The role of the anion exchange membrane thickness for CO_2 electroreduction in direct formic acid electrolysis

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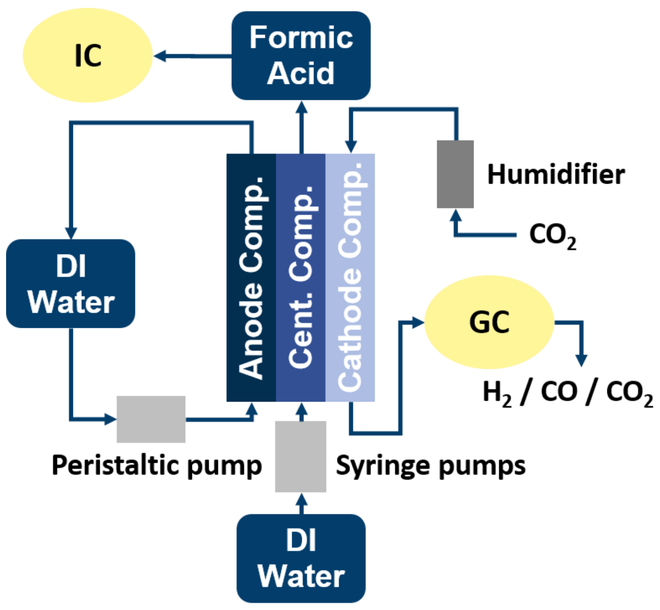
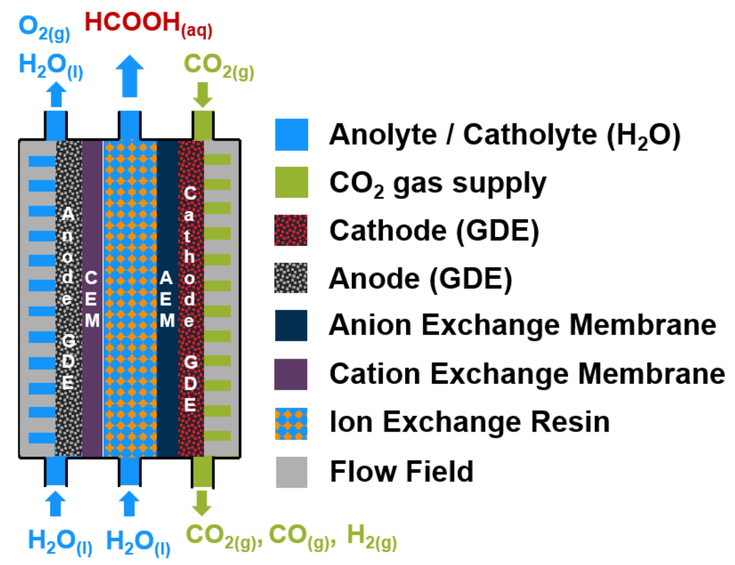
Introduction

The implementation of a closed carbon cycle by 'Power-to-X' (P2X) technologies is of great interest aiming at a CO_2 neutral economy. Especially formic acid is a relevant product of P2X processes, since it can be produced selectively and efficiently using earth-abundant catalysts. This study focuses on the investigation of a three-compartment flow cell, which allows to produce formic acid, instead of formate. Here, the electrolyzer performance using PiperION membranes of various thicknesses ranging from 13 – 80 µm is evaluated. [1 - 2]

Experimental Setup

- Experimental Parameters:
  - Active electrode area: 5 cm^2
  - Flow rate center compart.: 0.1 mL min^{-1}
  - CO_2 supply: 60 mL min^{-1} (λ = 8.0)
  - Flow rate anolyte: 3.0 mL min^{-1}
  - AEM: PiperION (A13, A22R, A35, A80)
  - CEM: Nafion 324
  - GDEs: Custom-made GDEs
- The ion exchange resin in the center compartment allows for a direct production of formic acid





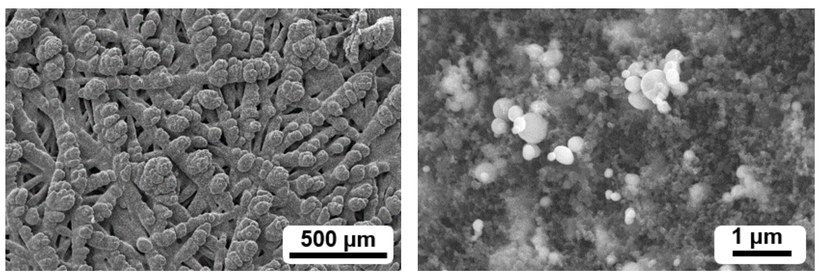
GDE Preparation

Ink preparation → Ultrasonication → Spray-coating

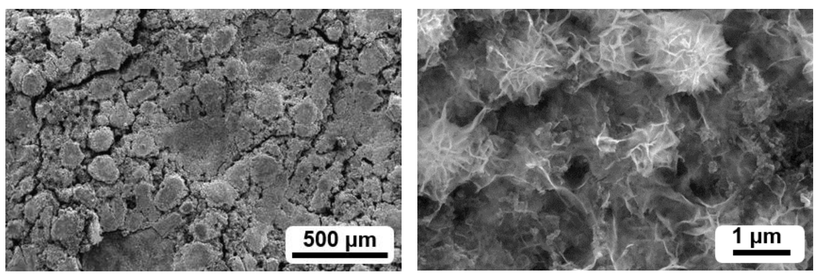
Catalyst: Bi_2O_3
Binder: PiperION
Additive: Carbon powder
Dispersion medium: Ethanol

