P 8: Low-temperature plasma and applications

Time: Tuesday 14:00–15:25 Location: b302

P 8.1 Tue 14:00 b302

Spoke-synchronized probe measurements in a high power impulse magnetron discharge — •Julian Held, Philipp Maass, Volker Schulz-von der Gathen, and Achim von Keudell — Experimental Physics II, Ruhr University Bochum, Germany

In high power impulse magnetron sputtering (HiPIMS) bright plasma spots are observed during the discharge pulses that rotate with velocities in the order of 10 km/s in front of the target surface. It has proven very difficult to perform any quantitative measurements on these so-called spokes, that emerge stochastically during the build-up of each plasma pulse. In this contribution, we present a new *time shift averaging* method to perform measurements integrating over many discharge pulses, but without phase averaging of the spoke location, thus preserving the information of the spoke structure. This method is then applied to perform Langmuir probe measurements, employing magnetized probe theory to determine the plasma parameters inside the magnetic trap region of the discharge. Spokes are found to have a higher plasma density, electron temperature and plasma potential than the surrounding plasma. The electron density slowly rises at the leading edge of the spoke to a maximum value of about $1 \cdot 10^{20}\,\mathrm{m}^{-3}$ and then drops sharply at the trailing edge to $4 \cdot 10^{19}\mathrm{m}^{-3}$. The electron temperature rises from 2.1 eV outside the spoke to 3.4 eV at the trailing end of the spoke. A reversal of the plasma potential from about -7 V outside the spoke to values just above 0 V in a spoke is observed, as has been proposed in the literature.

P 8.2 Tue 14:25 b302

Azimuthal particle transport in high power impulse magnetron sputtering plasmas — •Sascha Thiemann-Monjé, Julian Held, and Achim von Keudell — Experimental Physics II, Ruhr-University Bochum, 44780 Bochum, Germany

In the past years high power impulse magnetron sputtering (HiPIMS) has become a well established method for depositing high quality hard coatings. Nevertheless, knowledge about the processes inside the discharge is still incomplete. This includes the azimuthal rotation of heavy particles which is induced by the electron Hall-current and is believed to be influenced by rotating ionization zones, the so called 'spokes'.

In this work, optical emission spectroscopy (OES) and energy resolved ion mass spectrometry where used to gain further understanding of the above mentioned particle movement. While OES delivers information about the emitting particles inside the plasma the mass spectroscopy will see the particles which leave the plasma only. The measurements where done for a circular Ti-target with 50 mm diameter and 0.5 Pa Argon as working gas.

It could be shown that the maximum rotation velocity is in the range of 0.5 - 1.8 km/s depending on the measured species. Differences in the axial distribution of these velocities for Ar and Ti show an dependency on the axial movement of the particles. Furthermore power and time variations where performed showing no reasonable influence.

P 8.3 Tue 14:40 b302

Electric field measurements on the INCA discharge — Christian Lütke Stetzkamp, •Tsanko Vaskov Tsankov, and Uwe Czarnetzki — Institute for Plasma and Atomic Physics, Ruhr University Bochum, D-44780 Bochum, Germany

A periodically structured vortex electric field can lead to an efficient collisionless energy gain [1,2]. This theoretical concept was realized experimentally by the inductively coupled array (INCA) discharge and the first results reveal the great potential of the concept [2].

The exact structure of the electric field of this discharge is a vital part of the efficiency of the stochastic heating. Here results from measurements of the induced electric field in INCA with different diagnostics are shown and compared with theoretical predictions. In-situ measurements with RF modulation spectroscopy (RFMOS) and ex-situ B-dot measurements are used.

[1] U. Czarnetzki and Kh. Tarnev, *Phys. Plasmas* **21**, 123508 (2014)
[2] U. Czarnetzki, *Plasma Sources Sci. Technol.* **27**, 105011 (2018)
[3] Philipp Ahr *et al*, *Plasma Sources Sci. Technol. 27*, 105010 (2018)

P 8.4 Tue 14:55 b302

Experimental benchmark of radiation transport calculations in low pressure low temperature hydrogen discharges — •Stefan Briefi[1,2], Frederik Merk[1], Roland Friedl[2], Caecilia Fröhler[2], and Ursel Fantz[1,2] — [1]Max-Planck-Institut für Plasmaphysik, Boltzmannstr. 2, 85748 Garching, Germany — [2]AG Experimentelle Plasmaphysik, Universität Augsburg, 86135 Augsburg, Germany

In a discharge, the emissivity of the atomic hydrogen Lyman series is strongly affected by reabsorption of photons resulting in an underestimation of the population densities determined from VUV spectroscopy. This effect can be corrected via line escape factors. In general, the required correction increases with the atomic hydrogen density n_H. For $10^{18} < n_H < 10^{20}$ m^{-3} typical for low pressure plasmas, the correction can reach orders of magnitude making a careful benchmark inevitable.

Measurements have been carried out at a planar ICP at varying pressure (1 to 10 Pa) and RF power (700 to 1000 W) with an intensity-calibrated VUV spectrometer for determining the emissivity of the Lyman series up to L_ζ ($n = 7$). In addition, the population of the $n = 2$ state of atomic hydrogen was measured with tunable diode laser absorption spectroscopy on the Balmer-α line. Furthermore, the population of the higher lying states up to $n = 7$ is obtained from optical emission spectroscopy. The latter two diagnostics are not affected by reabsorption and hence the obtained population densities are used as reference values. They are matched very well when correcting the populations derived from VUV spectroscopy with line escape factors.

P 8.5 Tue 15:10 b302

Improved Analytic Response Function of the Planar Multipole Resonance Probe — •Michael Friedrichs[1], Dennis Pohle[2], Ilona Rolfes[2], and Jens Oberrath[1] — [1]Modeling and Simulation, Department of Electric Power Engineering, South Westphalia University of Applied Science, Soest, Germany — [2]Institute of Microwave Systems, Department of Electrical Engineering and Information Sciences, Ruhr University Bochum, Bochum, Germany

The planar multipole resonance probe (pMRP), which is mounted inside of the chamber wall, is a specific design of the Active Plasma Resonance Spectroscopy (APRS) and a promising candidate to monitor plasma processes without perturbing them. Based on the cold plasma model an analytic solution of the response function for the ideal pMRP could be derived, which allows to determine the resonance frequency of the probe plasma system. The geometry of the real pMRP is more complicated and requires a numerical model for full 3D electromagnetic simulation in CST. The calculated resonance frequencies of both models are qualitatively in agreement but differ in the exact position. This difference is dominated by the difference in the geometry, which cannot be considered directly in the analytic solution. Thus, a simulation of a more realistic geometry in electrostatic approximation will be presented in Comsol Multiphysics and a numerical adaption of the vacuum excitation in the analytic solution can be implemented in the analytic evaluation of the response function. This allows an improvement of the analytic solution and can be used to derive a more realistic formula for the resonance frequency.