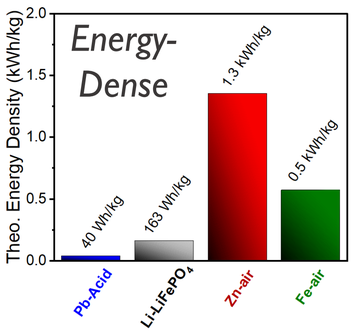
Sandia National Laboratories

FLOWING ZINC-AIR BATTERIES ENABLED BY NICKEL SULFOSELENIDE OXYGEN ELECTROCATALYSTS

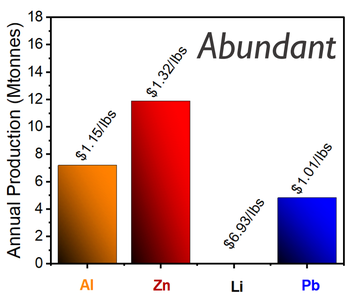
Bryan R. Wygant,[1*] Timothy N. Lambert[2,3†]

[1]Nanoscale Sciences, [2]Department of Photovoltaics & Materials Technologies, [3]Center for Integrated Nanotechnologies, Sandia National Laboratories, Albuquerque, New Mexico 87185, USA,
[*]bwygant@sandia.gov, [†]tnlambe@sandia.gov

Background

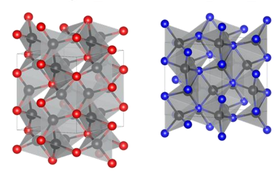


- Zn-air (and other metal-air chemistries) are promising earth-abundant alternatives to Li-ion batteries, and use non-flammable aqueous electrolytes



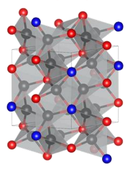
Aqueous and *Non-flammable*

Ni_3S_2 Ni_3Se_2



Tunable Chemistry and Properties

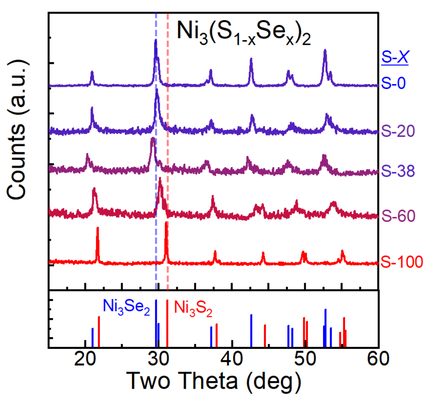
$Ni_3S_{(2-x)}Se_x$



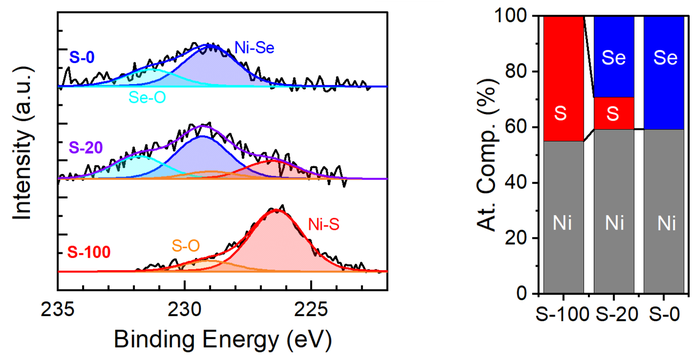
- Metal sulfoselenides (MSSe) are bifunctional oxygen electrocatalysts (BOEs) that are earth-abundant alternatives to monofunctional precious metals (e.g., Pt)

