Sorption Enhanced Methanation for the Power-to-X Research Platform

Graduate

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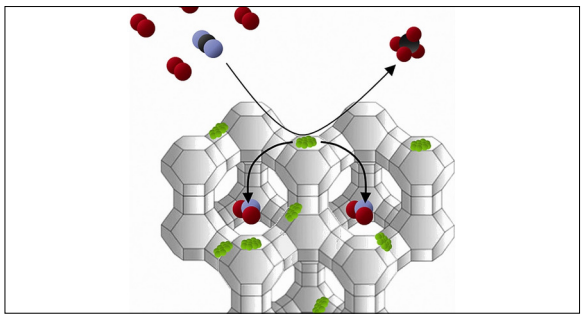
Initial Situation: In order to reach net zero greenhouse gas emissions by 2050 the defossilization of the energy sector is crucial. Therefore, a significant increase in renewable energy generation is required. A challenge of specific renewables namely photovoltaics and wind energy is their intermittency in energy production. Power-to-X has the potential to buffer energy generation and energy demand and thereby represents a potential solution to this problem.
In the scope of this thesis a novel power-to-methane technology is investigated. This process is called sorption enhanced methanation (SEM). The catalyst used in the SEM process consists of nickel nanoparticles impregnated on a zeolite support. The zeolite on one hand provides a large surface area for the catalyst's active sites, on the other hand it adsorbs the water produced during the methanation process. As a consequence, a complete shift of the reaction's equilibrium to the product's side is obtained. Therefore, unlike in conventional catalytic methanation, the SEM process is not subject to thermodynamic limitations and a methane yield of 100% is achievable at atmospheric pressure.
The full conversion of CO2 to CH4 allows to directly feed the product gas into the gas grid without the need for additional purification. The gas grid quality requirements are met.

Objective: In the framework of this thesis the following aims have been achieved: First of all, the new SEM reactor together with the temperature control unit were successfully put into operation. Second of all, several experiments with the pure zeolite were conducted to gain information about its interaction with CO2, Ar and H2. After that, the zeolite functionalized with nickel was activated. Successively, two methanation experiments were conducted, where functioning of the SEM reactor was proven and process information was gained. Finally, a concept for the integration of the reactor to the Power-to-X research platform was developed.

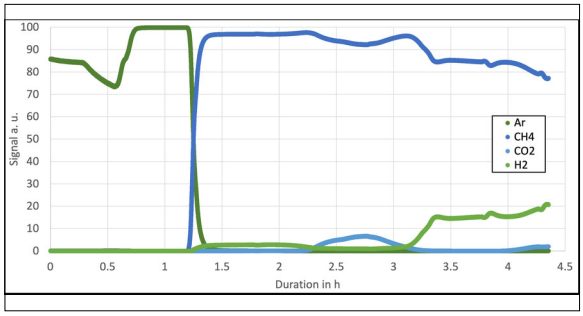
Result: A CO2 to CH4 conversion rate of 100% was obtained during the methanation experiments. Furthermore, in the second methanation experiment the purity of the product gas stream was 97% methane, with the remaining share being H2. Concerning the operating conditions, by applying a gas hourly space velocity (GHSV) of 19.5 h−1, the methanation phase lasts 5.8 h until the zeolite is completely saturated with water. The drying was conducted over night for 14 h by purging with argon under a GHSV of 8.8h−1
A challenge in the SEM process is the trade-off between a high adsorption capacity of the zeolite at low temperatures and a high catalytic activity at high temperatures. In order to keep the operating temperature at an optimum of 300°C, the reactor was designed to operate in a quasi isothermic manner. In this work the reactor's capability of limiting temperature hot spots to a maximum of 10.5 K was proofed.
Finally, the last milestone of this project is to bridge the laboratory-to-industry gap. To this end, the integration into the power-to-X research platform was planned.

Temperature control system by Regloplas (left) for the operation of the SEM reactor manufactured by Fluitec (right).
Samuel Hecht, UMTEC/OST

Catalyst for SEM showing the Ni catalyst (green) facilitating methanation and the water adsorption into the zeolite.
Andre Heel , UMTEC/OST



Product gas measurements during methanation showing the 100% CO2 to CH4 conversion and 97% methane purity.
Own presentment



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Subject Area
Thermal process engineering, Thermo- and fluiddynamics, General environmental technology