P 3: Low-temperature plasma and applications 1

Time: Monday 14:00–15:30 Location: b302

Invited Talk P 3.1 Mon 14:00 b302

Diagnostics of magnetized high frequency technological plasmas — •Julian Schulze[1,2], Moritz Oberberg[1], Birk Berger[1], Jens Kallähn[1], Dennis Engel[1], Christian Wölfel[1], Jan Lunze[1], Ralf Peter Brinkmann[1], and Peter Awakowicz[1] — [1]Institute of Electrical Engineering, Ruhr-University Bochum — [2]School of Physics, Dalian University of Technology, China

Capacitively coupled radio frequency (RF) magnetrons are frequently used for sputter deposition of ceramic layers. However, fundamentals of their operation such as the effects of the magnetic field on the electron power absorption dynamics and the formation of process relevant flux-energy distribution functions are not understood. In order to address these issues, we characterize such a discharge operated in argon with oxygen admixture at low pressure by a synergistic combination of different experimental diagnostics [current/voltage measurements, retarding field energy analyzer, multipole resonance probe, phase resolved optical emission spectroscopy (PROES), magnetic field measurements]. We find that the magnetron magnetic field induces a discharge asymmetry. This Magnetic Asymmetry Effect affects the DC self bias and ion flux-energy distribution functions at boundary surfaces, which can be controlled by adjusting the magnetic field. Tuning the magnetic field also allows to magnetically control the self-excitation of plasma series resonance oscillations of the RF current and, thus, Non-Linear Electron Resonance Heating. PROES reveals space and time resolved insights into the dynamics of the electron power absorption in the presence of the magnetic field.

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MEMS sensor for the determination of ion energy and ion angle distribution functions in low pressure plasmas — •Marcel Melzer[1], Kerstin Rössel[2], Jan Trieschmann[2], Chris Stöckel[1,3], Sven Zimmermann[1,3], and Thomas Mussenbrock[2] — [1]Technische Universität Chemnitz, Zentrum für Mikrotechnologien, 09126 Chemnitz — [2]Brandenburgische Technische Universität Cottbus-Senftenberg, Theoretische Elektrotechnik, 03046 Cottbus — [3]Fraunhofer-Institut für Elektronische Nanosysteme, Abteilung Multi Device Integration, 09126 Chemnitz

Low pressure plasmas are one of the most important tools for the manufacturing of integrated circuits and enable, for example, the dry etching of transistor structures with feature sizes below 14 nm. For such sophisticated plasma processes both the ion energy distribution function (IEDF) and the ion angular distribution function (IADF) of the applied plasmas are crucial parameters for the creation of the desired structures. By combining a silicon-manufactured retarding field analyzer and a microelectromechanical system (MEMS) for angular selection of the ions to be detected, the IEDF and the IADF are to be measured simultaneously by a novel sensor element. In this work, simulation results of the three-dimensional ion dynamics within the sensor system are presented. Furthermore, the first results of the measurements and the current experimental status are discussed.

P 3.3 Mon 14:45 b302

The transmission behavior of an energy selective mass spectrometer with a Bessel Box type energy filter — •Christian Schulze[1], Zoltán Donkó[2], and Jan Benedikt[1] — [1]Institute of Experimental and Applied Physics, Kiel University, Germany — [2]Institute for Solid State Physics and Optics, Wigner Research Centre for Physics, Hungary

Ions are responsible for the majority of plasma surface interactions, which are of scientific interest and widely used in commercial applications. Therefore, the accurate measurement of ion energy distributions (IED) for different ion species are essential for their understanding and control. In contrast to other ion diagnostics, energy selective mass spectrometry (ESMS) allows energy and mass selectivity. Unfortunately, ESMS is known to suffer from artifacts like chromatic aberration of ion lenses as well as an energy dependent acceptance angle, both effects distorting the measurement. Therefore, ESMS is typically used for qualitative measurements only. The thorough analysis of chromatic aberration effects on the accuracy of measured IEDs is available only for selected mass spectrometers in the literature. Even less information is available for effects of energy dependent acceptance angles on experimental results, where the angular distribution of sampled ions strongly depends on their energy. Here, results of ion trajectory simulations are presented in order to optimize the settings of the ion lenses and the Bessel Box energy filter. Additionally, measured IEDs will be compared with 1D-PIC simulations, which can provide an estimation of energy-dependent angular distributions of the ion flux.

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AC modulation technique for RFEA measurements — •Christian Lütke Stetzkamp, Tsanko Vaskov Tsankov, and Uwe Czarnetzki — Institute for Plasma and Atomic Physics, Ruhr University Bochum, D-44780 Bochum, Germany

Retarding field energy analyzers (RFEA) are an important diagnostic tool to measure the ion velocity distribution function (IVDF) in low-pressure plasmas. However, their dynamic range is usually limited to about one order of magnitude. RFEAs can in principle also measure the distribution function of the electrons that overcome the sheath potential and escape the plasma. However, in this case the capabilities of the devices are even more limited.

Here, a method is presented, that strongly increases the dynamic range of the RFEA measurements. It is based on an analog AC modulation technique that is similar to those used for Langmuir probe measurements. The modulated response signal is detected by a Lock-In amplifier to reduce the influence of noise on the measurement. First measurements show very promising results, in which a dynamic range of about 3 orders of magnitude is easily achieved. In this talk the method will be presented and its characteristics will be discussed.

P 3.5 Mon 15:15 b302

Kinetic modeling of the electric double layer at the plasma-wall interface — •Kristopher Rasek, Franz Xaver Bronold, and Holger Fehske — Institut für Physik, Universität Greifswald, 17489 Greifswald

If a solid is in contact with a plasma an electric double layer forms, with a positive space charge in the plasma, the plasma sheath, and a negative space charge in the solid. We develop a kinetic model for such a double layer at a dielectric wall based on the Poisson equation for the electric potential and two sets of Boltzmann equations for the charge carriers in the plasma and the wall. By solving the Boltzmann and Poisson equations we are able to determine the full distribution functions of all carriers and with them quantities like charge profiles or photon emission rates. Expanding our previous work of the collisionless case [1], the collision integrals in the Boltzmann equations for the wall include both relaxation and (radiative or non-radiative) recombination of conduction band electrons and valence band holes. Using only material parameters such as the dielectric function and the band gap of the wall material, we determine the potential curve as well as the carrier distribution functions which are responsible for it. The emerging picture of our model is thus a floating dielectric surface where the potential profile across the double layer is the result of a self-organization process balancing electron-ion generation in the plasma and electron-hole recombination/relaxation in the solid.

[1] F. X. Bronold, H. Fehske, J. Phys. D: Appl. Phys. **50** (2017) 294003