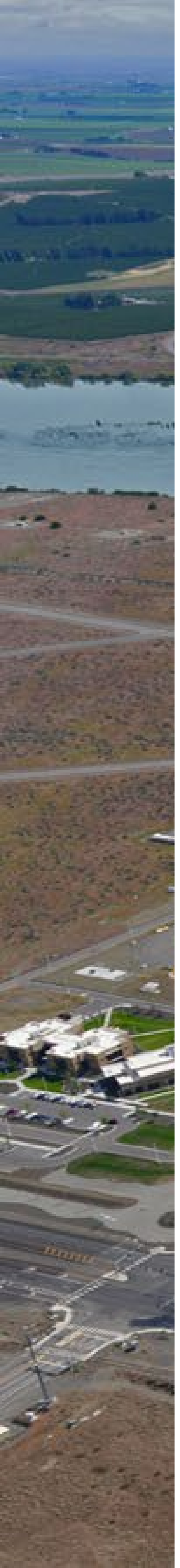
FY22 DOE OE Energy Storage Program
Peer Review Meeting
Oct. 11-13
Session 4: Na Battery Session

#402
Intermediate Temperature Na Battery Technologies

Guosheng Li

Battery Chem & Electrochem Group
Pacific Northwest National Laboratory



Intermediate Temperature Na Battery Task

- **Project Team:**

  Dr. Mark Weller (poster), Dr. Miller Li (#503), Dr. Eugene Polikarpov, Dr. Keesung Han
  Dr. David Reed, Dr. Vince Sprenkle, and Dr. Guosheng Li

FY22	
Journal publications & Milestone	• "Interfacial Engineering with a Nanoparticle-Decorated Porous Carbon Structure on β″-Alumina Solid-State Electrolytes for Molten Sodium Batteries" *ACS Appl. Mater. & Interfaces* 14, 25534 (2022). • Large stack cell testing (with RIST, #403)
IP& Invention Reports	• Provisional IP application filed (Advanced Na wetting agent)
Collaboration	• DOE/KETEP project (RIST & KEPCO, South Korea) • SBIR project (Nexceris, OH)

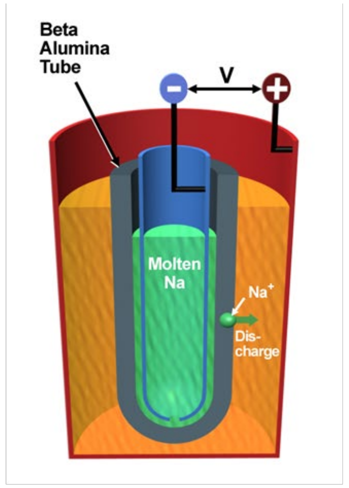
Challenges & Opportunities for High Temperature Na Batteries

Batteries	Temp. (°C)	OCV (V)	Duration (hours)	SSE	Cycle life	Safety	Cost ($/kWh)
Na-S	350	~2.0	**~4-6**	β″-alumina	> 3,000	Thermal runaway, limited thermal cycle	500
Na-$NiCl_2$	280	2.58	**~4-6**	β″-alumina	>1,000	No thermal runaway	1,000

Tubular type

Increase tube diameter for larger cathode loading (LDES).

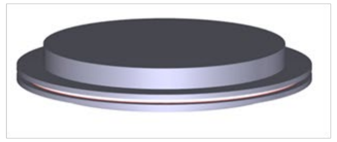
1. Manufacturing cost /challenges of large β″-tubes.
2. Cell processing cost & technical difficulties. Glass seal, TCB, etc.



