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IFBF The International Flow Battery Forum
24 - 26 JUNE 2025
VIENNA, AUSTRIA

Advancing aqueous zinc and iron-based flow battery systems

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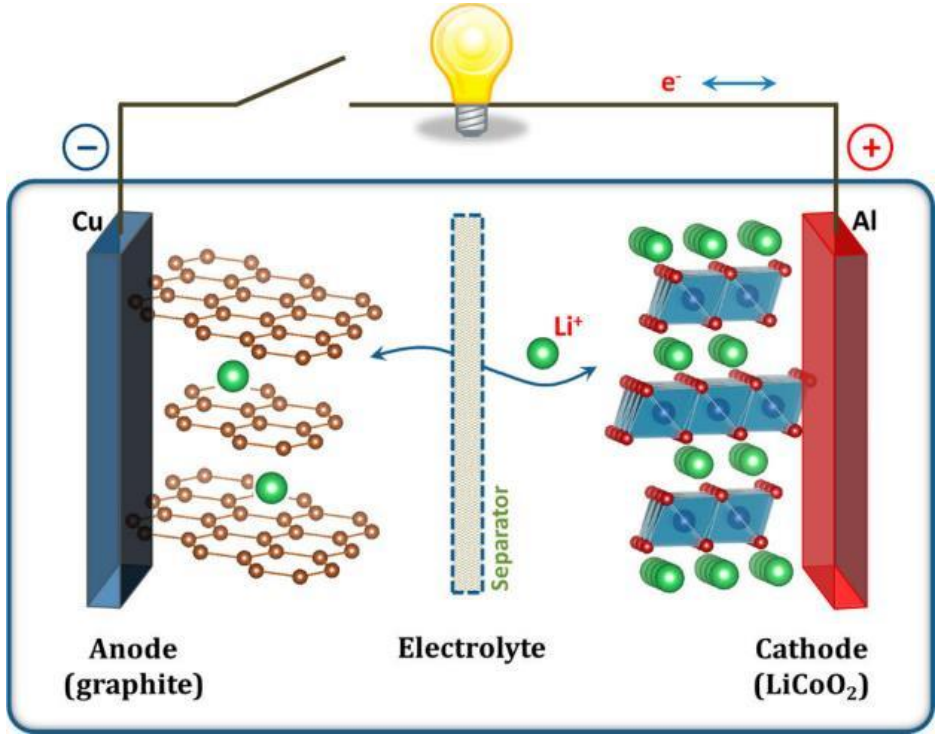
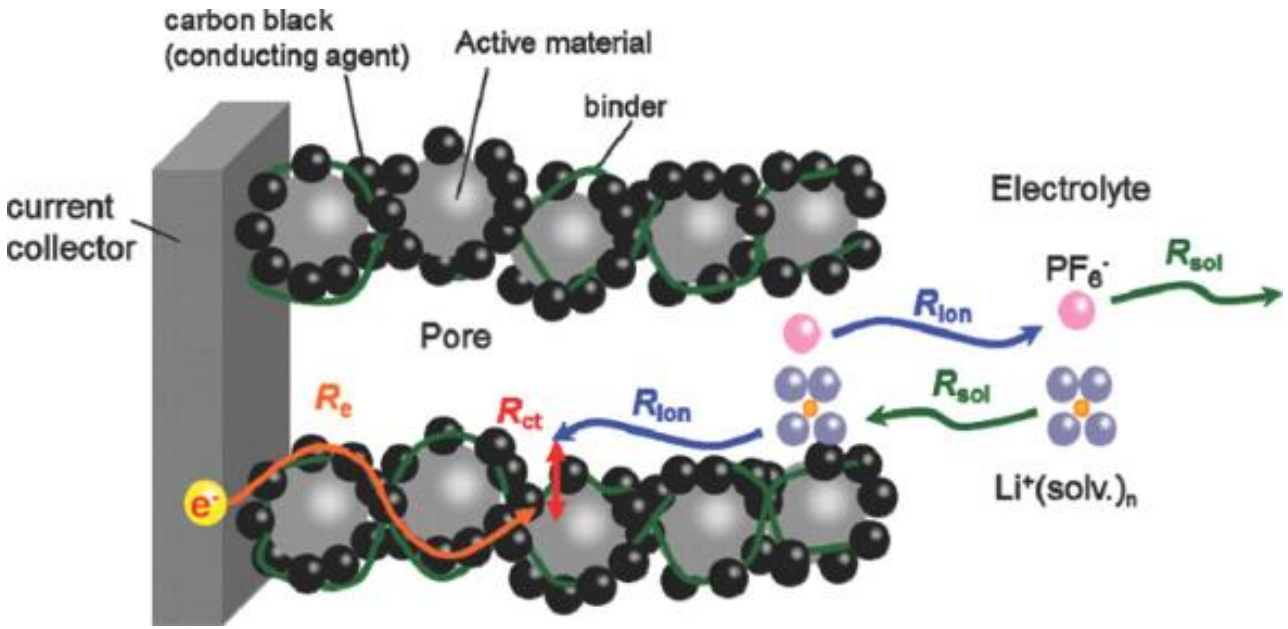
Functional Materials for Rechargeable Batteries



JB Goodenough, J. Am. Chem. Soc. 2013, 135, 1167.



J. Electrochem. Soc. 2012 vol. 159 no. 7 A1034-A1039

- Microstructure
- Conductivity
- Crystallinity
- Composition
- Surface/interface

Electrode, Electrolyte, Separator…

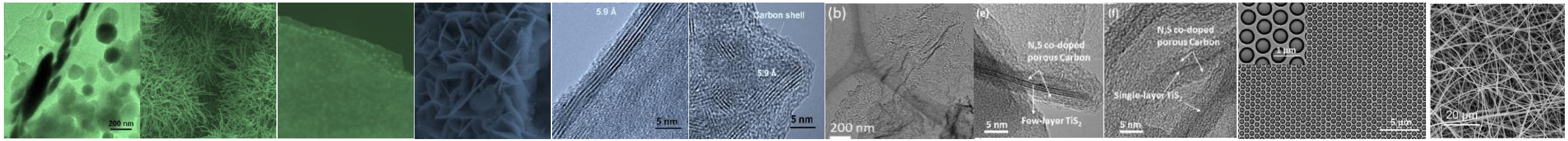
- Energy storge capacity
- Electron transport in solid
- Ion transport in solid and liquid
- Electrode volume change
- Solid electrolyte interface

Materials

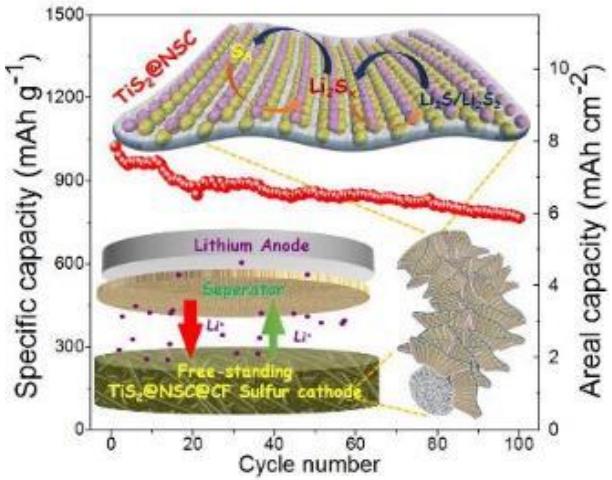
- Energy density
- Power density
- Cycling stability
- Safety
- Cost

