Perspectives and Strategies of Developing Long Duration and Seasonal Energy Storage Technologies for Improving Grid Resiliency and Reliability

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PNNL is operated by Battelle for the U.S. Department of Energy

Project Overview

- **Project Objective: (New project from 06/2020)**

  Develop low cost and reliable battery technologies to serve for long duration and seasonal energy storage applications.

- **Project Details:**

  Identify novel redox chemistries, Develop battery technologies, Materials synthesis/characterization, and Cell testing

- **Project Team:**

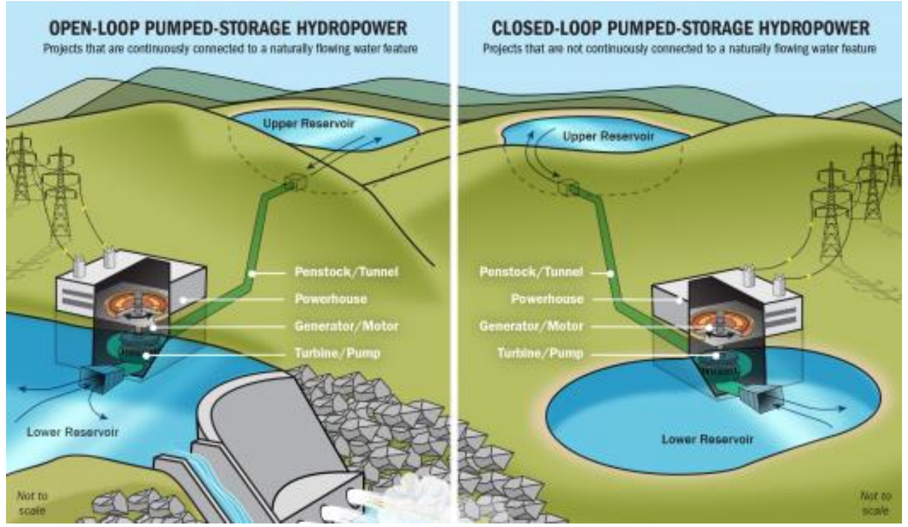
  Dr. Miller Li, Dr. Fred Parks, Dr. Aaron Hollas, Dr. Daiwon Choi, Dr. Xiaolin Li, Dr. David Reed, and Dr. Vince Sprenkle

Long Duration & Seasonal Energy Storage for Grid Resiliency and Reliability

- Long Duration Energy Storage:
  - Extended grid service (multi-days)
  - Better integration of renewable energy resources
  - 100% renewable electricity systems

- Seasonal Energy Storage:
  - Need to store electricity for long period of time (months or seasons)
  - Cycling once or twice per year
  - Provide unique capability for grid reliability and reduce environmental impacts

Current Technologies for Long Duration Energy Storage



- ❑ Pumped Storage Hydropower (PSH)
  - 95% of all utility-scale energy storage in US
  - 70-80% round-trip efficiency
  - Geographical restriction
  - Less than half a day for the generating period