NaS: 350°C (~$500/kWh)

ZEBRA: 280°C (~$1,000/kWh)

PNNL

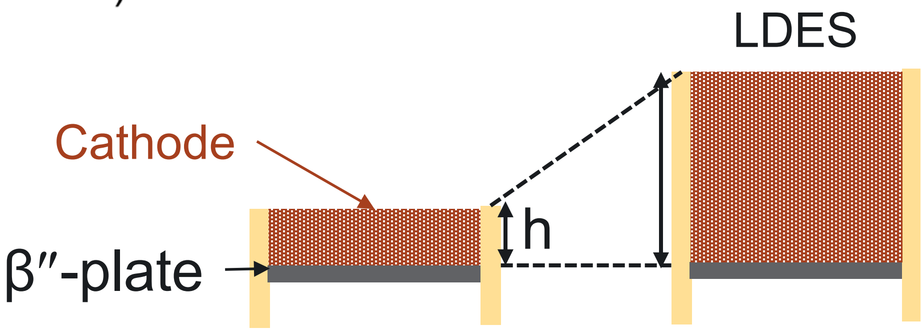


IT Na-MH: 190°C (< $100/kWh)

Planar type

Increase cathode thickness for larger cathode loading (LDES).

1. No size change for β″- plates.
2. Similar cell assembly.



Low-Cost Na-MH Batteries for LDES

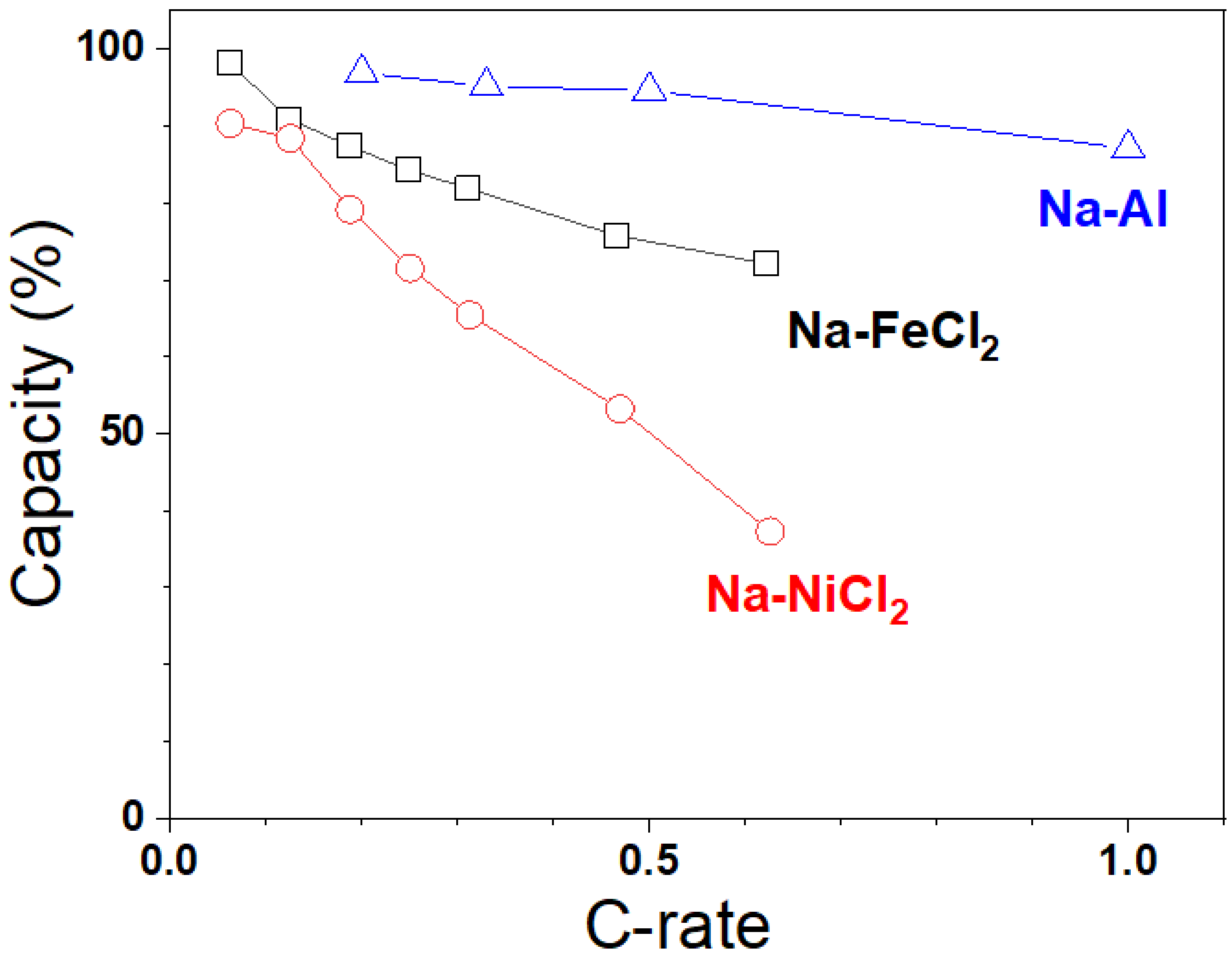
Advantages for Na-MH batteries:

