Spectroscopy of a windowless, electron-beam-pumped excimer lamp (EBEL) in the VUV spectral region of 50 – 200 nm

Sebastian Winkelmann, Sebastian Klopotowski, Hendrik Kersten, Thorsten Benter

Physical & Theoretical Chemistry
Wuppertal, Germany
Institute for Pure and Applied Mass Spectrometry

Introduction

Single photon ionization is widely used for a vast range of mass spectrometric analytical applications. Since the ASMS conference 2010 we have presented several contributions concerning the spectroscopic characterization of light sources providing ionizing radiation between 50–150 nm [1]. In this contribution we present spectroscopic data of a ***modified*** electron-beam-pumped rare-gas excimer lamp ***(EBEL)*** [2].

Principle of lamp operation:

- accelerated electron beam (continuous or pulsed) passes a thin foil from the vacuum region into the high pressure region (approx. 1 bar) of a discharge gas
- generation of a small, brilliant light spot

Modification:

- removal of the original MgF_2 window
- continuous flow of the discharge gas

➡ Windowless operation; provides insight into the emission characteristics even below 100 nm

Methods

VUV spectrometer

- ARC VM-502 VUV spectrometer (Acton Research Corporation, Acton, MA, USA) with a Al/MgF_2 coated parabolic grating
- modified for operation with helium at atmospheric pressure (counter helium flow of 100 mL/min; exits through the aperture slit)

EBEL - VUV Spectrometer coupling

- original MgF_2 window was removed
- continuous gas supply into the discharge volume (350 mL/min) with actively pumped outlet
- a disc with a 2 mm wide slit separates the discharge gas chamber from the spectrometer chamber

Detection/ signal processing system

- scintillator-coated lens with Na-salicylate (custom made via piezo-nebulizer)
- Photomultiplier tube, R955, Hamamatsu Photonics, K.K., Hamamatsu City, Japan
- custom made amplifier (factor 1000)
- A/D converter, R232-ADC16/24, taskit GmbH, Berlin, Germany
- custom software (VB 2010 Express)

Experimental Setup

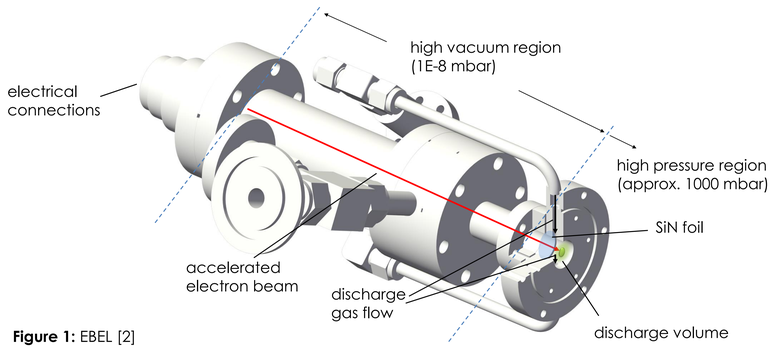


Figure 1: EBEL [2]

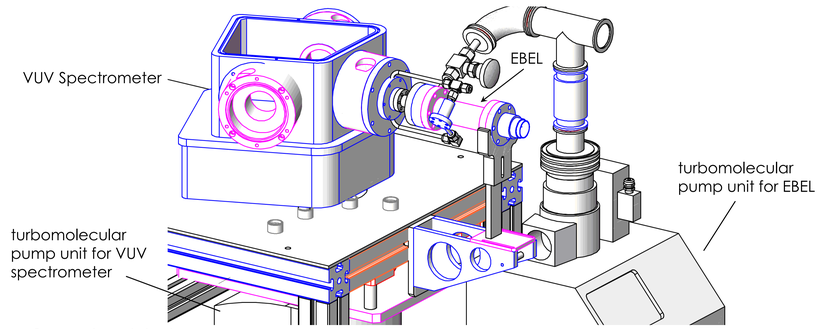
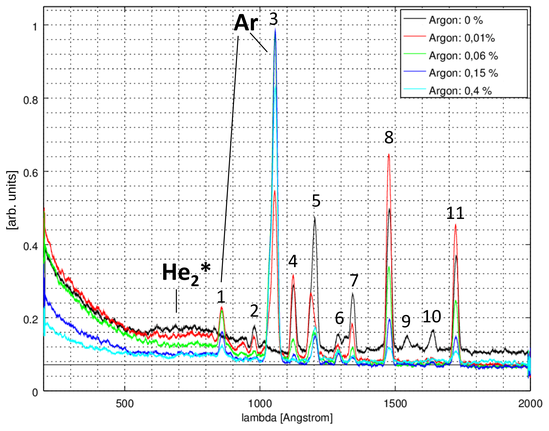


