

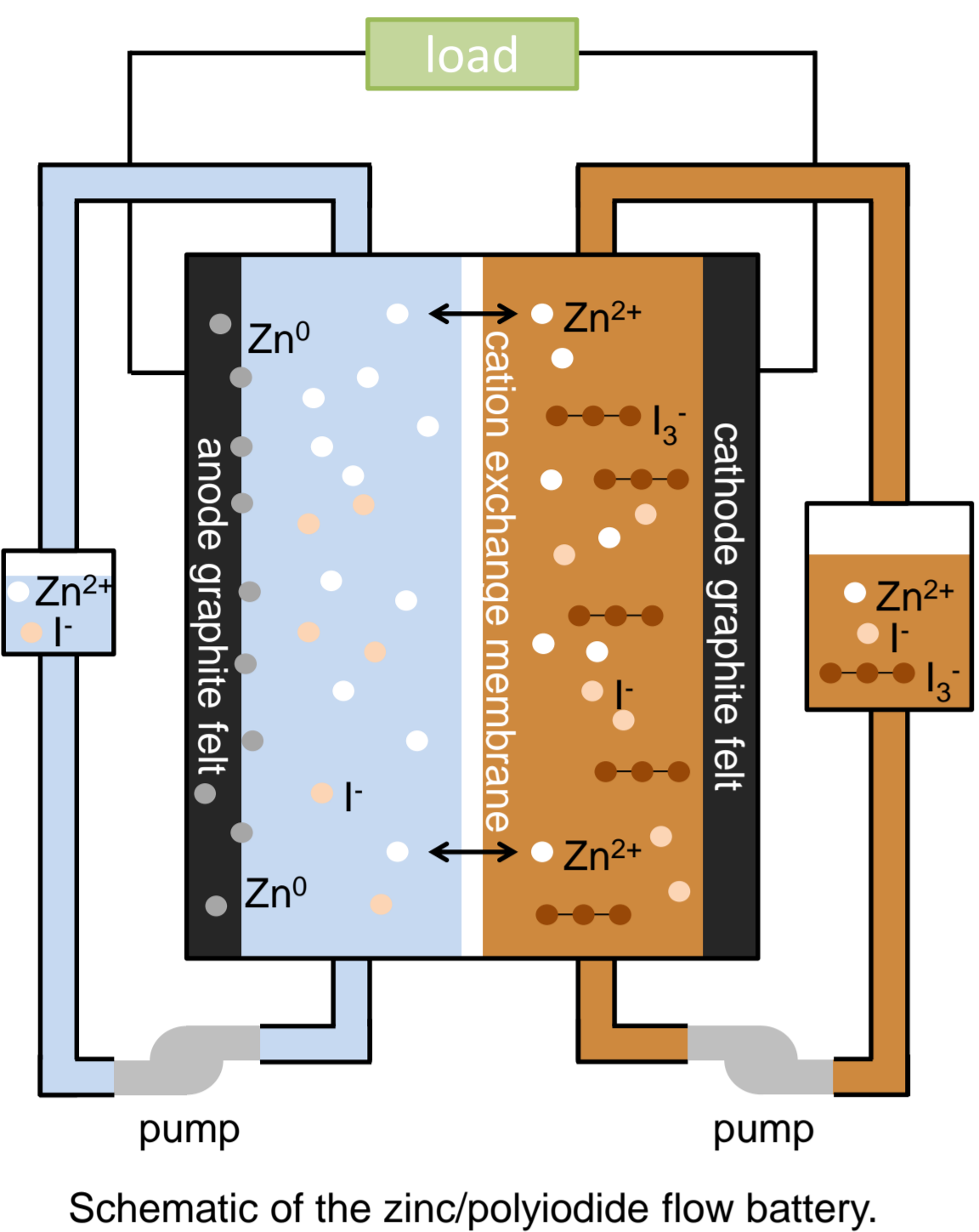


Characterisation of single cell performances within a ten-cell zinc/polyiodide flow battery stack

