Detection of ions generated in an intense pulsed EUV-light beam using different interfaces to a high resolution TOF-MS

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Introduction

A high-resolution time-of-flight mass spectrometer (TOF-MS) is used to detect ions generated in a surrounding gas phase consisting of hydrogen, in order to investigate the induced extreme ultraviolet (EUV)-light chemistry. The influence of several parameters is investigated as a follow up on surprising results found in previous experiments.

Of major interest were the parameters:

- **pressure** in the interface
- **distance** between the EUV light focus and TOF-MS
- interface **geometry** and **viewpoint**
- the effect of **light focusing**
- the **time interval** between ion generation and ion detection

To study the geometrical aspects, different interfaces were employed. An delay generator was used to synchronously trigger the TOF oa-stage and data acquisition system relative to the EUV light pulses to obtain time-resolved spectra.

Methods

EUV-HIEX

EUV high-intensity exposure for 13.5 nm (RWTH Aachen).

- discharge-produced Xe source
- beam conditioning system to focus the light
- intensity of 100 mW/mm2

Interface filter

Spectral purity filter a SiN/Zr layer system.

- transmission of 25% at 13.5 nm
- the spectral purity is > 100.000

Interface

Connecting environments from UHV CF parts.

- including gas inlet and turbo-molecular pump
- heaters for baking at 120° C

The interfaces differ in these geometrical aspects

- distance between EUV focus and TOF inlet
- rel. position to light beam and total volume

Ion source

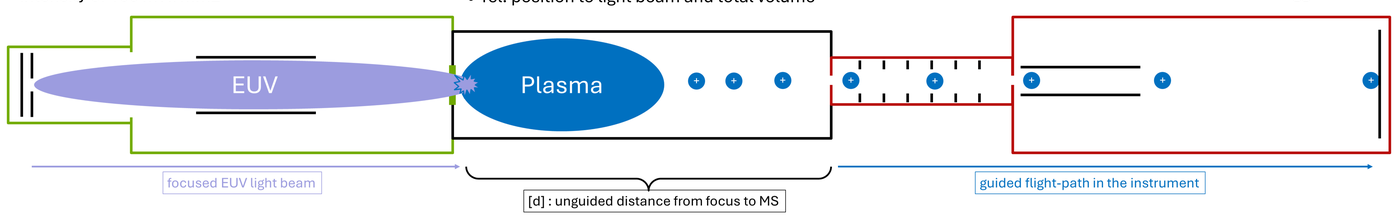
Custom-built ion source (University of Wuppertal).

- with a mode for native ion (NI) active sampling and transferring
- NI is exclusively used

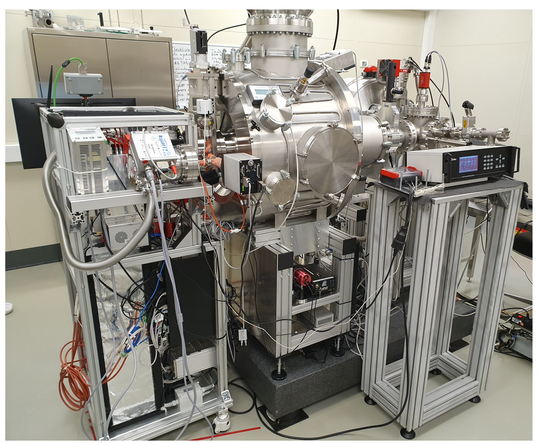
TOF-MS

Time-of-flight mass spectrometer (TOFWERK AG, Thun, Switzerland)

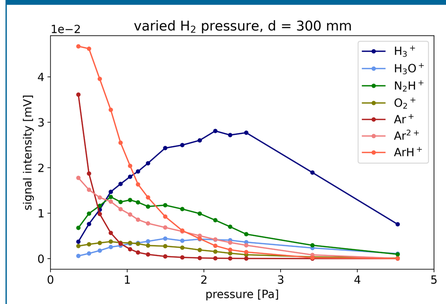
- ion transfer quadrupole (100 mm length)
- flight tube length (folded): 2700 mm
- external and internal trigger mode

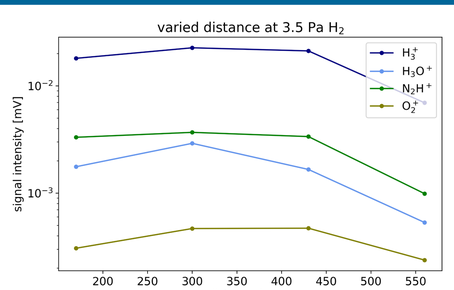


Setup



Results

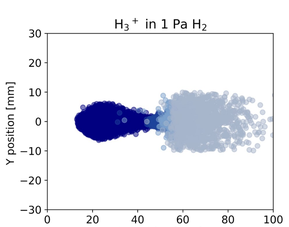


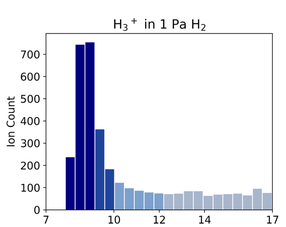


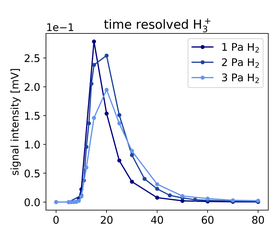
The left plot illustrate the behavior of the ionic species as the pressure in the interface is increased, via increasing hydrogen flows. For H_3^+ a signal maximum at approximately 2 Pa is observed. Upon further H_2 pressure increase, all ion signals decrease continuously. The plot on the right shows the influence of the distance [d] between light focus and the custom fly-through ion source of the TOF-MS. Ion signals were only detected when the MS was aligned on the same axis as the light beam. The experiments at the four different distances show minor changes in the signal intensities, without any clear trend.

SIMION[1] simulations were performed to identify the spawning area of the ions, which successfully pass the source and are sampled by the TOF-MS. The distribution is seen in the left plot. Only ions with flight times up to 17 µs are sampled, and 90% of the ions have flight times < 10 µs, as shown in the center plot. This suggest that in the experiments only show ions with very short flight times are detected. The simulations assume ideal hard sphere collisions and don't include chemical reactions.

The experimental results for the time-resolved H_3^+ are shown in the plot on the right. The time axis represents the duration between EUV pulse and ion arrival at the TOF's oa-stage. These results are in very good agreement with the simulation data. [1]D. A. Dahl, Int. J. Mass Spectrom., vol. 200, no. 3., pp. 3–25, 2000.







Conclusion and Outlook

The experimental data reveal an **unexpected behavior of the ion signal** as a function of different parameters. Only the linear dependence of the ion signal and the source frequency is readily rationalized. The results strongly suggest that the **sampled ions are not generated in the EUV plasma focus.**

The simulations show that ions detected in the TOF only a few microseconds after the ionization event, can only be located a few centimeters in front of the sampling port. The probability that plasma ions are sampled at longer delay times is very low, as such ions are essentially stopped by gas phase collisions or surface capture. It is most likely that **another EUV-dependent effect produces ions** in front of the sampling port.

For future experimental setups, it is strongly recommended to **integrate a transfer stage** that collects ions a few millimeters from the EUV focus point and actively transports them into the TOF. This will minimize interfering effects and ions from the plasma are collected.

Acknowledgement and Disclosure

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