P 7: Atmospheric-pressure plasma and applications 2

Time: Tuesday 11:00–13:00 Location: b305

Invited Talk P 7.1 Tue 11:00 b305
Simulation of microarcs: challenges and perspectives — •Margarita Baeva[1], Detlef Loffhagen[1], Markus M. Becker[1], Erwan Siewert[2], and Dirk Uhrlandt[1] — [1]Leibniz Institute for Plasma Science and Technology, 17489 Greifswald, Germany — [2]Linde AG, Geschäftsbereich Linde Gas, 85716 Unterschleissheim, Germany

Microarcs are generated on sub-millimetric scale. They are encountered in switching devices and are currently considered as promising tools in material processing. Experiments on microarcs are extremely difficult so that modelling can be seen as an alternative for their characterization. Studies on microarcs can greatly contribute to the overall arc plasma modelling. In particular, a unified numerical modelling of microarcs opens the opportunity to clarify questions of fundamental importance: to what extent do arc column and near-electrode regions interact with each other over different arc lengths; is the division of the arc plasma into sub-regions relevant to short-length arcs; what is the extension of the regions with considerable space-charge; how do the near-electrode regions change in space; do cathode and anode boundary regions merge when the arc length becomes minuscule. Results of a recent unified model of microarcs will be presented and discussed along with those obtained by means of a fully non-equilibrium approach, in which the space charge sheaths are so far unresolved.

The project on modelling of microarcs is funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) - project number 390828847.

P 7.2 Tue 11:30 b305
Vacuum ultraviolet spectroscopy of cold atmospheric pressure plasma jets — •Judith Golda[1], Beatrix Biskup[2], Vincent Layes[2], Tristan Winzer[1], and Jan Benedikt[1] — [1]Institute of Experimental and Applied Physics, Kiel University, Germany — [2]Experimental Physics II, Ruhr-University Bochum, Germany

Due to elevated pressure and thus high number of three-body collisions, cold atmospheric pressure plasmas generate excimer species that can emit highly energetic photons thus transferring energy inside the discharge and to treated substrates. However, they are difficult to assess as they are absorbed by air or window material.

Here, we present a method to measure vacuum ultraviolet (VUV) photons using a monochromator with an aerodynamic window. Emission spectra of an RF-excited atmospheric plasma jet (COST-Jet) [1] were analyzed for typical gas mixtures. The data suggest that helium excimers contribute notably to the excitation of molecular and atomic species. The emission intensities do not follow the densities of ground-state species, underlining the variety of excitation channels and the change of the electron energy distribution function under changing the gas composition.

[1] J. Golda et al., J. Phys. D: Appl. Phys. 49 084003, 2016.

P 7.3 Tue 11:45 b305
Verification of electric discharge modeling code developed in FEniCS — •Aleksandar P. Jovanovic, Detlef Loffhagen, and Markus M. Becker — Leibniz Institute for Plasma Science and Technology, Greifswald, Germany

The main goal of this work is to verify a newly developed fluid model code and to test its performance. The code is developed in FEniCS, open-source computing platform for solving partial differential equations by the finite element method. This platform is chosen due to support for symbolic representation of the weak form of partial differential equation, which simplifies problem definition significantly. In addition, it supports parallel processing by using MPI and provides various types of finite elements and numerical solvers. The code is verified by benchmarking and by the method of exact solution. Two benchmark studies, 1) modeling of an axisymmetric positive streamer in air, and 2) modeling of a low pressure glow discharge in argon are presented. The results are compared to the benchmark data in the first, and to the results obtained with a commercial software COMSOL Multiphysics® in the second study. In addition, the method of exact solution for a time of flight experiment is used for verification purpose. In all cases good agreement with the reference data is observed and a similar parallel performance as with COMSOL is achieved.

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P 7.4 Tue 12:00 b305
Atmospheric pressure RF plasma jets driven by tailored voltage waveforms in He/N_2 mixtures — •Ihor Korolov[1], Marc Leimkühler[1], Mark Böke[1], Zoltán Donkó[2], Volker Schulz-von der Gathen[1], Lena Bischoff[1], Gerrit Hübner[1], Péter Hartmann[2], Timo Gans[3], Yue Liu[4], Thomas Mussenbrock[4], and Julian Schulze[1,5] — [1]Ruhr-University Bochum, Germany — [2]Wigner Research Centre for Physics, Hungary — [3]University of York, United Kingdom — [4]Brandenburg University of Technology Cottbus-Senftenberg, Germany — [5]School of Physics, Dalian University of Technology, China

Micro atmospheric pressure plasma jets (μAPPJ) can efficiently generate different reactive species at the buffer gas temperatures which are close to the ambient temperature. These reactive species are suited for various applications: wound healing, sterilization, cancer treatment, surface modification, etc. In this work, we investigate the μAPPJ operated in mixtures of He and N_2 and driven by tailored voltage waveforms both experimentally by using tunable diode-laser absorption spectroscopy and via kinetic Particle-in-Cell/Monte Carlo simulations. We find an excellent agreement between the results of experiment and simulations over a wide range of conditions for the spatially resolved and averaged helium metastable density. The latter is found to be significantly enhanced by increasing the number of consecutive driving harmonics. The results show that voltage waveform tailoring allows one to enhance the control over the electron energy distribution function to optimize the excited species generation.