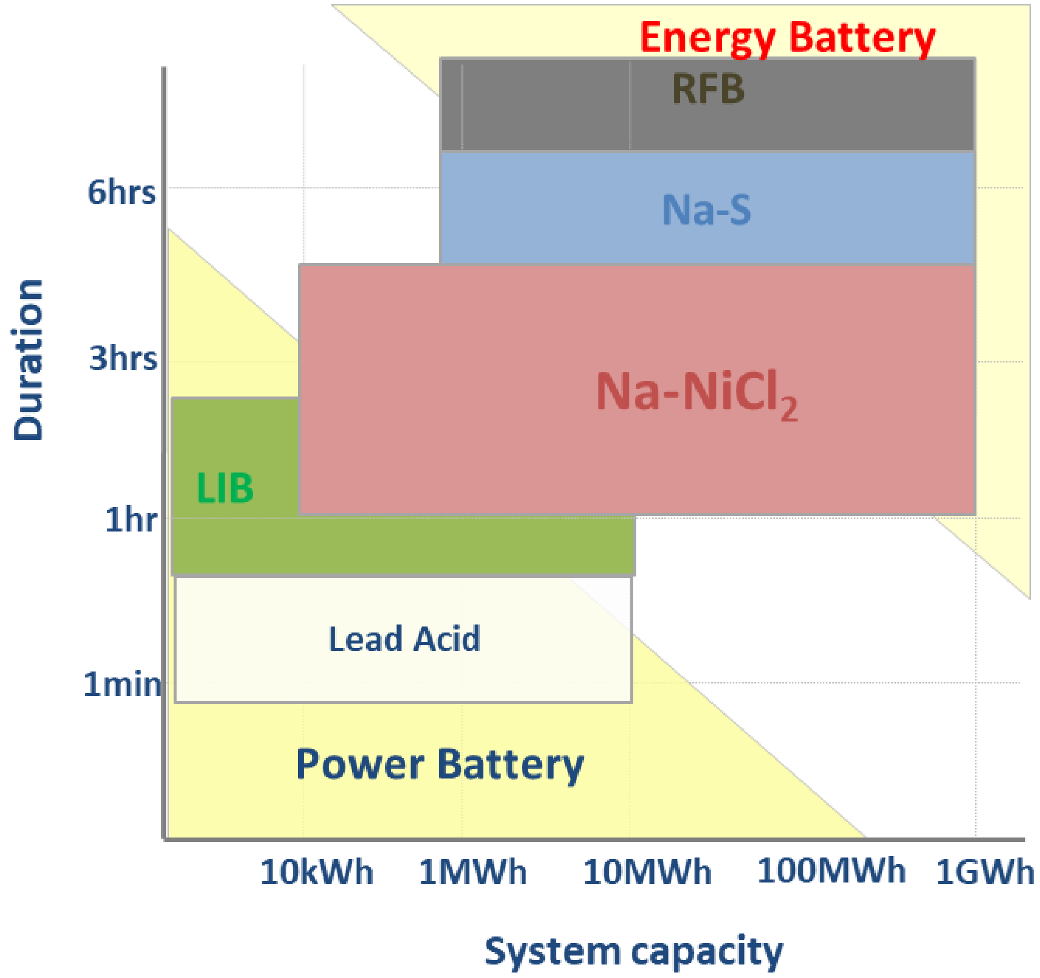
- ❑ Other Demonstration Projects:
  - Liquid Air Energy Storage (Pressure/generator)
  - Energy Vault Gravity Storage (Gravity/generator)
  - Thermal Storage (Temperature/steam/generator)

Need to consider cost (life span), efficiency, safety, etc.

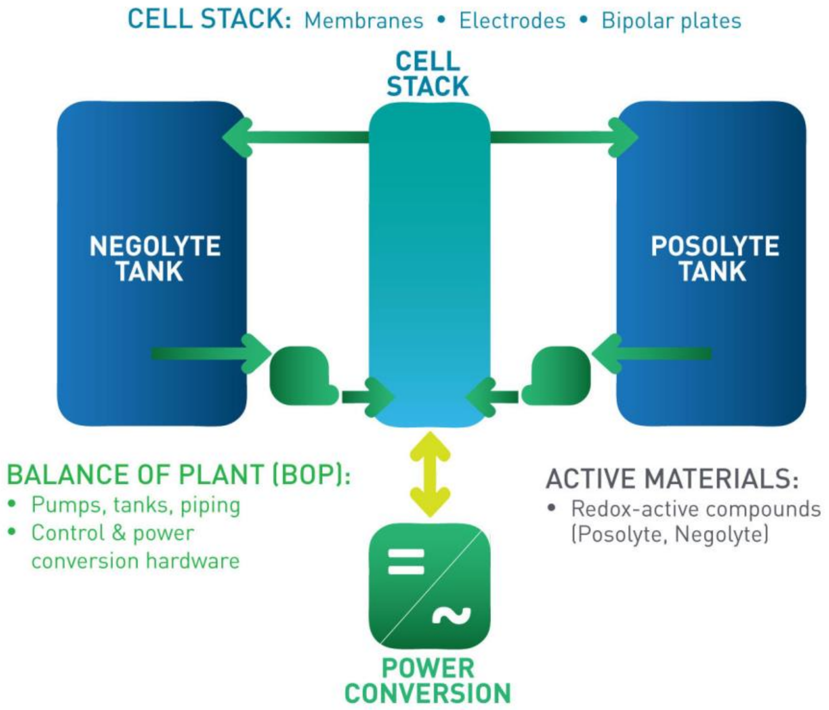
Battery Technologies for Long Duration Applications

