

Low Temperature Na-Metal Halide Batteries: Low Cost, Long Cycle Life, and Safe Energy Storage System

Henry H. Han, J. Mark Weller, and Guosheng Li

Battery Materials & Systems Group, Pacific Northwest National Laboratory, Richland, WA 99354

Conventional Molten Na Battery Technologies

Batteries	Temp. (°C)	OCV (V)	Duration (hours)	Cycle life	Safety	Cost (\$/kWh)
Na-S	350	2	4-6	> 3,000	Fire hazard	350
ZEBRA	260	2.58	4-6	>1,000	No thermal runaway	500-1,000

Advantages:

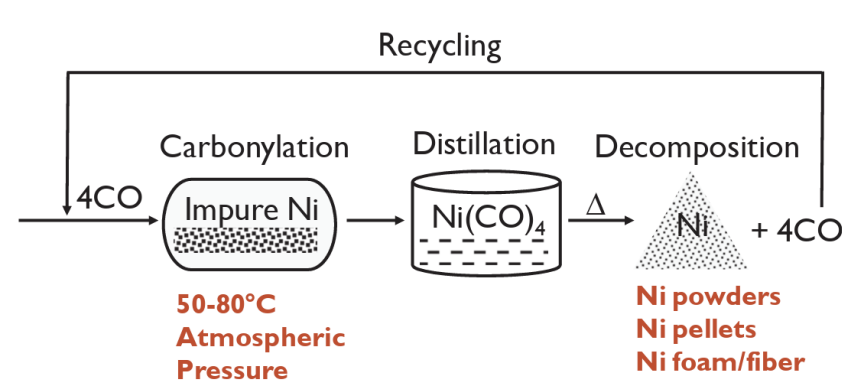
- No dendrite formation (molten Na anode)
- No thermal runaway (Na-Metal Halide)
- No HVAC requirement
- Assemble/shipping at discharge state
- High specific capacity (~100 Wh/kg)
- Long cycling and calendar life (>10 years)

Challenges:

- High materials cost (Ni cathode)
- High operating temperature
- Complicated cell manufacturing process

Fe/Ni Alloy Cathode¹

Possible low-cost process



ZEBRA Cathode: 70% Ni/30% Fe

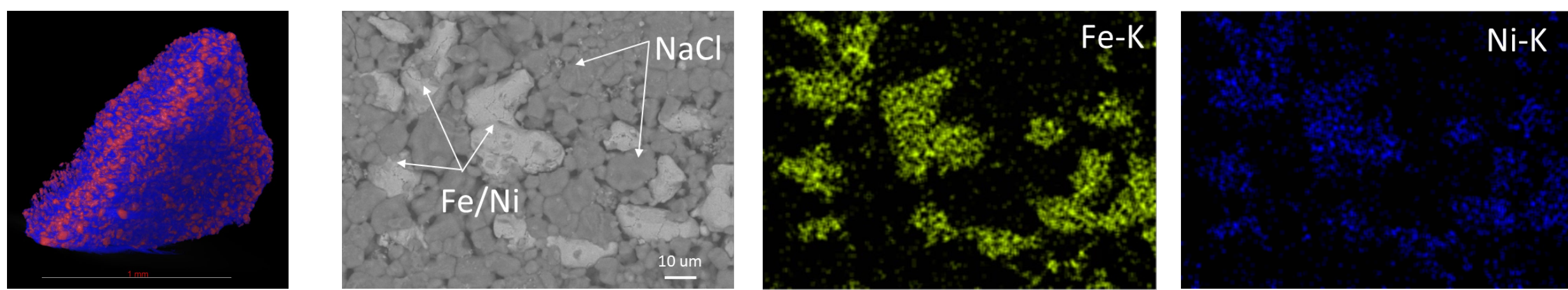


(Lower cost)

