

P 13: Atmospheric Pressure Plasmas II

Time: Wednesday 16:15–18:15

Location: KH 01.020

Invited Talk

P 13.1 Wed 16:15 KH 01.020

Thin film deposition with dielectric-barrier discharges at atmospheric pressure: open questions and some answers — •LARS BROECKER and CLAUS-PETER KLAGES — Institute for Surface Technology (IOT), Technische Universität Braunschweig, 38108 Braunschweig, Germany

Plasma-enhanced chemical vapour deposition (PECVD) with dielectric-barrier discharges (DBDs) at atmospheric pressure is still only partially understood, which makes choosing the most suitable discharge configuration and plasma parameters quite difficult. In particular, the relevance of possible film-forming species, e.g. radicals, charged particles or the monomer itself, and their influence on the mechanical properties and film chemistry is often speculated upon but not fully understood. The determination of characteristic times involved in the deposition process, namely the gas residence time, the times for the transport of neutral particles and ions to the surface by diffusion and drift, respectively, and the time scales of ionic or radical gas phase reactions, can provide important information about the significance of the species for the film deposition process. Interestingly, cations formed from neutral species by electron impact or chemo-ionization are often neglected, even though they drift to the substrate within a few microseconds. Recent experiments show that film deposition from ions dominates when the gas residence time is much shorter than the diffusion time of neutral particles. For certain monomers, cationic surface reactions appear to play a role, similar to initiated chemical vapour deposition (iCVD) processes.

P 13.2 Wed 16:45 KH 01.020

Impact of simultaneous laser irradiation and plasma treatment to a Cu catalyst for CO₂ reduction — •ALEXANDER SCHICKE^{1,2}, JANNIS KAUFMANN¹, SASCHA CHUR¹, MARC BÖKE², and JUDITH GOLDA¹ — ¹Plasma Interface Physics, Ruhr University Bochum, Germany — ²Experimental Physics II, Ruhr University Bochum, Germany

Catalysts are able to optimise selectivity, efficiency, and reaction rates in chemical reactions. Therefore, they are critical in industrial applications for enabling more environmentally friendly processes. The efficiency of a catalyst is influenced by surface characteristics such as surface morphology and chemical composition. The morphology can be changed by nanostructures produced by laser irradiation, and the chemical composition can be altered by reactive species produced by atmospheric pressure plasmas. The combined treatment increases the efficiency by oxidising the surface. However, this simultaneous interaction between laser, plasma, and surface is highly complex. We investigated this complex interaction in regards to optimise the efficiency of a Cu catalyst for the CO₂-Reduction Reaction (CO₂-RR). The electric fields and energy of pulsed laser irradiation produce Laser Induced Periodic Surface Structures (LIPSS) and Pulsed Laser Induced Dewetting Structures (PLIDS) which increase the effective area of the catalyst. Different reactive oxygen species (ROS), such as O₂(a), O₂(b) and ozone, produced by a helium-oxygen plasma, are measured. Up to 30% Cu₂O and further up to 50 % CuO could be produced. The combined treatment increases the overall selectivity to C₂₊ products.

P 13.3 Wed 17:00 KH 01.020

characteristics of plasma catalytic conversion of n-Butane in micro cavity plasma array — •YUE CHENG¹, HENRIK VAN IMPEL¹, DAVID STEUER¹, VOLKER SCHULZ-VON DER GATHEN², MARC BÖKE², and JUDITH GOLDA¹ — ¹Plasma Interface Physics, Ruhr-University Bochum, D-44801 Bochum, Germany — ²Experimental Physics II: Physics of Reactive Plasmas, Ruhr-University Bochum, D-44801 Bochum, Germany

n-Butane is a common volatile organic compound in automotive exhaust and exhibits acute toxicity, so its efficient and harmless removal is important for environmental and public health. This study investigates DBD plasma conversion of n-Butane by FTIR in MCPA, focusing on the effects of gas composition, catalyst and temperature on conversion and product selectivity. Introducing MnO₂, BiTiO₃ or BiVO₄ as catalyst substantially reduces the number of ignited cavities and lowers the maximum conversion to 20%, indicating an anti-synergistic interaction between these catalysts and the present discharge configuration. For BiVO₃ and BiTiO₄ raising the catalyst surface temperature accel-

erates carbon deposition on the dielectric, which further suppresses reaction efficiency. However, BiVO₄ shows the lowest carbon loss and BiTiO₃ gives the smallest unassigned fraction in the product selectivity, meanwhile MnO₂ delivers the highest conversion at elevated temperatures up to 34%. Overall, developing plasma catalytic systems with enhanced anti-coking properties is key to improving conversion rates and steering selectivity toward target products. This work is supported by DFG within SFB1316 (A6).

P 13.4 Wed 17:15 KH 01.020

The Influence of Catalyst Structure on Plasma Properties in Plasma Catalysis — •ALEXANDER QUACK¹, LENNARD BUCK¹, KERSTIN SGONINA¹, and JAN BENEDIKT^{1,2} — ¹Institute of Experimental and Applied Physics, Kiel University — ²Kiel Nano, Surface and Interface Science (KINSIS), Kiel University

In plasma catalysis, porous materials are often used to increase the catalyst surface area and number of active sites. However, the plasma often can not reach these sites directly, limiting the transport of excited species from the plasma to the catalyst surface. Therefore, we investigate the influence of dielectric materials and porous structures of many sizes inside the plasma region and study the resulting modification on the formation, intensity and coverage of the plasma.

