P 9: Atmospheric Pressure Plasmas and their Applications III

Time: Wednesday 11:00–13:00 Location: CHE/0089

Invited Talk P 9.1 Wed 11:00 CHE/0089

Modelling and analysis of single-filament dielectric barrier discharges at atmospheric pressure — •Markus M. Becker[1], Ronny Brandenburg[1], Tomáš Hoder[2], Hans Höft[1], Aleksandar P. Jovanović[1], and Detlef Loffhagen[1] — [1]Leibniz Institute for Plasma Science and Technology (INP), Greifswald, Germany — [2]Masaryk University, Brno, Czech Republic

This contribution gives an overview of research results of the last 10 years on the modelling of single-filament dielectric barrier discharges (DBDs). Two discharge configurations are used to highlight the possibilities and limitations of spatially one- (1D) and two-dimensional (2D) time-dependent fluid models. First, it is shown for a one-sided, sine-driven DBD in argon that 1D models are generally suitable to describe the discharge characteristics in periodic operation. Second, 1D models are found to be suitable for systematic determination of the influence of preionisation on repetitively pulsed, two-sided DBDs in nitrogen-oxygen gas mixtures up to time scales of milliseconds. However, 1D models lack the ability to correctly describe the appearance of striations (in argon) and the streamer breakdown phase (~ 1 ns). For this purpose, 2D models are applied, which show a very good agreement with measurement results. Since processes on longer time scales (μs to ms) can only be investigated in 2D with extreme computational effort, a smart combination of 1D and 2D models is most promising for a profound understanding of filamentary DBDs.

This work was partly funded by the DFG—projects 407462159 and 408777255, and Czech Science Foundation project 21-16391S.

P 9.2 Wed 11:30 CHE/0089

Kinetic modeling of the charge transfer across a negatively biased semiconducting plasma-solid interface — Kristopher Rasek, •Franz Xaver Bronold, and Holger Fehske — Institut für Physik, Universität Greifswald, 17489 Greifswald

We discuss the selfconsistent ambipolar charge transfer across a negatively biased semiconducting plasma-solid interface using a thin germanium layer with electron-phonon scattering sandwiched between an Ohmic contact and a collisionless argon plasma as a model system. The current-voltage characteristics of the interface is obtained from the distribution functions of the charge carriers on both sides of it. Due to quantum-mechanical reflection at the interface and collisions inside the solid, the characteristics differs substantially from the one obtained for a perfectly absorbing interface. The electron microphysics inside the solid affects thus the characteristics. In addition, the spatially and energetically resolved fluxes and charge distributions inside the germanium layer visualize the behavior of the charge carriers responsible for the charge transport. Albeit not quantitative, because of the crude model for the germanium band structure and the neglect of particle-nonconserving scattering processes, such as impact ionization and electron-hole recombination, which at the energies involved cannot be neglected, our results [1] clearly indicate (i) the current through the interface is carried by rather hot carriers and (ii) the perfect absorber model, often used for the description of charge transport across plasma-solid interfaces, cannot be maintained for semiconducting interfaces.
[1] K. Rasek *et al.*, Phys. Rev. E **105**, 045202 (2022).

P 9.3 Wed 11:45 CHE/0089

Challenges during the design of a DC microplasma cell intended for *in situ* TEM — •Luka Hansen[1], Niklas Kohlmann[2], Lorenz Kienle[2], and Holger Kersten[1] — [1]Institute of Experimental and Applied Physics, Kiel University, Kiel, Germany — [2]Institute for Material Science, Kiel University, Kiel, Germany

In situ observation of plasma surface modifications are possible if a microplasma is inserted into a TEM as shown by proof of principle experiments in 2013 [1]. Still, multiple challenges have to be overcome for the development of a microplasma cell suitable for TEM integration. The electrodes have to be electron beam transparent and are therefore restricted to tens of nanometers in thickness. The microplasma itself has to be vacuum-proof encapsulated and operated in a stable regime. A DC microplasma was designed and intensively studied to ensure its stable operation in the normal glow regime [2]. *Ex situ* performed measurements proved the possibility to setup the electrodes thin enough for TEM imaging and study the surface modifications [3]. Furthermore, the microplasma cell was successfully introduced into the TEM and first images without plasma could be taken. Electrical isolation problems prevented plasma ignition inside of the TEM, but will be solved by rebuilding the vacuum-proof encapsulation from ceramic. This contribution summarizes the already overcome challenges and updates about the recent steps towards *in situ* TEM imaging.

[1] K. Tai *et al.*, 2013 *Scientific Reports* **3** 1325
[2] L. Hansen *et al.*, 2022 *Plasma Sources Sci. Technol.* **31** 035013
[3] L. Hansen *et al.*, *Thin Solid Films* **(Accepted)**

P 9.4 Wed 12:00 CHE/0089

Characterization of Sputtered Polyethylene Naphthalate-Foil for Flexible Surface DBD Plasma Generation — •Sandra Moritz[1], Roman Bergert[2], Martin Becker[1], and Markus H. Thoma[1] — [1]I. Physikalisches Institut, Justus-Liebig-Universität Gießen, Deutschland — [2]II. Physikalisches Institut, Justus-Liebig-Universität Gießen, Deutschland

Plasma medicine demands for very specific plasma source configurations. Beside gasflow-driven jet-arrays, dielectrical barrier discharges (DBD) are commonly used to generate ambient air plasma at room temperature for sterilization. There, electrode and dielectric material limit its use in application. Especially, the sterilization of difficult, uneven or edged surface geometries with DBD can be rather challenging. Therefore, flexible polyethylene naphthalate-foil (PEN-foil) which was covered with electrode material by ion-beam sputtering is characterized regarding its electrical and bactericidal performance for different power and electrode thickness configurations. Operating temperature, ozone production capability and plasma parameters (electron temperature and density) were used as characterization parameters. Advantages as well as limitations of this new approach are presented.

