Catalysts and process design for the electro-chemical production of ethylene from carbon dioxide

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Ten Fraunhofer Institutes are jointly working on the Fraunhofer lighthouse project “Electricity as a Resource” coordinated by the Fraunhofer Institute for Environmental, Safety, and Energy Technology UMSICHT. Their objective is to develop and optimize processes enabling low-carbon power usage to synthesize economically relevant base chemicals. In this lecture results from the subproject “electrochemical reduction of CO_2 to ethylene using gas diffusion electrodes” are presented.

Introduction

Ethylene is one of the most important chemical building blocks in industry. Further carbon dioxide is a yet only partially valorized carbon source and also a greenhouse gas that needs to be diminished. Therefore the establishment of non-petrochemical ethylene production pathways along with CO_2 usage as a substrate has been identified as a techno-economically most viable concept. Clean power for such a production can be generated from various renewable sources like photovoltaics or wind.

Thus, a technology which is able to use this renewable energy to form building blocks like ethylene based on electrochemical reduction of CO_2 is promoted as one of the promising approaches for solving the problems of climate change, safeguarding energy supply and independence from fossil resources.

It is well-known that copper based catalysts show enhanced selectivity for the production of ethylene. The challenges to overcome are the optimization of these catalysts for maximum current efficiency, their implementation into gas diffusion electrodes (GDE) with high three-phase contact area, and the development of an integrated electrochemical reactor.

Objectives of the project

The presented project deals with three objectives a) the development, characterization and production of a catalysts with optimized faraday efficiency for the production of ethylene, b) the development of a gas diffusion electrode (GDE), based on the developed catalysts with a size up to 100°cm^2, and c) a lab-scale demonstrator capable to take the 100°cm^2 electrode and equipped with all necessary components to optimize the yield and entire performance of the electrochemical reduction of CO_2 to ethylene and/or other relevant building blocks.

Experimental

The production of catalyst systems was carried out via three different production methods. The co-precipitation followed by calcination delivers metal/metal oxide powders based on copper. In addition the catalyst production via deep eutectic solvents, an innovative matrix with increasing research attention, enables the production of catalysts with different chemical compositions and new catalytic activities. The generated powders are used to coat the electrode with the catalytically active system. The third preparation method uses the direct electrochemical precipitation of copper based systems from aqueous electrolyte as well as deep eutectic solvent systems.

For the production of GDEs different techniques besides the above mentioned electrochemical precipitation were carried out. E.g. slurries from the catalyst powder with a binder system and an electrically conductive material like carbon black were produced and casted or calendered onto an appropriate substrate material.

As a start, a commercial electrochemical cell was used to investigate the electro-catalytic activity of the produced catalysts and GDEs. As a first step to higher production rates for ethylene, we constructed a scalable electrochemical reactor integrated with a system with the possibility to use GDEs with a size up to 100 cm^2.

Results

More than 200 catalysts were produced and characterized. The lab-scale demonstrator was assembled and a risk assessment was carried out.

In this presentation results from the synthesized catalysts, GDE production as well as electrochemical conversion of CO_2 carried out in the lab-scale demonstrator are given and discussed.