- Lower cost & Abundant resource
- Reliability/Safety
- Long cycle life

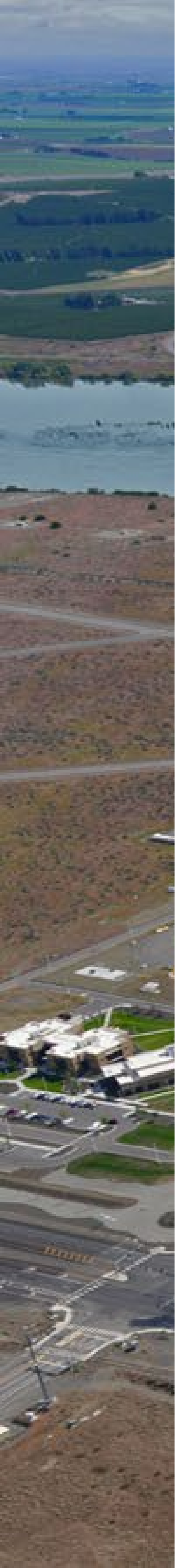
High-capacity loading:

- High ion conductivity of electrolytes
    - BASE, 20-100 mS (~0.5 mm)
    - Molten salts, >300 mS (~6 mm)
- Fast cathode kinetics

	Na-$NiCl_2$	**Na-$FeCl_2$**	**Na-Al**
Cathode	Ni/NaCl	Fe/NaCl	Al
E (V)	2.58	2.35	1.6
Materials cost ($/kWh)	**<100**	**<5**	**<5**
Duration (Hours)	**6-8**	**~15**	**>20**