- ❑ Advantages of Batteries for Long Duration
  - ❑ High round-trip efficiency
  - ❑ Portable with less geographical restriction
  - ❑ Relatively low maintenance

- ❑ Current Battery Technologies
  - ○ Conventional LIB: < 4 hrs
  - ○ ZEBRA ($Na\text{-}NiCl_2$): 4-8 hrs
  - ○ Na-S: 8-12hrs
  - ○ VRFB: > 8 hrs (high materials cost)



RFB Technologies for Long Duration Applications



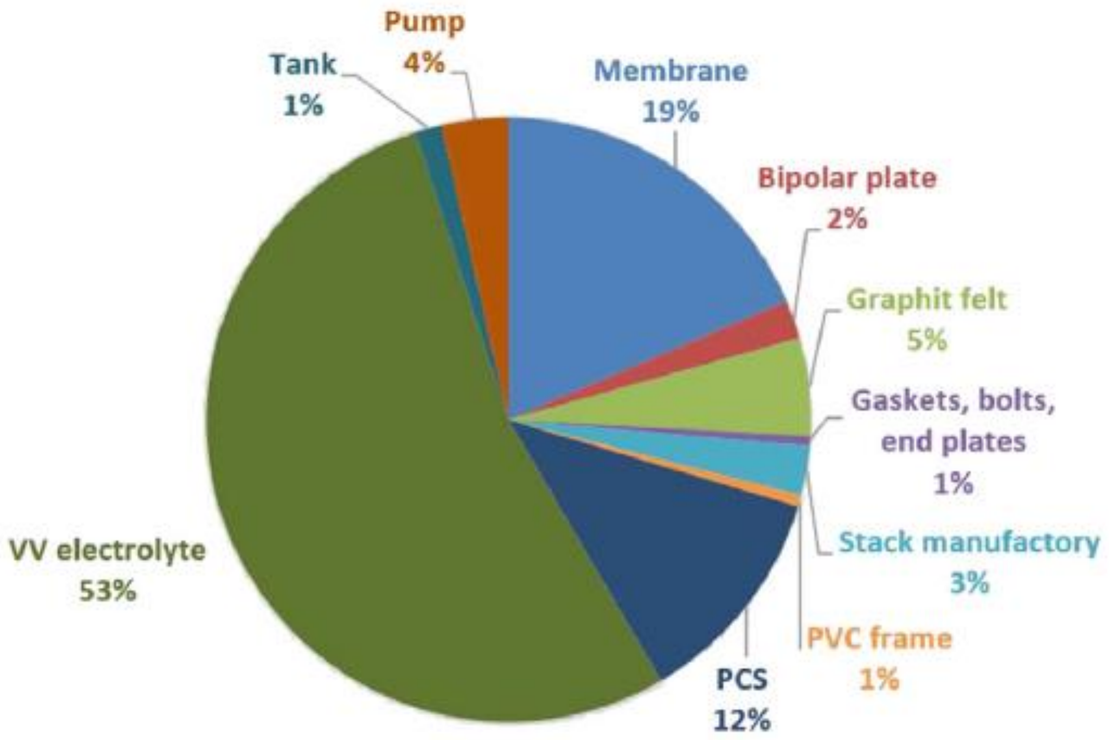
- ***Decoupling*** of power and energy capacity
- Vanadium-based chemistries (VRFB) have been known to be used in flow batteries. However, ***high cost of VRFB*** is the main obstacle for wider market penetration.
- Many other chemistries, such as Fe, Zn, ASO, are available.

PNNL's contributions to RFB technologies:

- Advanced VRFB
- Advanced low cost ASO and analogues
- Expertise for fundamental understanding
- Technical development/demonstration

Cost Breakdown for VRFB and Design Strategies

Power: ~$2000 /kW (50-100 hrs)
Battery cost: $ 40/kWh (50 hrs)
$ 20/kWh (100 hrs)



Capital cost: $229 KWh^{-1}

System Element	Cost (%)	Cost reduction
VV electrolyte	53%	√
Membrane	19%	√
Graphite felt	5%	?
Pump	4%	?
Tank/PVC frame/Stack	5%	?
PCS	12%	
Bipolar plate	2%	

