Influence of the carbon substrate on the electroreduction of CO_2 to formate using various gas diffusion layers

Verena Theußl[1,2], Henning Weinrich[1], Christine Heume[1,2], Hermann Tempel[1], Hans Kungl[1], Rüdiger A. Eichel[1,2]

[1]Insitute of Energy and Climate Research – Fundamental Electrochemistry (IEK-9) Forschungszentrum Jülich GmbH, 52425 Jülich, Germany
[2]RWTH Aachen University, Institute of Physical Chemistry, 52074 Aachen, Germany
v.theussl@fz-juelich.de

The increasing concentration of carbon dioxide (CO_2) from anthropogenic sources in the atmosphere is one of the major causes of climate change making carbon capture and utilization (CCU) a topic of great importance. In context of CCU, the electroreduction of CO_2 attracts particular attention, since it opens a way to use waste emissions for the production of value added products such as formic acid enabling its use as a green commodity in the chemical industry[1].

For the electroreduction of CO_2, the architecture of the gas diffusion electrode (GDE) plays a pivotal role[2], since the GDE carries the catalyst layer and promotes the reduction reaction. However, despite its importance, research in the field of electroreduction has mainly been focused on catalyst development and the investigation of cell designs, often neglecting the influence of the GDE on the cell performance. Therefore, aiming for an in-depth understanding of the underlying design principles, the influence of different gas diffusion layers (GDLs) on the electroreduction of CO_2 to formate was investigated. At this, our study with respect to formate shall be regarded as an exemplary investigation, which we expect to hold true for other dissolved reaction products as well.

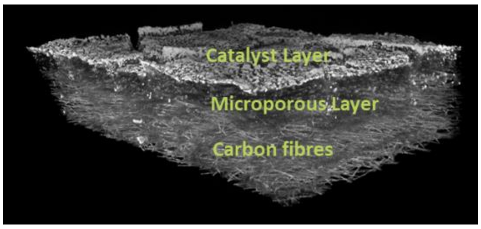

Figure 1: Micro-CT picture of Toray Paper 120 MPL coated with SnO_2 nanoparticles, after the electroreduction of CO_2 to formate. Bright spots identify the location of the nanoparticles after the experiment.

In our study, the investigated GDLs differed in their composition regarding the presence of a microporous layer (MPL), the extent of the hydrophobic treatment and the thickness of the GDL. The electrodes for the investigation of the influence of the GDLs on the electroreduction of CO_2 to formate were prepared via spray coating and were investigated by several physicochemical- and electrochemical techniques such as BET, SEM, X-ray microtomography (Micro-CT), contact angle analysis, capillary flow porometry, PEIS, LSV and CP afterwards. The quantification of the emerging formate during the electroreduction was implemented via offline ion exclusion chromatography (IC), while gaseous side-products were determined by online gas chromatography. A micro-CT image of the GDE prepared with Toray Paper 120 with MPL can be seen in Figure 1. The bright layer on top of the GDE is the catalyst layer that exhibits extended stability for short-term testing based on the applied preparation procedure. As an overall result of our study, it was found that the GDEs with a MPL show the best electrode performance identified by the least negative electrode potentials and the highest amounts of produced formate in comparison to the electrodes without MPL. This effect is mainly ascribed to the enhanced wettability of the electrode and the resulting improvement of the electrode-electrolyte interface. Furthermore, we observed that for the electroreduction of CO_2 also a sufficiently high hydrophobic treatment of the GDLs is important in order to prevent electrode flooding. However, a too high PTFE content causes repulsion of the electrolyte and may impede the electroreduction of CO_2. The GDL thickness on the other hand seems to play no decisive role on the electrode performance. To conclude, the decisive parameters describing a suitable GDL for the electroreduction of CO_2, are an interaction for the presence of a MPL and the amount of hydrophobic treatment, with the most important aspect being the presence of a microporous layer.

References:
1. M. Rumayor, A. Dominguez-Ramos, Appl. Sci., 8 (2018) 1–12 (https://doi.org/10.3390/app8060914)
2. T.N. Nguyen, C.T. Dinh, Chem. Soc. Rev., 49 (2020) 7488–7504 (https://doi.org/10.1039/D0CS00230E).