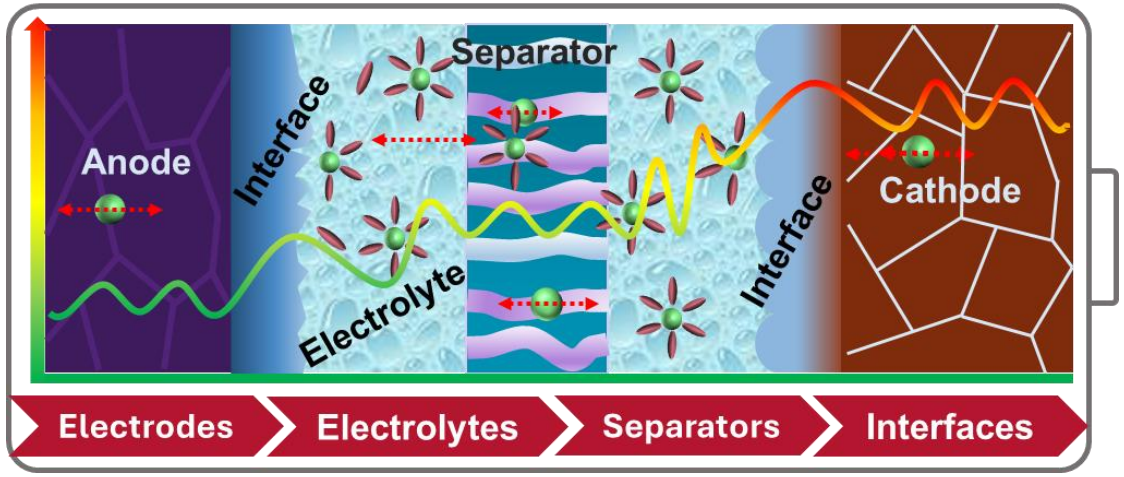
Battery Performance

Our Research @ UQ: Functional Materials for Electrochemical Energy Storage

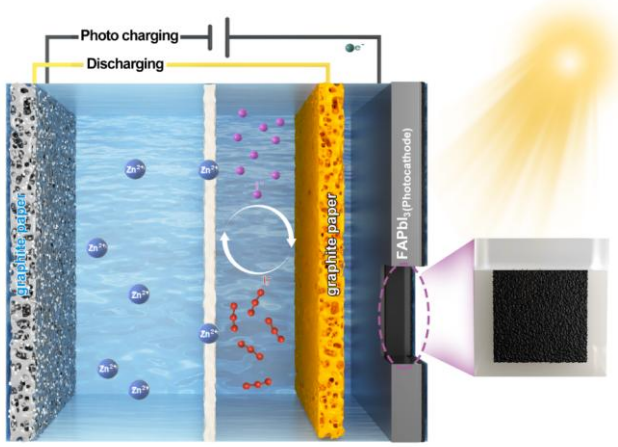


Lithium-Sulfur

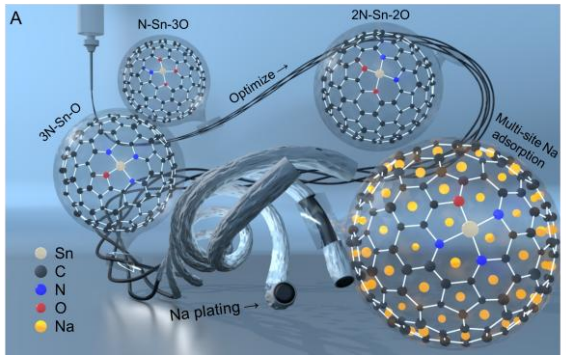




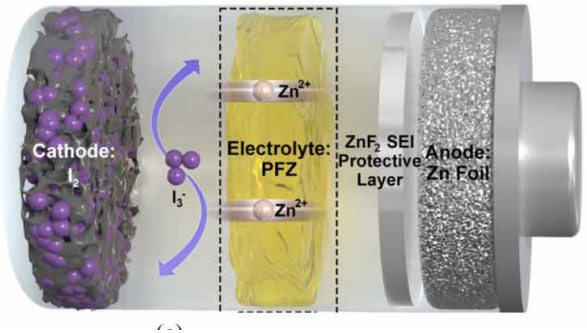
Solar batteries



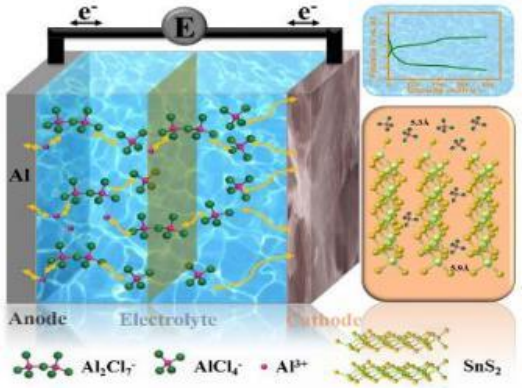
Sodium



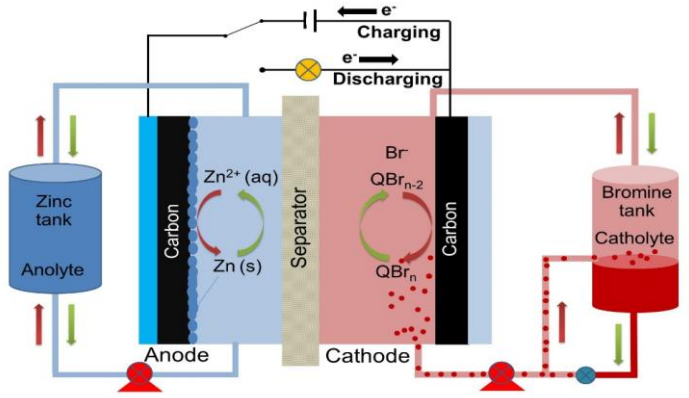
Zinc



Aluminium

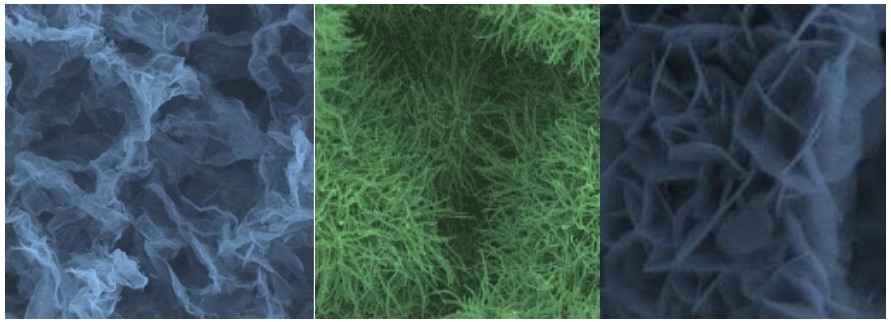


Flow Batteries (Zn-Br, Fe)



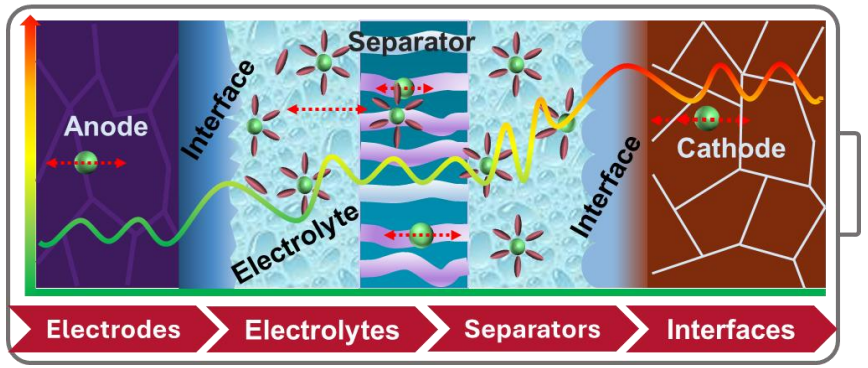
Q: complexing agent; QBr_n: Br_2 complex

Advanced Battery Materials & Technologies Group @ UQ AIBN



Material design and synthesis

- Electrode materials
- Electrolyte additives
- Membrane modification
- Interface engineering

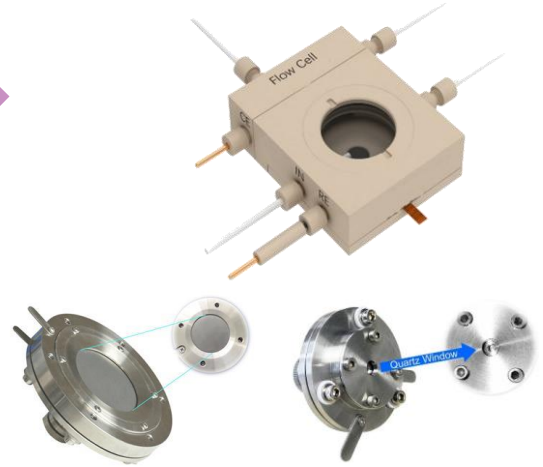


Battery assembly and performance

- Flow cells, coin cells, pouch cells, …
- Li, Na, Zn, Al, Fe, Br, I, S, V, etc.