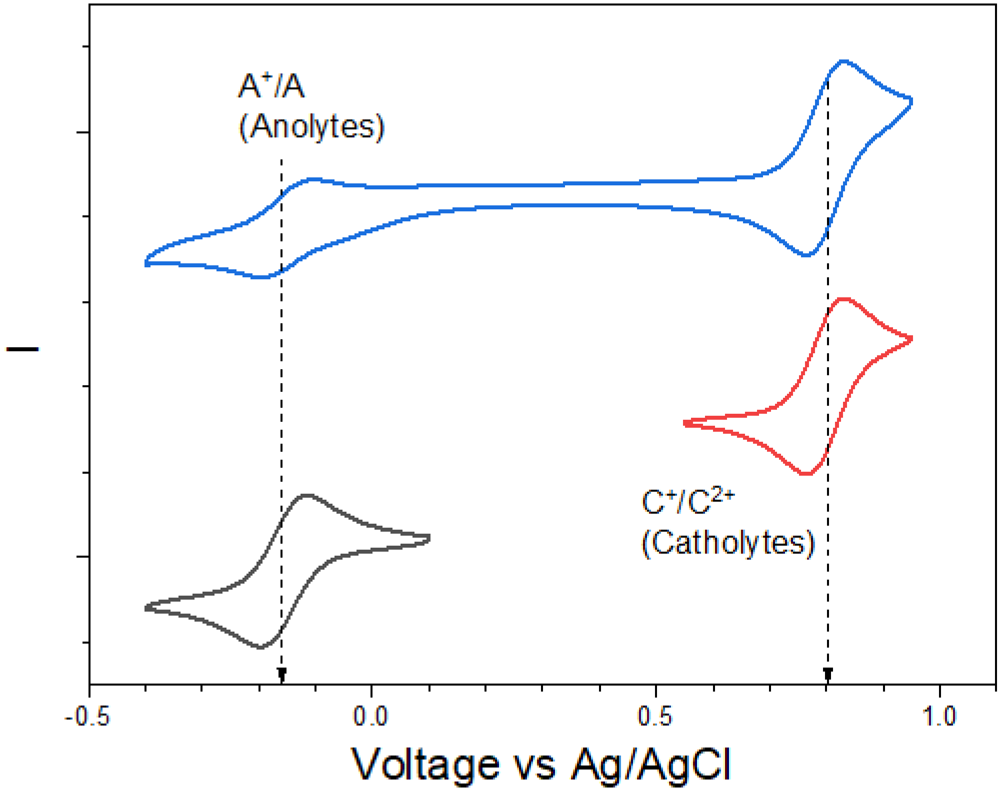
R&D Strategies of RFB for long duration:

- Low cost electrolytes
- Low cost separator or membrane
- Less corrosive electrolytes

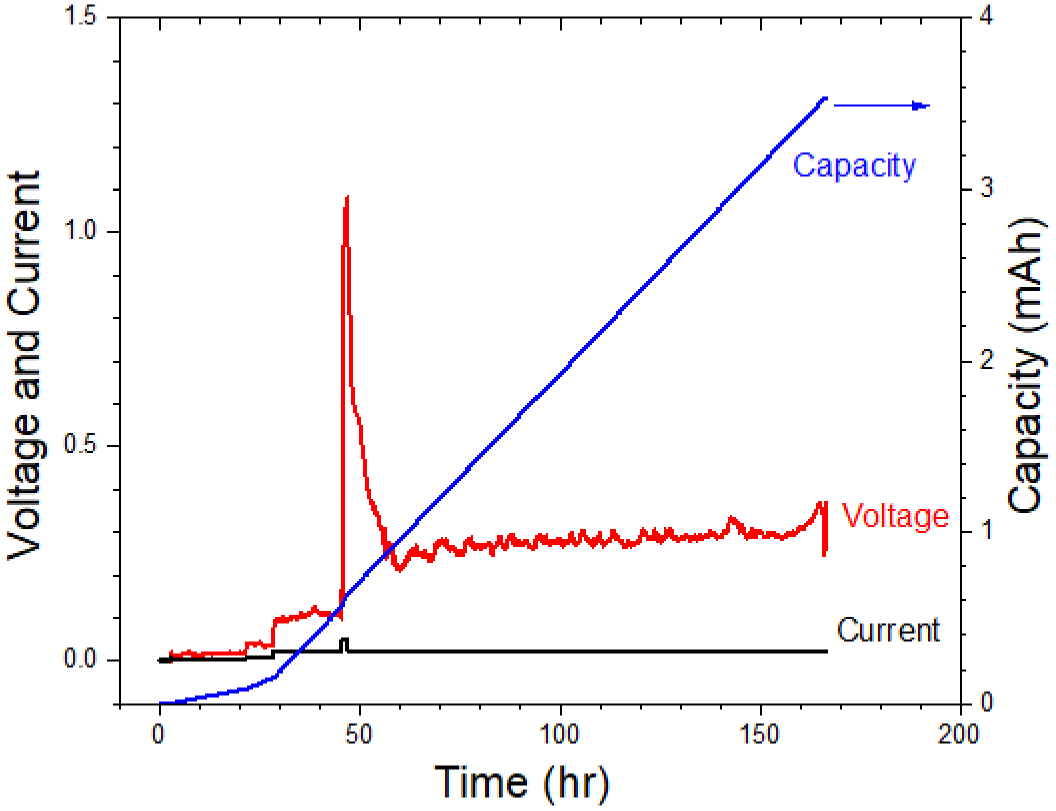
Zeng et al. *J. Power Sources* 300, 438 (2015)