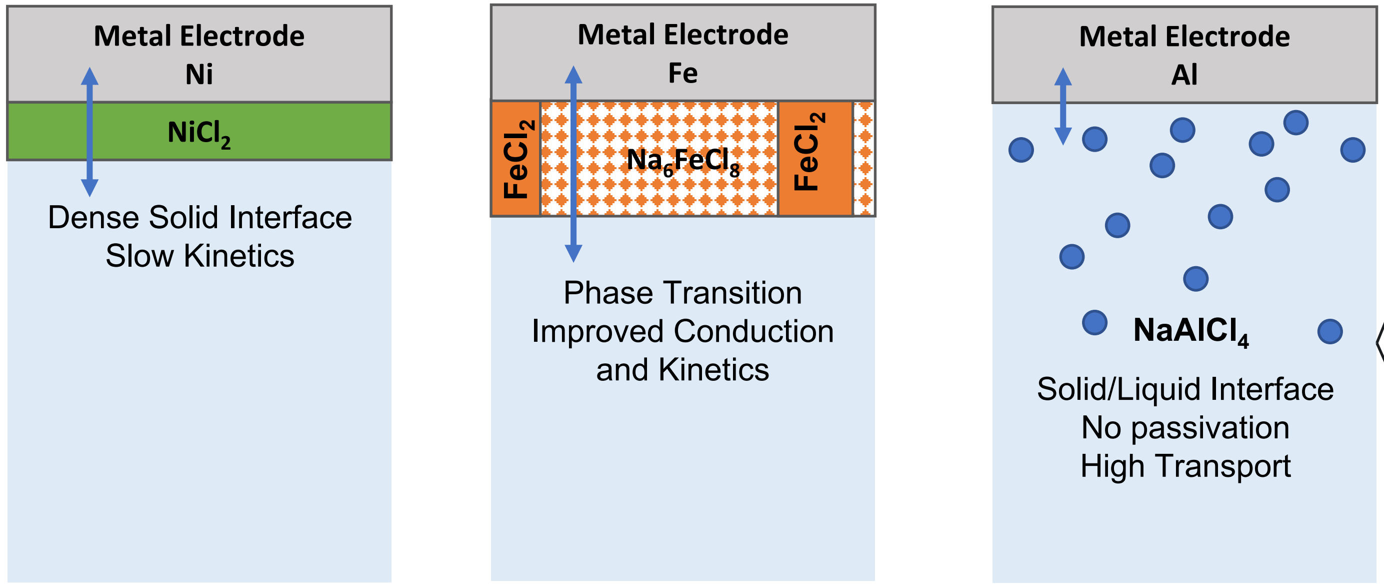


Zhan et al. *Adv. Energy Mater.* 10, 1903472 (2020);
Zhan et al. *Adv. Energy Mater.* 10, 2001378 (2020).



Na-Al Battery for LDES Applications

Faster kinetics of Na-Al vs Na-$NiCl_2$ and Na-$FeCl_2$



Ni ⇳ $NiCl_2$

Fe ⇳ Na_6FeCl_8 ⇳ $FeCl_2$

Al ⇳ $NaAlCl_4$

Nature Commun.. 7, 10683 (2016).

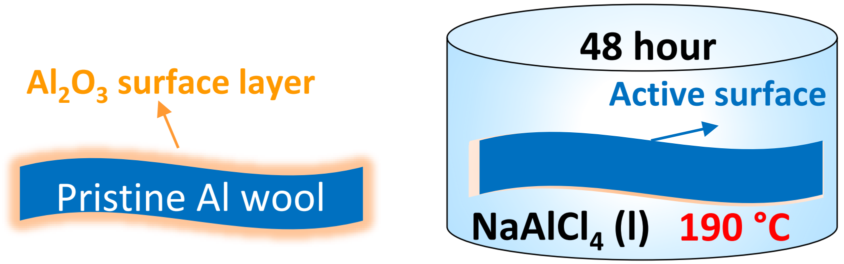
Adv. Energy Mater. 10, 1903472 (2020).

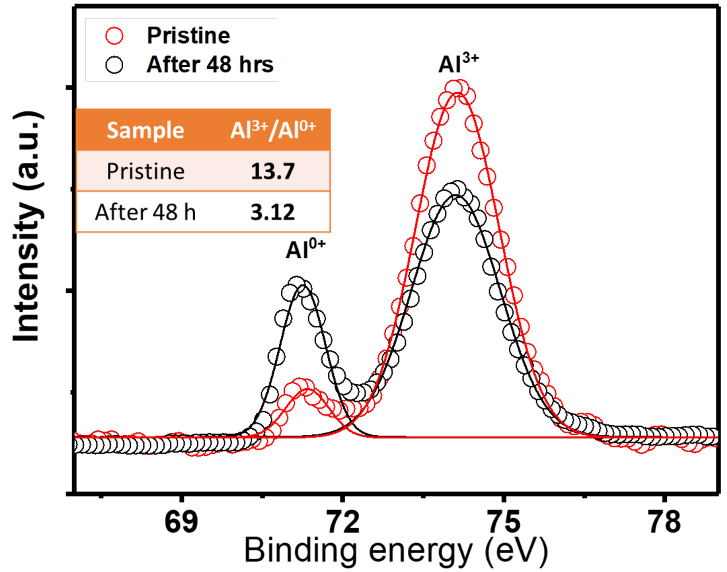
Adv. Energy Mater. 10, 2001378 (2020).