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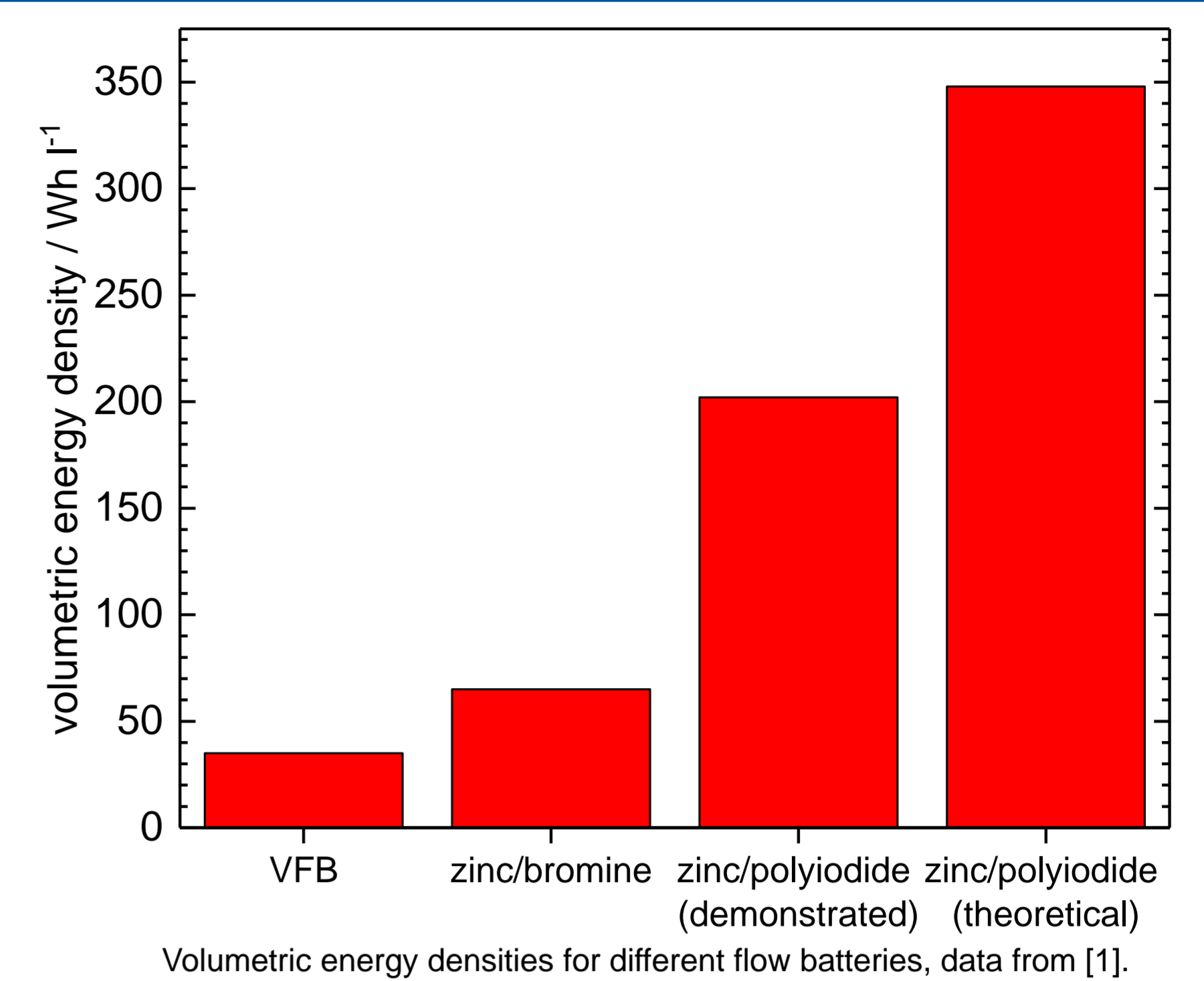


