BERGISCHE UNIVERSITÄT WUPPERTAL

Physical & Theoretical Chemistry

University of Wuppertal[1]

Chair for Technology of Optical Systems (TOS)

RWTH Aachen University[2]

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

Niklas Pengemann[1], Sanna Benter[1], Maja Hammelrath[1], Joshua Rieger[1], Franziska Schuler[1], Adelind Elshani[2], Linus Nagel[2], Ismael Gisch[2], Hendrik Kersten[1], Sascha Brose[2], Carlo Holly[2], Peter Gust[1], Thorsten Benter[1]

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 chemistry by extreme ultraviolet (EUV)-light. The influence of environmental parameters is being investigated due to surprising results found in previous measurements. The dependencies of major interest include the pressure of the gas phase, the distance between the EUV focus and TOF-MS inlet, the surrounding geometry and viewpoint, the effectiveness of light focusing, and the time interval between ion generation and ion detection. To vary the geometrical aspects, different interfaces were employed. An additional delay generator was used to trigger the TOF measurements depending on the light pulses to obtain time-resolved spectra.

Methods

EUV-HIEX

EUV high-intensity exposure for 13.5 nm (TOS, 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 (PC, University of Wuppertal).

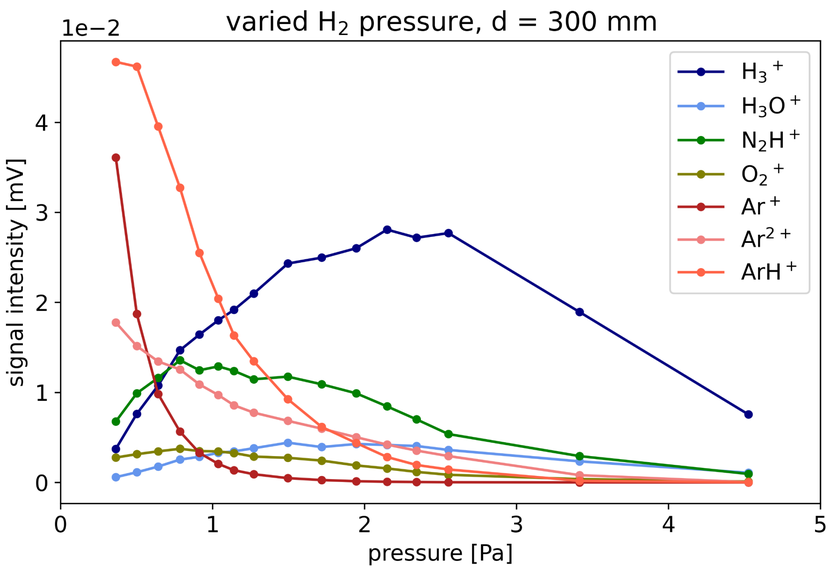
- with a mode for native ion (NI) active sampling and transferring
- NI is exclusively used