$$3Na + NaAlCl_4 \Leftrightarrow Al + 4NaCl$$

E_0= 1.62 V

Theo. Capacity = 308.4 mAh/g





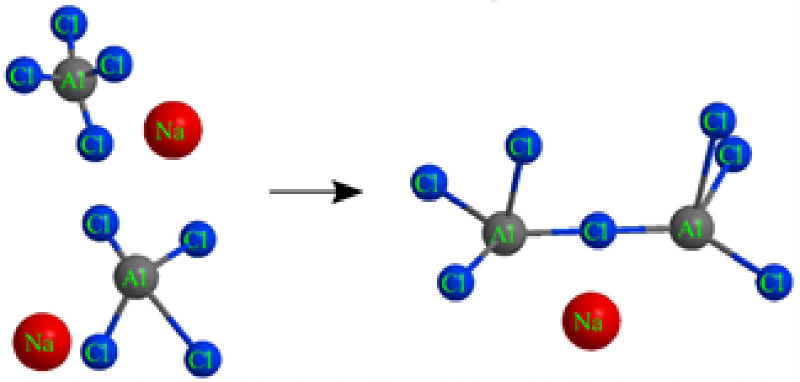
New Redox Chemistry for Na-Al Battery (Mark's Poster)

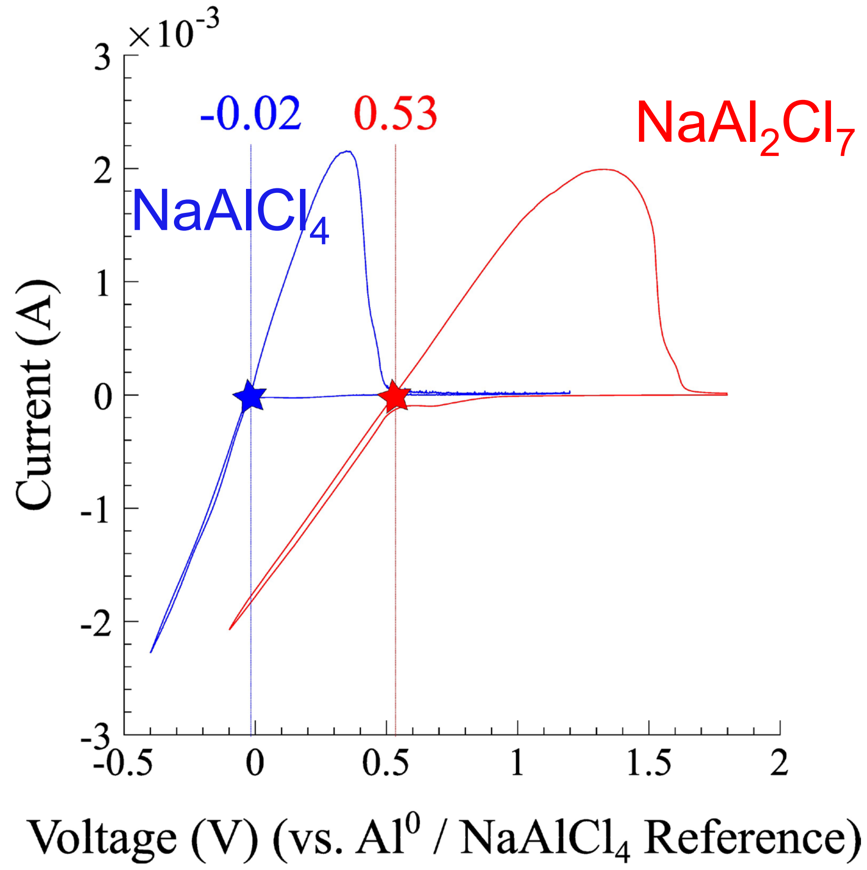
- $Al/AlCl_4^-$ redox: 308.4 mAh/g, ~1.62 V

