P 5: Atmospheric Pressure Plasmas and their Applications I

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

Invited Talk P 5.1 Tue 11:00 CHE/0089

Diagnostics of metal-grid micro cavity plasma arrays — •Marc Böke[1], David Steuer[2], Sebastian Dzikowski[1], Henrik van Impel[2], Volker Schulz-von der Gathen[1], and Judith Golda[2] — [1]Physics of Reactive Plasmas, Ruhr-University Bochum, D-44801 Bochum, Germany — [2]Plasma Interface Physics, Ruhr-University Bochum, D-44801 Bochum, Germany

Micro-structured plasma discharges offer great potential for a variety of applications, such as large-area treatment, catalytic conversion, or decomposition of volatile organic compounds. Therefore, they are of high relevance from a technical and scientific point of view. To understand the processes, fundamental knowledge about the discharge mechanisms and dynamics and generation of reactive species is necessary. Here, we investigate metal-grid micro cavity plasma arrays of well-defined microdischarges. They are modular in construction and allow stable operation and the use of catalysts. The plasma arrays are operated in helium with admixtures of reactive gases, typically in the percentage range, and excited by triangular voltage amplitudes of 400-800V at kHz frequencies. Diagnostics in these cavities are challenging due to their small dimensions in the range of 100μm and the limited access because of the encapsulation of the plasma cavities. Therefore, we apply optical emission-based methods to determine electric fields (Stark shift) or 2D resolved densities of reactive species (e.g. by state enhanced actinometry). The basic discharge behavior like discharge modes and spatial distribution, electrical characteristics and dynamics will be discussed. Supported by the DFG within SFB 1316.

P 5.2 Tue 11:30 CHE/0089

Modelling and experimental analysis of DBDs in Ar-TMS and Ar-HMDS mixtures — •Marjan Stankov[1], Markus M. Becker[1], Lars Bröcker[2], Claus-Peter Klages[2], and Detlef Loffhagen[1] — [1]Leibniz Institute for Plasma Science and Technology (INP), 17489 Greifswald — [2]Institute for Surface Technology (IOT), Technische Universität Braunschweig, 38108 Braunschweig

During the last two decades, plasma-enhanced chemical vapour deposition processes using atmospheric-pressure dielectric barrier discharges (DBDs) have become of great interest for fabricating various thin films and coatings. Here, fluid modelling and experimental analyses of such DBDs in argon with the addition of small amounts of tetramethylsilane (TMS) or hexamethyldisilane (HMDS) as precursors are reported. A plane-parallel and a single-filament discharge configuration are operated by sinusoidal voltages of few kV at frequencies of 86 and 19 kHz, respectively. A time-dependent, spatially one-dimensional fluid-Poisson model including an extensive reaction kinetic scheme for argon and the organosilicon presursors with about 90 species and 700 reactions is used for the modelling studies. Results for electrical discharge properties and relevant species in the DBD are represented and discussed. Penning ionization (PI) processes of excited argon species with the precursor gas are found to have a decisive impact on the discharge characteristics. In particular, it is found that cations generated due to PI processes are the dominant species for thin film formation.

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P 5.3 Tue 11:45 CHE/0089

State enhanced actinometry in a micro cavity plasma array — •David Steuer, Henrik van Impel, Volker Schulz-von der Gathen, Marc Böke, and Judith Golda — Ruhr-University Bochum, D-44801 Bochum, Germany

In recent years, plasma catalysis as an application of atmospheric pressure plasmas has become a research. Suitable reactors for investigating the fundamental interaction between plasmas and catalytic surfaces are micro cavity plasma arrays. To understand the plasma catalytic processes, it is important to monitor the densities of reactive species. In the case of atomic oxygen, this is typically done using laser spectroscopic methods. Due to the small dimensions of micro cavities between 50-200μm this is very complex. Therefore, a new approach, helium state enhanced actinometry (SEA)[1], was used. 2D resolved measurements are performed by using an ICCD camera in combination with a tuneable bandpass filter. The discharge is operated in helium with an oxygen admixture of 0.1%. An argon admixture of 0.05% is used as actinometer gas. The triangular excitation voltage between amplitudes of 400-800V is varied at a frequency of 15 kHz. Very high dissociation degrees up to nearly complete dissociation are observed. The spatial resolution allows density distributions within individual cavities to be resolved. Time resolved measurements show significant differences in oxygen density between the increasing potential phase and the decreasing potential phase. This work is supported by the DFG via SFB 1316 (project A6). [1]Steuer et al 2022 PSST 31 10LT01

P 5.4 Tue 12:00 CHE/0089

CO_2 splitting in 3D-printed barrier discharge reactors — •Dimas Adrianto[1], Milko Schiorlin[1], Volker Brüser[1], Ronny Brandenburg[1,2], and Sven Grundmann[2] — [1]Leibniz Institute for Plasma Science and Technology, Greifswald, Germany — [2]University of Rostock, Rostock, Germany

First attempts to use Dielectric Barrier Discharges (DBDs) for the conversion of carbon dioxide (CO_2) date back to the 1990's, and found a renewed interest in the 2010's due to the energy transition, i.e., the demand for PtX technologies for the generation of fuels or chemicals. DBDs still lack on energy efficiency, but provide a simple and robust design for plasma reactors. In contrast to the studies of microwave discharges, the impact of gas flow distribution in DBDs reactors is still a rather unexplored field. In this study, a 3D printer is used to realize DBD discharge chambers with a predefined gas flow pattern. Thus, the high flexibility of rapid prototyping enables to correlate fluid dynamic simulations with the plasmachemical performance of CO_2 splitting. DBD reactors are made of methacrylic acid polymer and have an overall dimension of 120 x 120 mm, with a powered electrode size of 55 x 55 mm, placed in the center. The influence of flow mechanics is investigated in three DBD reactors with different gas flow patterns and velocity profiles. Besides CO_2 splitting in pure CO_2, ozone generation in air is studied. It is shown that CO or O_3 yield can be influenced by the flow pattern and gas flow rate.

