P 14: Low Pressure Plasmas and their Application I

Time: Wednesday 11:00–12:30 Location: WW 1: HS

Invited Talk P 14.1 Wed 11:00 WW 1: HS

Insights into the Non-Thermal Character of Molecular Plasmas from Optical Frequency Comb Spectroscopy — •Ibrahim Sadiek, Norbert Lang, and Jean-Pierre H. van Helden — Leibniz Institute for Plasma Science and Technology (INP)

Our ability to model, optimize and control plasma-activated chemical processes depends strongly on the knowledge of the absolute concentrations and temperatures of reactive species in the plasma, and their reaction kinetics. This knowledge can be acquired through absorption spectroscopy using continuous wave (CW) lasers. However, the narrow spectral tuning range of these CW lasers limits the number of detectable molecules and cannot provide precise information about the non-thermal nature of plasma-generated species, particularly the distribution of energy among different molecular degrees of freedom. We overcome this hurdle by using state-of-the-art optical frequency combs as diagnostic light sources. We develop and apply frequency comb-based detection techniques, offering a unique combination of broad bandwidth and high spectral resolution. This enables the simultaneous detection of multiple species in the plasma.

In this paper, we will present insights into the non-thermal nature of low-pressure molecular plasmas containing nitrogen, hydrogen, and methane through frequency comb-based Fourier transform spectroscopy measurements. This technique enables us to provide quantum-state-resolved knowledge of plasma-generated molecular species, thereby paving the way for precise modelling of plasma chemical processes.

P 14.2 Wed 11:30 WW 1: HS

Ro-vibrationally resolved corona modelling for the Fulcher-α band of H_2 plasmas: a powerful tool for spectra analysis — •Richard C. Bergmayr[1], Dirk Wünderlich[1], Liam H. Scarlett[2], Mark C. Zammit[3], Igor Bray[2], Dmitry V. Fursa[2], and Ursel Fantz[1] — [1]IPP Garching, Germany — [2]Curtin University, Australia — [3]Los Alamos National Laboratory, USA

Collisional radiative (CR) modelling combined with emission spectroscopy enables the derivation of the plasma parameters (e.g. n_e and T_e) from the naturally emitted radiation of molecular hydrogen (H_2) plasmas. Under certain conditions discussed in this contribution the simplified approach of corona modelling is valid, wherein collisional excitation from the ground state is balanced with spontaneous emission in the form of rate equations depending on reaction probabilities (e.g. cross sections) as input. The flexible Yacora code can solve the underlying system of equations coupling the manifold of ro-vibrational levels in H_2. An electronically resolved CR model can determine for which plasma regimes the corona approximation must be extended by further process channels (e.g. cascades). This contribution discusses a corona model for the Fulcher-α band of H_2 applying fully ro-vibrationally resolved MCCC cross sections. The MCCC (molecular convergent close-coupling) method in the adiabatic-nuclei formulation is an ab initio approach for electron scattering problems able to provide accurate ro-vibrationally resolved cross sections. The model derived spectra are compared with various benchmark cases demonstrating the model's suitability as part of a non-invasive diagnostic.

P 14.3 Wed 11:45 WW 1: HS

Plasma sheath tailoring by a magnetic field for three-dimensional plasma etching — •Elia Jüngling[1], Sebastian Wilczek[2], Thomas Mussenbrock[2], Marc Böke[1], and Achim von Keudell[1] — [1]Chair Experimental Physics II, Ruhr University Bochum, Bochum, Germany — [2]Chair of Applied Electrodynamics and Plasma Technology, Ruhr University Bochum, Bochum, Germany

Three-dimensional (3D) etching of materials by plasmas is an ultimate challenge in microstructuring applications. A method is proposed to reach a controllable 3D structure by using masks in front of the surface in a plasma etch reactor in combination with local magnetic fields to steer the incident ions in the plasma sheath region towards the surface to reach 3D directionality during etching and deposition. This effect can be controlled by modifying the magnetic field and/or plasma properties to adjust the relationship between sheath thickness and mask feature size. Since the guiding length scale is the plasma sheath thickness, which for typical plasma densities is at least tens of microns or larger, controlled directional etching and deposition target the field of microstructuring, e.g. of solids for sensors, optics, or microfluidics. In this proof-of-concept study, it is shown that $\vec{E}\times\vec{B}$ drifts tailor the local sheath expansion, thereby controlling the plasma density distribution and the transport when the plasma penetrates the mask during an RF cycle. This modified local plasma creates a 3D etch profile. This is shown experimentally as well as using 2d3v Particle-In-Cell/Monte Carlo collisions simulation.

P 14.4 Wed 12:00 WW 1: HS

Simulation and Modeling of DC Glow Discharges — •Tim Bolles[1], Maximilian Klich[1], Katharina Nösges[1], Máté Vass[1,2], and Thomas Mussenbrock[1] — [1]Ruhr University Bochum, 44780 Bochum, Germany — [2]Wigner Research Centre for Physics, 1121 Budapest, Hungary

DC (Direct Current) discharges are well established systems with extensive applications, particularly in the high gas pressure regime. Their physics is more complex than initially assumed. The reason for this is that they are very sensitive to external conditions and internal fluctuations such as the plasma density or the electron temperature. The simulation of DC discharges, especially if kinetic effects need to be considered, can be rather complex, as it needs to accurately capture the variable and often unstable properties of the discharge. Kinetic models, which consider the movements and interactions of individual particles within the plasma, must be able to handle these instabilities and fluctuations, presenting a significant challenge. This contribution focuses on addressing the complexities in the kinetic simulation of DC discharges, outlining the challenges and proposing solutions. Specifically, it will illustrate the indispensable elements of a kinetic simulation model for DC discharges, as demonstrated through a case study. Valuable discussions with Zoltan Donko (Wigner Research Center for Physics) are gratefully acknowledged.

P 14.5 Wed 12:15 WW 1: HS

Deposition system for graphene nanostructures — •Simeon Marinov, Ivan Ivanov, and Zhivko Kissovski — Faculty of Physics, Sofia University, St. Kl. Ohridski, Sofia, Bulgaria

A microwave plasma system has been developed for the deposition of carbon nanostructures on metal and ceramic substrates at low and atmospheric pressure. The microwave surface wave discharge at frequency of 2.45 GHz is applied for PECVD (Plasma Enhanced Chemical Vapor Deposition), because it produces a dense plasma providing efficient decomposition of the carbon precursor (methane CH_4 or ethanol C_2H_5OH). At atmospheric pressure a plasma jet is used while at low pressure (0.4-8 Torr) a planar microwave plasma source as both discharges create a large number of reactive particles which results in lower substrate temperature for graphene deposition compared to CVD method. Optimization of the gas mixture of H_2, Ar and the precursor, and the gas pressure in the chamber for the second setup results in a homogeneous graphene structures deposition on the substrates of Ni-foil, Ni-foam and ceramic substrates (SiC) at substrate temperatures in the range 600-750 °C. The plasma parameters such as gas temperature, electron temperature and density are obtained by measuring OH and CN-bands, H_β broadening and Ar-lines using optical emission spectroscopy. The morphology of the carbon structures is obtained using SEM analysis and the characteristics of the graphene layers are determined by Raman spectroscopy. A self-consistent model of the atmospheric plasma jet is developed in COMSOL Multiphysics and plasma parameters in argon gas are obtained.