Advantages of zinc/polyiodide flow batteries



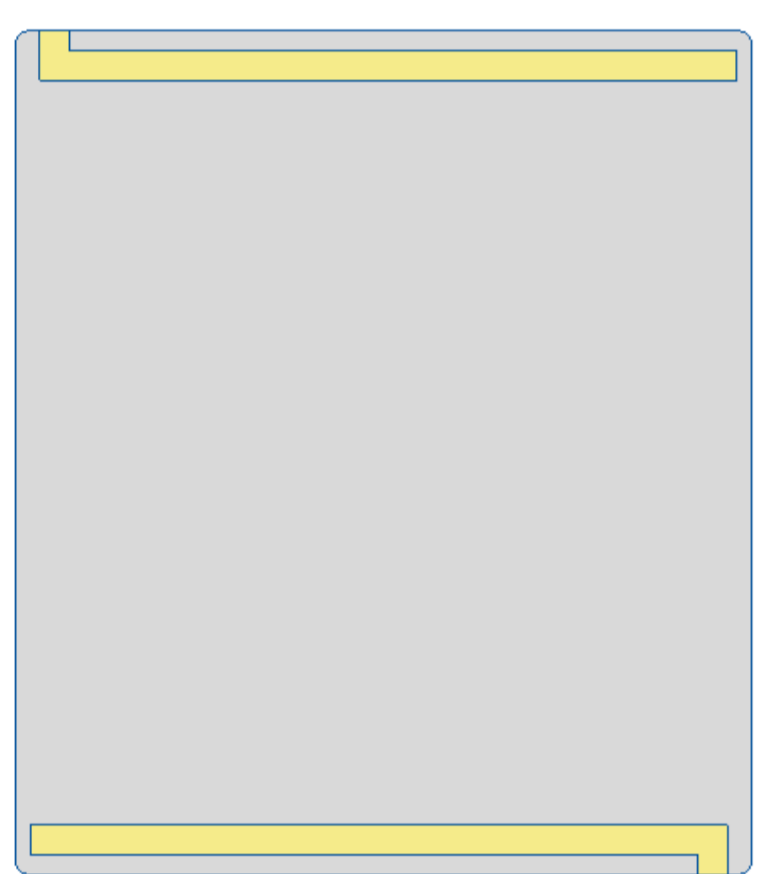
Schematic of the zinc/polyiodide flow battery.

- electrolyte: aqueous ZnI_2 solution contains both active species [1]
 - ZnI_2 is soluble up to at least 5 mol l^{-1}
 - Zn^{2+} as charge carrier, diffuses through membrane
 - no additional acid/base or salt necessary
 - anolyte volume can be kept small
 - 2 electrons transferred per redox process
 - up to 10 times higher volumetric energy density compared to VFB
- anode: $Zn \rightarrow Zn^{2+} + 2 e^- \quad E^0 = -0.76 \text{ V}$
 cathode: $I_3^- \rightarrow 3 I^- \quad E^0 = 0.54 \text{ V}$
 overall: $Zn + I_3^- \rightarrow Zn^{2+} + 3 I^- \quad E^0 = 1.30 \text{ V}$
- adding zinc bromide as an additive: increasing experimentally achievable energy density (202 Wh l^{-1} , shown on the right) [2]

