Process design and economics of electrochemical CO_2 reduction to value added products

by
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Abstract
Carbon capture and utilization (CCU) has been proposed as a complementary measure to mitigate CO_2 emissions. An interesting example of CCU is the electrochemical conversion of CO_2 to chemicals and fuels using renewable electricity (i.e., power-to-X). Currently, it is very challenging for electrochemical processes to compete with the fossil-fuel-based counterparts in the chemical industry. Nevertheless, a tremendous effort has been made the last decade to improve the performance metrics of the CO_2 reduction reaction (CRR). However, the majority of the studies have mainly concentrated on catalyst development to obtain high faradaic efficiencies (FEs) and current densities (CDs) at low overpotentials.

In this colloquium I will demonstrate that, in addition to high FEs and CDs at low overpotentials, a high product concentration and reactant conversions are needed to commercialize CO_2-electrolyzers. As an example, the electrochemical reduction of CO_2 to formic acid (HCOOH) will be considered. A techno-economic analysis of the full value chain, including CO_2 capture, electrochemical conversion, reactant recycling, and downstream product separation, will be presented. I will show that even for a FE of 100% for HCOOH and CD of 200 mA/cm^2 at 2.5 V, a product concentration of at least 20 wt% formic acid will be needed to compete with the commercial BASF process. The cost of formic acid separation increases exponentially with decreasing concentrations, which is conform the well-known 'Sherwood plot'. Finally, I will discuss possibilities to improve the performance and economics of CO_2 electroreduction processes.