Advanced characterizations

- Structural and compositional analysis
- In situ/ex situ measurements (XRD, Raman, optical microscope, SEM, TEM, synchrotron techniques)



Australian Synchrotron

ANFF

Australian Government
Australian Research Council

MM

SafeREnergy

ENERGY STORAGE INDUSTRIES ASIA PACIFIC

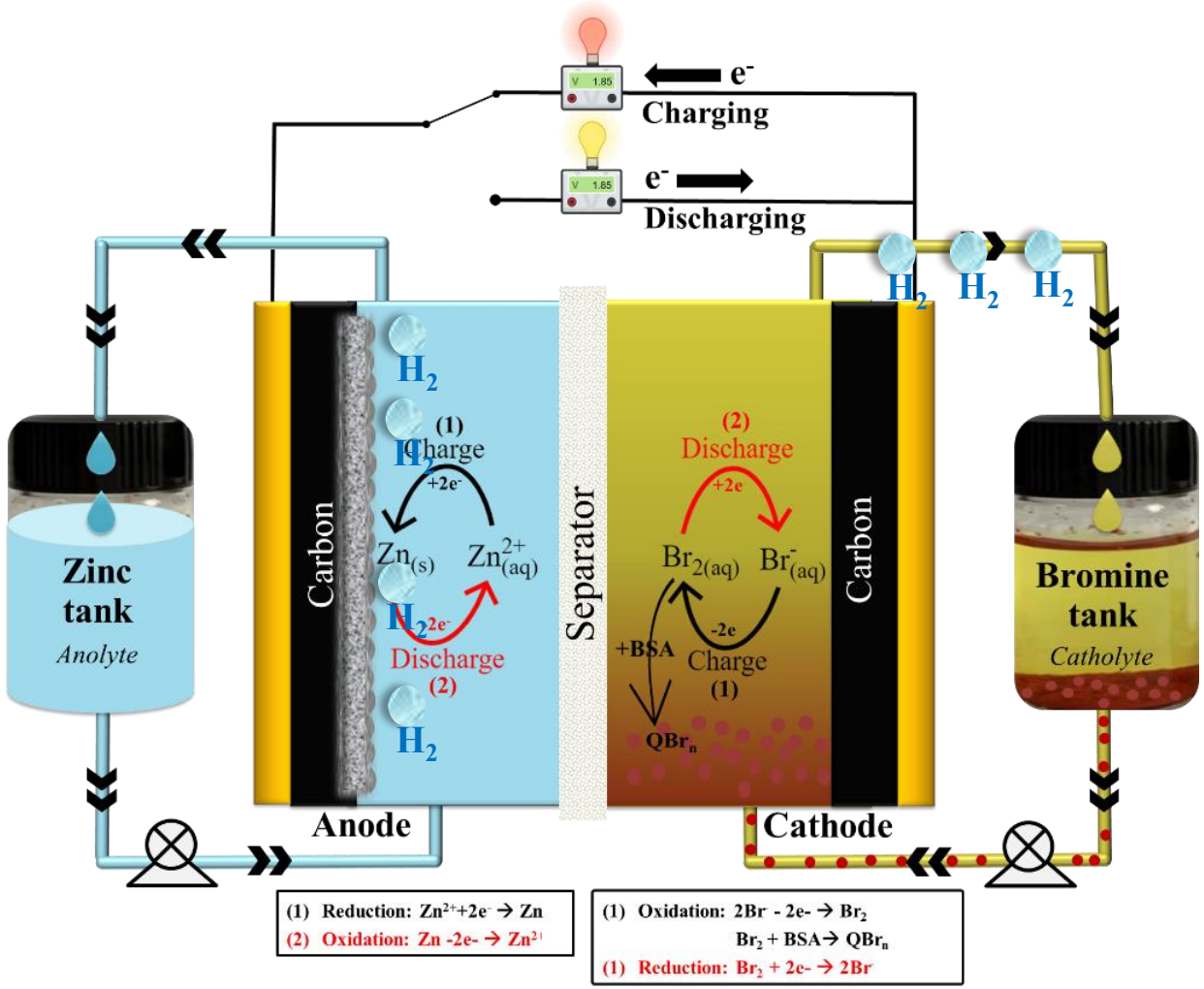
Lithium Australia NL

PURE BATTERY TECHNOLOGIES

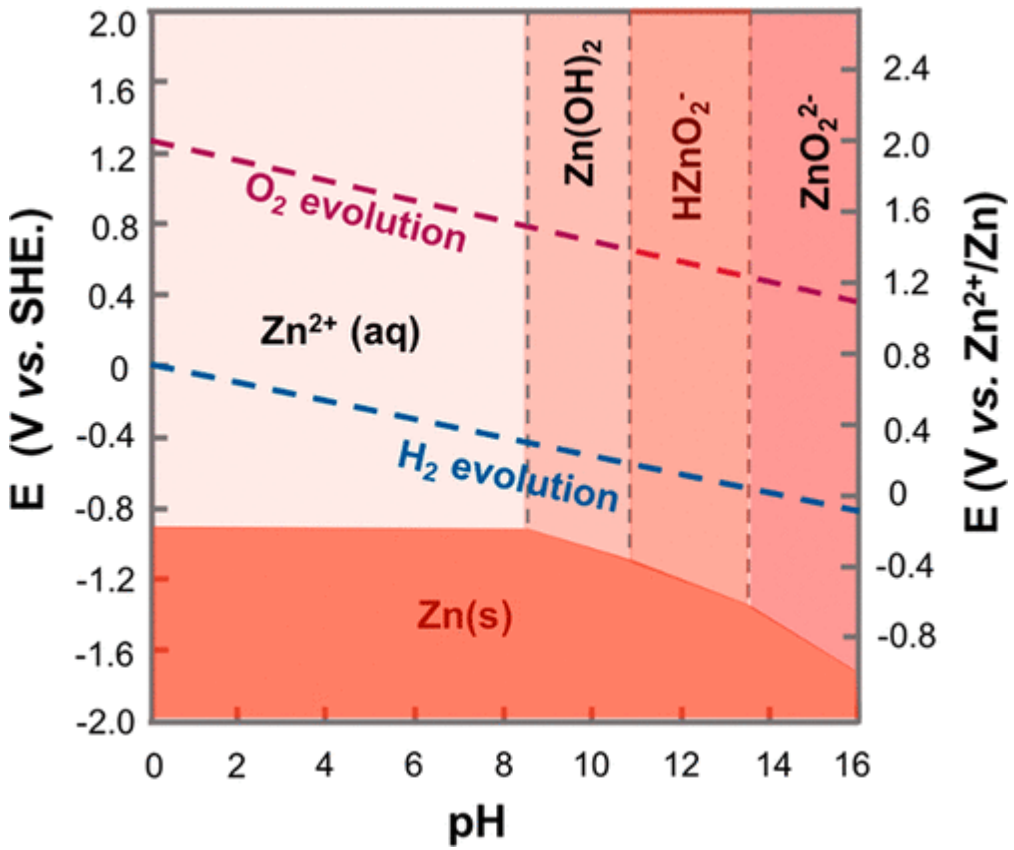
redflow

ARC FT, DPs, LPs, Hub project with Industry, and Industry Fund

Zinc-Bromine Flow Batteries



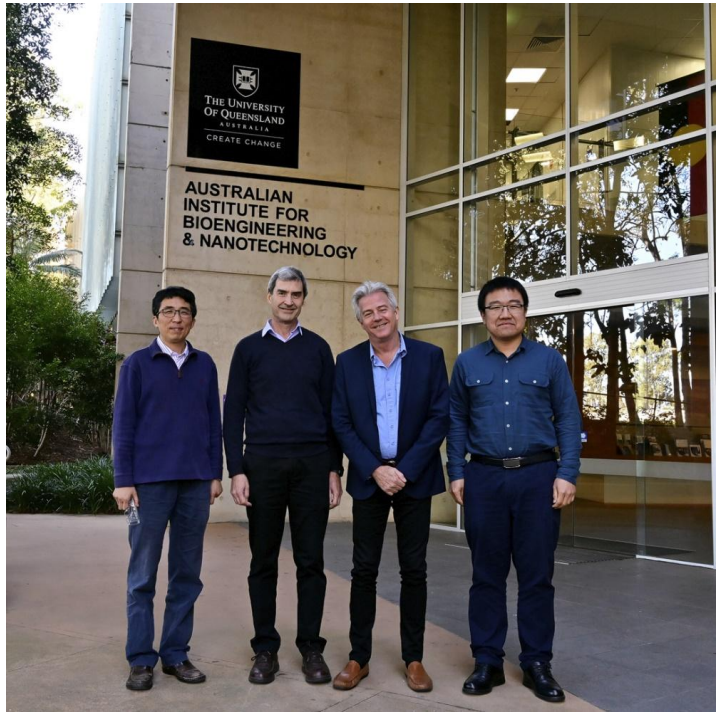
BSA: bromine sequestration agent
Q: complexing agent; QBr_n (n = 3, 5, 7): Br_2 complex



