Spectroscopy of a miniature spark discharge in the range of 40 - 1200 nm

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Physical & Theoretical Chemistry

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Introduction

At the conference of the American society for mass spectrometry (ASMS) in 2011 our group introduced a photoionization source, which employs a spark discharge lamp mounted windowless on a custom glass transfer capillary of an API mass spectrometer [1].

The hollow electrode assembly is supplied with a continuous gas flow at one electrode and actively pumped at the counter electrode. The discharge gap is < 1 mm. A small circuit board with a high-repetitive capacitor charger provides up to 1.5 kV with a repetition rate of 1.5 kHz and an output capacity of 2 nF. Operation of the spark discharge design has proven to be temporally, as well as spatially highly stable and reproducible.

Accordingly, this plasma drew our attention to general, systematic investigations on the prevailing plasma chemistry. A setup was designed to operate, investigate and correlate the VUV to NIR emission, the current/voltage profile and the electron emission of the discharge under well defined conditions.

Methods

discharge

- main gas flow of helium (150 mL/min)
- admixture of N_2, O_2, H_2, Ne and Ar (< 1 mL/min)
- power supply: custom designed DD20_10 C-Lader (Hartlauer Präzisions-elektronik GmbH, Grassau, Germany)

spectrometer

- ARC VM-502 VUV spectrometer (Acton Research Corporation, Acton, MA, USA), modified for operation with helium at atmospheric pressure (counter helium flow of 50 mL/min through the entrance slit):
  - scintillator-coated lens with Na-salicylate (custom made via piezo-nebulizer)
  - Photomultiplier tube, R928, Hamamatsu Photonics, K.K., Hamamatsu City, Japan
  - A/D converter, R232-ADC16/24, taskit GmbH, Berlin, Germany
  - custom software (VB 2010 Express)
- UV-NIR: AvaSpec-3648 (Avantes BV, Eerbeek, The Netherlands)

oscilloscope

- RTE 1054, R&S, Cologne, Germany

Conclusions & Outlook

For every experimental condition the presented setup provides a reproducible dataset of: i) a VUV spectrum, ii) UV/VIS/NIR spectra with selectable integration times and iii) current/voltage profiles of the breakdown, from which essential parameters such as the electron density can be derived.

outlook:

- establishing a systematic database of VUV and UV/VIS/NIR spectra for different discharge gas compositions and correlated them
- time resolved VUV and UV/VIS/NIR emission spectroscopy
- use the generated data to gain deeper insight into the mechanisms of the discharge process

Literature

[1] Kersten, H.; Derpmann, V.; Barnes, I.; Brockmann, K.; O'Brien, R.; Benter, T.: A Novel APPI-MS Setup for In Situ Degradation Product Studies of Atmospherically Relevant Compounds: Capillary Atmospheric Pressure Photo Ionization (cAPPI). Journal of the American Society for Mass Spectrometry. 22, 2070-2081 (2011).
[2] Kurunczi, P.; Lopez, J.; Shah, H.; Becker, K.: Excimer formation in high-pressure microhollow cathode discharge plasmas in helium initiated by low-energy electron collisions. International Journal of Mass Spectrometry. 205, 277-283 (2001).
[3] Yu, B. G.; Maiorov, V. A.; Behnke, J.; Behnke, J. F.: Modelling of the homogeneous barrier discharge in helium at atmospheric pressure. Journal of Physics D: Applied Physics. 36, 39 (2003).
[4] Benderskii, A. V.; Zadoyan, R.; Schwentner, N.; Apkarian, V. A.: Photodynamics in superfluid helium: Femtosecond laser-induced ionization, charge recombination, and preparation of molecular Rydberg states. *The Journal of Chemical Physics.* **110**, 1542-1557 (1999).
[5] Kramida, A., Ralchenko, Yu., Reader, J. and NIST ASD Team (2014). NIST Atomic Spectra Database (version 5.2), [Online]. Available: http://physics.nist.gov/asd [Sunday, 05-Jul-2015 23:31:19 EDT]. National Institute of Standards and Technology, Gaithersburg, MD.

