Sodium-Metal Halide Battery Technologies for Grid Energy Storage Applications

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PROJECT PROFILE
Topic: Na-based battery | Vertical: Materials and Systems Innovation Strategic Pathway: Accelerating the development and testing of advanced energy storage technologies that are more cost-effective, safe, and durable is crucial to meeting the Administration's goal of providing reliable, secure, and resilient energy. Project start and finish: FY26

PROBLEM

Zebra	Duration (hours)	Cycle life	Safety	Cost ($/kWh)
Na-$NiCl_2$	4-6	>1,000	No thermal runaway	500-1,000 (Ni)

Conventional sodium–metal halide (Na–MH) batteries are high-temperature, sodium-based systems that offer inherently **nonflammable**, **long-cycle-life** energy storage for grid applications.

- Replace Ni cathode with more affordable, abundant alternatives such as Fe and Al to strengthen domestic supply chains.
- Reduce operating temperature to <200 °C for lowering manufacturing costs and extending battery cycle life.
- Develop and implement new materials that enable these chemistries to operate reliably at lower operating temperatures.

APPROACH

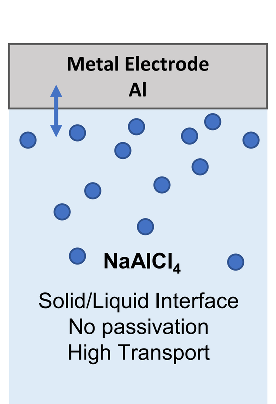
	Na-$NiCl_2$	Na-$FeCl_2$	**Na-Al**
Cathode	Ni/NaCl	Fe/NaCl	**Al**
E (V)	2.58	2.35	**1.6**
Capacity (mAh/g)	305.4	310.4	**308.4**
Materials cost ($/kWh)	>100	<5	**<5**
Duration (hr)	4-6	12	**20**

(1) Na-Al Battery

Overall reaction

Neutral: $3Na + NaAlCl_4\,(L) = 4NaCl + Al$

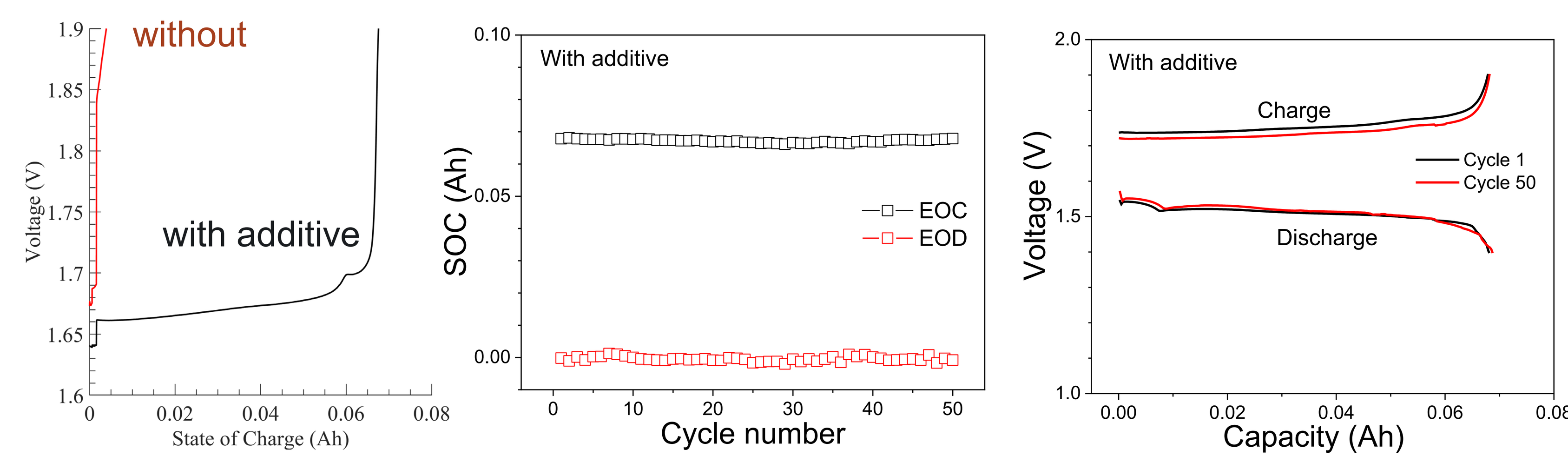
Acidic: $3Na + 4NaAl_2Cl_7\,(L) = Al + 7NaAlCl_4$



- Faster kinetics of $AlCl_4^-$ liquid phase diffusion
- Faster NaCl + $AlCl_3$ reaction vs NaCl dissolution
- Aluminum wools (low cost) instead of Ni powders

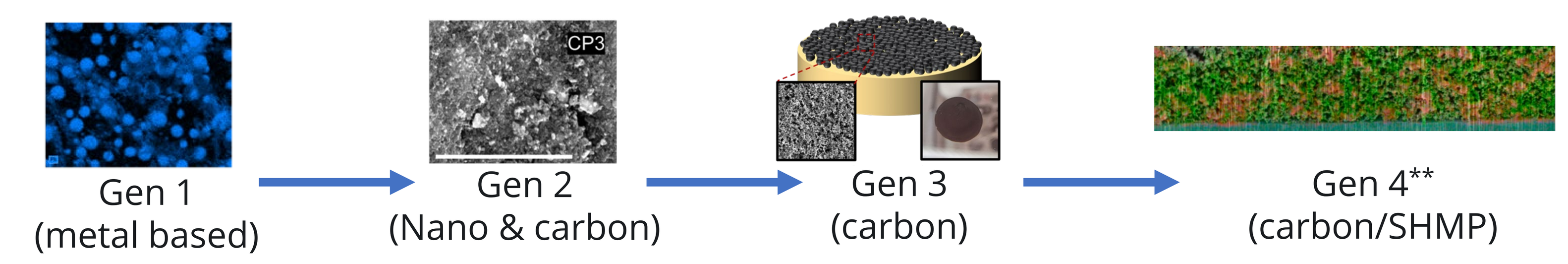
Challenge: Surface passivation on Al wools
Solution: Immediate/more consistent activation via additive
Activation Additive*:

