P 8: Atmospheric Plasmas and their Applications III

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

Invited Talk P 8.1 Tue 13:45 ZHG006

Status and outlook for CO_2 conversion with microwave plasmas — •Ante Hecimovic, Christian K. Kiefer, Arne Meindl, Rodrigo Antunes, and Ursel Fantz — Max Planck Institute for Plasma Physics, Boltzmannstr. 2, D85748 Garching b. München

Carbon dioxide (CO_2) gas is regarded as a valuable building block in a non-fossil fuel economy, and if captured from the atmosphere it allows creating a closed carbon cycle, leading to net zero emissions. Low temperature plasmas have the potential to contribute to the field of CO_2 utilization through unique reaction pathways that are not accessible by other conversion technologies. The reaction pathways in the plasma can be driven either by electrons, a combination of electron-driven and heavy species driven mechanisms, or by elevated temperatures (2000-6000 K). In this contribution, conversion of CO_2 into CO using the microwave plasmas in large pressure range (1-1000 mbar) is presented, demonstrating effect of these mechanism on the achieved conversions. Relatively high conversion rates obtained in the microwave plasmas could potentially be applied in an industrial process. Two main obstacles towards the application: gas separation in the plasma effluent, and up-scaling towards CO flow rates compatible with the Fischer-Tropsch process are discussed.

P 8.2 Tue 14:15 ZHG006

High power atmospheric microwave plasma torch for CO_2 conversion — •Marc Bresser, Katharina Wiegers, Stefan Merli, Andreas Schulz, Matthias Walker, and Günter Tovar — IGVP, University of Stuttgart, Germany

Due to global warming and the increase in Earth's surface temperature the concentration of CO_2 in the atmosphere and the CO_2 pollution must be reduced. A renewable alternative to the use of fossil fuels in the chemical industry, as one of the largest producers of CO_2, must be found. An attractive way is to utilize CO_2 as a starting chemical to generate a sustainable alternative and close the carbon cycle. An innovative process is a microwave plasma to activate CO_2. The generated CO can then be used together with hydrogen form renewable resources such as electrolysis to produce synthesis gas. This process has the advantage of on-demand operation with fluctuating and intermitted electric energies. In this work, a 2.45 GHz atmospheric microwave plasma torch is used to convert CO_2 into CO. The torch is operated in a reverse vortex flow configuration. A nozzle behind the torch prevents the back reaction of the product gas. To analyze the cold product gas, the conversion was measured using absorption Fourier-transform infrared spectroscopy, mass spectrometry, and a X-Stream gas analyzer from Emerson. The influence of microwave power and CO_2 gas flow on the conversion was investigated. Based on the conversion values, the energy efficiency was determined. The plasma process achieved maximum conversions of up to 21 % and an energy efficiency of over 40 %.

P 8.3 Tue 14:30 ZHG006

Process optimization of iron oxide (in-flight) reduction in a high-performance microwave argon-hydrogen plasma torch — •Jonas Thiel, Simon Kreuznacht, Marc Böke, and Achim von Keudell — Experimental Physics II - Reactive Plasmas, Ruhr University Bochum, Bochum, Germany

Using an argon-hydrogen microwave plasma torch, the experiments aim at advancing nearly climate-neutral iron ore reduction. These atmospheric-pressure hydrogen plasmas provide advantages such as faster reduction rates, lower energy consumption, in-flight treatment, and scalability compared to other methods. The experimental setup can be used in two operation modes: exposing defined sample amounts to the plasma effluent or directly injecting iron oxide powder into the gas flow for in-flight treatment. A swirl-like flow pattern is employed to shield the reactor's quartz tube from the hot core. However, for the latter case, this swirl also leads to particles being adhered to the wall before reaching the collection system. Therefore, an optimization of the process parameters assisted by fluid simulations examining particle trajectories, residence times, and melting/evaporation behavior under varied flow and geometric conditions is crucial for efficient long-term in-flight treatment. In addition, optical emission spectroscopy and X-ray diffraction are employed to analyze on the one hand plasma properties as gas temperature and electron density/temperature, and on the other hand the reduction degree of treated samples.