Carbonyl Ni powder
Carbonyl Fe powder
Ni/Fe cathode
Byproducts

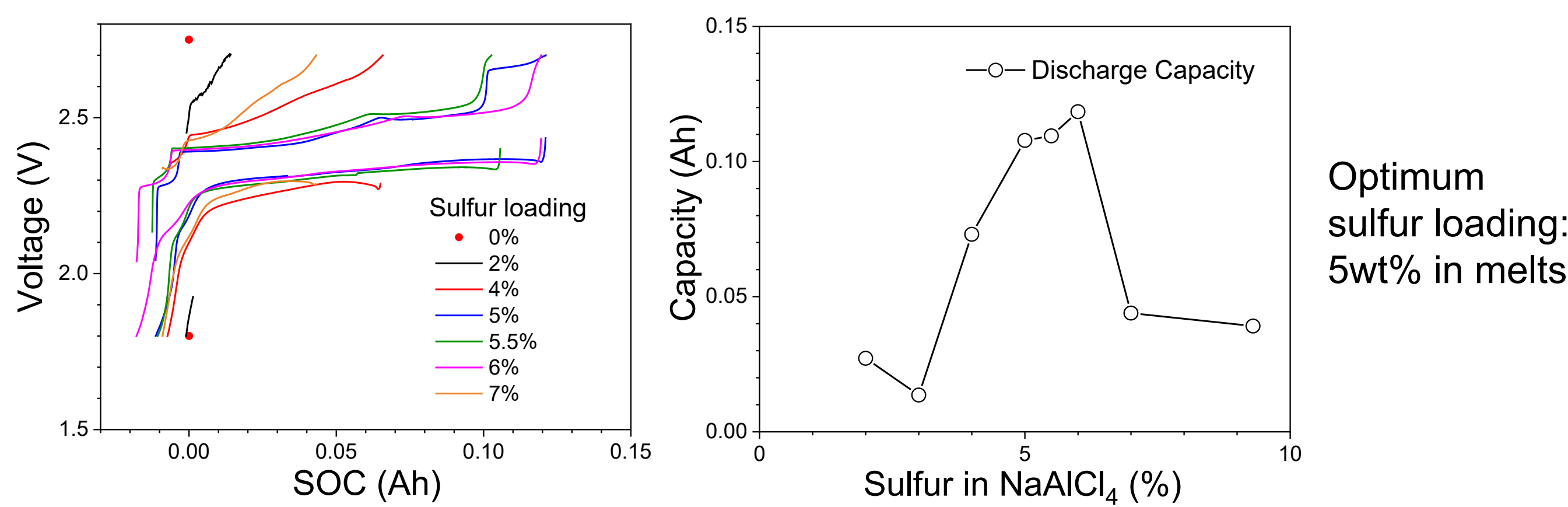
Fe/Ni cathode and its morphology

uCT X-ray microscopy & SEM/EDS:

