Fluid Dynamic Optimization of Electrodes Design for CO2 Electroreduction to Formate

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Converting CO2, for example from flue gasses, to platform molecules represents a valuable way to create a new CO2 cycle and to reduce the overall emissions and fossil fuels consumption. The electrochemical reduction of CO2 to Formic Acid represents a valuable alternative when relying on renewable energy, since it is characterised by high Faradaic Efficiency (over 80%) and high current densities (over 200 mA/cm^2) thanks to relatively cheap Sn catalysts. Formic Acid, besides being the cheapest among the possible products, is also the most profitable, being commonly used in food and textile industry or for fuel cells.

The major limitation to the industrialization of this technology is the difficult scale-up. In fact, common flow cells with gas diffusion electrodes can only be scaled modularly, increasing capital costs but retaining strong mass transfer limitations. In the last years most of the efforts were focused on the research of new catalysts, while the scale-up remains a technological challenge. For this reason, this research project aims to propose and test an innovative electrode design, based mainly on fluid dynamics considerations.

The cathode, where the CO2 reduction to Formate ions will take place, will allow for the tri-phase contact between catholyte, gaseous CO2 and the Sn based metallic catalyst. It will present a cylindrical geometry, being composed by porous sparger, which grants CO2 bubbling inside a Sn foam, where the tri-phase reaction will take place. The forced gas bubbling removes cathode flooding issues, and it grants efficient mixing of the reactive mixture, improving mass transfer. The anode will have a similar geometry, with a porous septum diffusing the anolyte in a Ni catalytic foam. To reduce the Formate ions crossover, weak anionic exchange resin beads will surround the anode, instead of classical membranes. This allows for easier mass transfer and longer electrolytic cell life duration.

The firsts steps for the electrode design started with the characterization of the CO2 feeding system. Following the principles of capillary flow porometry, an experimental setup for macropores diameters distribution in porous septa has been built and tested. In addition, the effects of gas flowrate, presence of surfactants and pores diameters on the diameter of bubbles formed in water was studied to be able to control and predict the CO2 feed behaviour together with the exposed bubbles surface.

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