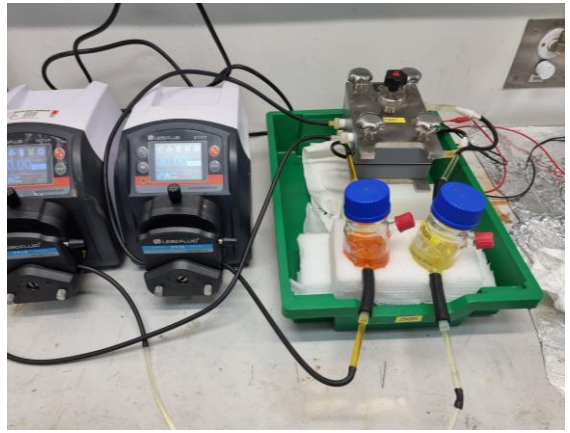
- Side reactions (e.g. HER)
- Slow kinetics of Br_2/Br^- reactions
- Electrode degradation
- Shuttle effect

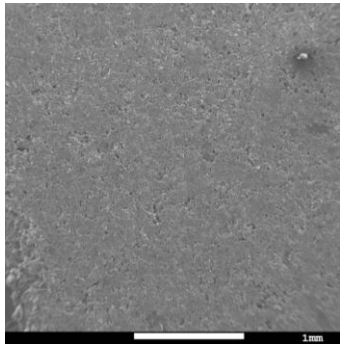
Norah, Luo, et al. Nano-Micro Letters. 2023, 15, 209. https://doi.org/10.1007/s40820-023-01174-7

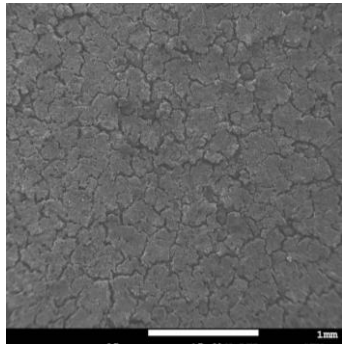
Zinc-Bromine Flow Battery (collaboration with Redflow)



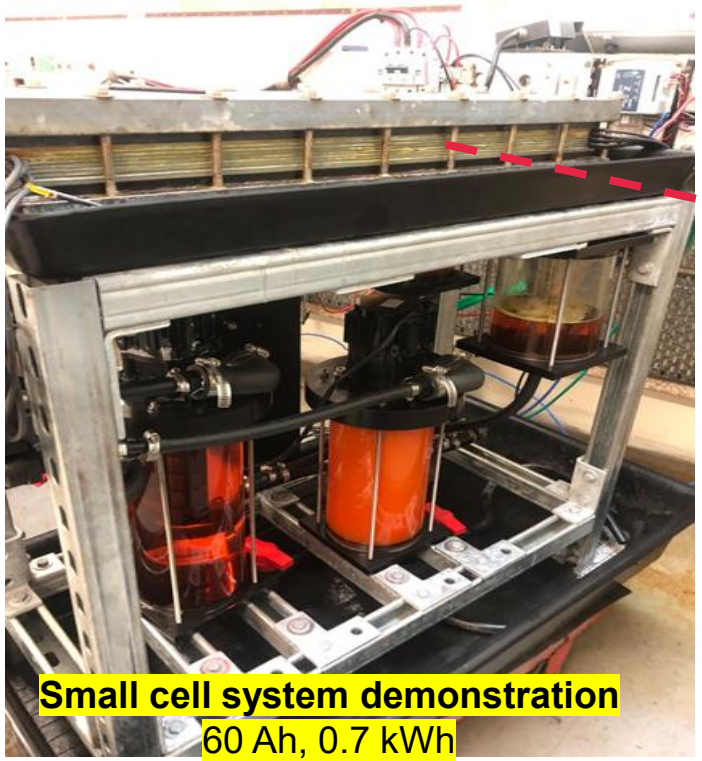
09-Sep-2022 Joined the ARC Hub







Electrode surface before (L) and after (R) operation

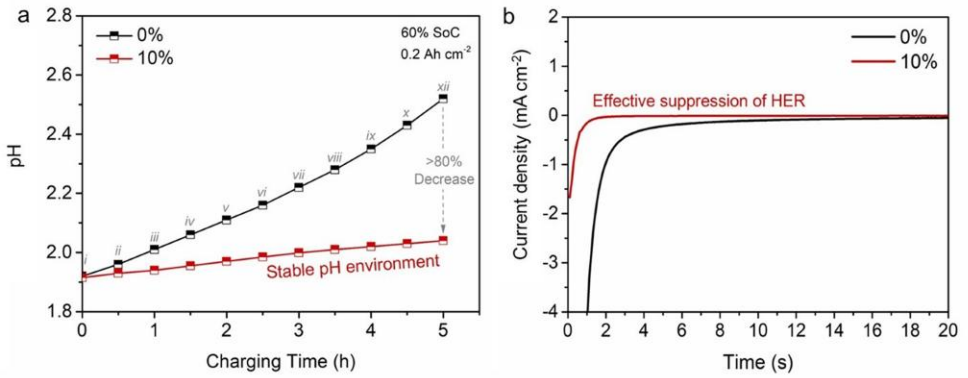


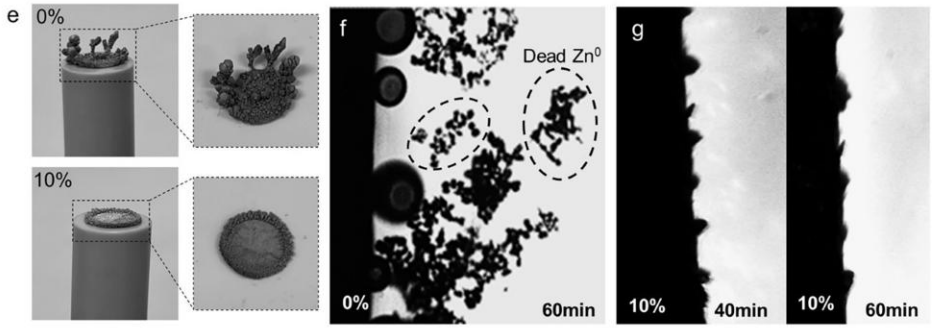
Small cell system demonstration
60 Ah, 0.7 kWh

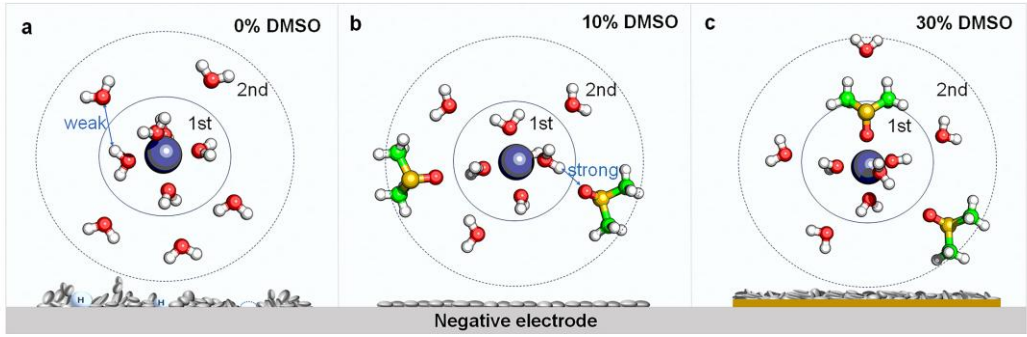
240 Ah, 10 kWh

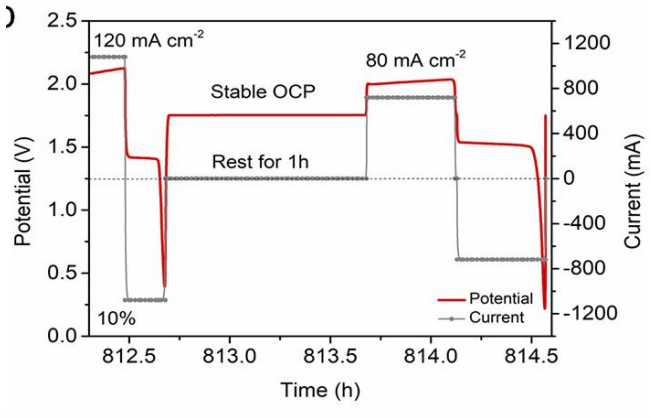
Zinc-Bromine Flow Batteries

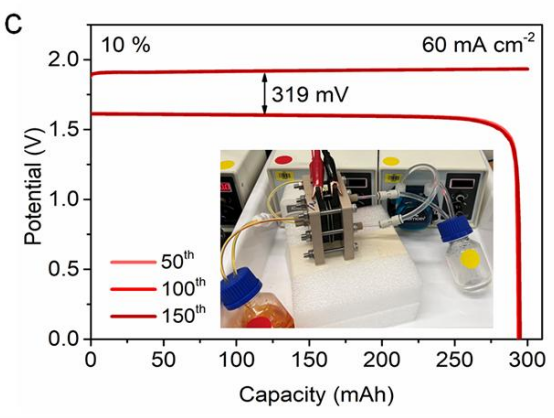
Tailoring Zn-ion Solvation Structures for Enhanced Durability and Efficiency