Figure 2: experimental setup

Helium/Argon Discharge Gas



peak	wavelength [Ångstrom]	species
1	840-894	Ar(I)
2	988	O(I)
3	1048/1066	Ar(I)
4	1134	N(I)
5	1190-1121	N(I)/C(I)/H(I)
6	1277/1330	C(I)/O(I)
7	1329	C(I)
8	1492	N(I)
9	1560	C(I)
10	1657	C(I)
11	1745	N(I)

Table 1: Peak assignments from fig. 3 and 5

Figure 3: VUV spectra of the EBEL with helium and admixtures of argon at a total pressure of 1000 mbar. Operation of the electron beam in continuous mode.

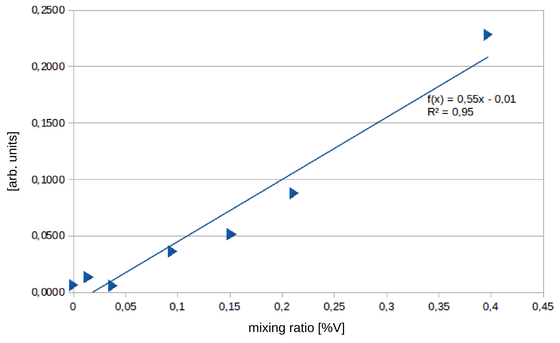


Figure 4: Intensity of the total argon emission in dependency of the argon admixture in helium at a gas pressure of 1000 mbar. Operation of the electron beam in continuous mode

Theory

$e^- + He \rightarrow He^* + e^-$

$He^* + 2\,He \rightarrow He_2^* + He$

$He_2^* \rightarrow 2\,He + h\nu\ (80\ nm)$ ➡ pressure dependent

efficient energy transfer through collisional quenching

$Ar \quad N_2 \quad O_2 \quad CO_2? \quad C_nH_m?$

$Ar^* \quad N^* \quad O^* \quad C^*$

$h\nu$

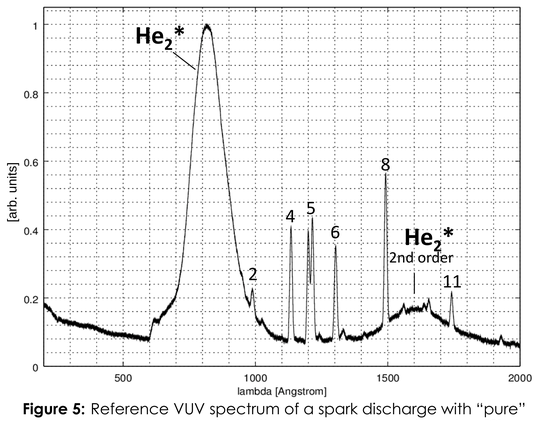


Figure 5: Reference VUV spectrum of a spark discharge with "pure" helium, recorded with the same spectrometer setup [3]

Conclusions

- Increasing argon concentration results in significant intensity loss of the He_2^* emission, as well as a decrease of the nitrogen, oxygen and carbon impurity lines (c.f. Fig. 3).
- Though the measurement procedure started with evacuating the VUV spectrometer to 1E-6 mbar and subsequent rapid filling with purified helium to 1000 mbar, the spectra showed abundant impurity lines and merely minor helium dimer emission. The error in this procedure is under current investigation.
- Interestingly, the C* emission is disproportionately high.

Outlook

Problems with the pump unit of the EBEL caused a prolonged experimental break. The following issues need to be tackled:

- measurements within a cleaner gas matrix in the spectrometer
- additional gas mixtures
- operation in pulsed mode with time resolved emission spectroscopy

Literature

[1] Kersten, H.; Brockmann, K. J.; Benter, T.; O'Brien, R., Windowless Miniature Spark Discharge Light Source for efficient Generation of VUV Radiation below 100 nm for on-capillary APPI, Proceedings of the 59th ASMS Conference on Mass Spectrometry and Allied Topics; Denver, CO, USA, 2011

[2] Mühlberger F, Streibel T, Wieser J, Ulrich A, Zimmermann R; Single photon ionization time-of-flight mass spectrometry with a pulsed electron beam pumped excimer VUV lamp for on-line gas analysis: setup and first results on cigarette smoke and human breath. Anal Chem. 2005 Nov 15; 77(22):7408-14.

[3] Barnes, I.; Klopotowski, S.; Kroll, K.; Kersten, H.; Benter, T., Measurements of electronically excited noble gas species radiating in the far VUV, Proceedings of the 62nd ASMS Conference on Mass Spectrometry and Allied Topics; Baltimore, MD, USA, 2014

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