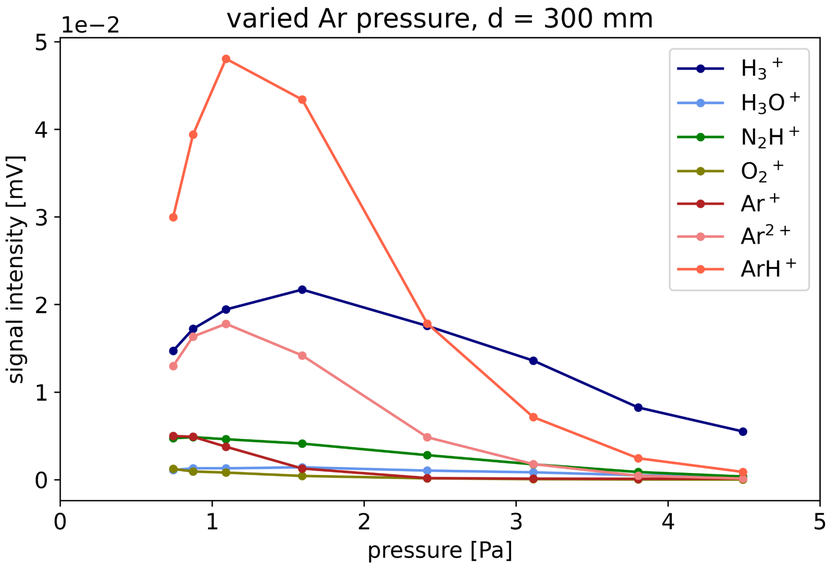
TOF-MS

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

Experimental Results



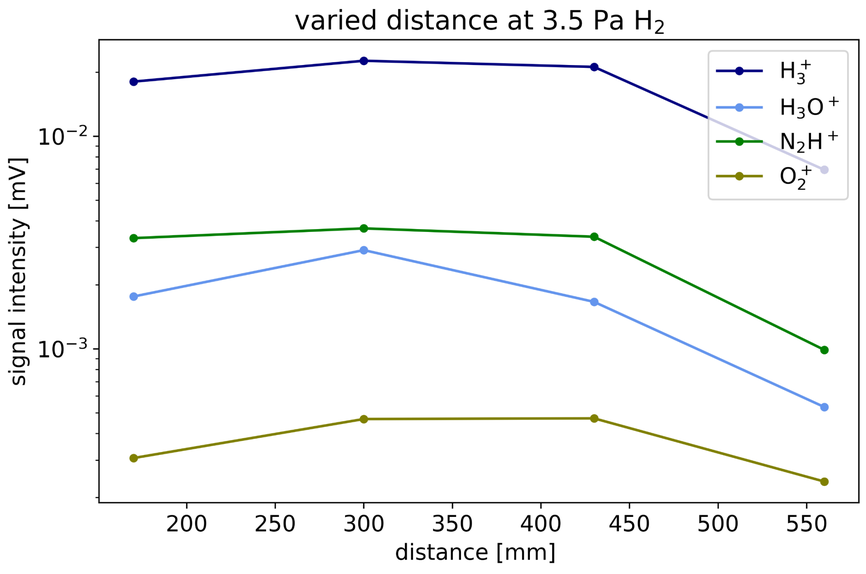


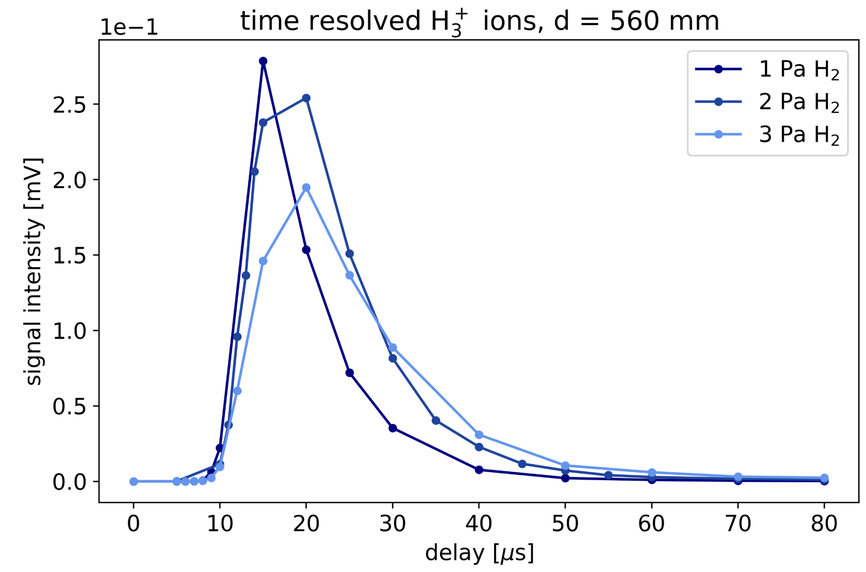
At the start of the campaign, a linear dependency was observed between the signal intensity of the ions and the frequency of the EUV source. As the ion signal is seen at the lower detection limit, a maximum source frequency of 1 kHz was used for all subsequent measurements.