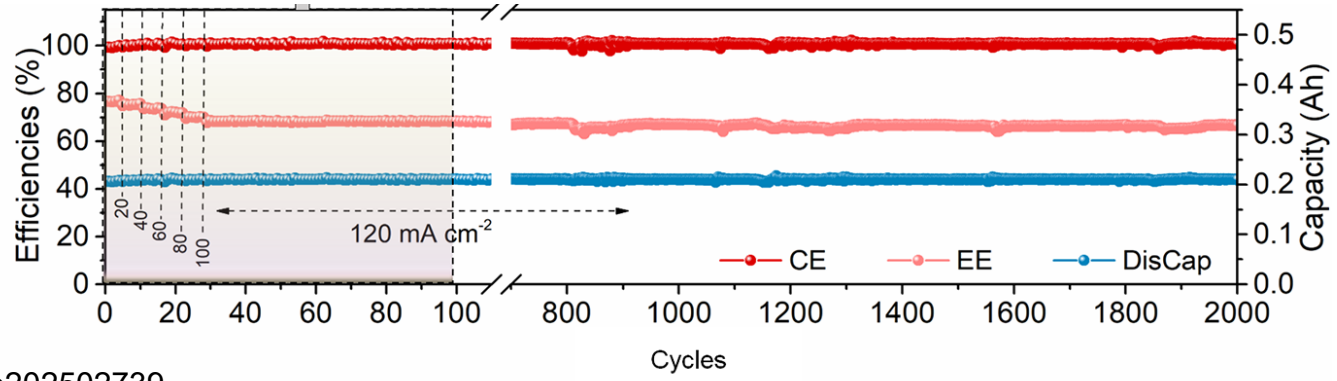








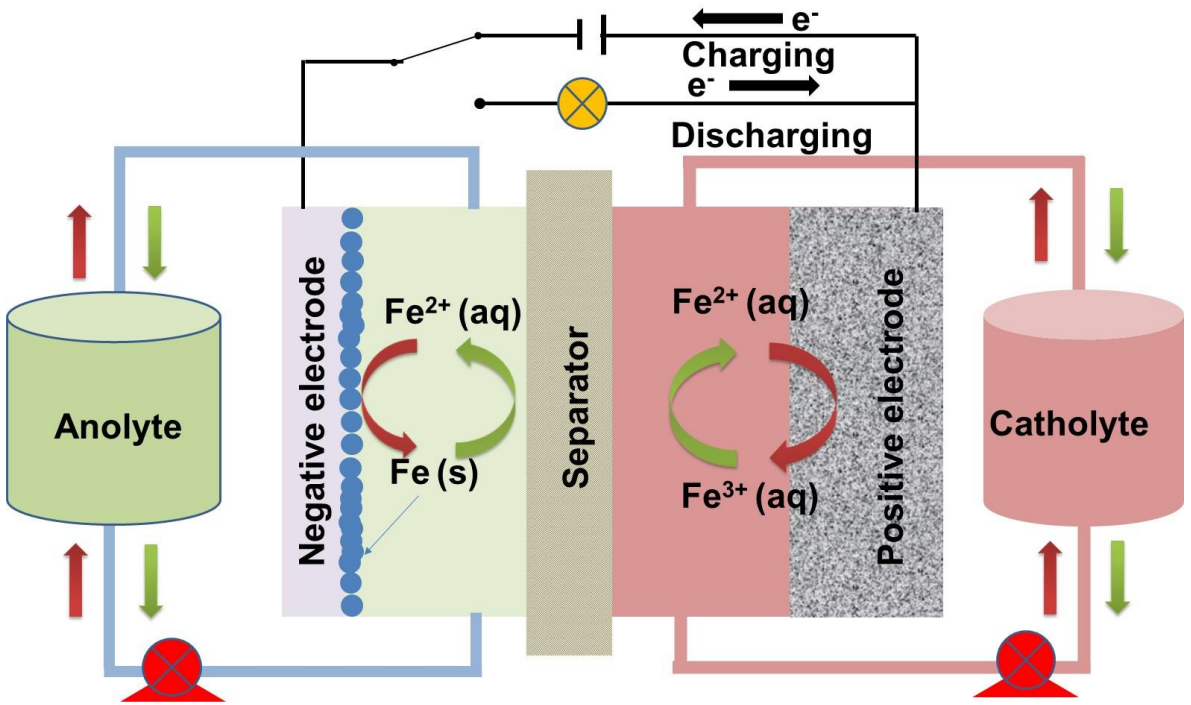




N. Alghamdi, D. Rakov, B. Luo, et al. *Angew. Chem. Int. Ed.* 2025, e202502739.

All-Iron flow batteries

Collaboration with Energy Storage Industries - Asia Pacific (ESI)



Announcement of the National Battery Strategy on 23 May 2024.

Positive electrode: $2FeCl_3 + 2e^- \leftrightarrow 2FeCl_2 + 2Cl^-$ $E^0 = 0.77$ V [1]

Negative electrode: $Fe + 2Cl^- \leftrightarrow FeCl_2 + 2e^-$ $E^0 = -0.44$ V [2]

Overall Reaction: $Fe + 2FeCl_3 \leftrightarrow 3FeCl_2$ $E^0_{cell} = 1.21$ V [3]

Parasitic Hydrogen Evolution: $2H^+ + 2e^- \leftrightarrow H_2$ $E^0 = 0$ V [4]

