Characterization of an organic aqueous alkaline all-iron flow battery with a scalable test bench system

Lars Henry Fischer[1,2], Luis Fernando Arenas[1,2], Torben Lemmermann[1,2], Ulrich Kunz[1,2], Thomas Turek[1,2]

[1] Institute of Chemical and Electrochemical Process Engineering, Clausthal University of Technology, Clausthal-Zellerfeld, Germany

[2] Research Center Energy Storage Technologies, Goslar, Germany

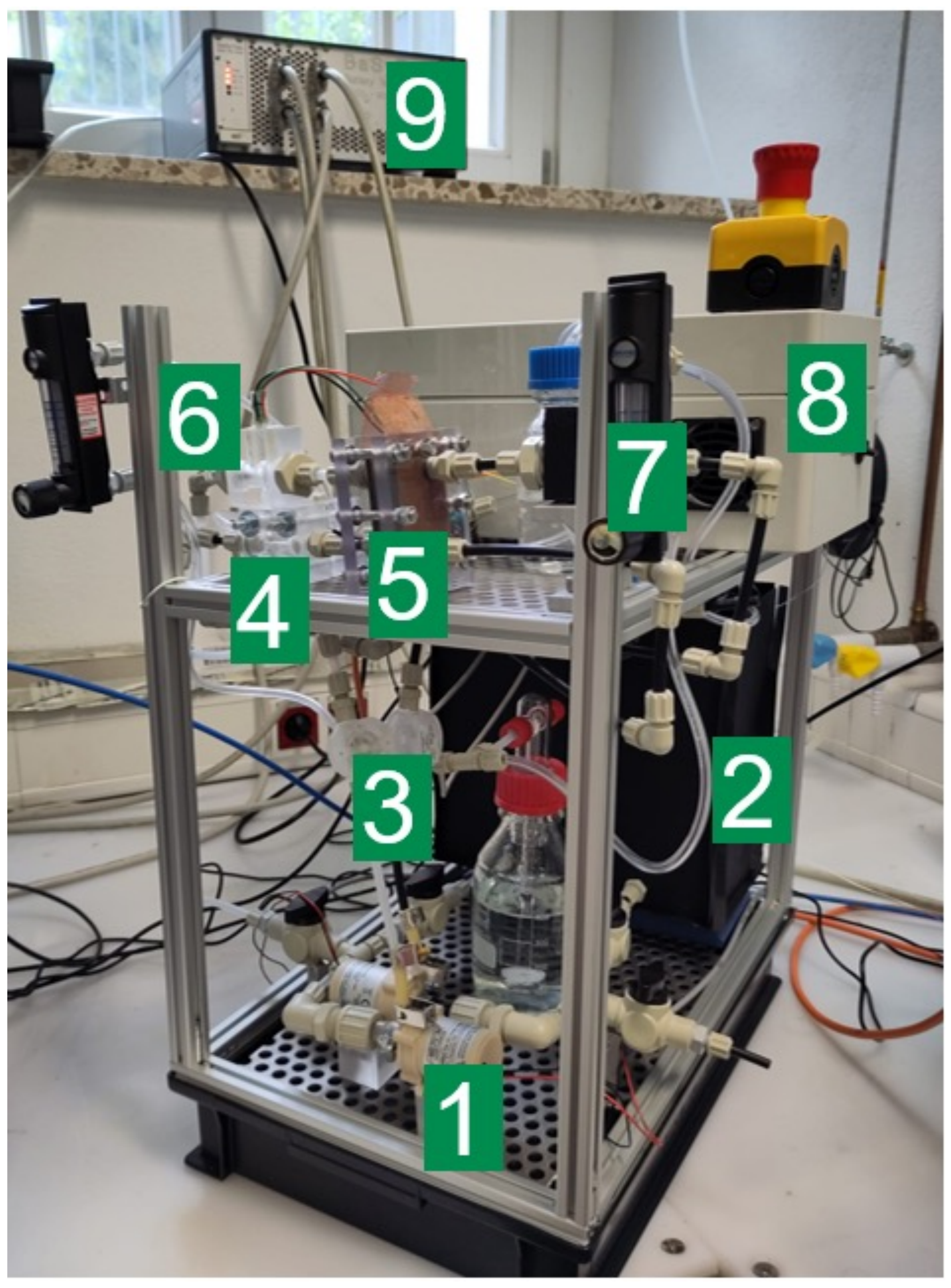
Introduction

- Iron-based flow batteries are an interesting option for energy storage as they are based on inexpensive and abundant resources [1].
- Recent research interest focuses on the stabilization of iron species by incorporating them into organic ligands [2].
- New systems are often tested at small laboratory cells measuring a few parameters. A more comprehensive view would be beneficial [3].

