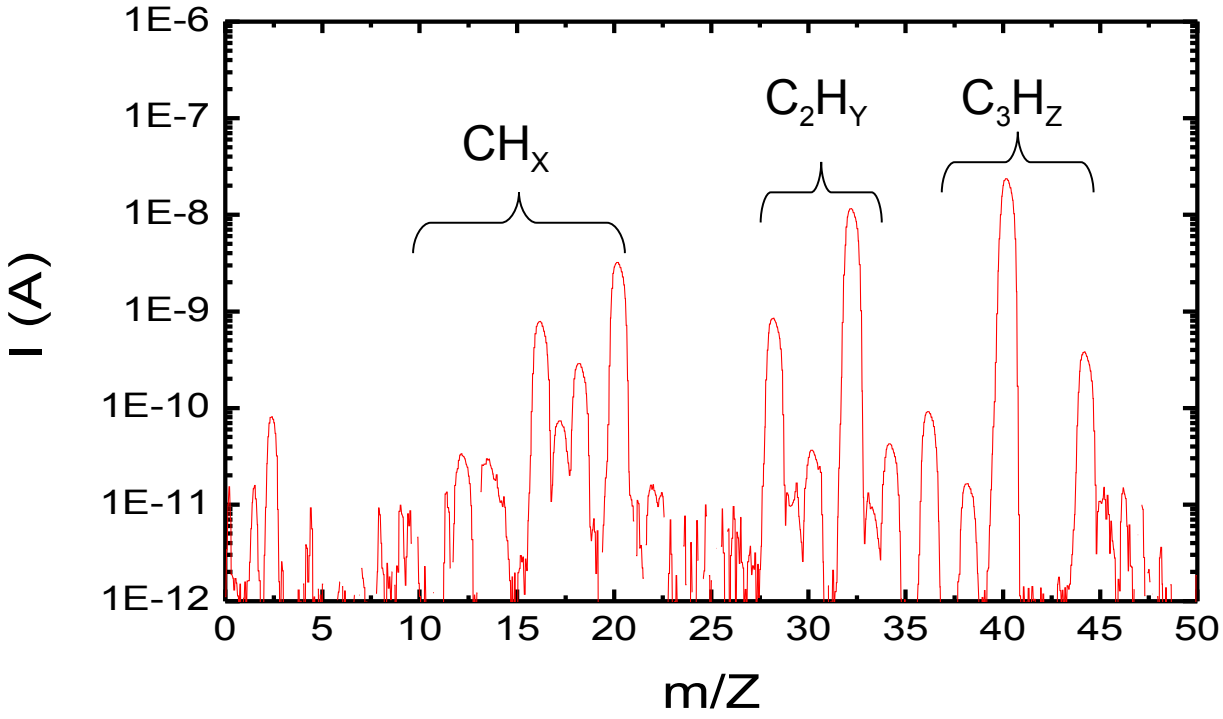
Results: mass spectrometry





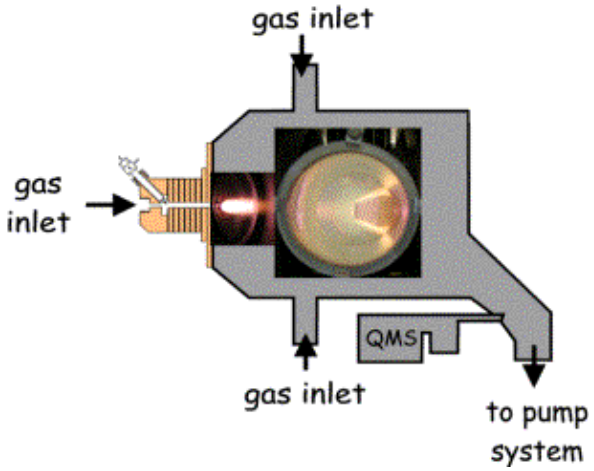
Results: mass spectrometry

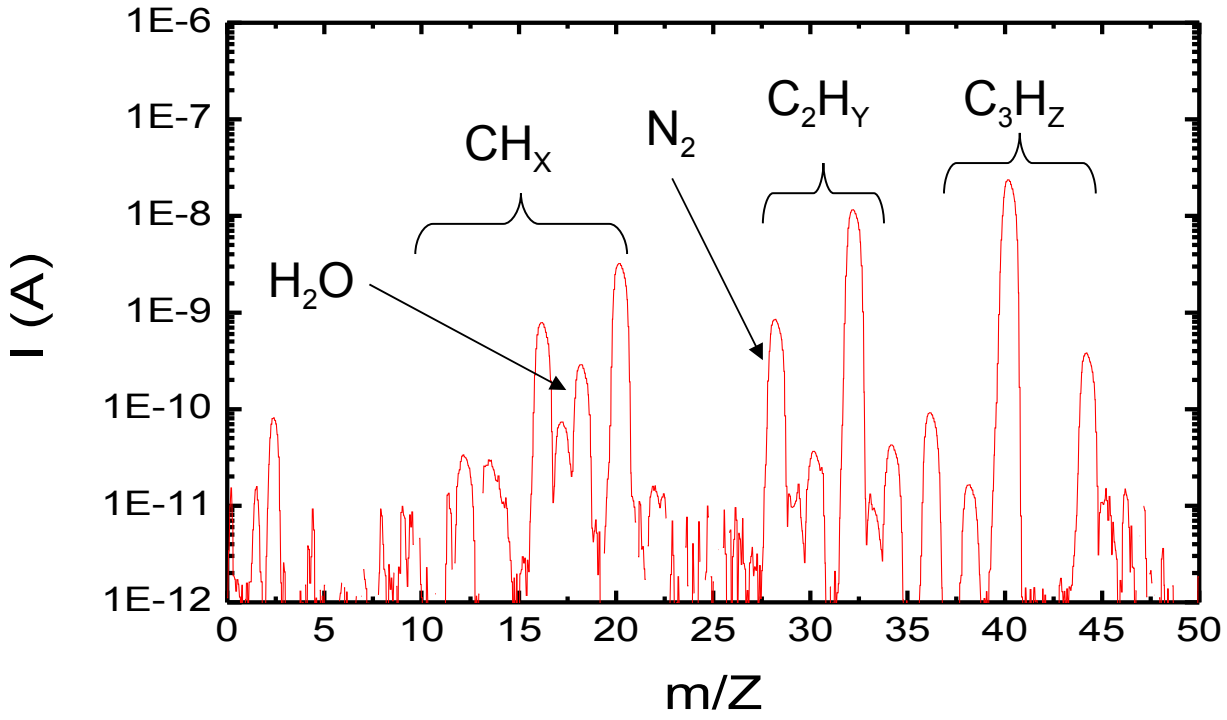




No hydrocarbons detected between 50 amu and 100 amu

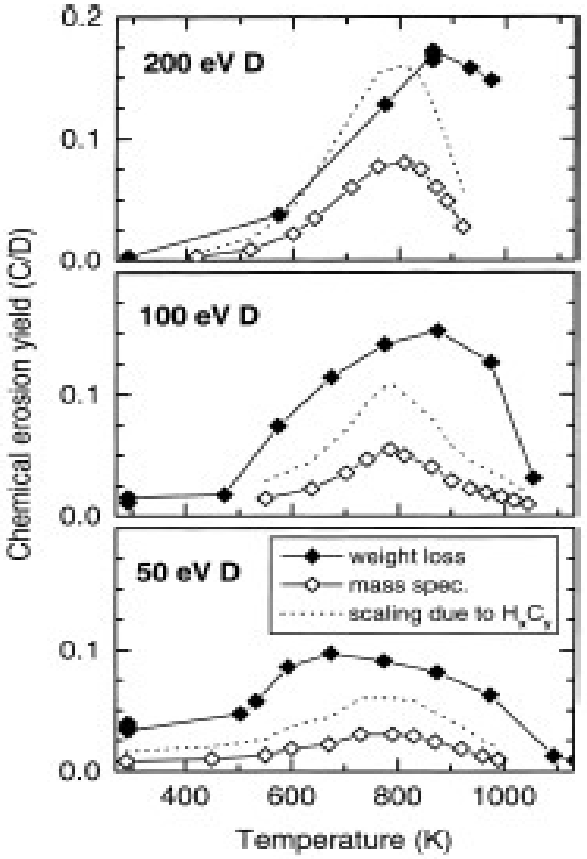
Results: mass spectrometry





Always impurities like N_2 and H_2O

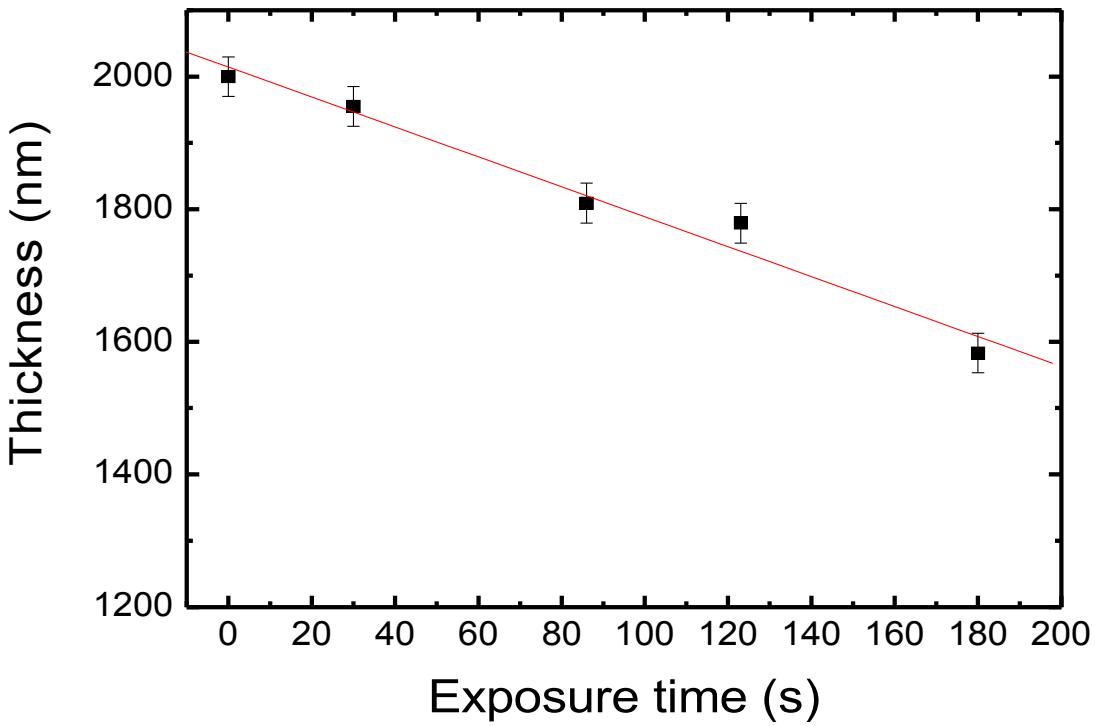
Results: mass spectrometry



- **Mass spectrometry less efficient to determinate erosion rate:**
  fraction of eroded particle sticks to wall
- **Another kind of diagnostic** must be used to calculate erosion yield

M. Balden and J. Roth, *J. of Nucl. Mater.* **280**, 39-44 (2000).

Results: ex-situ SE



Erosion rate: 2.26 ± 0.21 nm/s

Summary

- **Erosion rate determine for 1 kind of sample hardness**
  - Radicals like CH detected by OES,
  - Mass spectrometry less efficient to calculate erosion yield,
  - Erosion rate determinate with good precision with ex-situ SE.

Outlook

- In-situ SE,
- Measurement of atomic hydrogen density by using TALIF,
- Measurement of ionic hydrogen density by using a langmuir probe.

Acknowledgments

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