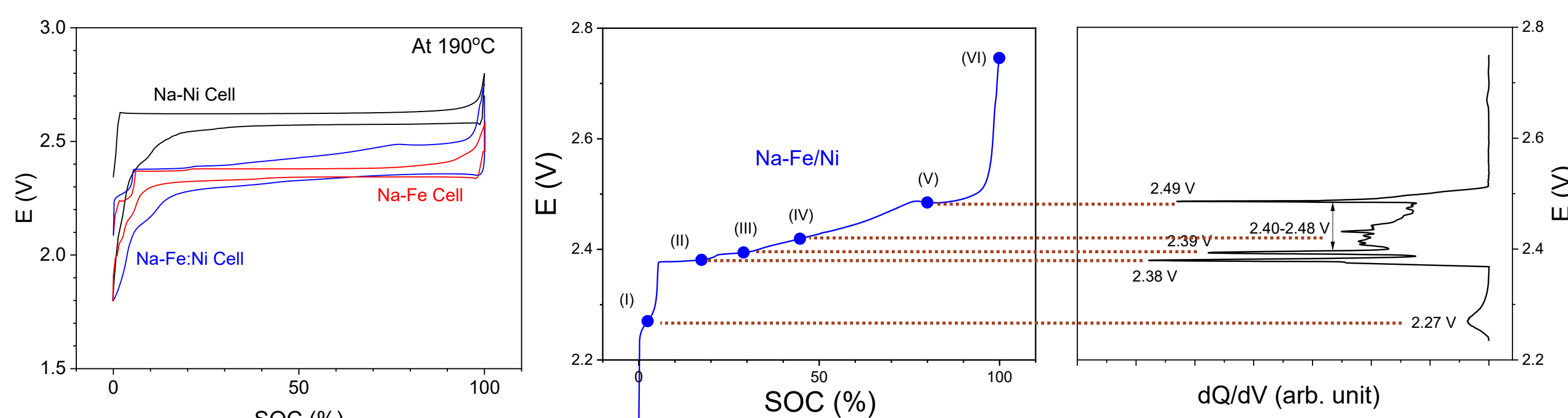


Invar powder (64%Fe / 36%Ni, ~45 μm) / NaCl powder = 1.8 / 1

Fe/Ni cathode activation

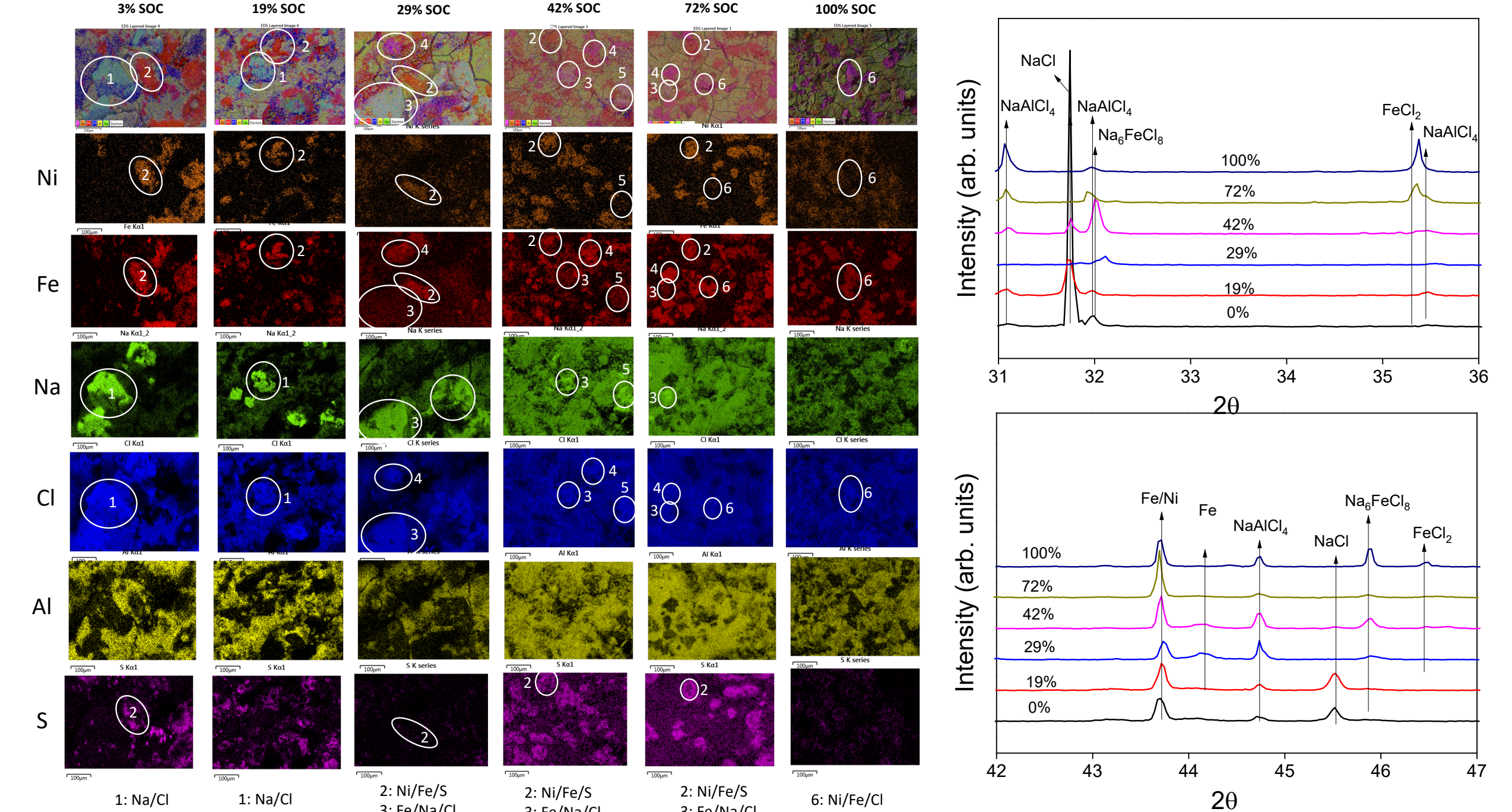


Battery performance of Invar cathode

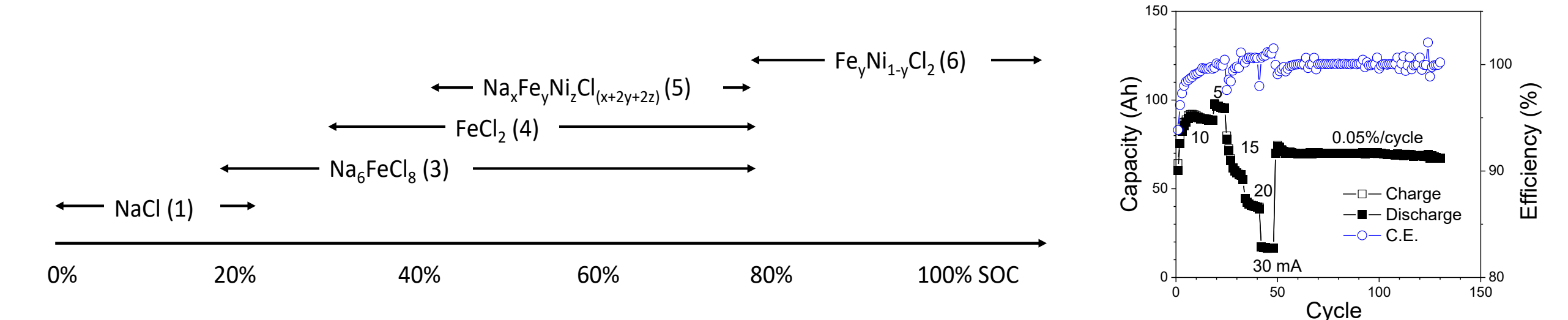


- I (2.27 V) : Sulfur based redox
