P 21: Atmospheric Plasmas and their Applications V

Time: Thursday 13:45–15:45 Location: ZHG006

Invited Talk P 21.1 Thu 13:45 ZHG006

Vacuum UV spectroscopy at atmospheric pressure plasmas utilizing silicon nitride membranes — •Luka Hansen[1,2], Görkem Bilgin[1], Hendrik Kersten[3], and Jan Benedikt[1,2] — [1]Institute of Experimental and Applied Physics, Kiel University, Kiel, Germany — [2]Kiel Nano, Surface and Interface Science KiNSIS, Kiel University, Kiel, Germany — [3]Institute for pure and applied mass spectrometry, University of Wuppertal, Wuppertal, Germany

Vacuum ultraviolet (VUV) radiation is crucial for several applications including, e.g., the biomedical field or photocatalysis. A fundamental problem is the transfer from VUV radiation produced in an atmospheric pressure environment into the vacuum for further diagnostics, as typical window materials like LiF or MgF_2 are not suited for this transfer due to their cut off wavelength at 115 nm. Different approaches have been pursuit in the past to overcome this problem involving, e.g., differential pumping [1] or an aerodynamic window [2].
A new approach is utilizing a ultra-thin Si_3N_4 membrane with a thickness of 20 nm as entrance window. These membranes can withstand the pressure gradient of one atmosphere and showed resistance against plasma and plasma-generated species [3].
This approach allows to resolve spectra down to 58.4 nm (He resonance line) and reveal interesting self-absorption effects of noble gases influencing previously reported VUV spectroscopy measurements.

[1] F. Liu *et al.*, 2020 *Plasma Sources Sci. Technol.* **29** 065001
[2] J. Golda *et al.*, 2020 *Plasma Process. Polym.* **17** 201900216
[3] L. Hansen *et al.*, 2023 *Thin Solid Films* **765** 139633

P 21.2 Thu 14:15 ZHG006

controlled synthesis of NO and helium metastable measurement in atmospheric pressure RF plasma — •Siqi Yu, Steijn Vervloedt, Laura Chauvet, and Achim von Keudell — Ruhr-Universität Bochum, Bochum, Germany

Non-thermal plasma catalytic technology has promising potential to improve gas conversion efficiency. Our research focuses on nitrogen oxide synthesis, especially NO production, because of its broad range of applications in biological processes. NO_x species are generated in a parallel-plate atmospheric pressure RF plasma from N_2/O_2 admixed to helium. The concentrations are measured by FTIR spectroscopy using a multi-pass cell. The results show that NO's is further oxidized with increasing oxygen admixture and ozone generation. It can be controlled by increasing the surface temperature and by using a catalytic material that preferentially quenches O_3. Helium metastable species act as an energy pool and play a crucial role during the discharge. Broadband absorption spectroscopy is used as an in-situ method to measure absolute densities of atomic $He(2^3S_1)$ and molecular $He_2(a^3\Sigma_u^+)$ metastable species. A 1D global model is developed to fit the experimental data and analyze metastable generation and destruction mechanisms. The helium metastable induced desorption of adsorbed water causes a decay of the metastable density along the plasma channel. Surface materials with a lower work function exhibit stronger secondary electron emission, affecting the local heating at the plasma boundary sheath. This increases the rate for $He(2^3S_1)$ and $He_2(a^3\Sigma_u^+)$ conversion.

P 21.3 Thu 14:30 ZHG006

Impact of Long-Term Stability of Atmospheric Pressure Plasmas on Vacuum UV Spectroscopy — •Görkem Bilgin[1], Luka Hansen[1,2], and Jan Benedikt[1,2] — [1]Institute of Experimental and Applied Physics, Kiel University, Kiel, Germany — [2]Kiel Nano, Surface and Interface Science KiNSIS, Kiel University, Kiel, Germany

The diagnostic of vacuum ultraviolet (VUV) photons generated by atmospheric pressure plasmas is challenging due to strong absorption of VUV photons in air and common window materials like lithium fluoride (LiF) and magnesium fluoride (MgF_2) [1]. Ultra-thin silicon nitride (Si_3N_4) membranes (20 nm) can withstand the pressure gradient and are resistant to plasma exposure, enabling VUV spectroscopic measurements.
During the operation of a capillary jet plasma source [2], the electrodes and plasma heat up, altering matching and reducing power input to the plasma. Stable operating conditions are essential to investigate potential changes in the Si_3N_4 membranes (e.g., chemical composition, transmission). Therefore, the existing setup was upgraded with a liquid cooling system.
VUV spectra with and without cooling highlight the need for active cooling to ensure stable operation. A stable VUV photon source is essential for studying long-term effects on the membrane. Additionally, the plasma source's tunability is shown by measuring VUV spectra while varying the working gas mixture.