  $Al + 4NaCl \Leftrightarrow 3Na + NaAlCl_4$ (75% NaCl utilization)

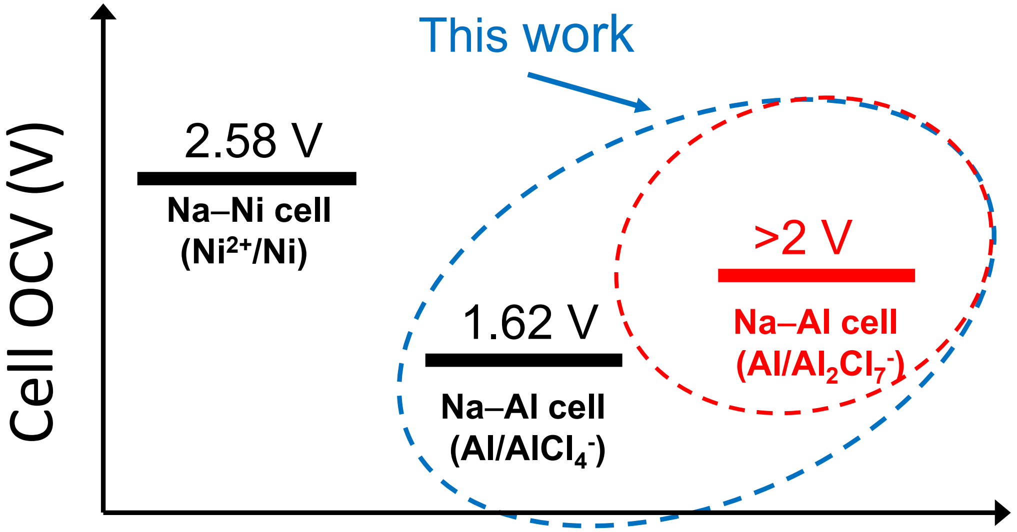
- $Al/AlCl_4^-/Al_2Cl_7^-$ redox: >2 V

  $Al + 7NaAlCl_4 \Leftrightarrow 3Na + 4NaAl_2Cl_7$