- II and III (2.38 & 2.39 V): Na_6FeCl_8 & FeCl_2
- IV and V (2.40-2.48V & 2.49 V): Possible contribution from both Fe and Ni

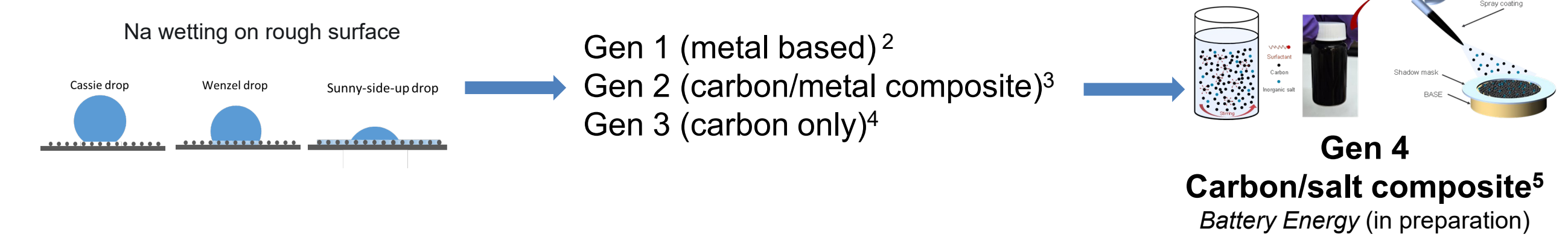
SEM/EDS and beamline XRD measurements



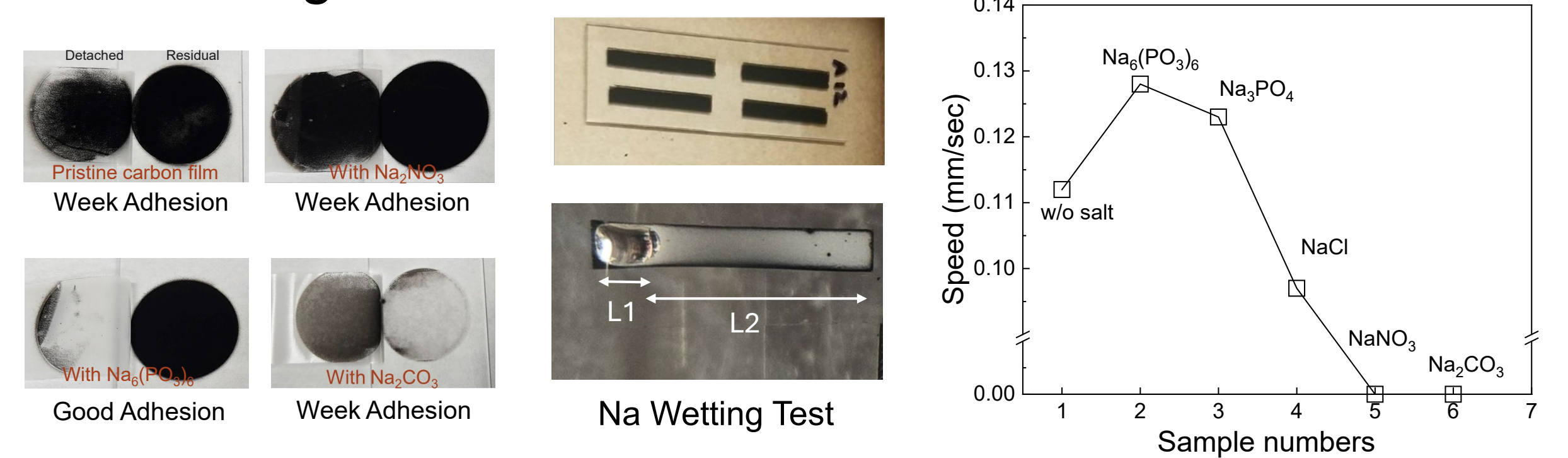
Cathode reaction mechanism & long-term cycling