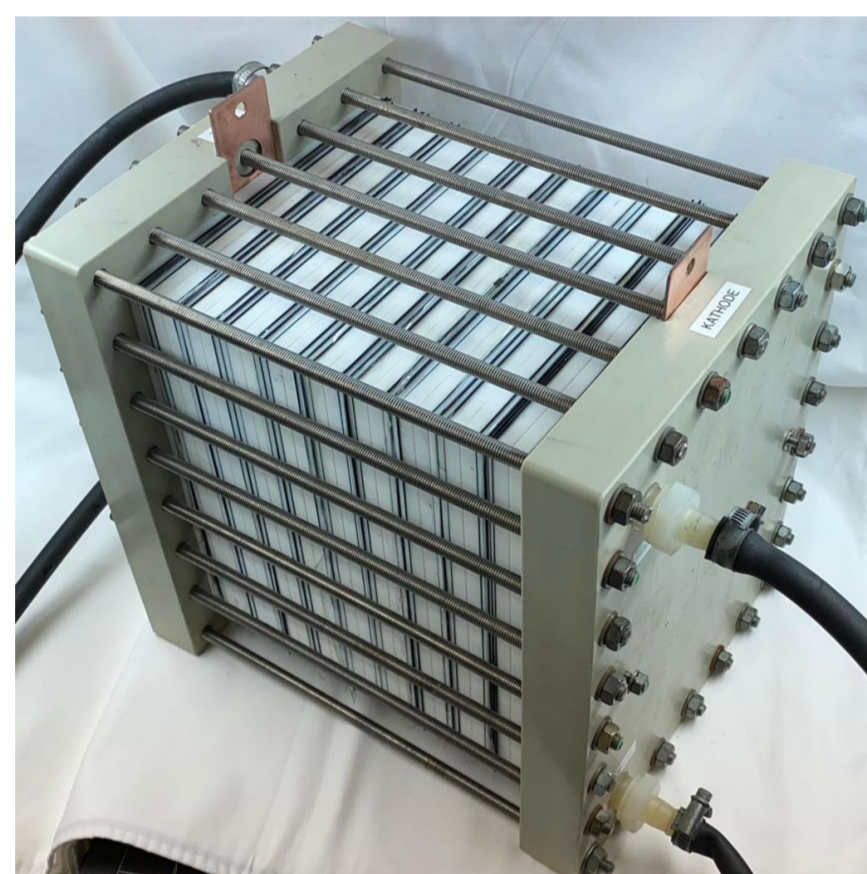


250 cm² ten-cell stack

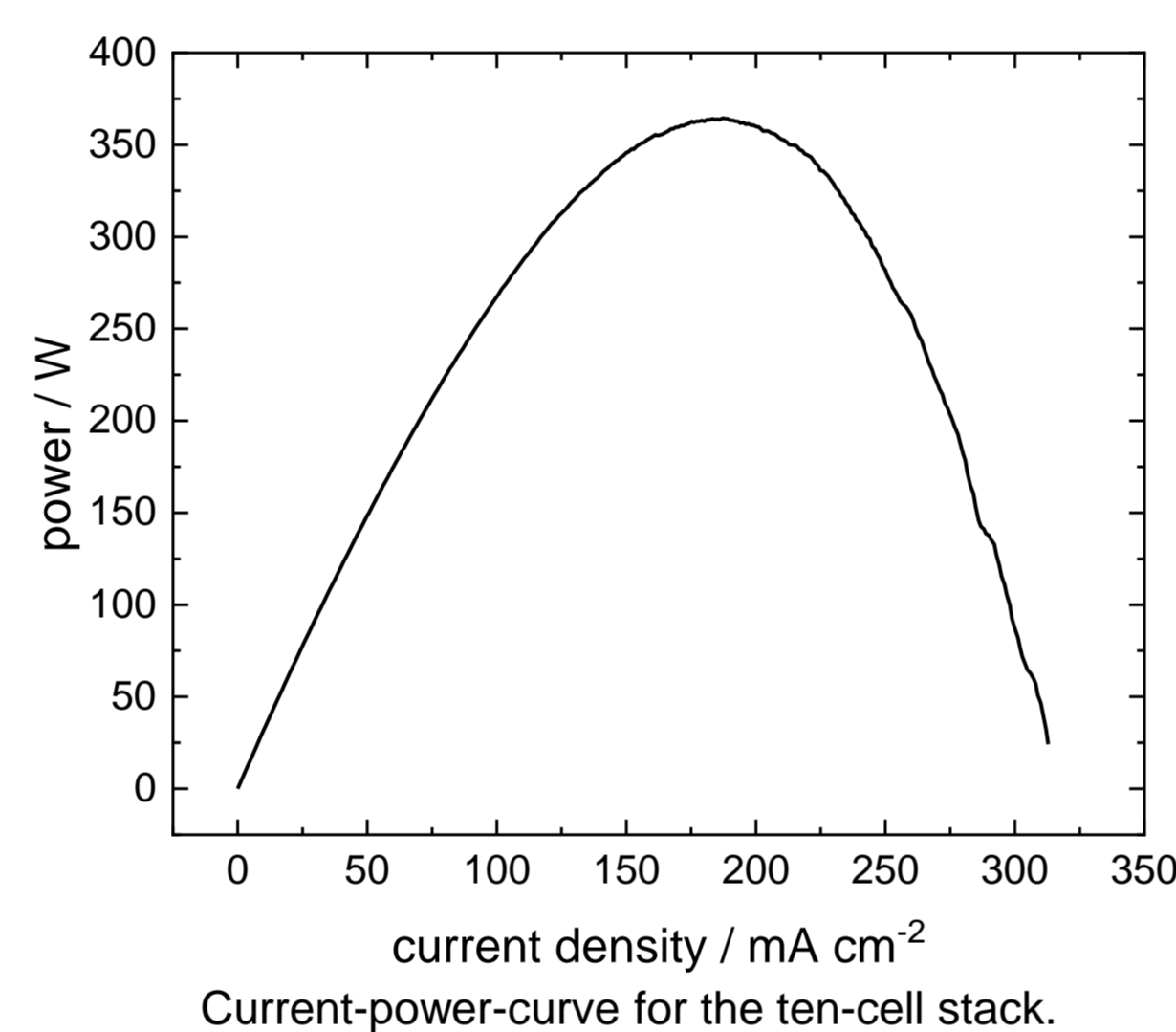
- single-cell results were presented at last year's IFBF [3]
- cells connected in series with 9 bipolar and 2 monopolar plates
- flow-through flow field with equal path length design (inlet: bottom right, outlet: top left in bottom left figure)
- graphite felts fabricated and activated by Mersen
- Nafion NR-212 membrane (pristine)
- current-voltage-curves: $2 \text{ mA cm}^{-2} \text{ s}^{-1}$
- electrolyte: $2.5 \text{ M ZnI}_2 + 4 \text{ M NH}_4\text{Br}$ (1.2 l per half-cell)
- design goal: 150 W