[1] J. Golda *et al.*, 2020 *Plasma Process. Polym.* **17** 201900216
[2] T. Winzer *et al.*, 2022 *J. Appl. Phys.* **132** 183301

Invited Talk P 21.4 Thu 14:45 ZHG006

Hybrid fluid/MC simulations of radio-frequency atmospheric pressure plasma jets — •Mate Vass[1,2], Peter Hartmann[2], Zoltan Donko[2], Ihor Korolov[1], Thomas Mussenbrock[1], and Julian Schulze[1] — [1]Chair of Applied Electrodynamics and Plasma Technology, Ruhr-University Bochum, 44780 Bochum, Germany — [2]Institute for Solid State Physics and Optics, HUN-REN Wigner Research Centre for Physics, 1121 Budapest, Hungary

Radio-frequency (RF) driven atmospheric pressure micro plasma jets have a wide range of industrially relevant applications. In order to optimize them, a quantitative understanding of how the neutral species densities build up along the jet channel is needed. This is a result of the complex interplay between multiple processes on different timescales. While fluid simulations are usually employed for the description of these jets, they are unable to account for kinetic effects in case of the electrons, which however directly influences the plasma chemistry. Fully kinetic simulation methods, such as PIC/MCC, are, on the other hand, too impractical at atmospheric pressure, particularly for the complex gas mixtures relevant to applications. In this talk, a hybrid simulation method is presented, leveraging the time scale separation of physical processes and the kinetic description of electrons. The method combines a fluid model for charged and neutral species and a Monte Carlo module for electrons only. This approach achieves significant speedup compared to fully kinetic simulations while maintaining accuracy. Simulations of a He/O_2 mixture are presented, showing excellent agreement with experimental results.

P 21.5 Thu 15:15 ZHG006

Tunable diode laser absorption spectroscopy of all four Ar*($3p^5$4s) states in a pulsed-operated single-filament dielectric barrier discharge at atmospheric pressure — •Levin Krös[1], Hans Höft[1], Jean-Pierre H. van Helden[1,2], and Ronny Brandenburg[1,3] — [1]Leibniz Institute for Plasma Science and Technology (INP), Greifswald, Germany — [2]Faculty of Physics and Astronomy, Ruhr University Bochum, Bochum, Germany — [3]Institute of Physics, University of Rostock, Rostock, Germany

Dielectric barrier discharges (DBDs) are a common plasma source for plasma enhanced chemical vapour deposition (PECVD), i.e. of thin functional films. Excited argon species have sufficient energy to dissociate or ionise molecular species and thus influence the discharge dynamics. Tunable diode laser absorption spectroscopy is utilised to measure absolute number densities of the Ar*($3p^5$4s) states. Detailed knowledge of the population distribution of the four lowest energetically excited states of argon (Ar*($3p^5$4s) states, i.e. the resonance states ($1s_2$, $1s_4$) and the metastable states ($1s_3$, $1s_5$)), is of major interest for the benchmarking of numerical models to tailor the operating parameters for PECVD, e.g., the characteristics of the applied high-voltage pulse and the gas flow rate. We report the first results of density measurements of these states in a pulsed-operated DBD with a 3 mm gas gap flown through with argon at atmospheric pressure.
This work is funded by the DFG (project number: 504701852).

P 21.6 Thu 15:30 ZHG006

N-butane conversion in an RF plasma combined with a catalyst — •Fatma-Nur Seferoglu[1], Steijn Vervloedt[2], and Achim von Keudell[2] — [1]Institute of Fusion Energy and Nuclear Waste Management, Forschungszentrum Jülich GmbH, Jülich, GERMANY — [2]Experimental Physics II, Ruhr-University, Bochum, GERMANY

Volatile organic compounds (VOCs) such as n-butane can negatively impact the environment, contribute to air pollution and can affect human health. Plasma catalytic systems are a promising technology for VOC removal. These systems, particularly in-plasma catalysis, can be very complex due to numerous chemical and physical processes that

can take place simultaneously. Recently, different reaction kinetic models for the plasma-assisted conversion of n-butane have been proposed. However, the key reaction channels are still not fully known yet. In this work, a capacitively coupled plasma is generated at 13.56 MHz in atmospheric pressure between two plane-parallel electrodes spray-coated with MnO_2 as a catalyst. Fourier-Transform Infrared spectroscopy has been performed for a helium flow of 250 sccm and two different gas admixtures O_2: C_4H_{10}: He = 0.135%: 0.124%: 99.741%, and CO_2: He = 0.81%, to determine the species concentration inside the plasma-catalytic system. The comparison between the experiment and the proposed models reveals that O_2 adsorption is less dominant than CO_2 adsorption on the catalytic surface in the case of the oxygen-deficient n-butane conversion. In all cases, electron-impact CO_2 dissociation plays a mayor role in the plasma-catalytic system.