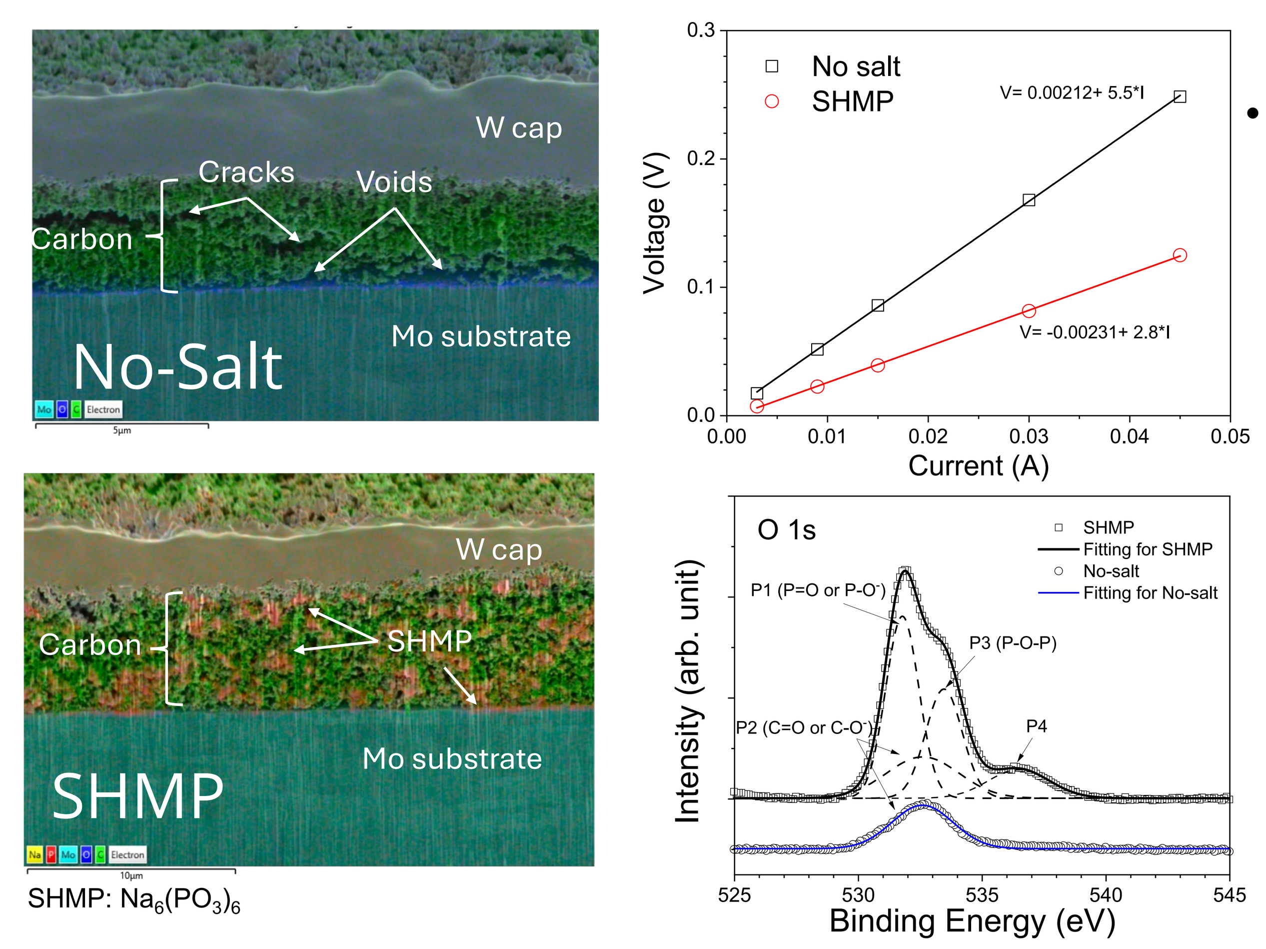
- < 0.5% vs Al cathode
- Full capacity at the 1st charge
- More consistent activation vs previous approach
- Suitable for practical applications.



- Without additive Na-Al battery experiences large overpotential and shows no capacity at the 1st charge.
- <0.5 % of additive in Na-Al battery enables full charge capacity at the 1st cycle.
- Initial testing indicates stable battery cycling after the activation.

(2) Na Wetting Agent:





- Lower over potential for carbon/SHMP treated Na symmetric cell.
- XPS (O 1s) spectra for No-salt and carbon/SHMP.

- Superior cell performance was observed for carbon/SHMP vs No-salt cells.
- Demonstrate the multifaceted benefits of SHMP as a structural binder.

CONCLUSIONS & IMPACT

- Na-Al battery offers a viable pathway for low cost and long duration battery applications.
- In-situ activation of Al cathode provides solution for simpler BMS in practical applications.
- SHMP as a structural binder provide superior Na wetting and lower resistance.

FUTURE DIRECTIONS

- Continue to pursuit the mechanism of Al cathode activation.
- Long term cycling for Na-Al battery.
- Applying new Na wetting agent for full cell testing.

References

* Patent application under preparation.
** Han et al. *Frontiers in Batteries and Electrochemistry* 5, 1759353 (2026)

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