H_2 generation → low energy efficiency & pH increase

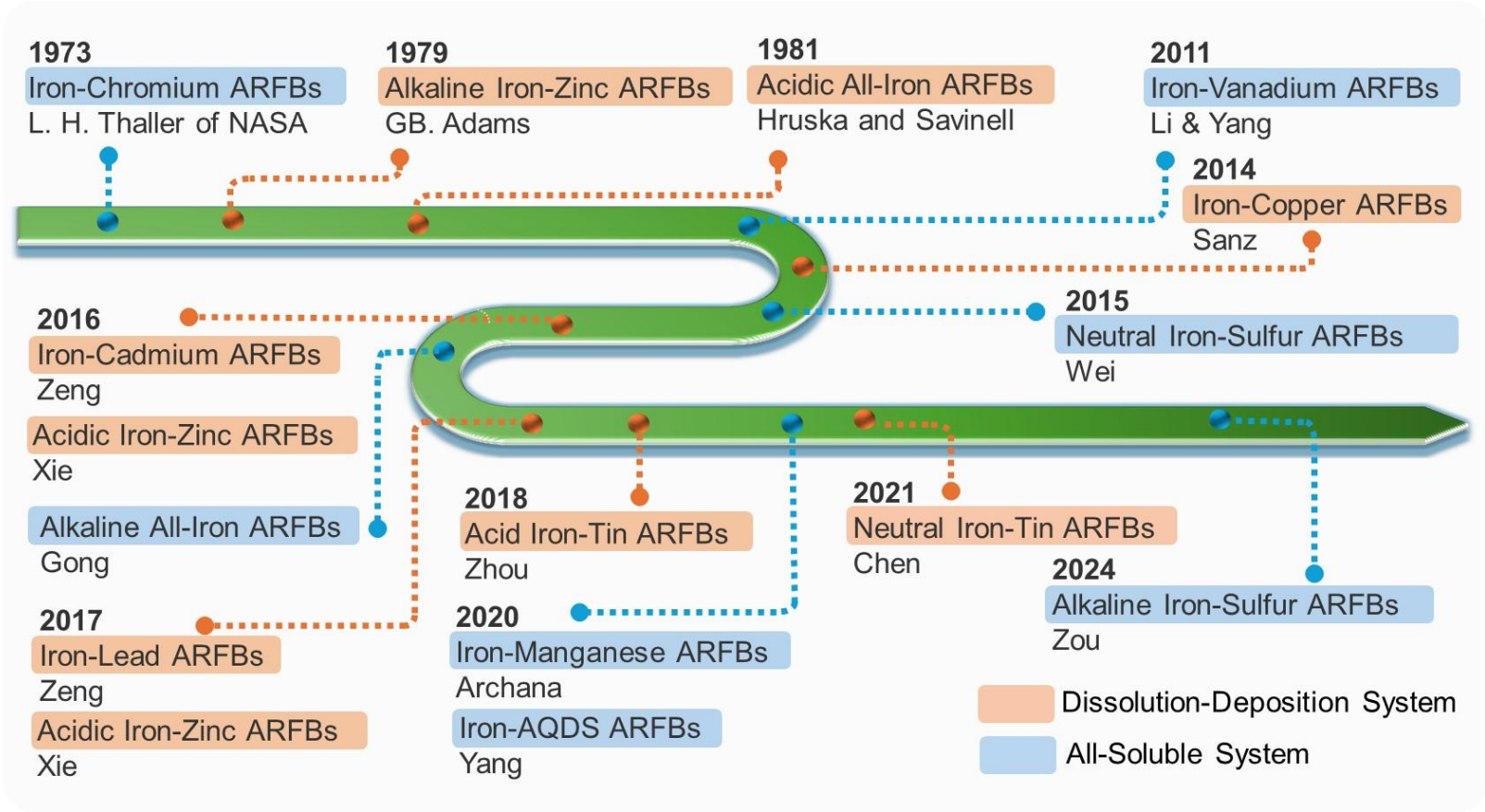
ENERGY STORAGE INDUSTRIES ASIA PACIFIC

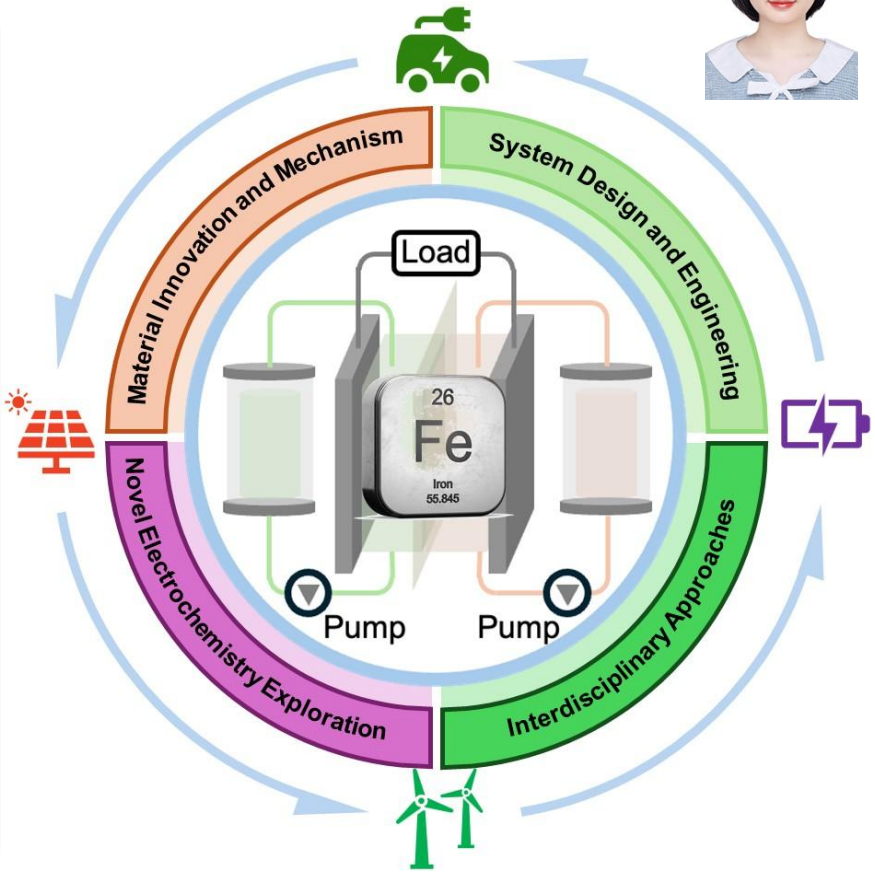
ANSTO

Fraunhofer ICT

- Innovation connections Grants
- Advance QLD fellowship
- ARC Linkage Project (2024-2027)
- National Industry PhD Program

Aqueous iron-based redox flow batteries

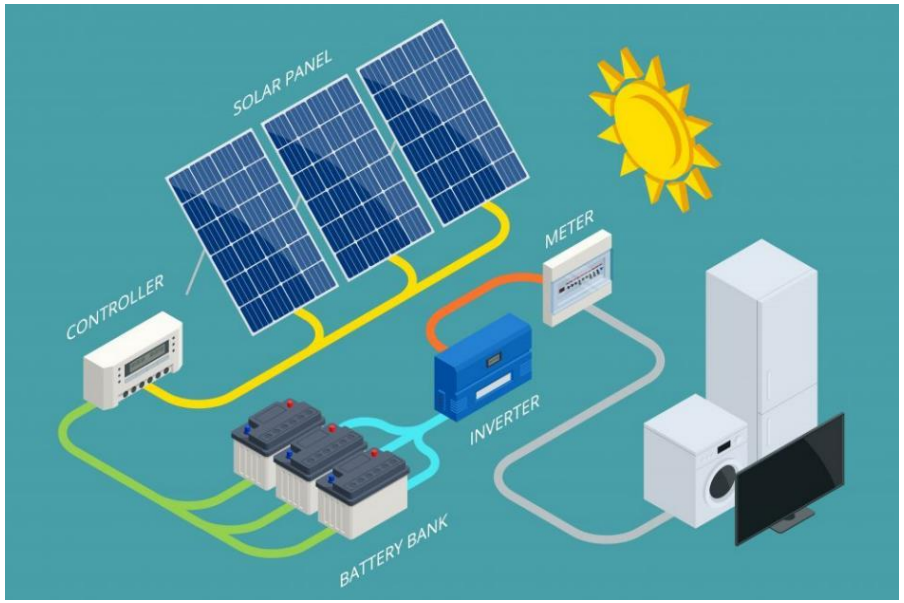




Aqueous iron-based redox flow batteries for large-scale energy storage
Cailing He , Yiming Zhang , Shuangbin Zhang , Xiyue Peng , Jens Noack , Maria Skyllas-Kazacos , Lianzhou Wang , Bin Luo.
National Science Review, **2025**, nwaf218, https://doi.org/10.1093/nsr/nwaf218 (***Open Access***)

Integrated Solar Energy Storage System

An energy system or device that can realise the solar energy conversion and storage simultaneously.



https://sunbadger.com/solar-battery-bank/

https://www.commodoreaustralia.com.au/

•Photovoltaic (PV) + Battery (**two-component system** connected through external circuitry.)

- **Advantages:** Mature technology, modular, flexible design.
- **Limitations:** Energy loss due to multiple energy conversions (light → electricity → storage).

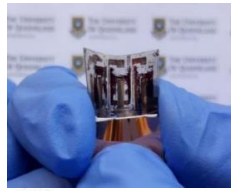
•Photoelectrochemical (PEC) + Battery (photoelectrode driven electrochemical reactions in a single unit)

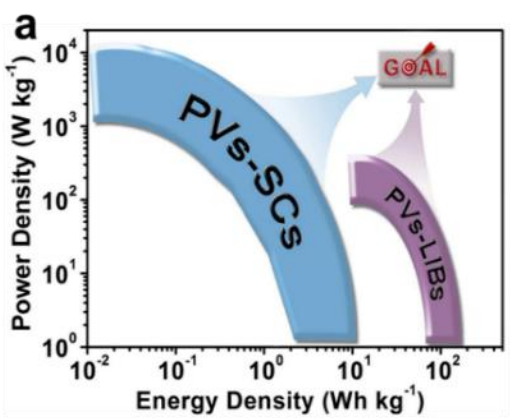
- **Advantages:** Potential for higher overall efficiency, simplified architecture.
- **Limitations:** Still in early research stages, limited stability and scalability.