Substrate: TP120 (30%)
Catalyst loading: 4 mg cm^{-2}

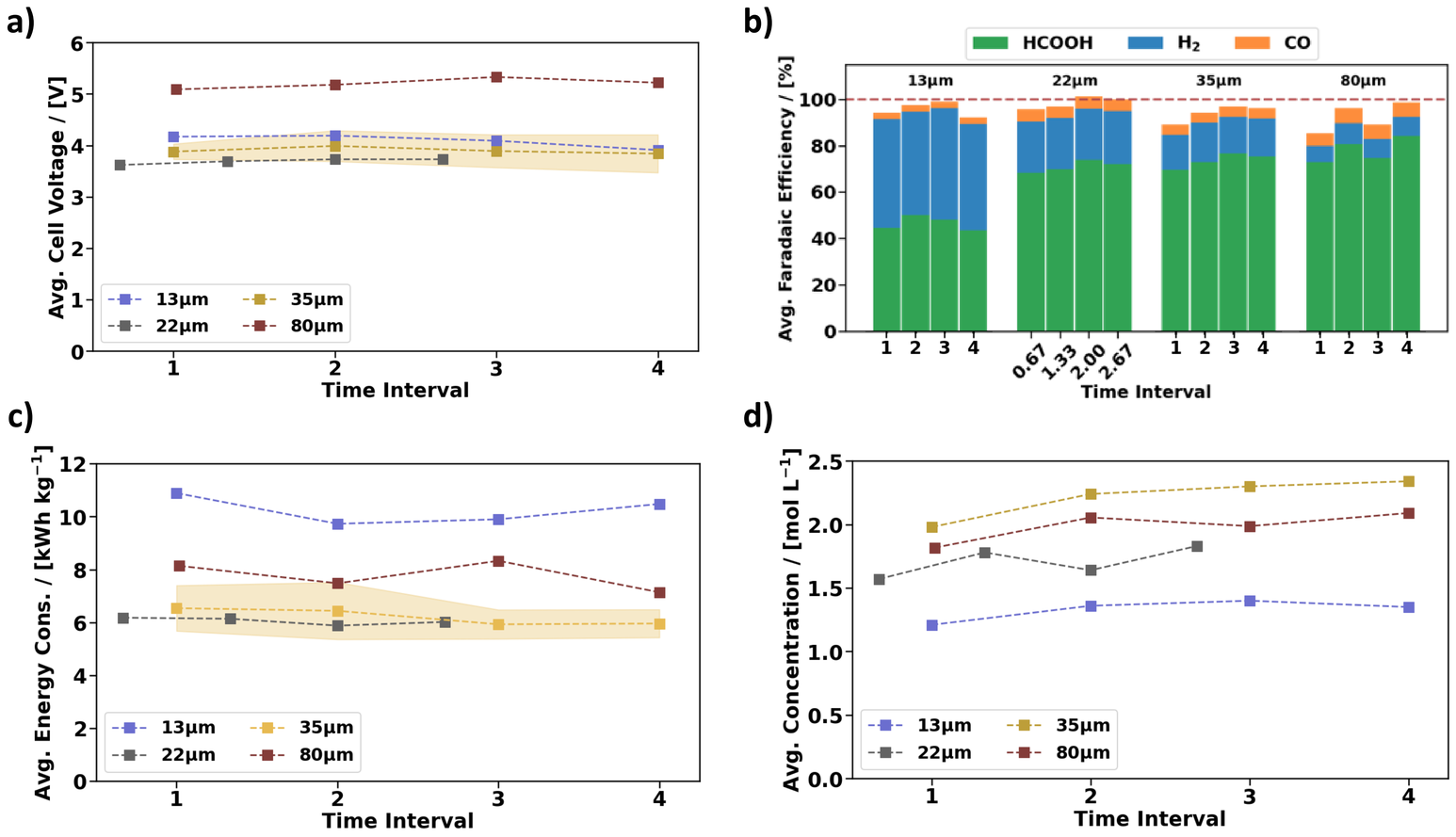
GDE as prepared



GDE after electrolysis



Results



Electrolyzer performance for CO_2 electroreduction to formic acid depending on the AEM thickness during up to 4 hours of continuous testing at 200 mA cm^{-2}. a) Average cell voltage, b) average faradaic efficiency of formic acid, H_2 and CO, c) average energy consumption and d) average concentration of resulting formic acid.

Conclusion

The performance of a three-compartment flow cell for direct formic acid production by CO_2 electroreduction using 13 µm, 22 µm, 35 µm and 80 µm thick PiperION anion exchange membranes was investigated for up to 4 hours. Within this study, the best results in terms of electrolysis performance were obtained for PiperION (35 µm), which allowed up to 76%, about 6.0 kWh kg^{-1} and 2.3 mol L^{-1}, respectively. Similar values, except for a lower formic acid concentration, were obtained for PiperION (22 µm). In contrast, PiperION (80 µm) lead to high cell voltages above 5 V and PiperION (13 µm) showed very low faradaic efficiencies for formic acid with around 45%. Thus, there is no linear correlation between membrane thickness and cell performance. This suggests a superimposition of various effects.

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[2] J. M. Spurgeon et al., Energy Environ. Sci., vol. 11, 1536–1551, 2018.