Schematic of the flow field.

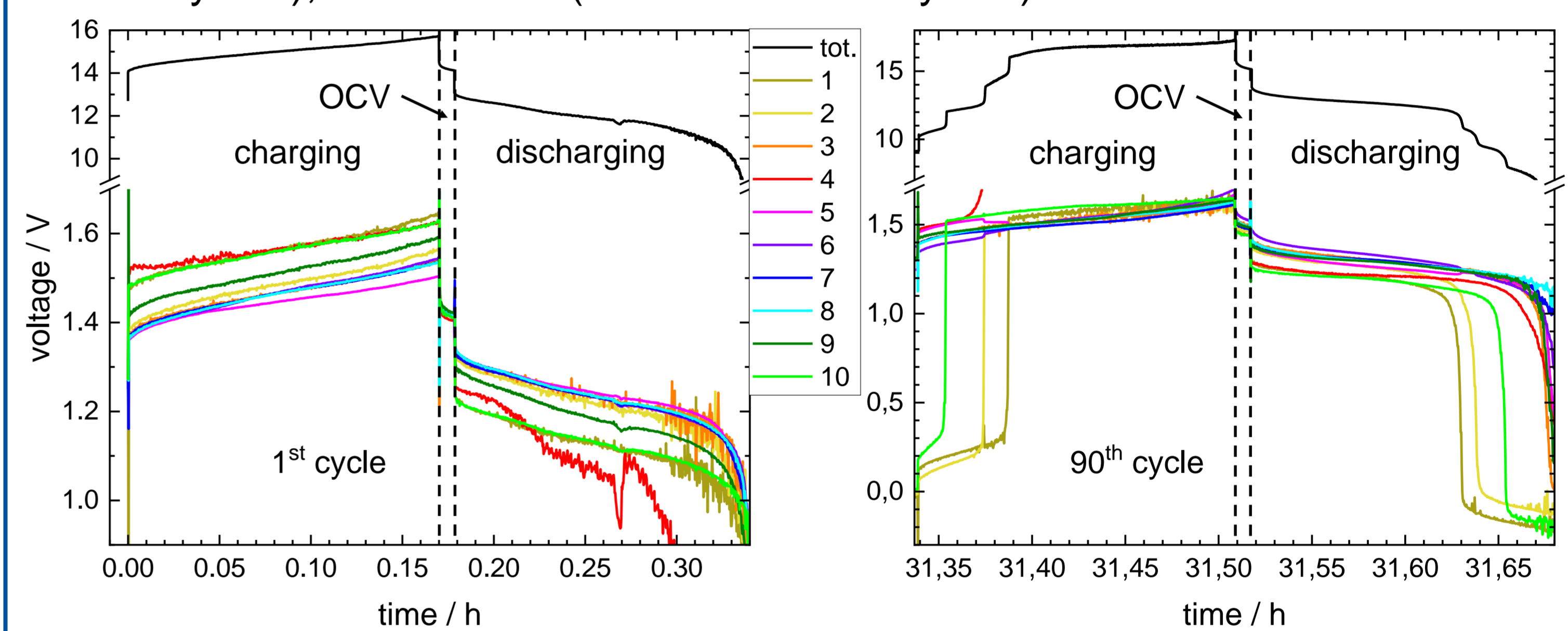


Photograph of the ten-cell stack.



Single-cell voltages

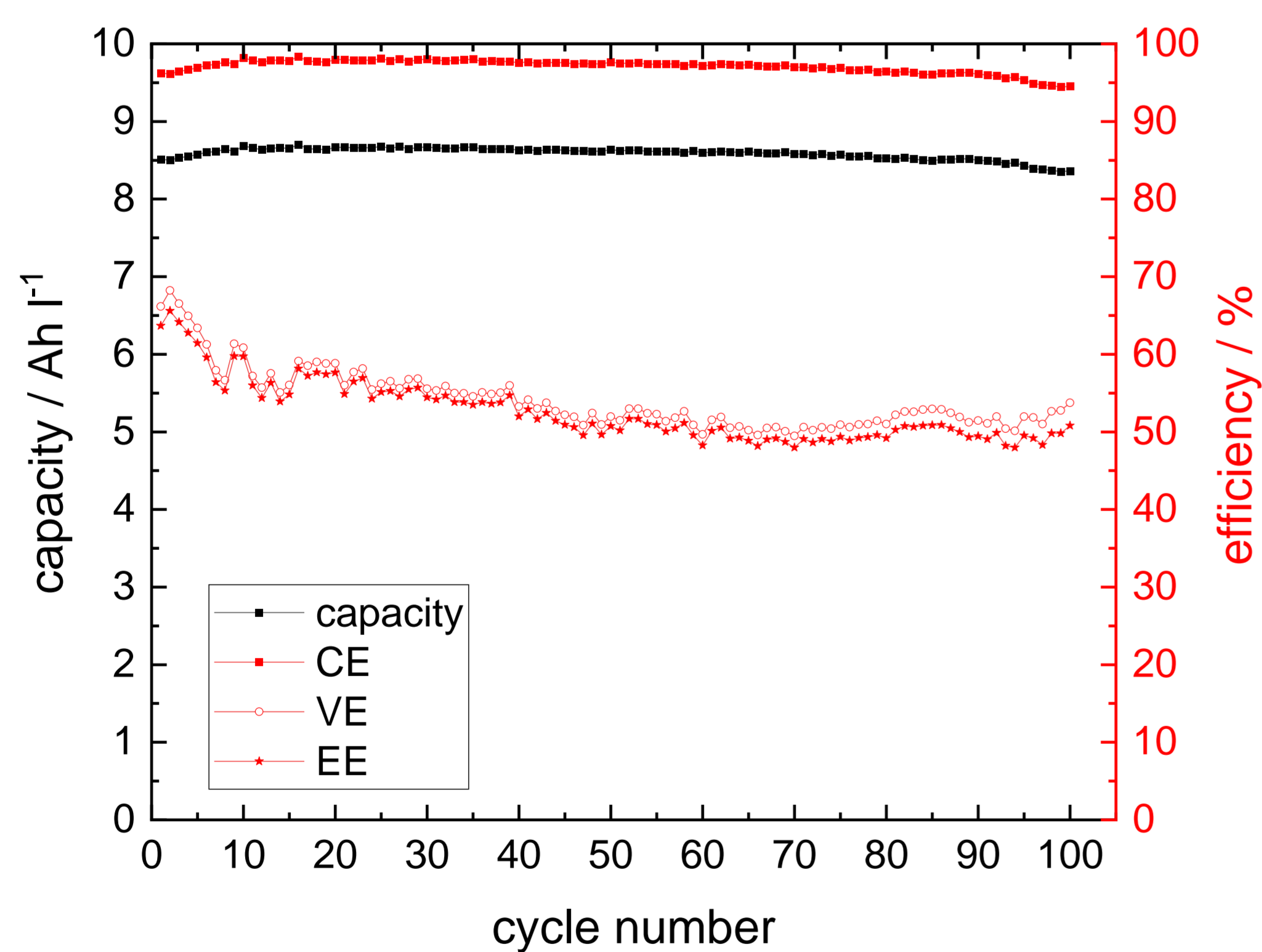
- 1st cycle: highest charging and lowest discharging voltages for outer cells 1 & 10, followed by 9 & 2, all others very close to each other
- results match those for other flow batterie stacks reported in literature [4]
- 90th cycle: voltage plateaus close to 0 V at the beginning of charging and end of discharging for outer cells (1, 2 & 10), corresponding plateaus in total voltage
- charge/discharge curves of previous cycles (not included here): plateaus first for cell 1 (starting in the 2nd cycle), then cell 2 (after around 70 cycles), then cell 10 (after around 80 cycles)