The left-hand plots illustrate the behavior of the ionic species as the pressure in the interface is increased. The top plot shows the effect of increasing the hydrogen flow, while the bottom plot shows the effect of increasing the argon flow. For H_3^+, a signal maximum of approximately 2 Pa can be observed, and the argon species also exhibits a maximum of 1 Pa when the argon flow is increased. Afterward, all ion signals, including these, decrease continuously.

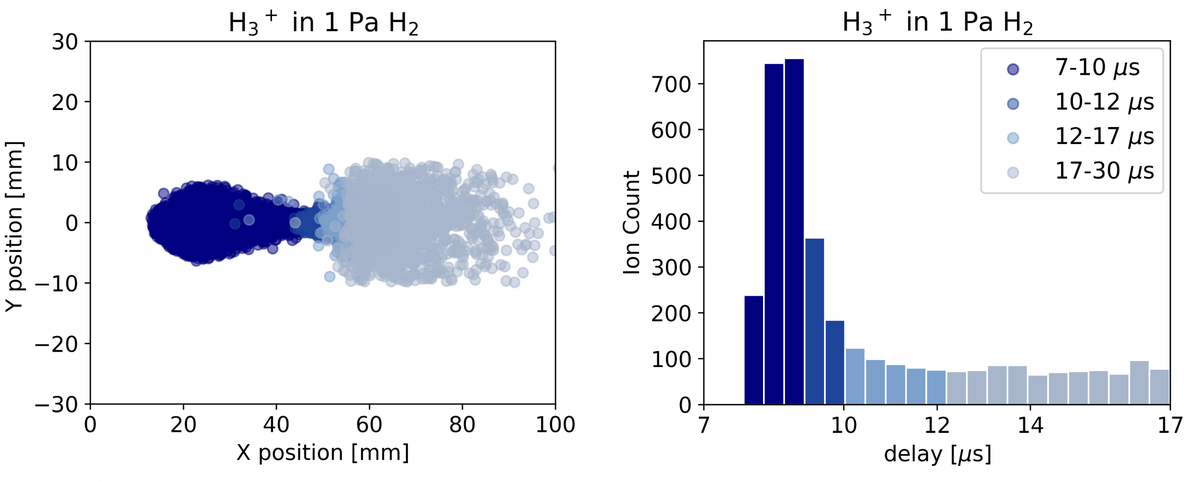
The plot in the top right shows the influence of the distance between light focus and the transferring ion source of the TOF. An ion signal was only detected when the MS was aligned with the light beam. The measurements of the four different distances show changes in signal intensities, but no unambiguous trend.

The ion cloud's time-resolved plot for H3+ is shown in the bottom right corner. It represents the duration between the EUV pulse and the arrival of ions at the MS at various background pressures.





Simulation Results



SIMION[1] simulations were performed to demonstrate the area where ions that successfully passed through the ion source and were sampled by the TOF-MS were spawned. The simulations show that only ions with flight times up to 17 µs are sampled, with ions having flight times up to 10 µs representing 90% of the total sampled ions. It is to be expected that the experimental results only show the ions with shorter flight times since the simulations assume ideal hard sphere collisions and don't include chemical reactions.

[1]D. A. Dahl, Int. J. Mass Spectrom., vol. 200, no. 3., pp. 3–25, 2000.

Conclusion and Outlook

This experimental data reveals a surprising behavior of the ion signal as a function of different parameters, only the linear dependence of ion signal and source frequency is easy to explain. The results provide the first indication that ions may not be directly sampled from the plasma focus.

The simulations also show that ions analyzed in the TOF within a few microseconds after the ionization event can only be located a few centimeters in front of the transfer source. The probability that plasma ions will still be sampled in the further course of time is very low, as they are stopped by collisions or remain on the surfaces. It is most likely that another EUV-dependent effect produces ions directly in front of the inlet geometry of the MS, which are subsequently drawn in and analyzed.

For future measurement setups, it is recommended to integrate a transfer unit that collects ions a few millimeters from the EUV focus point and transports them to the TOF. This will allow for direct collection of ions from the plasma and minimize any interfering effects.

Acknowledgment

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