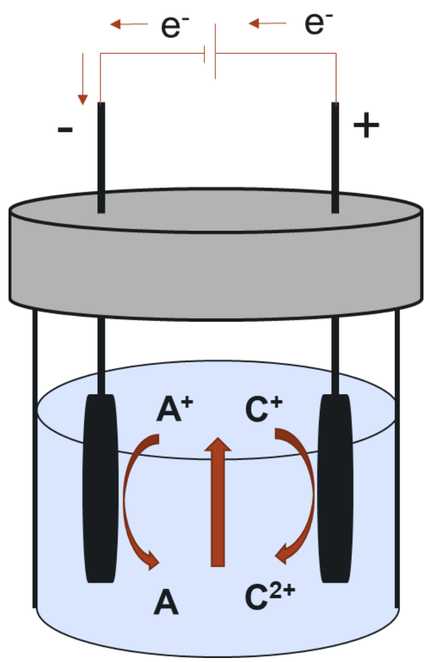
Preliminary CV and CC Test

CV testing



CC testing





- ❑ E_o= ~ 0.96 V
- ❑ Good reversibility for both couples
- ❑ Fast redox kinetics

- ❑ Good stability observed for redox couples within operating voltage window
- ❑ Need to validate the cycling performances in H-cell or flow cell configuration.

Advantages of PNNL New RFB Electrolytes

Possible advantages of new RFB:

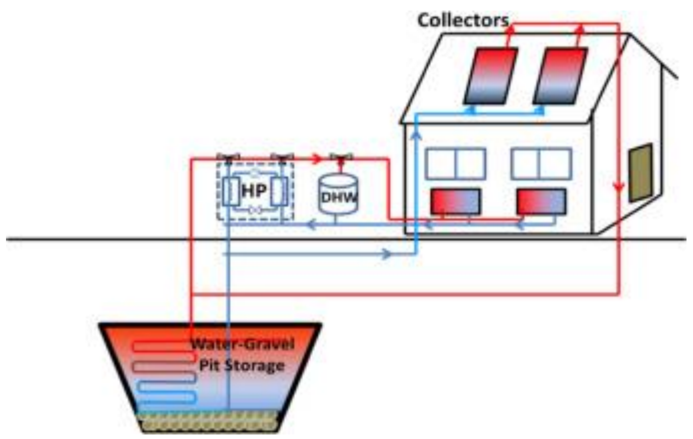
- **Low materials cost**: Abundant resources and readily available materials.
- **No destructive degradation:** Catholyte and anolytes are chemically stable from the cross over.
- **Rebalance:** The anolyte and catholyte electrolytes can be simply mixed for rebalancing.
- **Wide selections of the separator:** Use porous separator instead of Nafion or AEM.
- **Design freedom:** Using various commercially available or lab synthesized materials for scale up.

Necessity of Seasonal Energy Storage

- Seasonal energy storages:
  - Electricity to fuels (H_2 and NH_3, etc.) or thermal storage:

    High cost infrastructure, low round-trip efficiency, hazardous chemicals, safety concerns, etc.
  - Electrical energy storage (Batteries):

    Higher round-trip efficiency, relatively simple infrastructure, etc.