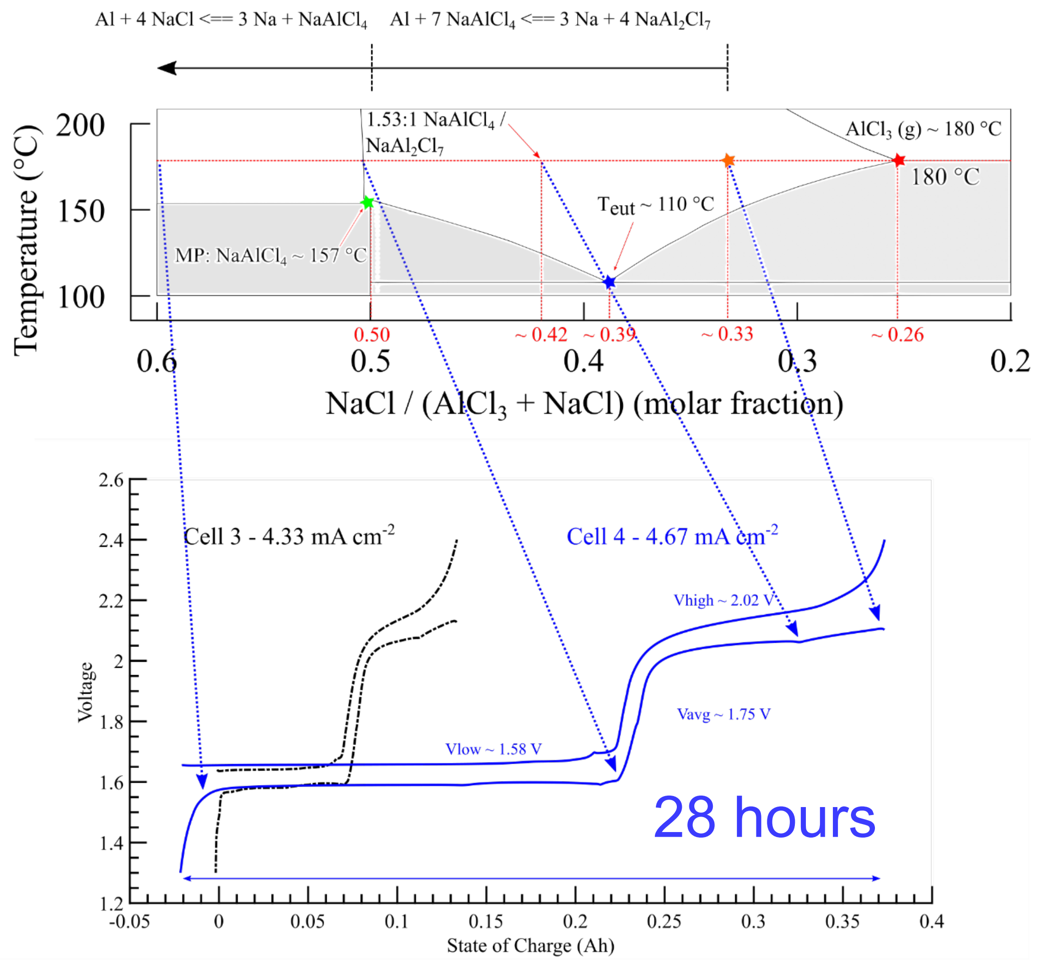


Overall: $2Al + 7NaCl \Leftrightarrow 6Na + NaAl_2Cl_7$ (85.7% NaCl utilization, 347.3 mAh/g)



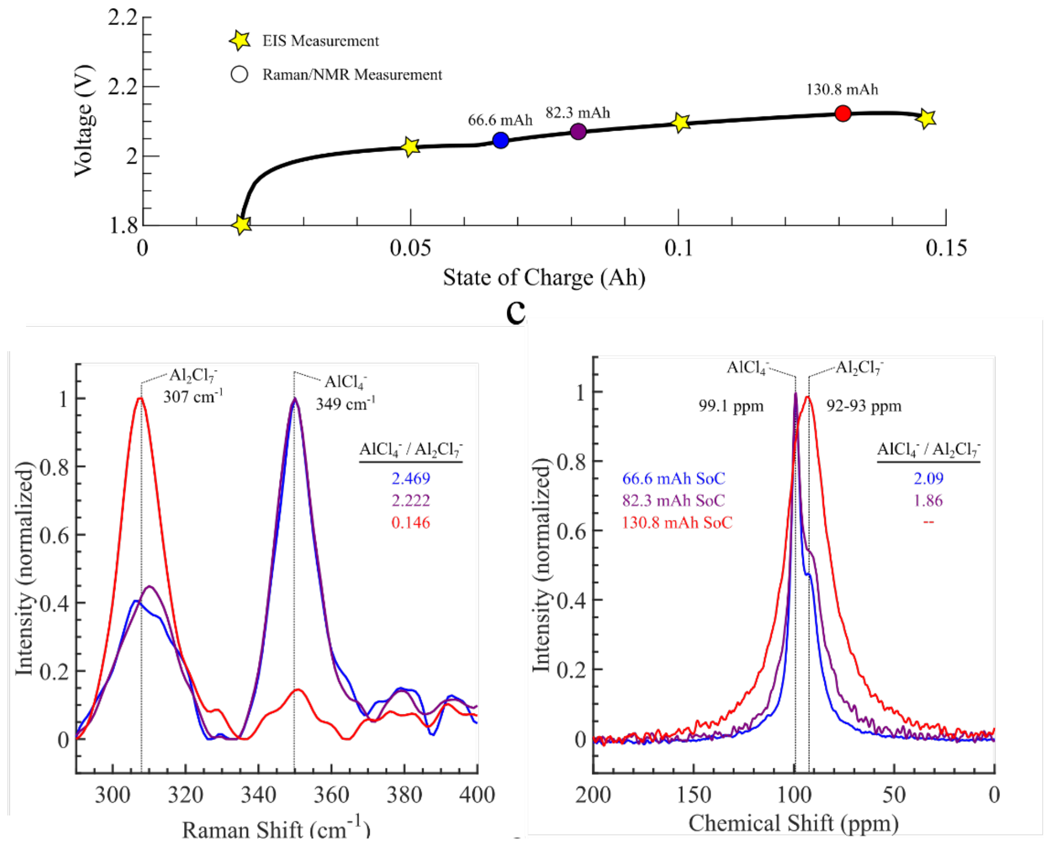
Weller et al. (in preparation)

