Magnetic insulated plasma targets for ion beam plasma interaction experiments

M. Iberler, R. Berezov, J. Jacoby, Ch. Teske

Inst. für Angewandte Physik, J.W.Goethe-Universität, D-60438 Frankfurt/Main, Germany

Interaction experiments of ion beams with plasmas became possible only after gas discharge plasmas have been integrated into the accelerator beam lines at GSI. It has been shown, that the stopping power for heavy ions of a fully ionised plasma is up to forty times higher than of cold gases [1]. The disadvantages of previous gas discharge plasmas however were a short plasma life time, which corresponds to a short and time dependent measurement period together with moderate or low plasma temperatures. To overcome these restrictions a new kind of gas discharge plasma target is now under investigation at Frankfurt.

The new plasma target is based on an electrode less set up to avoid plasma impurities. The energy deposition into the plasma is performed by inductive coupling using a coil antenna [2].The fact that the plasma is a mixture of charged particles means, it can be controlled and influenced by magnetic fields. Here, a radial time independent quadrupole magnetic field is applied to confine the plasma. Due to the linear magnetic field gradient the confinement of the radio-frequency plasma is achieved by the stronger focusing than defocusing forces on the alternating electrons during the discharge.

During this focusing effect of the magnetic field influenced by the electric fields of the rf-coil the ionisation and excitation of the atoms and ions is very effective. A high current density is achieved within a small area near the centre axis. Because of the magnetic minimum close to this axis the electrons follow the inductive coupled electrical field. In order to restrict the movement of the charged particles along the axis two additional ring magnets have been placed at the exit of the quadrupole magnet functioning as magnetic mirrors. The inductive coupled plasma is run in a CW mode. The main section of this experimental set-up consists of a glass tube of about 21 mm inner diameter wrapped with a radial field coil. The bias pressure of the discharge tube was in the range of 10^{-7} Pa, later filled with argon at a pressure in the range from 0.5-1.5 Pa. Figure 1 shows a schematically drawing of the experimental set-up with the confined plasma.

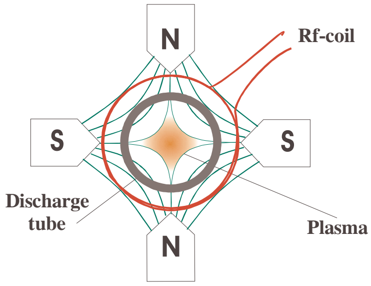

Fig.: 1 Principal set up of the rf-heated magnetic confined static gas discharge plasma. The plasma is confined near the axis shaped like a star pointing to the magnetic poles

By spectroscopic measurements we are studying the parameters of the argon plasma depending on the magnetic quadrupole field strength, the gas pressure and the rf power input. The measurements presented here have been performed at a magnetic field strength between 0-0.5 T and with a rf-power input of about 300 W.

The spectroscopic measurements were performed using three different rf-coils. The inductivity of these three coils varies from 2.1 µH for the coil with 18 cm in length and 7 windings to 3.5 µH with 12 cm length and 15 windings. With respect to the skin effect a 10 mm^2 copper wire was used for the antennas.

To estimate the plasma temperature and the ionisation degree the spectra of the argon plasma were analysed. For this purpose two emission lines of neutral and one time ionised argon have been compared. Using [3] the electron temperature can be determined from the relative line intensities of these lines. In case of the long rf coil with 2.1 µH the maximum electron temperature was measured between 1.1-1.2 eV. Using however the coil with the 3.5 µH the electron temperature could be enhanced to almost 2.9 eV at an argon pressure of 1 Pa. Figure 2 shows the so obtained electron temperature as a function of pressure. Now under progress are spectroscopic measurements for the determination of the electron density. For this purpose a 1 m spectrometer has been set up at the rf plasma.

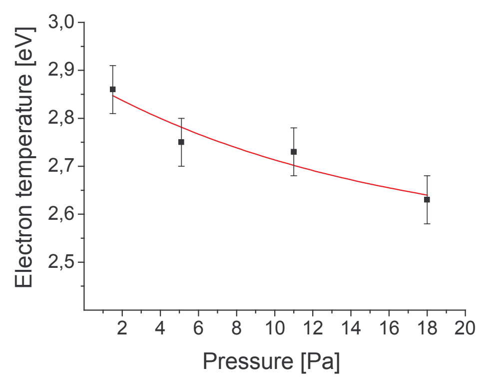

Fig. 2: Electron temperature in dependence of the applied argon pressure using the 3.5 µH rf-coil.

Future investigations are proposed in the field of heavy ion interaction using optimised plasma parameter. For this purpose a cylindrical time independent rf plasma target should be used which still may achieve much higher plasma temperatures just by increasing the rf power.

This work was partially founded by the BMBF.

References

[1] J. Jacoby, D. Hoffmann, W. Laux, R. Müller, H. Wahl, K. Weyrich, E. Boggasch, B. Heimrich, C. Stöckl, H. Wetzler, S. Miyamoto, Phys. Rev. Lett., **74**, (1995), 1550.

[2] Peiyuan Zhu, R.W. Boswell, "A new argon-ion laser based on an electrodeless plasma", Journal of applied Physics, 68, No 5, September 1990.

[3] H. Griem. "Plasma Spectroscopy" *McGraw-Hill Book Company* 1964.