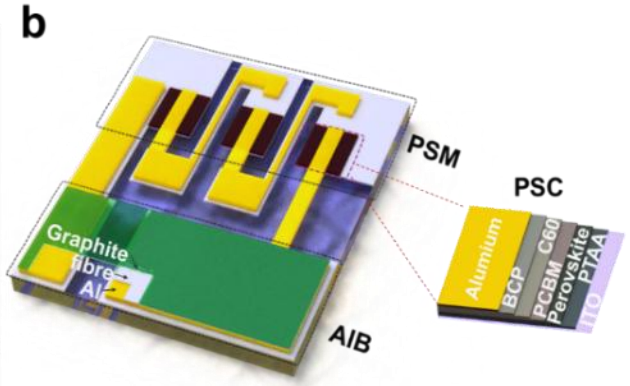
Integrated solar energy storage system (PV+Battery)

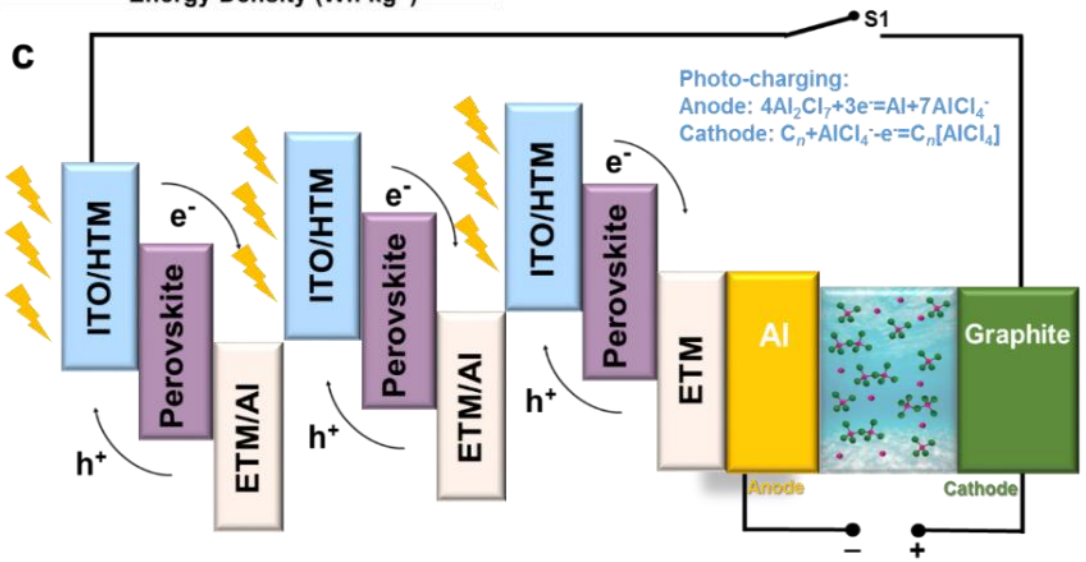
❖ **Solar Rechargeable Battery** based on perovskite solar cells and aluminium-ion battery

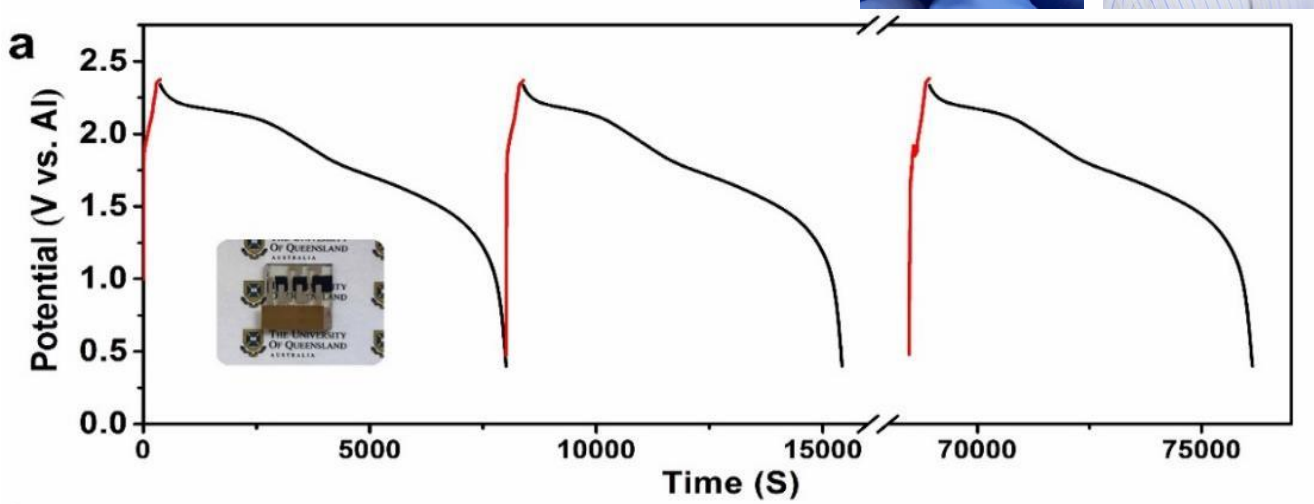
- ❑ **High photoelectric conversion and storage efficiency (12.04%).**
- ❑ **Ultrafast solar charge and discharge rates.**

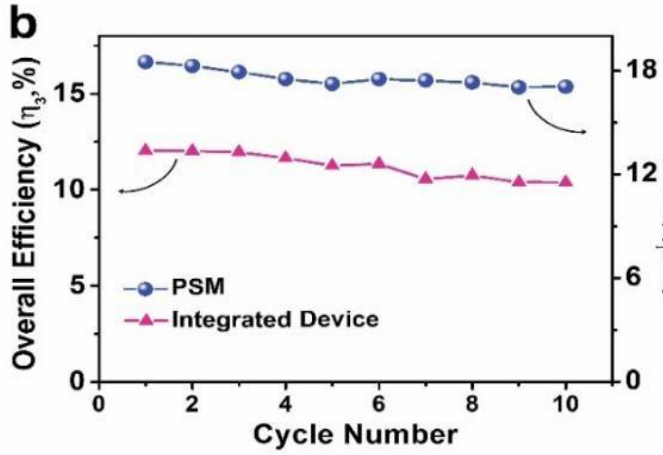


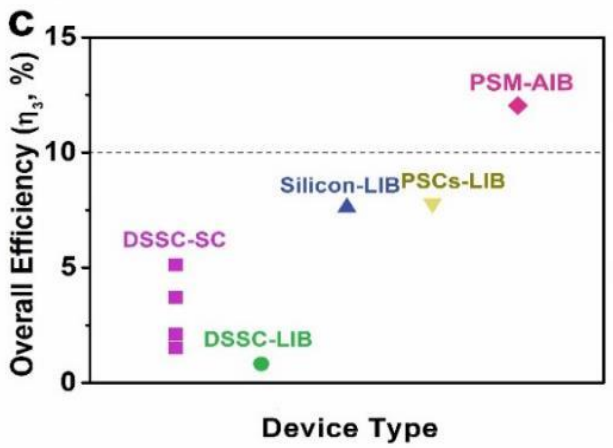








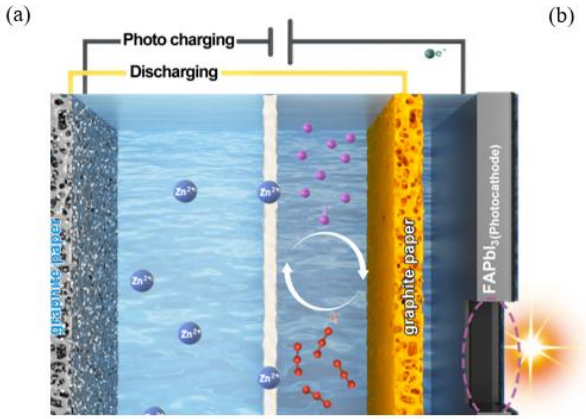


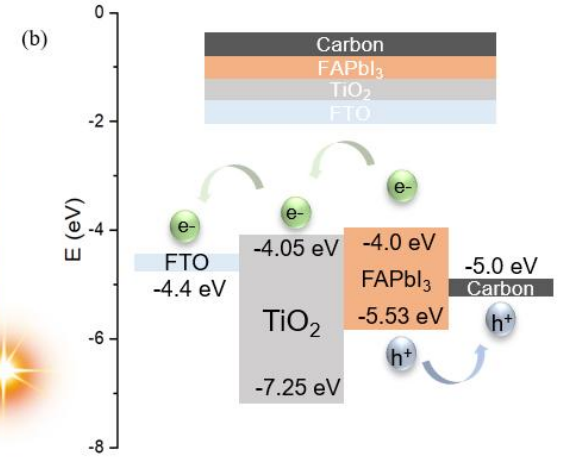


Y. Hu, Y. Bai, B. Luo, L. Wang, et al. Adv. Energy Mater., 2019, 9, 1900872 .

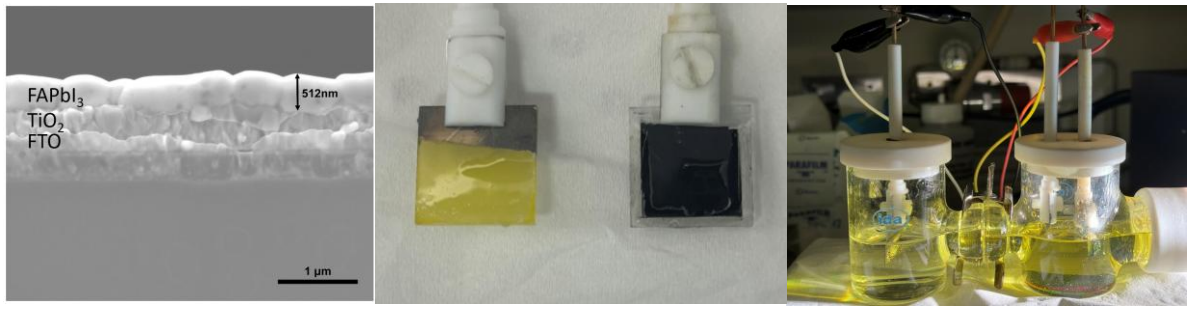
Integrated solar energy storage system (PEC+Battery)