Reaction Mechanisms & LDES Demonstration (Poster)



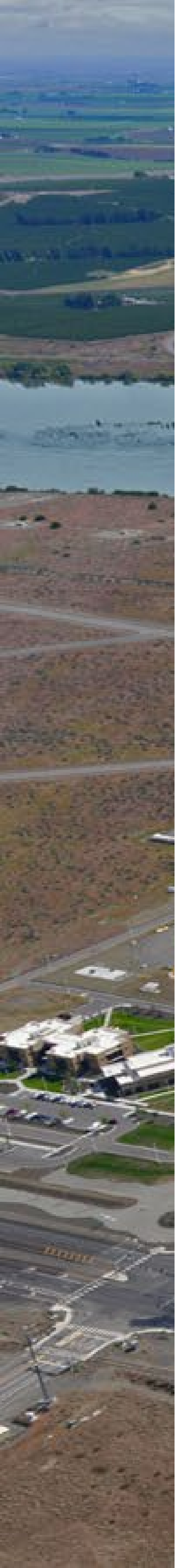
Preliminary LDES demonstration:

- Area capacity: ~130 mAh/cm^2
- Discharge duration: ~ 28 hours



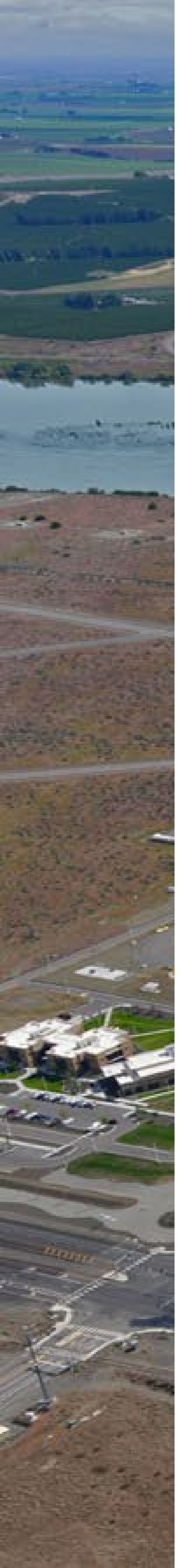
- Raman and ^{27}Al NMR measurements identify/quantify $AlCl_4^-$ and $Al_2Cl_7^-$ products at different SOCs.

Weller et al. (in preparation)



Plans for FY 23

- Demonstration of Na based battery chemistries for long duration application.
  - Na-Al battery chemistry & performances for LDES
  - Other low-cost Na battery chemistries for LDES
- Large cell demonstration for OE/KETEP project (last year of phase 2)
- Continue to participate/support on SBIR project (Nexceris, OH)



Pacific Northwest
NATIONAL LABORATORY

U.S. DEPARTMENT OF
ENERGY

Office of Electricity
(Dr. Imre Gyuk)

Thank You!

POC: Guosheng Li, Ph.D.
Email: guosheng.li@pnnl.gov