For the presented work, we use a custom-build reactor, which can be heated up to 600°C and has a transparent driven electrode for optical analysis with a camera. Additionally, the plasma gap can be modified from 0.5 to 8 mm changing the special dimension of the discharge and altering the plasma properties. The plasma is created at about 20 kHz and 8–20 kV_{PP} and analyzed with current-voltage measurements deriving the plasma power, capacitances and coverage. A gas mixture of H₂:CO₂ (3:1) is chosen to study the catalytic properties of the plasma with CH₄ and CO as chemical products that are detected by mass spectrometry as residual gas analysis. As dielectric materials, we use ceramic (ZrO₂) spheres of different sizes (0.7–2.5 mm) as model material and Co₃O₄ and CuZnO in forms of porous beads and powder as catalytic materials.

P 13.5 Wed 17:30 KH 01.020

Investigating the influence of pulsed plasmas in water on copper surface — •PIA-VICTORIA POTTKÄMPFER, OLIVER KRETTEK, NILS HUBER, SVEN WELLER, and ACHIM VON KEUDELL — Ruhr University Bochum, Germany

In-liquid plasmas enable a variety of applications. For instance, they can be used to induce nanoparticle formation both in the treated liquid and on a surface in contact with the liquid. Plasmas in liquids, when ignited by voltage pulses with fast rise times and nanosecond pulse lengths applied to a small electrode wire, yield a high degree of dissociation of the molecules in the liquid, a high mass transport and efficient reaction rates. The in-liquid plasma causes the formation of reactive oxygen species from the water molecules. The reactive species can propagate through the liquid. When a surface is in direct contact with the liquid, the species can induce modifications of this surface.

In this project, the modification of copper surfaces by in-liquid plasma treatment is investigated. On copper surfaces, growth of Cu_xO nanocubes can be induced. One application of these nanocubes is the catalysis of the electrochemical reduction of CO₂. The activity of these nanocube catalysts decreases with use over time. Therefore, the catalytically active surface needs to be replaced regularly. It is postulated that by an in-situ in-liquid plasma treatment a re-activation of the surface could be achieved, thereby extending the lifetime of the copper oxide catalysts.

P 13.6 Wed 17:45 KH 01.020

Enhancing plasma-surface interaction at atmospheric pressure by multiscale aeromaterials — •KERSTIN SGONINA¹, JAN-NIS CHRISTIANSEN¹, JONAS LUMMA², RAINER ADELUNG^{2,3}, FRANKO GREINER^{1,3}, and JAN BENEDIKT^{1,3} — ¹Institute of Experimental and Applied Physics, Kiel University, Germany — ²Department of Materials Science, Kiel University, Germany — ³Kiel Nano, Surface and Interface Science (KINSIS), Kiel University, Germany

The field of plasma-assisted catalysis is continuously growing in the last few years. However, a large breakthrough is still pending. One problem that has received more attention lately [1] is the huge distance

between the plasma and the catalytic material that hinders the plasma activated species to interact with the materials surface. To overcome this challenge, multiscale aeromaterials could be the game changer, which have not been studied in this respect until now. With their high porosity, ultra low density and therefore extremely high surface area (several 100 m²/g), they could enhance the plasma-surface interaction at atmospheric pressure.

Different reactor types have been used to, on the one hand, prove the feasibility of plasma ignition inside aeroglass at atmospheric pressure using high voltages at kHz, and on the other hand, prove the transparency of aeromaterials for ions. The ions transmitting through different thicknesses of aeromaterials of different plasmas at sub-atmospheric pressure (ranging from 20 to 80 mbar) has been detected using an ion mass spectrometer.

[1] Van Turnhout *et al.*, EES Catalysis **3**, 669-693, 2025.

P 13.7 Wed 18:00 KH 01.020

Post-Plasma Catalysis Schemes in Ammonia Synthesis —
•DANIEL HENZE and ACHIM VON KEUDELL — Ruhr Universität Bochum, 44801 Bochum, Germany

Current research in plasma catalysis focuses on in-plasma catalysis,

where the plasma is operated directly in front of the catalyst surface. This approach poses significant scientific challenges, as the plasma-catalyst interaction may lead to synergisms or anti-synergisms when aiming at maximizing species conversion or species selectivity. This question is explored for plasma catalysis for ammonia production. We use a kHz DBD plasma jet array to study the role of plasma-generated species in ammonia synthesis. The discharge initiates guided streamers that impinge on the catalyst surface as shown in a previous experiment with a comparable plasma source [1]. Due to their short lifetime, the plasma-catalyst contact occurs only for about 2% of the pulse duration. This reduces the coupling of the plasma and the catalyst, to separate the plasma dynamics from the surface chemistry. The jet array consists of two sets of three individual jets. Each set of electrodes is powered independently and fed with different gases. They are operated sequentially to separate nitridation and hydrogenation steps in time similar to chemical looping for thermal catalysis. We characterize the discharge setup and investigate the impact of species injection and discharge timing on the ammonia yield by measuring the product density via a sampling orifice coupled to a molecular beam mass spectrometer.

[1] Daniel Henze *et al* 2025 Plasma Sources Sci. Technol. 34 095017