P 7.5 Tue 12:15 b305
Laser-induced fluorescence of magnetized plasma with magnetic sub-level resolution — •Roman Bergert, Slobodan Mitic, and Markus H. Thoma — I. Physikalisches Institut, Justus-Liebig Universität Gießen

The behaviour of a dielectric barrier discharge (DBD) jet influenced by an external constant magnetic field (0.3 T) at different pressures was investigated by tunable diode laser absorption spectroscopy (TDLAS) and laser-induced fluorescence (LIF) in perpendicular observation to the magnetic field. TDLAS and LIF were done with magnetic sub-level resolution on π (linear) and σ (circular) polarized transitions of Argon $1s_4$ at 842.47 nm and $1s_5$ at 801.48 nm. Unpolarized laser light was used for the measurements. For LIF the 842 nm transitions were used for pumping.
The $1s_4$ magnetic sub-level densities were reconstructed from linear polarized transitions for different pressures. The densities were later used for modeling of the magnetic sub-level and polarization resolved fluorescence of 842 nm and 801 nm for different pressures. 'Forbidden' transitions were observed and could be explained with a model including level mixing of the $2p_8$ sub-level states through neutral collisions. A strong visible pressure dependence of LIF and the development of the 'forbidden' transition could be observed and modeled successfully.

P 7.6 Tue 12:30 b305
Ro-vibrational distribution measurements in transient atmospheric pressure plasmas by coherent anti-Stokes Raman scattering — •Jan Kuhfeld, Dirk Luggenhölscher, and Uwe Czarnetzki — Institute for Plasma and Atomic Physics, Ruhr University Bochum, Germany

Ro-vibrational excited molecules govern the plasma wall interaction and the chemical reactions in atmospheric pressure plasmas. Excitation of a molecule can occur by an energetic electron or by collisional transfer from an already excited molecule. One of the key goals in discharge design is optimizing these excitation processes in order to achieve maximum energy efficiency in chemical conversion, e.g. CO_2 into CO. The experimental approach for investigating these processes introduced here is based on a particular coherent anti-Stokes Raman scattering (CARS) scheme. This single shot dual pump CARS scheme provides information on the ro-vibrational population of two molecular species simultaneously, here N_2 and CO_2. Additionally, one of the laser beams for the CARS technique is used to perform electric field measurements via E-FISH (electric field induced second harmonic generation). Excited molecules are created by two separate ns-pulsed APPJ with effluents intercepting. Space and time resolutions are determined by the interaction volume of the lasers and the pulse length respectively. Those are in the order of 100 μm and 10 ns. Here, first measurements of the electric field and the vibrational excitation of Nitrogen in a Helium-Nitrogen mixture are presented.

P 7.7 Tue 12:45 b305

Gliding arc plasmatron- plasma chemical reactor for methane conversion — Simon Böddeker, •Nikita Bibinov, and Peter Awakowicz — Institute for Electrical Engineering and Plasma Technology, Ruhr-University Bochum, 44801 Bochum, Germany

A gliding arc plasmatron (GAP) is applied as part of plasma chemical reactor for methane conversion and synthesis of carbon containing materials without associated carbon dioxide production. This plasma source can be operated in two different modes, namely gliding arc channel with diameter of 0.2-0.3 mm similar to conventional GA in vortex gas flow and plasma plume mode, with one (or several) hot and broad plasma object(s) with diameter 4-5mm incorporated into the gliding arc channel. Plasma conditions and efficiency of methane conversion in these two modes are very different. The first GAP mode is characterized by gas temperature of 2000K-2500K, electron density of about 10^{14} cm^{-3} and methane dissociation frequency of about 10 s^{-1}. Under these plasma conditions mainly formation of methyl radicals is expected. Plasma of plasma plume is very hot, 5500K-6000K, electron density amounts to about 10^{15} cm^{-3} and frequency of thermal methane dissociation is about 10^{7} s^{-1}. Under these plasma conditions methane will be completely dissociated. In optimized GAP geometry, gas flow rate and electric current (200-300 mA) plasma plume has contact to the plasma reactor surface only via thin GA channels. At that material of electrodes is not thermal overloaded. Switching between modes is possible by variation of plasma reactor geometry and gas flow.