Nickel Sulfoselenide Materials

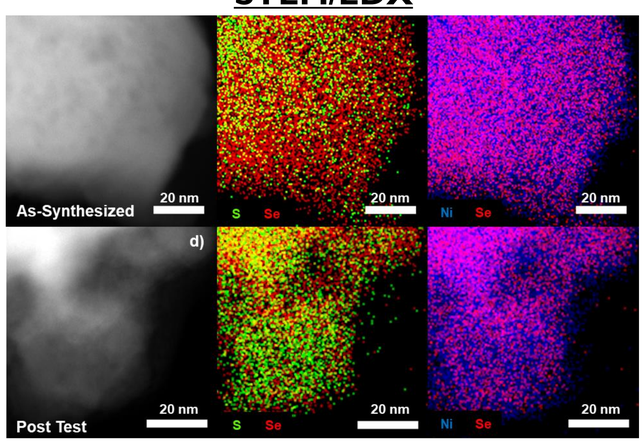
XRD



XPS



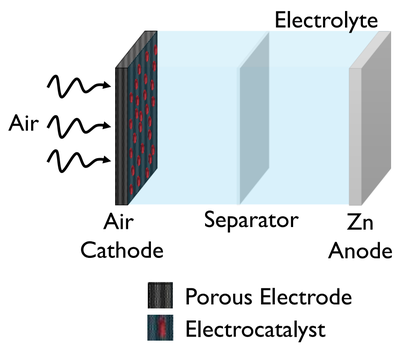
STEM/EDX



- Hydrothermal synthesis of phase pure Ni_3X_2 materials (X = S, Se)
- Testing under both OER and ORR conditions showed only minor differences in the elemental distribution

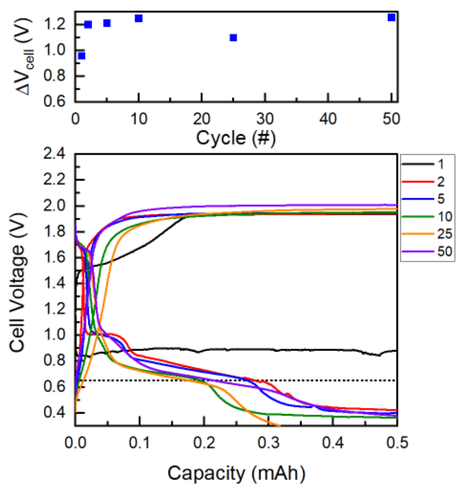
Cell Design and Development

Breathing ZAB

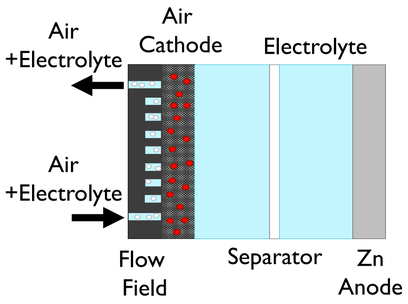


+ *Simple design/scalable*
+ *Minimal electrolyte*
× *Reliant on O_2 diffusion*
× *Evaporation of electrolyte*

- Design tested with Swagelok-style cell
- PTFE-coated electrode to allow air diffusion to Pt/C electrocatalyst
- Exhibited low current densities, high ΔV_{cell}, and electrolyte loss

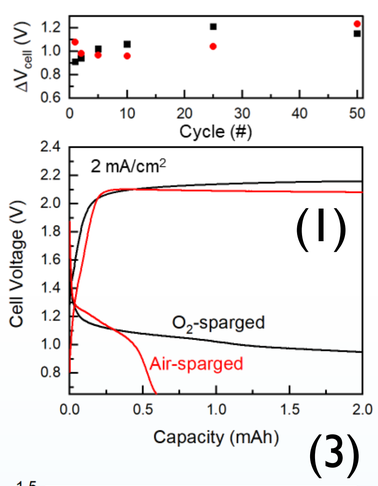


Flowing ZAB (*f*ZAB)

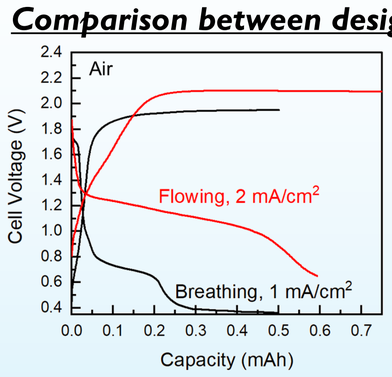


+ *Control over O_2 transport*
+ *Closed cell design*
× *Increased cell complexity*

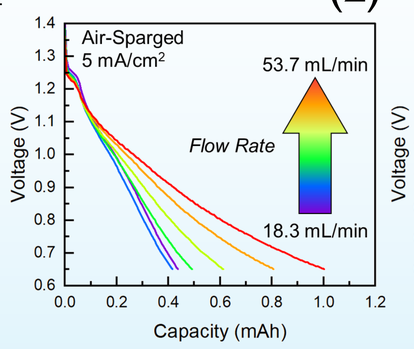
- Design tested with modified fuel cell and peristaltic pumps
- Performance improved by (1) changing feed gas, (2) flow rate, and means of (3) O_2 introduction (sparge vs. inject)



