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Plasma-wall-interaction in ECRIS II

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Abstract

In an ECR-discharge, where the plasma is confined inside a copper-resonator by a simple magnetic mirror, it could be shown that sputtering of wall material has an important influence on the plasma. Spectroscopic measurements in ECRIS II with a copper vessel confirmed this model. Evidence for the presence of copper atoms and ions in the plasma could be found by ion extraction as well as by VUV-spectrometry. In a nitrogen discharge by adding helium as a mixing-gas we found that the extracted current of Cu-ions decreased and measured line intensities of copper emission lines dropped down, while the densities of high nitrogen charge states increased.

Introduction

In our ECR discharge, where the plasma is confined by a simple magnetic mirror, spectroscopic measurements have shown that sputtering of wall material, e. g. copper in this case, have an important effect on the stability of the plasma ([1], [2]). At optimum conditions the plasma in a pure nitrogen discharge showed oscillations in emitted line intensities of nitrogen ions as well as in the diamagnetic signal. Under these conditions a considerable amount of copper ions could be measured by VUV spectroscopy. By adding helium to the discharge the plasma could be stabilised and simultaneously the density of highly charged nitrogen ions could be increased. Shielding the plasma exposed edges (limiters) with steel plates to reduce the copper density in the plasma also lead to a stable discharge. Thus a model was proposed, which leads back the effect of the gas-mixing to the fact, that the plasma potential ϕ is depending on the mass of the ions in the plasma ([1], [2]), see Eq. (1).

$$\Phi = -\frac{kT}{e}\ln\left(\frac{\sqrt{m_e}}{n_e}\cdot\sum_k \frac{q_k\, n_{i_k}}{\sqrt{m_{i_k}}}\right) \qquad (1)$$

According to this model a lighter ion species can reduce the plasma potential and thus the energy of ions reaching the wall is lower. Because the sputtering yield drops with the energy of the particles reaching the wall, a lighter mixing gas can reduce the amount of wall material coming into the plasma by sputtering.

On the other hand higher charge states require high electron energies for step ionisation processes. Once the amount of heavy ions like copper in the plasma rises, electrons are cooled down, which leads to a decrease of the density of highly charged ions.

Until now measurements confirming this model have only be performed in an ECR discharge without hexapole magnets creating a minimum B configuration.

The measurements of this examination have been performed on our ECR ion source (ECRIS II), which is equipped with magnetic coils creating an asymmetric mirror field and a hexapole magnet for the minimum B configuration.

Experimental Setup

In order to investigate whether the model set up for the ECR discharge can be confirmed also for the ECR ion source, emission line intensities and extracted ion currents were measured. The discharge was run in nitrogen and nitrogen/helium mixtures. An absolutely calibrated VUV spectrometer [4] was used to measure line intensities end-on (Fig. 1). The discharge vessel of the ECRIS II is made of copper.

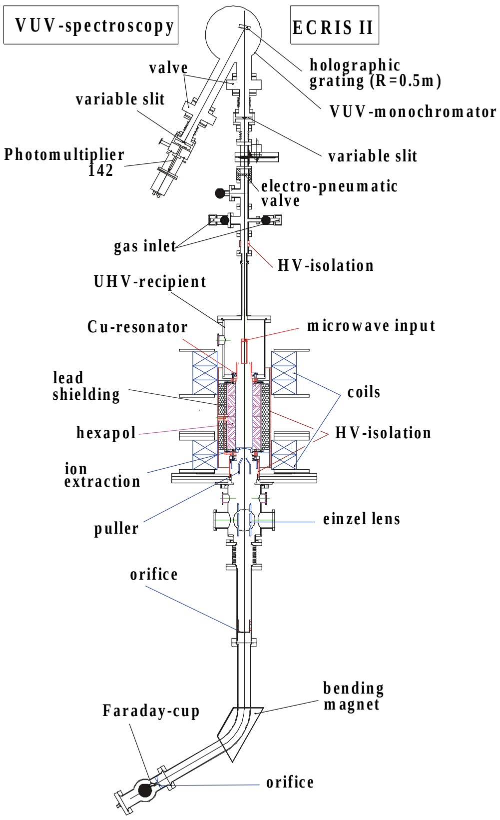

Fig. 1: ECRIS II with VUV spectrometer

Line intensities of several CuI and CuII lines as well as lines of ionic and neutral nitrogen were measured simultaneously with the extracted ion currents of nitrogen and copper ions (Cu^+). The mixture ratio of nitrogen and helium was varied, keeping the total pressure of the discharge constant. The extraction voltage applied to the ion source was 5 kV.