P 9.5 Wed 12:15 CHE/0089

Study on interaction of two single-filament DBDs — •Hans Höft[1], Chiel Ton[2], Tom Huiskamp[2], and Torsten Gerling[1,3] — [1]Leibniz Institute for Plasma Science and Technology (INP), Felix-Hausdorff-Str. 2, 17489 Greifswald, Germany — [2]Department of Electrical Engineering, Electrical Energy Systems group, Eindhoven University of Technology, PO Box 513, 5600 MB Eindhoven, The Netherlands — [3]Competency centre for diabetes (KDK), Greifswalder Str. 11, 17495 Karlsburg, Germany

A dielectric barrier discharge configuration consisting of two identical single-filament arrangements with variable radial distance between them was investigated by means of synchronised, fast electrical and optical diagnostics. For that purpose, two single, alumina-covered electrode pairs featuring two 1 mm gaps were put in a stainless-steel chamber flushed with 0.1 vol% O_2 in N_2 at atmospheric pressure. A high-voltage pulse with ≈ 45 ns rise time was simultaneously applied to the electrode (10 kV amplitude and variable repetition frequencies). The diagnostics consisted of fast voltage and current probes, which were synchronised with an iCCD camera to record individual discharge structures. The current was measured at the grounded side for each single-filament to calculate the discharge power and transferred charge. The interaction between two adjacent discharges was investigated to better understand upscaling challenges and opportunities, e.g. by using an electrical circuit model and the synchronised single-shot data of the electrical measurements and the corresponding iCCD images.
Funded by the DFG – project number 466331904.

P 9.6 Wed 12:30 CHE/0089

Binary nanocrystal synthesis using atmospheric pressure plasmas — •Maren Dworschak[1], Martin Müller[2], Lorenz Kienle[3], and Jan Benedikt[1] — [1]Institue of Experimental and Applied Physics,Kiel University, Germany — [2]Institute of Physics, Czech Academy of Sciences, Czech Republic — [3]Faculty of Engineering, Kiel University, Germany

Nanocrystals of binary or multinary compounds with group IV semiconductors offer great flexibility in composition, morphology and structure. The resulting tunable band gap is associated with enhanced optical properties and tuneable luminescence ranging from the UV to the near-infrared region. The variety of possible nanocrystals offers a great selection of materials for energy conversion and storage application, yet the synthesis of such compounds on the nanometer scale is still challenging due to the complexity of the synthesis process. We report on possible methods that could facilitate the generation of metal-silicide nanocrystals while using atmospheric pressure plasmas as a tool. Silicon nanocrystals are generated in the plasma source from the reactive gas silane. An additional electrode inserted in to the plasma can be coated with the metal of choice. When the electrode is heated, the metal evaporates and gets incorporated in the produced nanoparticles downstream of the jet. A second possible method involves a post synthesis in-flight annealing stage. Particles synthesized in the plasma jet pass through a furnace at 1100°C, in which the desired metal is present in gaseous phase. Here, the high temperature has proven to facilitates the formation of crystalline polyelemental compounds.

P 9.7 Wed 12:45 CHE/0089

Modelling of self-pulsing discharges at atmospheric pressure — •Aleksandar P. Jovanović[1], Hans Höft[1], Detlef Loffhagen[1], Torsten Gerling[1,2], and Markus M. Becker[1] — [1]Leibniz Institute for Plasma Science and Technology (INP), Felix-Hausdorff-Str. 2, 17489 Greifswald, Germany — [2]Competency centre for diabetes KDK Karlsburg, Greifswalder Str. 11, 17495 Karlsburg, Germany

Non-thermal atmospheric-pressure plasmas are of considerable interest due to their wide relevance for technical and medical applications over the past decade. Self-pulsing discharges are a common way to generate these plasmas. Here, the discharge current is limited by a suitably designed electrical circuit to prevent thermalisation. Current oscillations observed in these discharges were attributed to the existence of ion acoustic waves (IAWs) and can be used for plasma diagnostics. Therefore, a detailed understanding of the electron and ion kinetics during the discharge evolution is of great interest. For this purpose, a time-dependent, spatially one-dimensional fluid-Poisson model coupled with an equation of electrical circuit has been applied to study a self-pulsing discharge in argon at atmospheric pressure. The characteristic phases governed by different charge carrier production and loss processes as well as the dominant ions produced during the discharge have been analysed. The two-cathode effect has been identified as a potential excitation mechanism of IAWs at atmospheric pressure.

Funded by the Deutsche Forschungsgemeinschaft (DFG) – project number 466331904.