Motivation: Need for a scalable test platform for the intensive monitoring of flow batteries and for enabling a faster scale up.

Implementation in the laboratory

- Ability to monitor cell and half-cell potentials versus a reversible hydrogen electrode (RHE) in KOH.
- Control by Arduino microcontroller (µC) and LabVIEW user interface.



No.	Component of test bench
1	Centrifugal pump
2	Electrolyte tank with level sensor on the top and heating device on the rear side
3	Flow sensor
4	RHE in KOH
5	10 cm² test cell
6	Temperature sensor
7	Nitrogen supply
8	Control unit
9	Battery analyzer

Figure 1: Prototype of the plant and its instrumentation.

Concept of the test bench

- Level of nitrogen-flooded tanks containing positive and negative electrolyte (PE and NE) is measured by ultrasonic sensors.
- Valves available to drain the cell or to empty the tanks separately.
- Heating of the electrolytes by heating pads at the tanks.
- Temperature measurement at the cell outlet.
- Centrifugal pumps allow fluid flow without pressure pulses.
- Flow velocity is continuously measured by Hall-effect sensors.

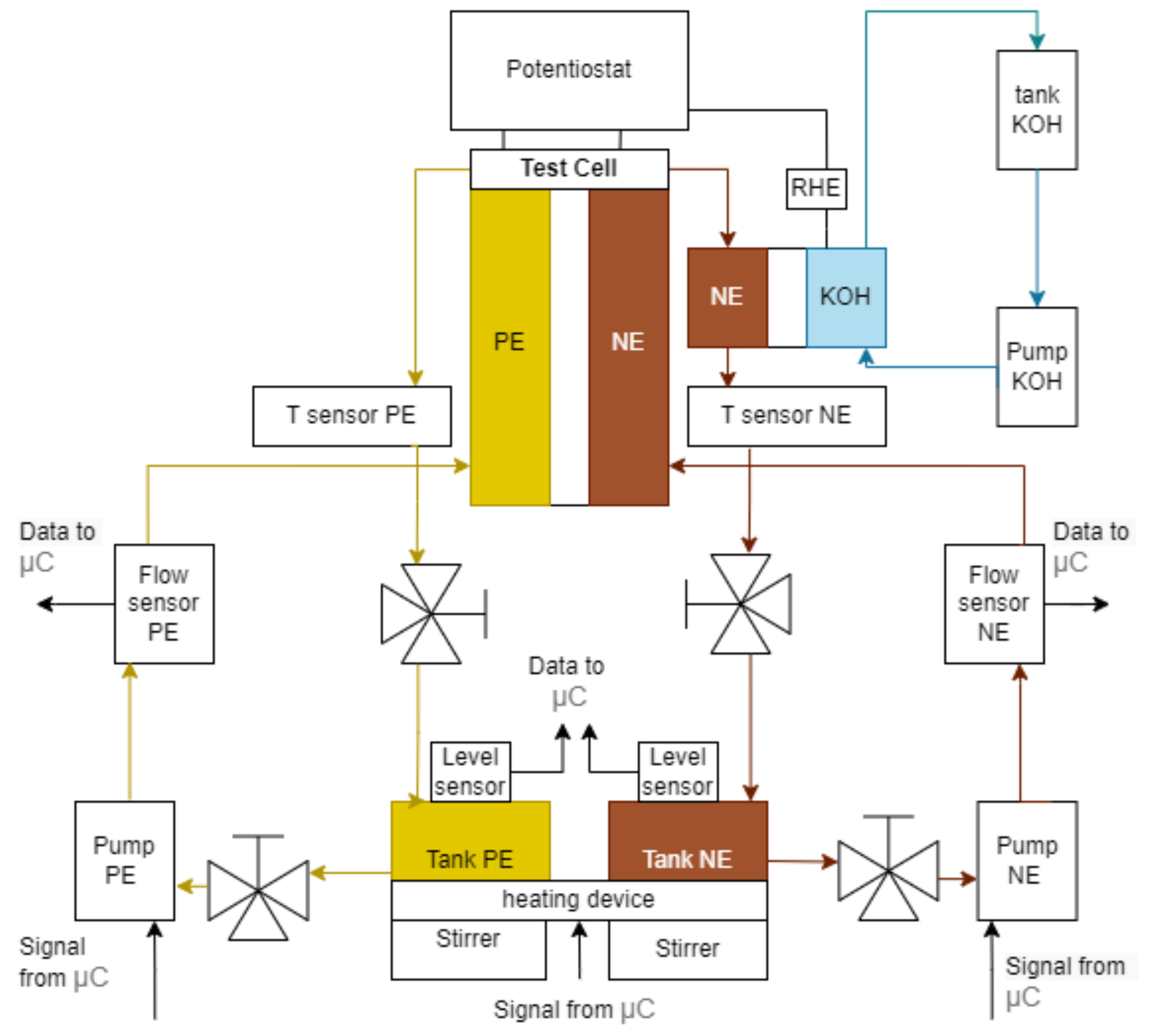


Figure 2: Schematic diagram showing the pre-pilot plant.

Iron to ligand ratio for negative electrolyte

- Positive electrolyte: $K_3[Fe(CN)_6]$ in KOH.
- Negative electrolyte: complex of 0.2 mol l^{-1} iron and the organic acid DIPSO in 2 mol l^{-1} KOH.
- Test of different DIPSO to iron ratios in negative electrolyte.

Results

- For a ratio of DIPSO to iron lower than 1.5 not all of the iron is bound as a complex, but reacts to iron hydroxide.
- The lower the ratio of DIPSO the higher the conductivity. See Figure 3.
- The lower the ratio of DIPSO the higher the current density as shown in the LSVs in Figure 4 and the CVs in Figure 5.

Optimum is 1.5 giving the best performance under the ratios where all the iron is bound by the ligand.

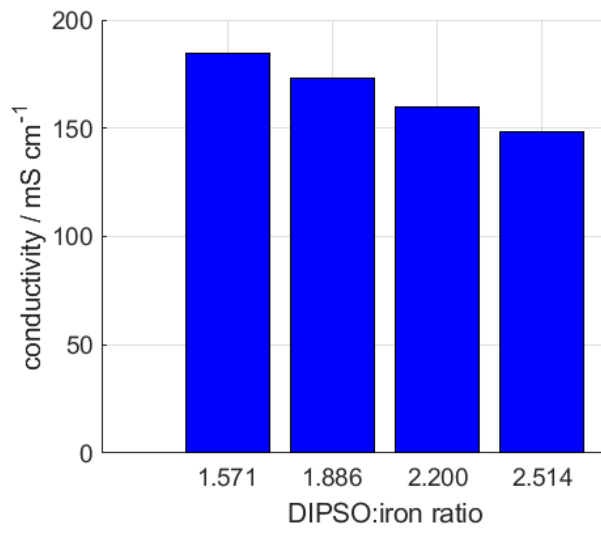


Figure 3: Conductivity of NE at c_{Fe} = 0.2 mol l^{-1} and c_{KOH} = 2 mol l^{-1} and different DIPSO to iron ratios.