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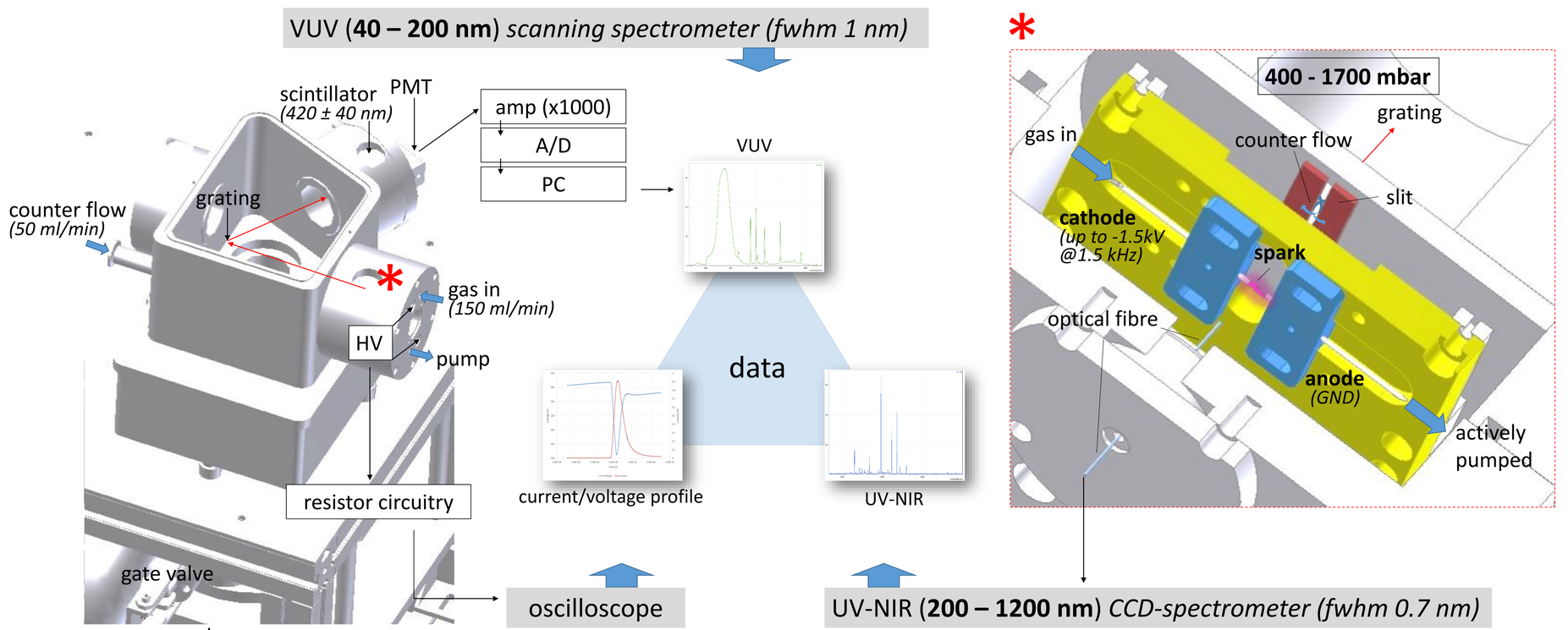
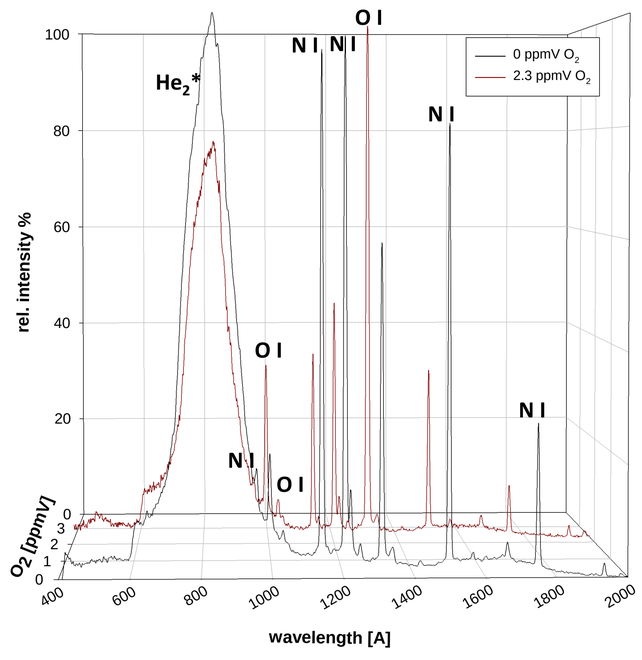
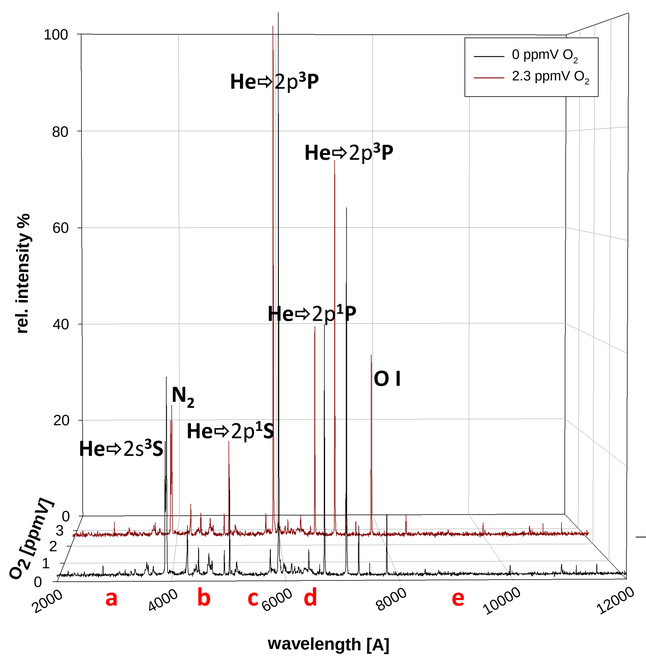
Experimental Setup