P 5.5 Tue 12:15 CHE/0089

Gas Separation of O_2 in a CO_2 Plasma Membrane Reactor — •Katharina Wiegers[1], Andreas Schulz[1], Matthias Walker[1], Günter Tovar[1], Frederic Buck[2], Thomas Schiestel[2], and Stefan Baumann[3] — [1]University of Stuttgart IGVP, Stuttgart, Germany — [2]Fraunhofer IGB, Stuttgart, Germany — [3]Forschungszentrum Jülich IEK-1, Jülich, Germany

Mankind nowadays is strongly affected by ongoing climate change, mainly caused by the increasing emission of CO_2. CO_2, a very stable molecule, can be activated by a plasma process. It converts CO_2 into the value-added chemical molecule CO. In order for this method to become competitive with electrolysis, the simultaneously produced O_2 must be separated from the gas mixture. In order to do so, oxygen-conducting ceramic hollow fibers can be used. The first and well-investigated ceramic is $La_{0.6}Sr_{0.4}Co_{0.2}Fe_{0.8}O_{3-\delta}$ by Tereoka [1]. Changing the *A* site cations or using a dual-phase material can improve the temperature stability and chemical resistance against the CO_2 and CO atmosphere in the plasma membrane reactor.

In this work, $La_{0.6}Ca_{0.4}Co_{0.5}Fe_{0.5}O_{3-\delta}$ hollow fibers are investigated in terms of their oxygen separation ability. They are temperature stable up to 1200°C. To increase the viable region for O_2 separation in the plasma torch, new ceramic materials (e.g. 60 wt% $Ce_{0.8}Gd_{0.2}O_{1.9}$-40 wt% $Gd_{0.85}Ce_{0.15}Fe_{0.75}Co_{0.25}O_3$) with higher temperature resistance have to be developed and investigated. The idea is that different fiber materials can be used depending on the local plasma temperature.

[1] Y. Teraoka et al., Chemistry Letters, 1985, 14 (11), 1743,17-46.

P 5.6 Tue 12:30 CHE/0089

Evaluation of an electron beam sustained atmospheric pressure plasma for the conversion of carbon dioxide — •Lars Dincklage[1], Burkhard Zimmermann[1], Gösta Mattausch[1], and Ronny Brandenburg[2,3] — [1]1Fraunhofer Institute for Org. Electr., EB and Plasma Technol. FEP, Dresden, Germany — [2]Leibniz-Institute for Plasma Science and Technology, Greifswald, Germany — [3]University of Rostock, Germany

Carbon dioxide (CO_2) conversion processes will play an important role in closed carbon cycles for zero carbon emission economies in the future. Even though plasmas exhibit numerous technical advantages, they are not yet economically feasible in terms of CO_2 conversion,

since they struggle to simultaneously achieve high energy efficiency and high conversion degree for the splitting of CO_2 molecules and are often bound to sub-atmospheric pressures. Therefore, a new hybrid approach for the plasma-chemical conversion of CO_2 is presented, consisting of an atmospheric pressure glow discharge sustained by an electron beam. This hybrid approach potentially allows to transfer energy from the plasma mainly into vibrational dissociation pathways by working at low reduced electric field strengths (about 20 Td), while sufficient ionization in the plasma is ensured by the electron beam. Based on this principle a reactor for gas conversion processes was developed. Furthermore, preparatory electron beam dose measurements for estimating ionization rates in the plasma were conducted and power deposition by the electric field and the electron beam into the plasma were calculated for continuous and pulsed operation modes.

P 5.7 Tue 12:45 CHE/0089

Control of the gas flow by a surface barrier discharge — •Soad Mohsenimehr, Marc Böke, and Achim Von Keudell — Experimental Physics II, Ruhr-University Bochum, Bochum, Germany

Surface Dielectric Barrier Discharges (SDBD) are well-known plasma sources for gas stream purification and gas conversion due to their easy scalability in various applications. In addition, SDBDs are used as plasma actuators to generate thrust in a gas for flow control. The aim of this project is to combine plasma chemistry and plasma-based flow control concepts. The plasma-flow interaction and its contribution to the chemistry of transported species is evaluated. In this work, a twin SDBD is employed, which consists of an aluminium oxide plate (190x88x0.63 mm) that is covered by nickel metallic grid printed on both sides. The SDBD is generated at atmospheric pressure using damped sinusoidal voltage waveforms (G2000 Redline Technologies). To investigate the flow pattern, the Schlieren technique was carried out to visualize the refractive index gradients in the medium and to compare this with a fluid dynamic simulation in two dimensions performed by COMSOL. The fluid simulation uses the 2D Navier Stokes equations for compressible Laminar flow assuming small Reynolds numbers. This simulation model is used to predict the plasma aerodynamic and how it could influence the surrounding fluidic flow. The formation of distinct vortices in the flow pattern in both simulation and experiment is observed. The electrode design of the SDBDs is optimized to maximize the plasma-induced thrust on the species conversion.