Carbon2Chem®

L-III | Scale-up of a Dielectric Barrier Discharge for Industrial Applications at Elevated Pressure

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The removal of oxygen traces from coke oven gas is an intermediate step necessary for the gas conditioning in Carbon2Chem®. A non-thermal plasma was successfully utilized to perform the desired gas conversion. The reactor consists of stacked plane parallel electrodes allowing to operate the process at high volumetric flow rates and elevated pressure while retaining low flow resistance. An optimized new generator design was tested that facilitates plasma ignition and can improve the energy efficiency.

Scale-up concept: Higher flow rate through numbering-up

Investigations on the plasma-assisted oxygen trace removal are performed in close contact with partners from industry. Here, thyssenkrupp AG provides necessary information about the composition of the coke oven gas and other parameters like the flow rate. On a laboratory scale, the complex gas mixture is reproduced and the influence of different parameters is analyzed in detail. Lastly, the requirements of subsequent processing steps, namely the pressure swing adsorption are provided by Linde. Through this mutual exchange of information, the process feasibility can be discussed and evaluated on the laboratory scale already under near-industrial conditions.

A scale-up reactor was designed in-house, featuring several stacked plane parallel electrodes (Fig. 1). The current design is targeted towards flow rates of 10 m³/h and pressures up to 3 bar (g). The reactor was successfully taken into operation in the Carbon2Chem® Technical Center in Duisburg in different mixtures of H_2, N_2 and O_2. It is planned to perform measurements with real coke oven gas at elevated pressures in the near future and prove conclusively the operability under industrial conditions. Plasma ignition above atmospheric pressure poses new challenges that require generator design beyond just state of the art.

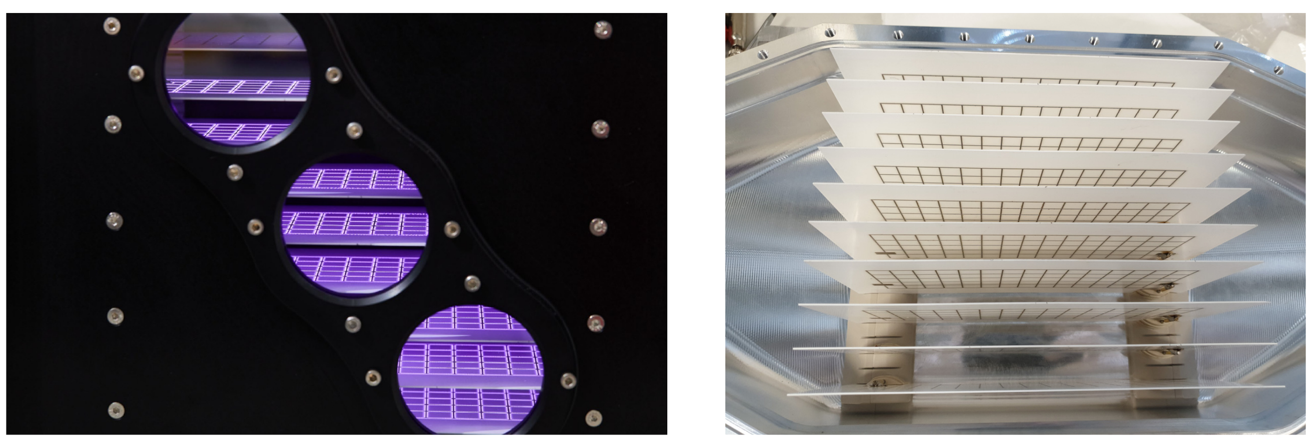

Figure 1: Scale-up prototype reactor with plasma ignited on all electrodes (left). Stacked electrodes in the opened reactor assembled in the Carbon2Chem® Technical Center in Duisburg (right).

Fundamental measurements: Understanding influence factors and challenges

In first measurements with the scale-up reactor the very high conversions of O_2 previously demonstrated with the single-electrode laboratory-scale reactor were reproduced. For an O_2 content of 1,000 ppm the conversion was steadily increasing with H_2 up to a maximum of 98 %. However for 10,000 ppm O_2 the conversion maximum of ~60 % was reached at the desired operating point of 50-60 % H_2. For an increasing flow rate of up to 3 m³/h the conversion dropped to 71 % and 18 % using an O_2 content of 1,000 and 10,000 ppm, respectively (Fig. 2).