Results

In the extracted ion beam Cu^+ ions can be detected, although the Cu^+ ion current is a factor 50 below that of N^+ (Fig. 2).
The line intensities of the various CuI and CuII emission lines show a distinct dependence of the copper density on the helium/nitrogen mixture ratio (Fig. 3).

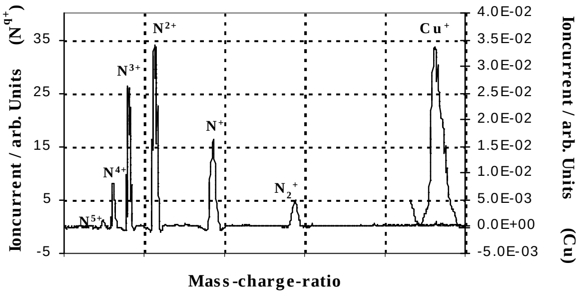

Fig. 2: Extracted ion current

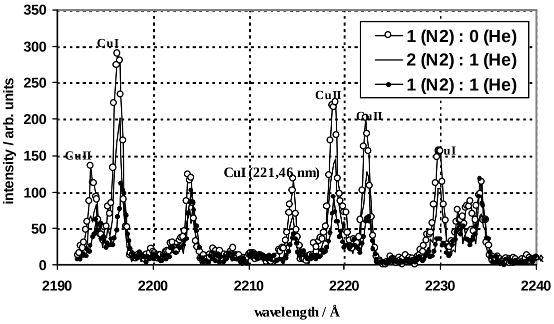

Fig. 3: VUV spectra at different gas mixture ratios

The CuI (221,5 nm) emission line is reduced by a factor of 10 in a pure helium discharge compared to a pure nitrogen discharge. The extracted ion current of Cu^+ drops by a factor of 30 (Fig. 4).
On the other hand, when the pure helium discharge is turned into a pure nitrogen discharge, an increase of the CuI emission line can clearly be observed (Fig. 5).

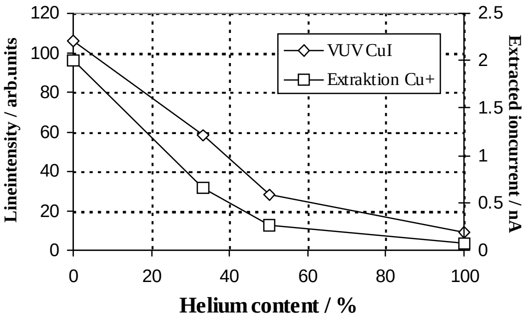

Fig. 4: Comparision of CuI (221,5 nm) emission line and extracted Cu^+ ion current

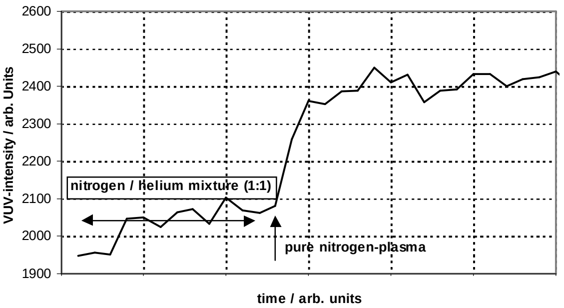

Fig. 5: Temporal development of the CuI emission line, when stopping the helium admixture

Furthermore it can be seen from the intensity ratios of NI and NV lines, that the densities of the higher charge states in the plasma increase, as earlier measurements in the ECR discharge as well as in other ECRIS already had shown [3], see Fig. 6.

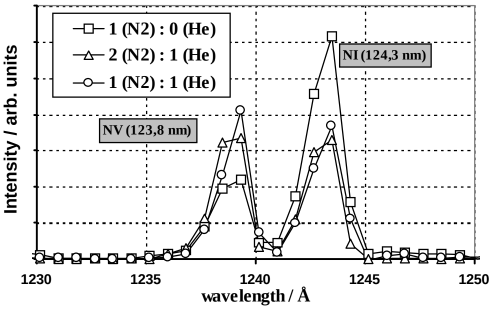

Fig. 6: Improvement of the charge state distribution with higher helium admixtures in ECRIS II

Conclusion

In the ECRIS II the influence of sputtered wall material on the charge state distribution was demonstrated, though the ECR ion source has better radial confinement than a simple ECR discharge.

Acknowledgements

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