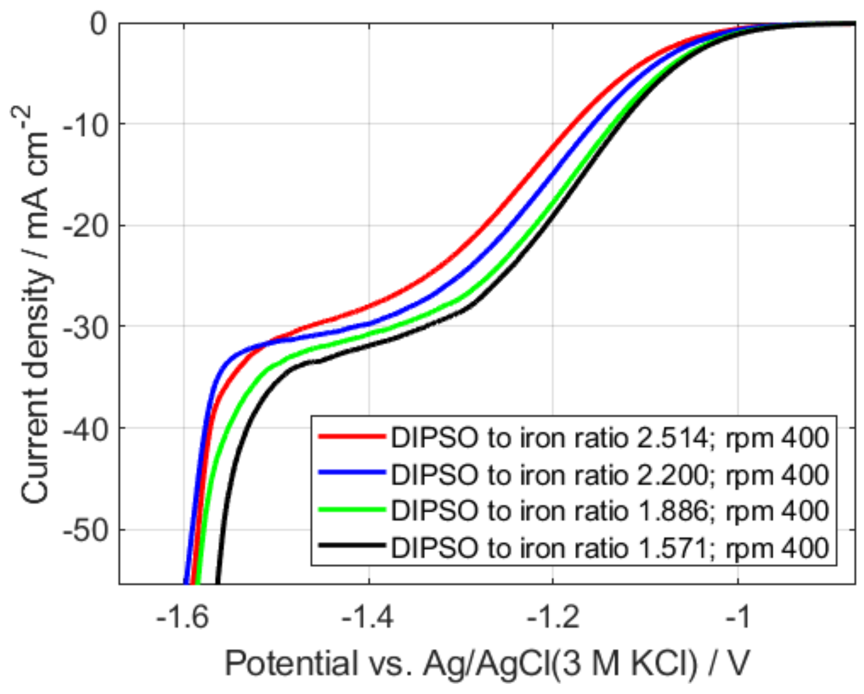


Figure 4: Linear Sweep Voltammograms of NE at c_{Fe} = 0.2 mol l^{-1} and c_{KOH} = 2 mol l^{-1} and different iron to DIPSO ratios and a scan rate of 20 mV s^{-1} and a rotational speed of 400 rpm.

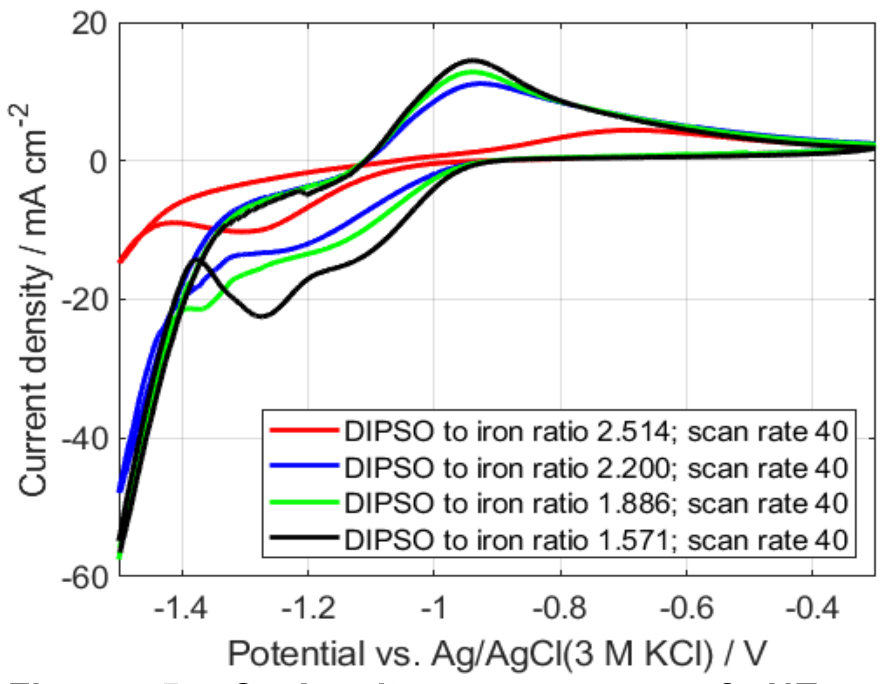


Figure 5: Cyclovoltammograms of NE at c_{Fe} = 0.2 mol l^{-1} and c_{KOH} = 2 mol l^{-1} and different iron to DIPSO ratios and a scan rate of 40 mV s^{-1}.

Future work

- Variation of different parameters:
  - Current density
  - Flow rate
  - Temperature
  - Electrolyte composition
- Evaluation of different membranes and bipolar plates.

Contact

Lars Henry Fischer, M. Sc.
Clausthal University of Technology
Research Center Energy Storage Technologies
Am Stollen 19A
E-Mail: fischer@icvt.tu-clausthal.de
Phone: +49 5323 72-8121

References

[1] U.S. Geological Survey Mineral, Commodity Summaries (2022), doi: 10.3133/mcs2022

[2] F. Fenini, E. Drazevic, A. Bentien, J. of Power Sources 540 (2022) 23164

[3] Arenas et al. Current Opinion in Electrochemistry (2019) 16:117–126

Acknowledgement

The authors thank for financial support of the Federal Ministry for Economic Affairs and Climate Action in Germany for the project Metallo FlowBat KK5156701 SN0.

Homepage