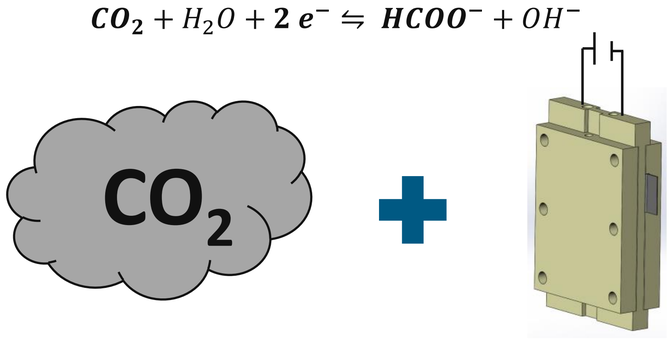
Electrochemical formate production
sustainable feedstock from CO_2 for biotechnological processes

M. Stöckl[1], M. Pfitzer[2], F. Meisel[2], N. D. Kalamarski[2], D. Holtmann[2] | markus.stoeckl@dechema.de
[1]DECHEMA-Forschungsinstitut, Frankfurt a.M./D; [2] TH Mittelhessen University of Applied Sciences, Gießen/D

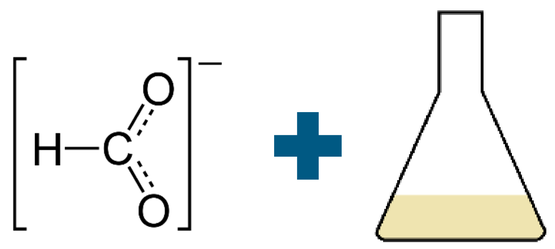
1

CO_2 electrolysis to formate

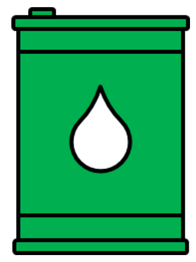
$$CO_2 + H_2O + 2\,e^- \leftrightharpoons HCOO^- + OH^-$$



Formate as feedstock for biotechnological processes



bioproducts



2

Electrochemical formate production

- CO_2 electrolysis in a self designed electrolysis reactor
- Application Sn-based gas-diffusion electrodes (GDE)

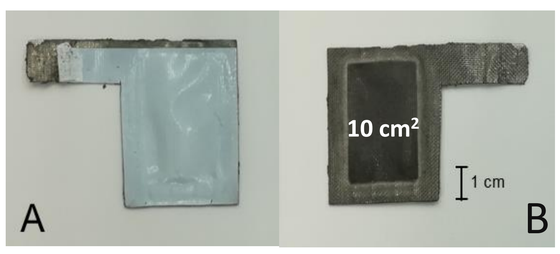


Fig. 1: photographs of Sn-based GDE. A: PTFE covered gas-site. B: electrolyte-site

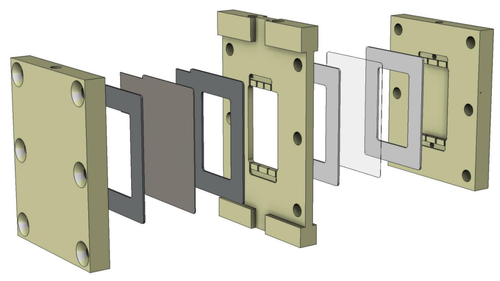


Fig. 2: scheme of designed electrolysis reactor for CO_2 reduction.

Electrolysis parameters:

Electrolyte flow rate: 20 mL/min
Electrolyte: 200 mM PO_4^{3-}buffer
CO_2 pressure: 40 mbar
Current density: -50 mA/cm²
Temperature: 35°C
Duration: 240/420 min (Fig.3/4)

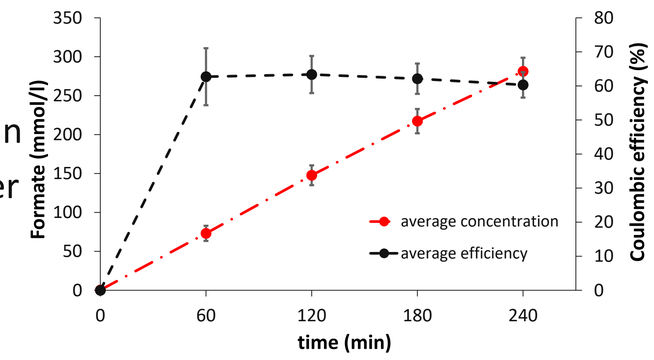


Fig. 3: Formate production from CO_2 and coulombic efficiency (n=3).

