Master's Thesis Engineering Technology 2022-2023

Optimization of hydrocarbon production through electrochemical reduction of CO_2

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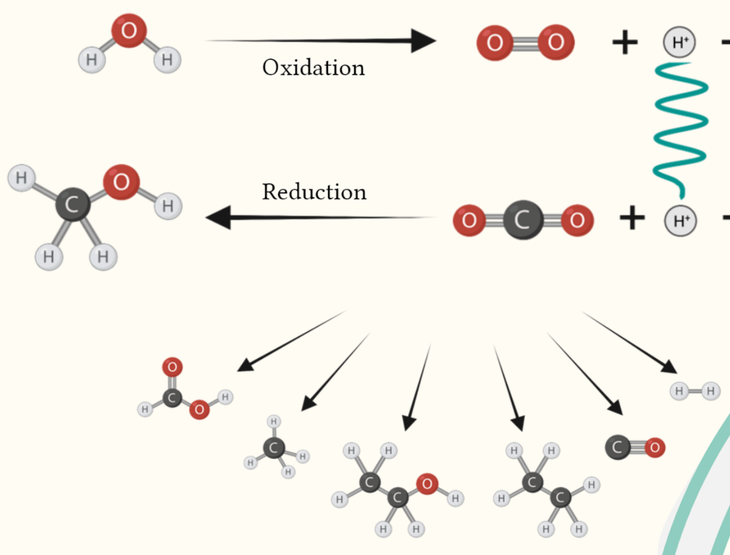
Master of Chemical Engineering Technology

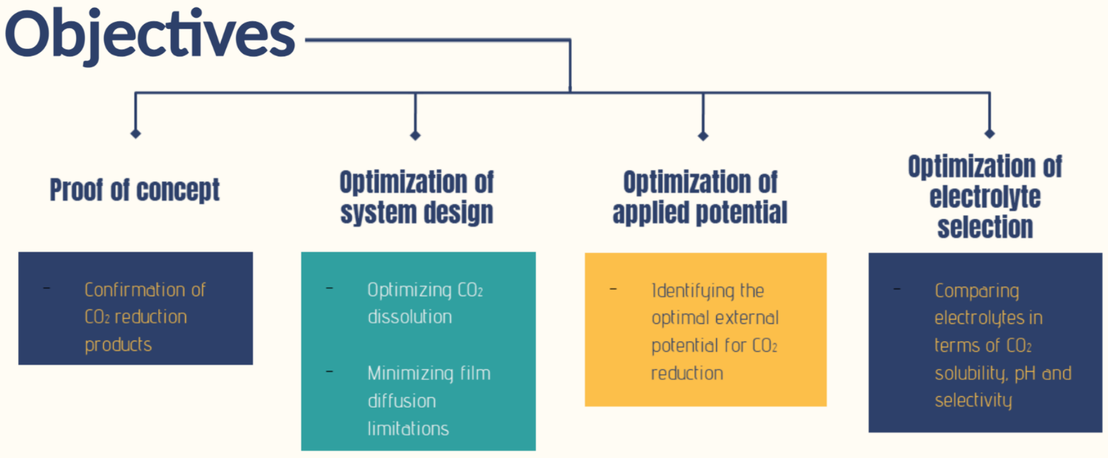
Electrochemical CO_2 reduction

Electrochemical carbon reduction applications can offer an environmentally friendly approach to help mitigate climate change problems. By converting CO_2 into valuable chemicals and fuels, reliance on fossil fuels could be reduced. This would in turn promote a sustainable, carbon-neutral economy.

Due to differences in catalyst material, electrolyte, pH and applied voltage, a wide range of reaction products has been reported. However, exact mechanisms are still subject to debate.



Objectives



Analysis technique

Chrono amperometry: Chronoamperometry is an electrochemical technique used to study the kinetics of electrode processes by monitoring the current response of an electrode over time.

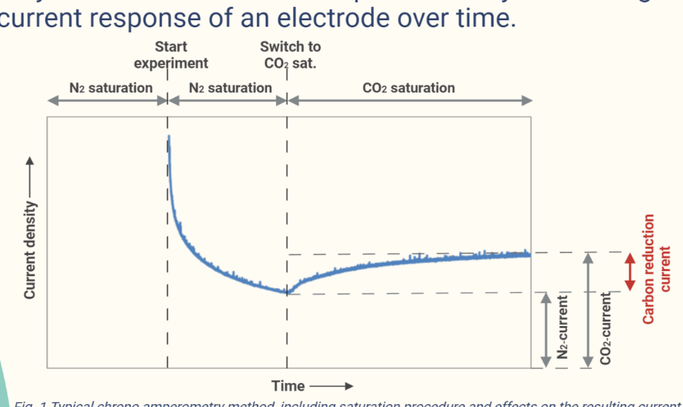


Fig. 1 Typical chrono amperometry method, including saturation procedure and effects on the resulting current.