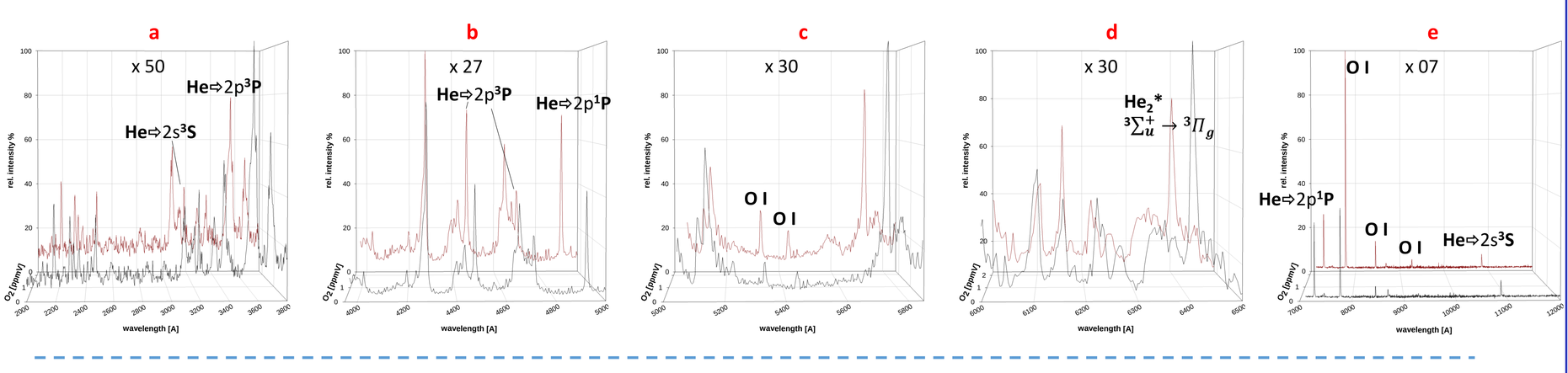
Results

gas composition

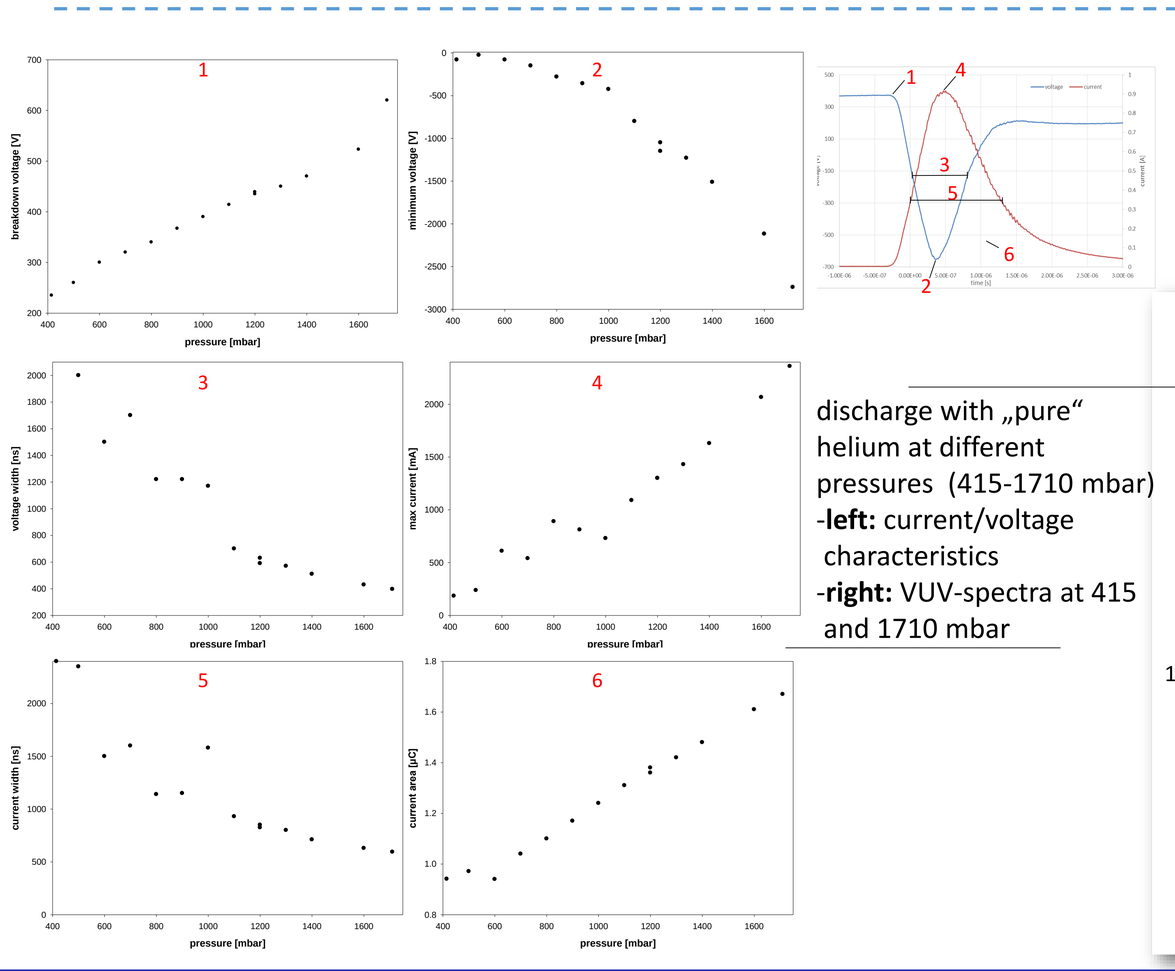




Helium discharge with varying mixing ratios of additives. Exemplarily shown are VUV, UV/VIS/NIR spectra of "pure" helium and with 2.3 ppmV O_2 at 1014 mbar.
Spectra a-e are close ups from the UV/VIS/NIR regime with increased integration time.



gas pressure



discharge with „pure" helium at different pressures (415-1710 mbar)
-**left:** current/voltage characteristics
-**right:** VUV-spectra at 415 and 1710 mbar