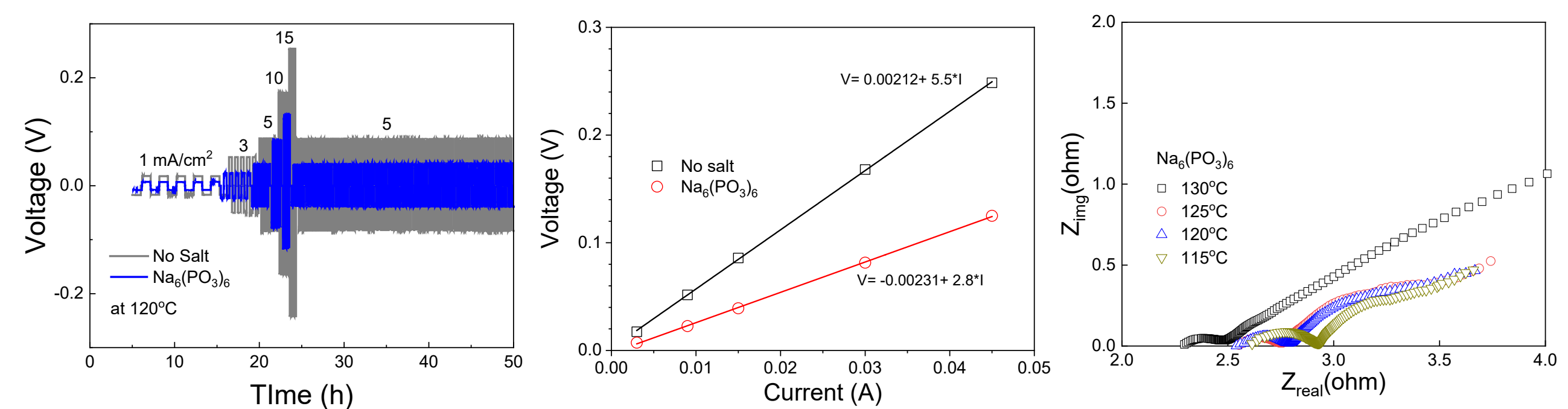
Superior Na Wetting



Na wetting test



Na symmetric cell testing



Future Works

- Advance the development of low-cost cathode materials, such as Fe and Al, while enhancing Na wetting at lower temperatures to achieve high-performance, safe, and reliable battery chemistries.
- Strengthening industry collaborations to enable scalable implementations

Acknowledgment

This material is based upon work supported by the U.S. Department of Energy, Office of Electricity (OE), Energy Storage Division. Pacific Northwest National Laboratory is a multiprogram national laboratory operated by Battelle Memorial Institute for the DOE under Contract DE-AC05-76RL01830.

Reference:

- Polikarpov, et al. *ACS Appl. Energy Mater.* (accepted).
- Chang, et al. *J. Mater. Chem* (2018); Li, et al. *Chem. Comm.* (2021).
- Li, et al. *ACS Appl. Mater. & Inter.* (2022); Weller, et al. *Nano Energy* (2024).
- Han, et al. *Battery Energy* (in preparation).

For additional information, contact:

Guosheng Li, Ph.D.
509-3716520
guosheng.li@pnnl.gov