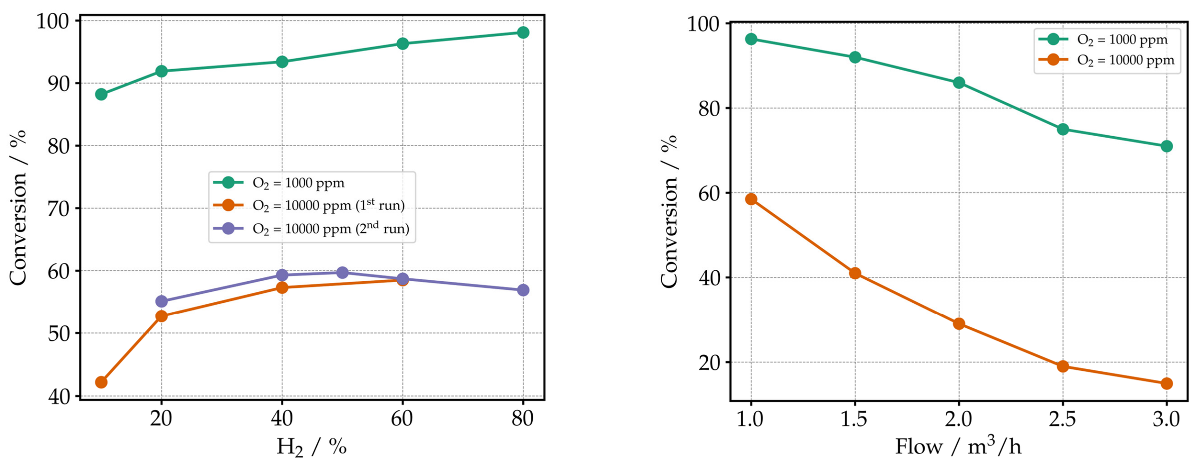

Figure 2: O_2 conversion for varying H_2 concentration (left) and flow (right).

To further improve the conversion and energy efficiency a new generator design was tested. By increasing the pulse width the intermediate circuit current was significantly reduced while retaining the high voltage amplitude (Fig. 3). This allows for higher dissipated powers which increased conversion and enable/facilitate plasma ignition at higher pressures. First measurements with the system are currently under preparation.

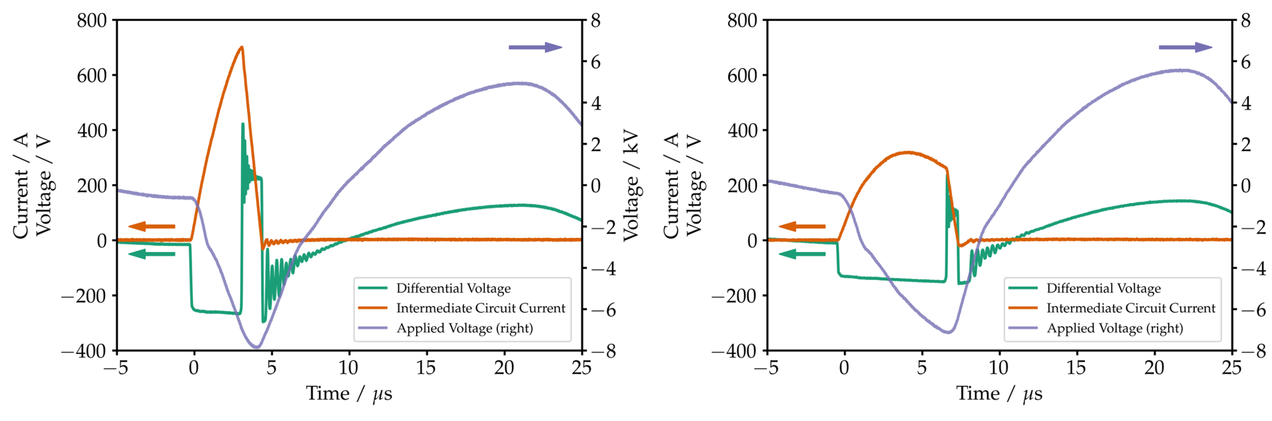

Figure 3: Current voltage characteristics of the new generator design at a high voltage amplitude of 13 kV and a pulse width of 3.2 µs (left) and 7 µs (right).

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A KEY BUILDING BLOCK FOR THE CLIMATE PROTECTION

CO_2 reduction by cooperation of process industrial sectors