- High battery cost and high self-discharge rate are the bottlenecks for seasonal energy storage applications.
  - Diffusion or recombination of active materials via electrolytes
  - Parasitic reactions with electrolytes
  - High cost

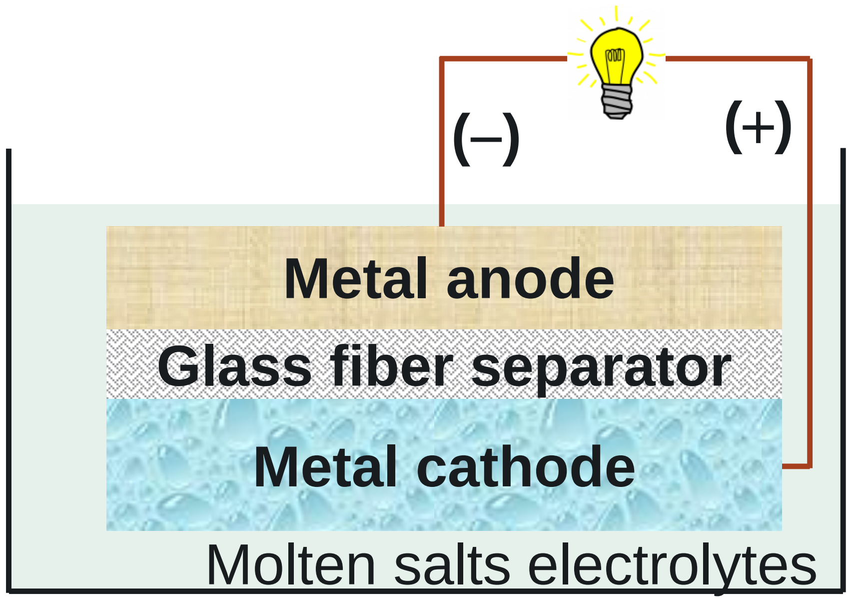
Battery Chemistry	Self-discharge Rate (per month)
LIB	2-5%
Lead Acid	4-6%
NiMH	~30%
NiCd	15-20%

From Wikipedia, https://en.wikipedia.org/wiki/Self-discharge

Molten Salt Metal Battery (MSMB) Chemistry

- ❑ Molten salt metal battery will cool to room temperature after being fully charged in order to eliminate its self-discharge. (Provisional IP Application)

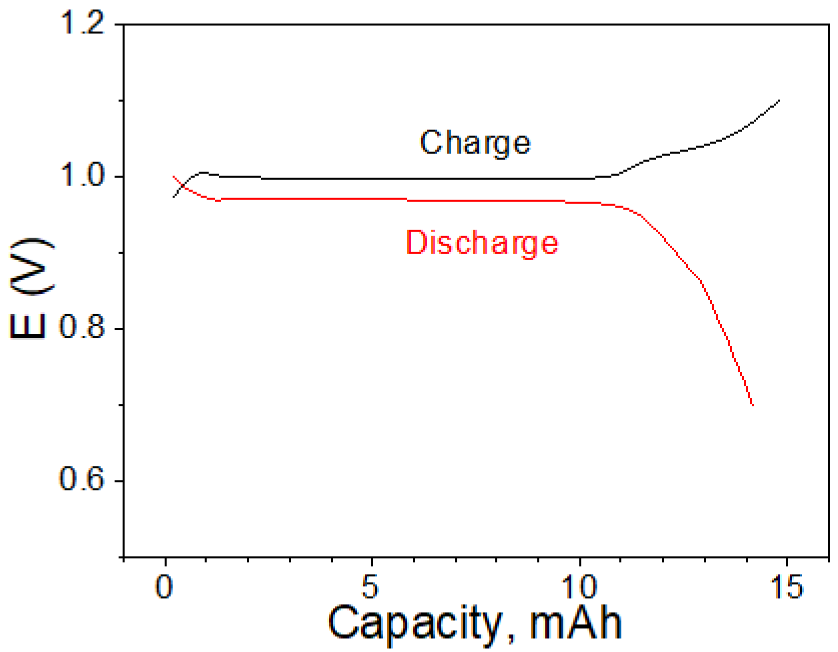
Liquid electrolytes (< 175^{o}C) → **Solid salts** (store at ambient temp.)