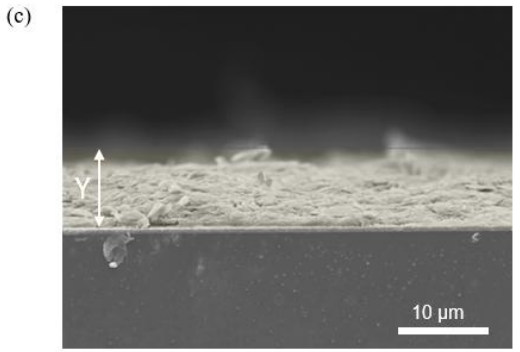
Photo-assisted Rechargeable Zinc-iodine Aqueous Battery with Perovskite Photocathode

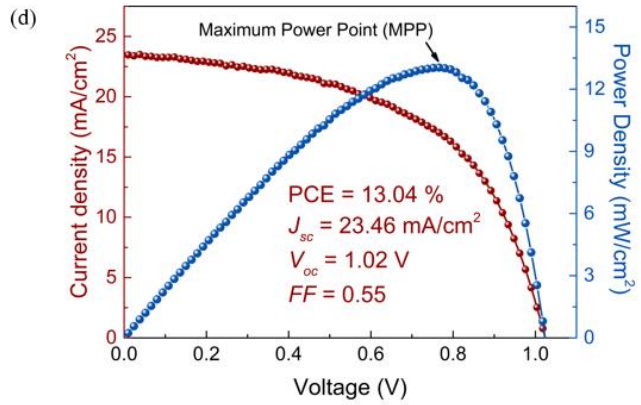


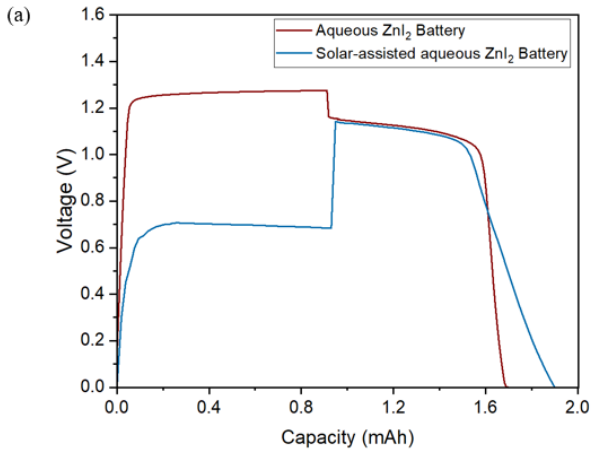


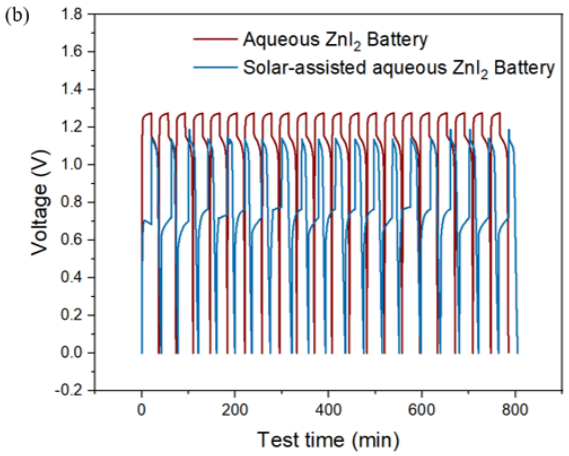
Perovskite stability → Protective carbon coating electrode











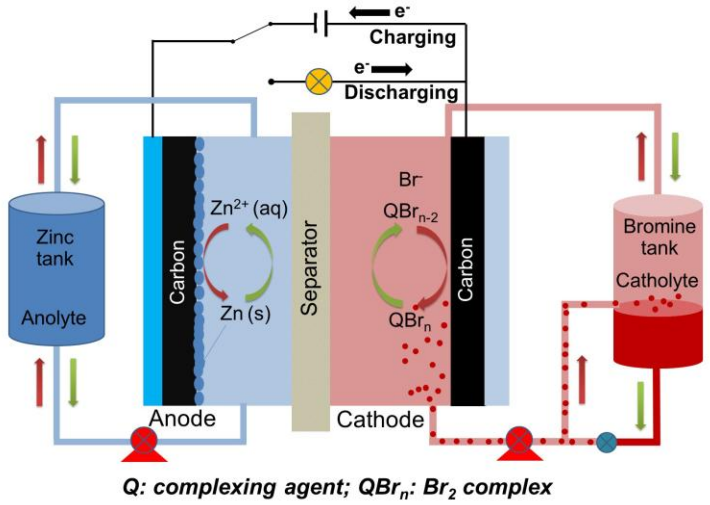
- **Abundant and relatively benign elements** (zinc and iodine).
- **Iodine-based catholytes** offer high reversibility and stability.

Y. Huang, B. Luo, et al. EcoMat, 2025, under revision.

Summary

❑ **Hybrid flow systems (Zn-Br, All-Fe, Solar batteries)**

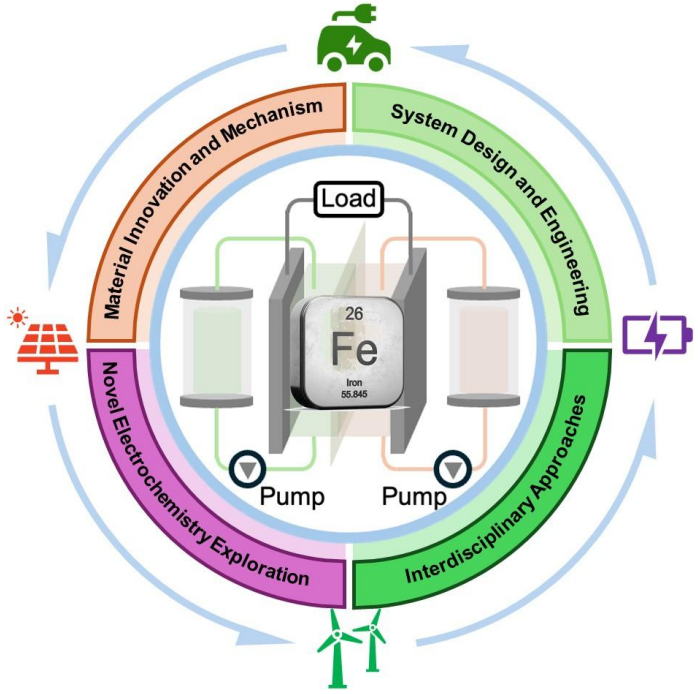
- Challenges in electrode/electrolyte (H_2 evolution, electrolyte stability, dendrites, electrode degradation)
- Gap between lab research and real application (Interdisciplinary & Industry collaboration)



Q: complexing agent; QBr_n: Br_2 complex

Future and collaborations

- System-level design and engineering improvements
- Material innovation and mechanism (i.e. membranes, interfaces)
- Exploration of novel electrochemical systems (Solar-rechargeable (photo-assisted) flow batteries)
- Interdisciplinary approaches (AI, operando characterisations)



Acknowledgements

Prof Maria Skyllas-Kazacos (UNSW), AA Prof Jens Noack (Fraunhofer ICT), AA Prof Shane Scarinci (ESIAP) visiting AIBN @ UQ in 2024











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Thank you for your attention!