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

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Introduction

Single photon ionization is widely used for a vast range of mass spectrometric analytical applications. Since the ADM 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 MgF₂ 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/MgF₂ 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 MgF₂ 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
- spectrally-coated lens with Na-salicylate (custom made via pico-nebulizer)
- Photomultiplier tube, R955, Hamamatsu Photonics, K.K., Hamamatsu City, Japan
- custom made amplifier (Bector 1000)
- A/D converter, Rs232-ADC16/24, taskit, Berlin, Germany
- custom software (VB 2010 Express)

Experimental Setup

Helium/Argon Discharge Gas

![Figure 1: EBEL (2)](image)

<table>
<thead>
<tr>
<th>peak</th>
<th>wavelength (Å)</th>
<th>species</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>840, 894</td>
<td>Ar(I)</td>
</tr>
<tr>
<td>2</td>
<td>988</td>
<td>O(I)</td>
</tr>
<tr>
<td>3</td>
<td>1048, 1066</td>
<td>Ar(I)</td>
</tr>
<tr>
<td>4</td>
<td>1134</td>
<td>N(I)</td>
</tr>
<tr>
<td>5</td>
<td>1190–1122</td>
<td>N(I)/(C(I)/N(I))</td>
</tr>
<tr>
<td>6</td>
<td>1277–1330</td>
<td>C(I)/O(I)</td>
</tr>
<tr>
<td>7</td>
<td>1329</td>
<td>C(I)</td>
</tr>
<tr>
<td>8</td>
<td>1492</td>
<td>N(I)</td>
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<tr>
<td>9</td>
<td>1560</td>
<td>C(I)</td>
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<tr>
<td>10</td>
<td>1657</td>
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</tr>
<tr>
<td>11</td>
<td>1745</td>
<td>N(I)</td>
</tr>
</tbody>
</table>

Table 1: Peak assignments from Fig. 2 and 5

Theory

\[ \text{e}^- + \text{He} \rightarrow \text{He}^* + \text{e}^- \]

\[ \text{He}^* + 2 \text{He} \rightarrow \text{He} + \text{He}^* + 2 \text{He} + \text{hv} \ (80 \text{ nm}) \]

Efficient energy transfer through collisional quenching

![Figure 2: experimental setup](image)

![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.](image)

![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.](image)

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

Conclusions

- Increasing argon concentration results in significant intensity loss of the He* 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 16 mbar and subsequent fast 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.

Literature


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