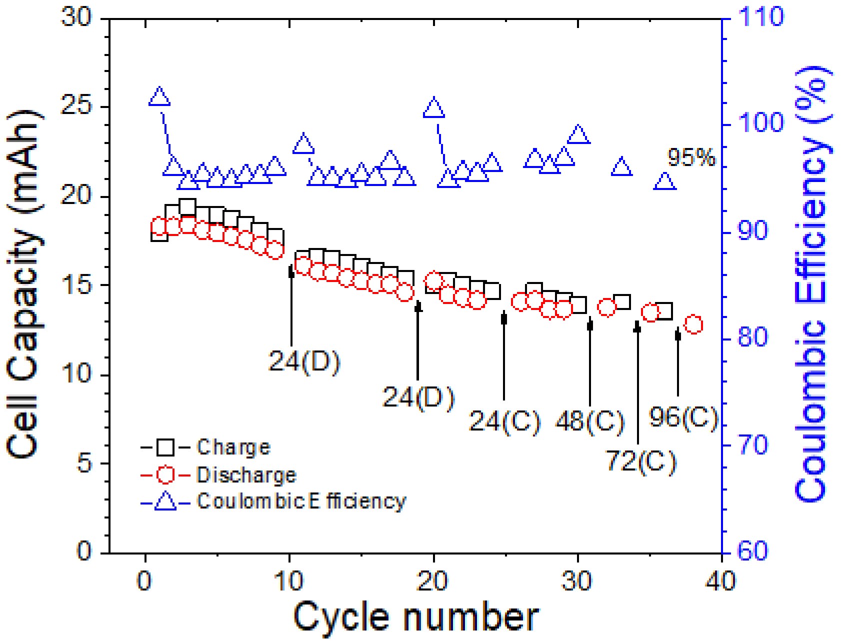


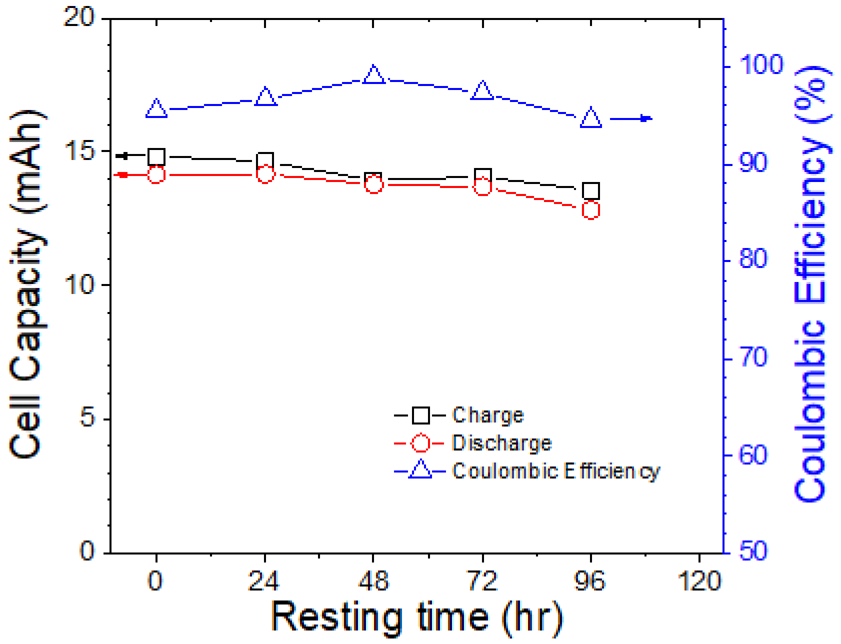
Schematic of MSMB

- ***Low self-discharge***
- ***Simple cell architecture***
  - Metals for anode and cathode
  - Conventional glass fiber separator
- ***Low cost***
  - Low materials cost for electrode and electrolytes
- ***High safety***
  - Low fire hazard materials
  - Easy transportation

Preliminary Cell Test for MSMBs







- ❑ MSMBs can be operated after multiple thermal cycles.
- ❑ Coulombic efficiency remains stable after resting at ambient temperature for a long period of time.

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Thank you

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