Invited Talk P 8.4 Tue 14:45 ZHG006

Plasma activation of low-energy molecules using the example of nitrogen — •Mariagrazia Troia, Katharina Wiegers, Andreas Schulz, and Matthias Walker — Institute for Interfacial Engineerinf and Plasma Technology, University of Stuttgart, Stuttgart, Germany

A key chemical in the manufacture of fertilizers is nitric acid, usually produced via the well-established combination of the Ostwald and the Haber-Bosch processes, with an average energy cost that amounts to 2% of the world*s total, and a side production of several greenhouse gases. An ongoing global effort is being currently carried out in order both to achieve climate neutrality and to reduce the overall production costs of raw chemicals. Plasmochemical processes open up attractive alternative routes, thanks to their flexible, on-demand operating mode which allows for an in-loco production of the fertilizers precursor NOx at low costs. In the current work, a commercially available microwave atmospheric plasma torch is used to synthesize NOx from dry air over a wide set of operating parameters. Resulting concentrations, comparable to the current state-of-the-art for plasma processes, have been further improved by optimizing the gas management in the plasma volume and in its after-glow region, by means of a custom-made nozzle with different geometries and operating principles. High-speed camera measurements and characterization via emission spectroscopy further elucidate the chemistry taking place in the plasma phase. Paired with extensive *cold* gas numerical simulations, they offer promising avenues for further improvements of the NOx yield thus obtained.

P 8.5 Tue 15:15 ZHG006

Nanosecond resolved vibrational kinetics of CO_2 in CO_2/N_2 mixtures: experiment and model — •Christian Alexander Busch[1], Tiago Silva[2], Vasco Guerra[2], Nikita Lepikhin[1], Inna Orel[1], Jan Kuhfeld[1], Dirk Luggenhölscher[1], and Uwe Czarnetzki[1] — [1]Ruhr University Bochum, Institute for Plasma and Atomic Physics, Bochum, Germany — [2]Instituto Superior Técnico, Institute for Plasmas and Nuclear Fusion, Portugal

In this work, the vibrational kinetics of CO_2 in a ns-pulsed near-atmospheric pressure plasma jet operated in a CO_2/N_2 mixture is studied experimentally [1] and by modeling using the LisbOn KInetics codes (LoKI). This discharge allows for a temporal separation and thus an independent study of the excitation during the discharge pulse and the V-V and V-T transfer in the afterglow. The densities of individual rovibrationally excited states of CO_2 are measured with ns resolution by absorption spectroscopy using a quantum-cascade laser.

Notably, a short-lived non-equilibrium was observed between the populations of the Fermi resonant states and the bending mode. Additionally, the excitation of the asymmetric stretch mode was found to deviate from a commonly applied scaling law.

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[1] Christian A Busch et al 2025 *J. Phys. D: Appl. Phys.* **58** 065202

P 8.6 Tue 15:30 ZHG006

Impact of a plasma window arc discharge on the transmission properties of a 48-Ca heavy ion beam — •Andre Michel, Fateme Ghaznavi, Michael Händler, Adem Ates, Marcus Iberler, and Joachim Jacoby — Goethe Universität Frankfurt

With the increase of particle beam energies and intensities in accelerator facilities around the world, a reliable technique for the separation of accelerator vacua to high-pressure targets is needed where conventional techniques such as differential pumping stages or solid membranes might fail. A promising technique that allows the transmission of such ion beams even at short distances is the so-called plasma window [1]. It is based on a cascaded arc discharge that enables the active control of the pressure gradient depending on the selected working gas, flow rate and arc current.

In 2018 the Plasma Physics department of Goethe University Frankfurt developed a prototype of the plasma window, which has since been optimized for its purpose as an active pressure separation component in particle accelerators. As part of its further development, the plasma window has been successfully used to demonstrate the transmission of a heavy ion beam while maintaining the pressure gradient up to 10h in a single run.

This contribution gives an insight into the plasma physical properties as well as the operating parameters of the developed plasma window and highlights its impact on the properties of the transmitted ion beam.

[1] Hershcovitch, A., J. Appl. Phys., AIP Publishing, 1995, 78, 5283