Reactor design

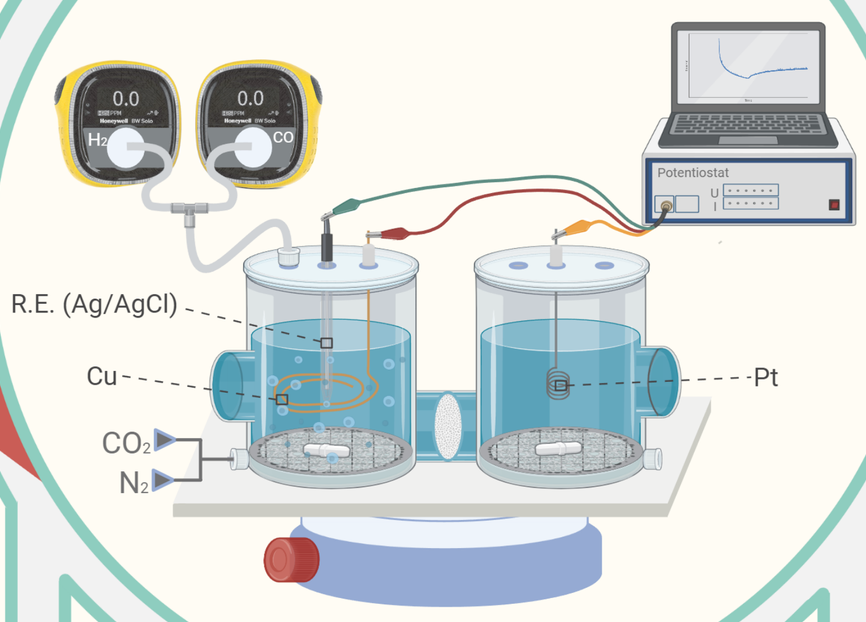


Fig. 2 Optimized reactor design featuring efficient mixing through magnetic stirring and in-reactor CO2 dissolution.

H_2/CO selectivity

The selectivity of a metallic Cu electrocatalyst towards H2 and CO was analyzed at external voltages ranging between 1-1,6 V.

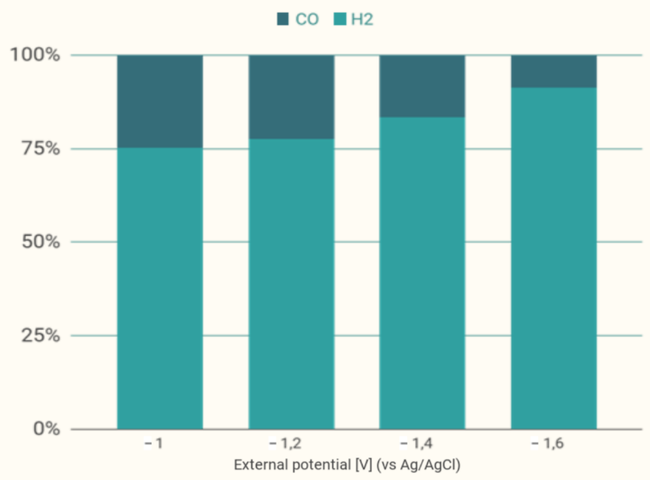


Fig. 3 External potential effect on the relative H2 and CO concentrations.

The results show a significant decrease in CO selectivity at higher voltages. The highest selectivity towards CO is achieved at 1V.

Electrolyte analysis

Four different electrolytes were analyzed and categorized according to several important characteristics.

Table 1 Overview of electrolyte characteristics detailing average current, carbon reduction current, current stability, pH, and CO/H2 selectivity.

	KI	KI+$NaHCO_3$/Na_2CO_3	$NaHCO_3$/Na_2CO_3	Na_2SO_4
Average current density	High	High	Medium	Low
Average carbon reduction current	Medium	Low	Low	High
Current stability	Stable	Stable	Unstable	Very stable
pH	7	9	9,5	6
CO/H_2 selectivity	CO	CO	CO	H_2

TiO_2 catalyst loading

Different thicknesses of the TiO_2 catalyst layer are analyzed as it can influence the catalyst loading through pore diffusion limitations.

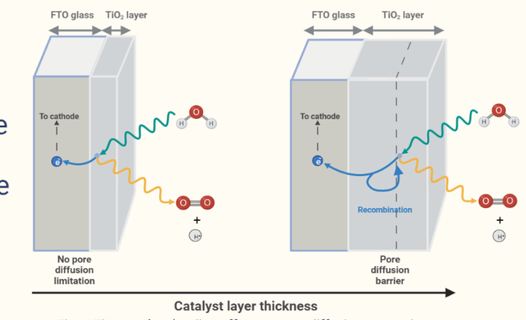


Fig. 4 TiO_2 catalyst loading effect on pore diffusion properties.

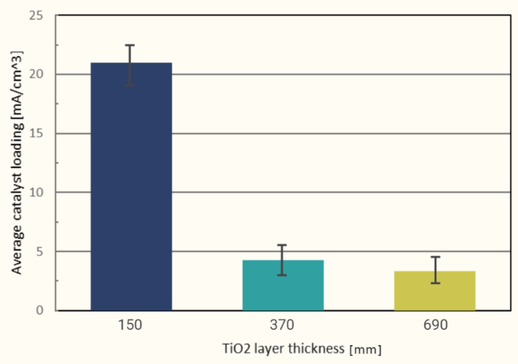


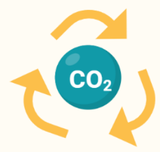
Fig. 5 Average catalyst loading for varying TiO_2 catalyst thicknesses.

The catalyst loading reaches its peak at 150 nm. It is suspected that this is caused by its high active surface area which is not significantly pore diffusion limited.

Conclusions and future projections

Investigations in this thesis focused on optimizing various parameters to enhance an electrochemical system for carbon reduction in chemical engineering. Specifically, film diffusion, CO_2 dissolution, electrocatalyst configuration, external potential, electrolyte selection, and TiO_2 electrocatalyst configuration were explored. Notably, GC-MS analysis yielded limited results; however, a custom chronoamperometry analysis method successfully established a carbon reduction current as a benchmark parameter for data evaluation. This is an important indication that a carbon reduction chain occurs.

Moving forward, future research directions could center around CO or syngas production, which would further advance the field of circular carbon utilization. Moreover, implementing liquid chromatograph analysis featuring a bonded-phase silica column could provide accurate measurements of hydrocarbon concentrations, facilitating the determination of faradic efficiencies and enabling further optimization of the process.



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