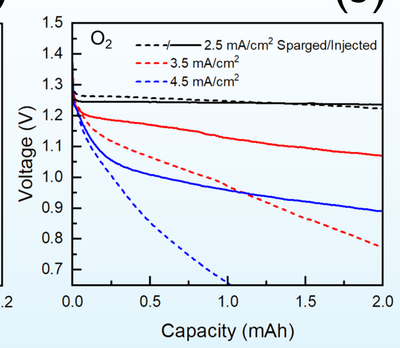
Comparison between designs



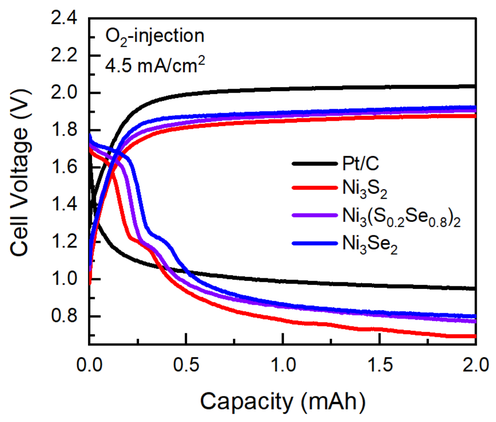
(2)

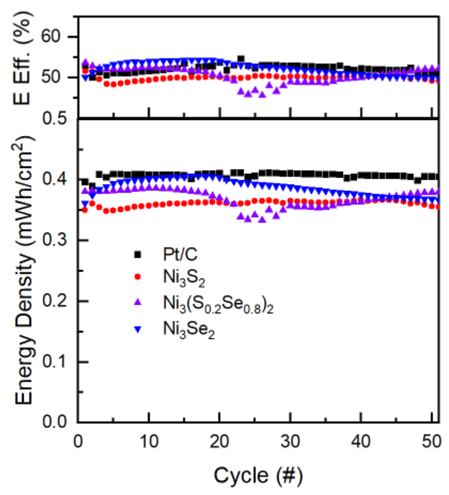


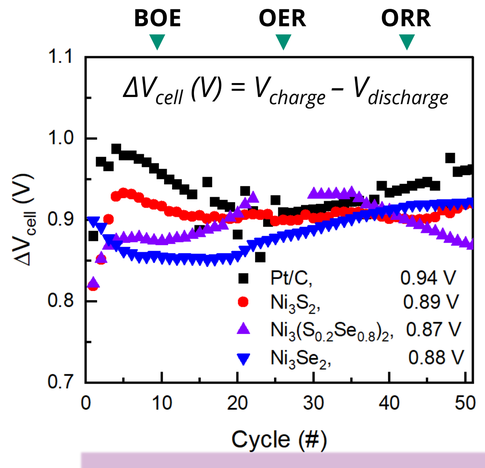
(3)



Peformance of NiSSe in ZABs







- Testing NiSSe BOEs against Pt/C, able to see obvious differences in charge/discharge
- ΔV_{cell} tends to be lower with increasing Se, to a point
- Energy efficiency still poor, need to increase capacity

Conclusions + Future Directions

1. *f*ZABs show improved performance over Breathing ZABs, allowing for better control over O_2 introduction and limiting evaporation
2. NiSSe BOEs can be used with the SNL *f*ZABs, and demonstrate better performance than Pt/C with S/Se tuning

What next?

- Improved flow *f*ZAB cell and flow field design should improve reliability and performance (i.e., rate) of *f*ZABs by enabling increased control of O_2 flow to the BOE
- Longer term, higher capacity cycling of NiSSe BOEs to approach 35 mW/cm²
- Development of Mn-based sulfoselenides to replace Ni

Wygant *et al.*, *ACS Catal.*, **2023**, *13*, 9245−9253

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.
This material is based upon work supported by the U.S. Department of Energy, Office of Electricity (OE), Energy Storage Division.

SAND2024-09343C

OFFICE OF ELECTRICITY ENERGY STORAGE PROGRAM

LDRD Laboratory Directed Research and Development

Sandia National Laboratories