Total and single-cell voltages for the 1st and 90th cycle of charge/discharge cyclisation with the ten-cell stack.

Cyclisation results

- electrolyte: $0.5 \text{ M ZnI}_2 + 0.25 \text{ M ZnBr}_2 + 2 \text{ M NH}_4\text{Cl}$ (1.2 l per half-cell)
- charge & discharge current density: 50 mA cm^{-2}



Capacity as well as coulombic (CE), voltaic (VE) and energy efficiencies (EE) for charge/discharge cyclisation of the ten-cell stack.

- promising capacity and CE across 100 conducted cycles
- however, VE and EE quickly drop from 66% (1st cycle) to less than 50% (60th cycle)

inhomogeneous electrolyte supply of the ten cells

insufficient Zn^{2+} supply of outer cells

less zinc deposition during charging than expected (and side reactions, likely H_2 formation)

self-reinforcing cycle

not enough zinc for discharging, iodide is oxidized instead
 $3 I^- \rightarrow I_3^- + 2 e^-$

formed I_3^- is reduced in next charging step before zinc deposition
 $I_3^- + 2 e^- \rightarrow 3 I^-$

same reactions in both half-cells, only in opposite directions
 \rightarrow voltage close to 0 V at the end of discharging, plateau in total voltage

same reactions in both half-cells, only in opposite directions
 \rightarrow voltage close to 0 V at the beginning of charging, plateau in total voltage

- aim for future research: improve electrolyte distribution into the ten cells
- alleviate this problem of iodine formation at anodes of outer cells

Literature

- [1] B. Li et al., Ambipolar zinc-polyiodide electrolyte for a high-energy density aqueous redox flow battery, *Nature Communications*, 2015.
- [2] G.-M. Weng et al., Unlocking the capacity of iodide for high-energy density zinc/polyiodide and lithium/polyiodide redox flow batteries, *Energy & Environmental Science*, 2017.
- [3] L. Siefert et al., "Comparison of flow fields with CFD simulations and electrochemical experiments within a 250 cm² zinc/polyiodide RFB", *IFBF 2023*.
- [4] R. Suman et al., "Developing Shunt-Current Minimized Soluble-Lead-Redox-Flow-Batteries", *J. Electrochem. Soc.*, 168, 120552, 2021.

Acknowledgment

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