- Linear formate production over time
- Stable long-term operability with slightly decreasing performance over time
- Maximum formate concentration of 400 mM was achieved

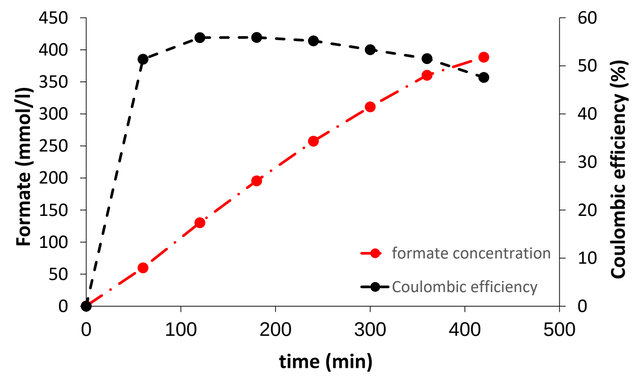


Fig. 4: Development of performance parameters in long-term operation

3

Formate as feedstock for bioproduction

- *Cupriavidus necator* as formatotrophic model organism
- Gram-negativ, facultativ chemolithoautoprophic β-Proteobacterium

Biomass production with *C. necator* wild type

- Growth in parallelized cultivation system (DASGIP®)
- Continuous feed with 1 M formate containing phosphate buffer
- 25 % of formate from electrolysis origin
- Production of up to 0.6 g biomass (1 g/L) on formate
- Dilution effect (not shown) due to relatively low feed concentration

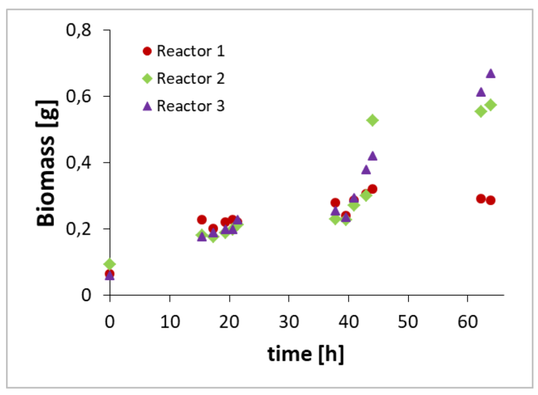


Fig. 5: Development of total biomass of *C. necator* with formate feed in paralyzed bioreactors

Isopropanol synthesis with *C. necator* Re2133/pEG7c

- Incubation of resting cells in septum-flasks on NH_4^+-free medium containing 80 mM formate originating from CO_2 electrolysis
- Complete formate consumption by resting cells
- Increasing isopropanol concentration up to 0.36 mM
- No further isopropanol synthesis due to substrate limitation

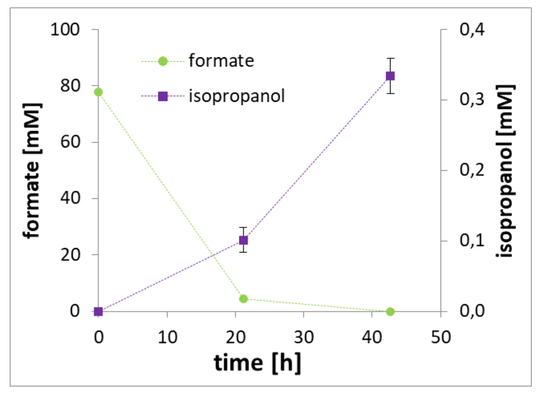


Fig. 6: Development of formate and isopropanol concentrations with *C. necator* Re2133/pEG7c resting cells (n=3).

5

Conclusions and outlook

- Formate was produced from CO_2 with Sn-based GDE.
- Stable formate production process over time with coulombic efficiencies as (CE) high as 60 %.
- With increasing electrolysis duration and increasing formate concentration CE was slightly decreased.
- Formate originating from CO_2 electrolysis was successfully employed as feed in a parallelized bioreactor. To prevent dilution, higher feed concentrations from electrolysis are required.
- Isopropanol synthesis on formate has been shown with a resting cells in principle.
- However, the product to substrate ratio clearly indicates that an optimization of the metabolic pathways for formate usage is needed.

6

Acknowledgement

We gratefully acknowledge financial support by German Federal Ministry of Education and Research:

number 031B0523

number 031B0851D

Federal Ministry of Education and Research