# Towards Sustainable High-Performance Sodium-Ion Battery Cathodes

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## Introduction

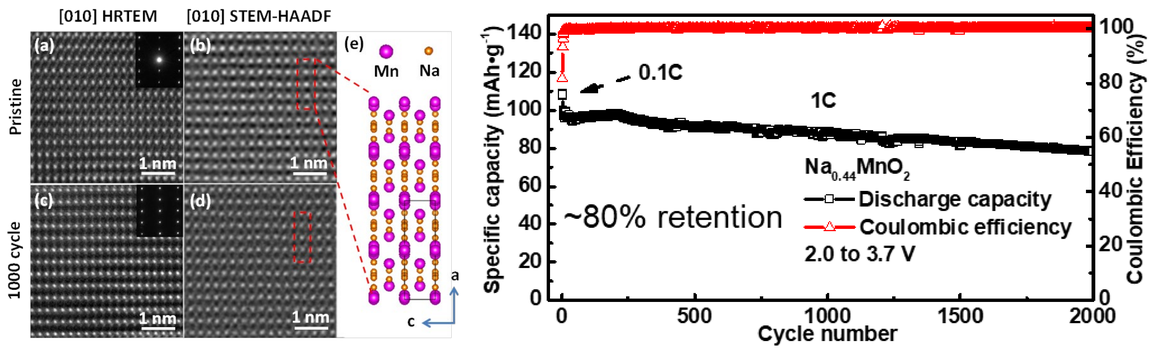
Sodium-ion batteries have similar architecture/mechanism as state-of-the-art Li-ion batteries and can be a drop-in technology to the existing manufacturing infrastructure. The abundance of sodium and other elements reduces some of the supply chain issues associated with lithium and other critical materials. Gravimetric energy densities are reported in the range of 100-200 Wh/kg making them a potential complementary/substitutional technology to lithium iron phosphate/graphite-based batteries. Sodium-ion batteries can have improved power and low-temperature performance over lithium-ion technologies and can be shipped uncharged (0% state of charge) for improved safety.

## Objectives and Methodology

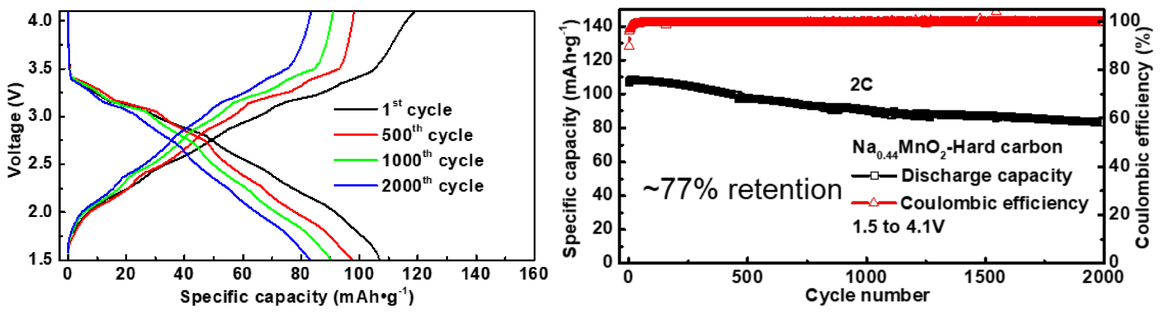
- ❑ Examine various chemistries towards high-performance and sustainable sodium-ion batteries
- ❑ Understand the cathode structures and electrode-electrolyte interactions
- ❑ Development of coin and single layer pouch full cells

## Results and Discussion

### $Na_{0.44}MnO_2/Na_4Mn_9O_{18}$ Cathodes



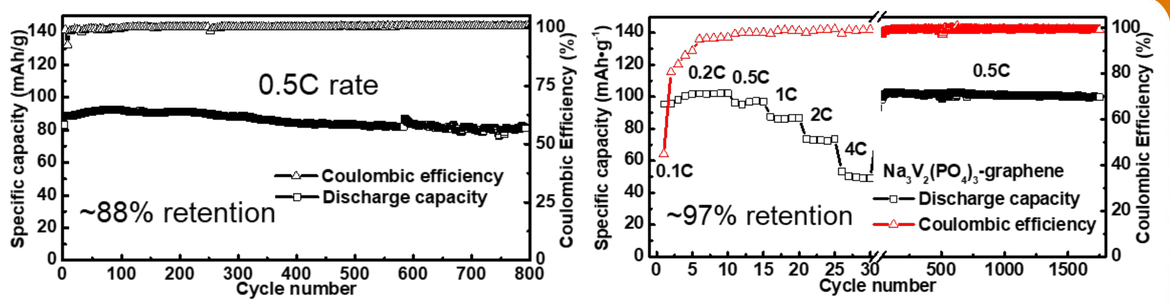

- The earth abundant cathode has stable structure over long-term cycling (1000 cycles).
- The capacity retention is ~80% after 1000 cycles in a half cell.




- The full cell demonstrated ~77% retention over long term cycling (2000 cycles).
- Pre-sodiation treatments need to be developed as the material is sodium deficiency.

### NASICON Structured $Na_3V_2(PO_4)_3$ Cathodes

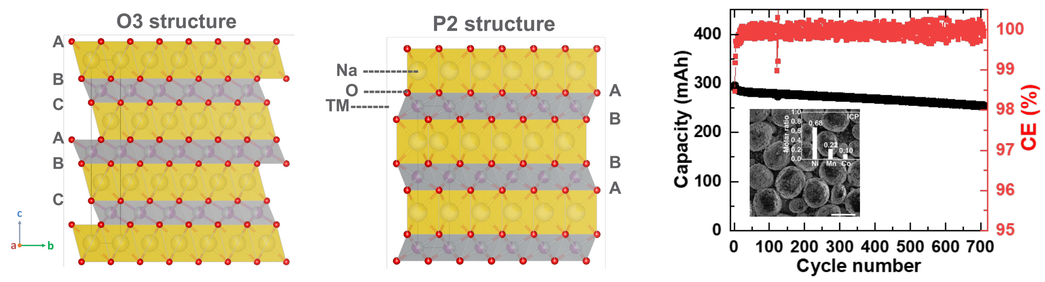
NASICON is sodium (**Na**) **S**uper **I**onic **CON**ductor. The polyanion class of materials with appropriate compositions can be high-performance, sustainable sodium-ion battery cathodes. While the materials usually have low electrical conductivity like the olivine lithium iron phosphate, proper control of the physical parameters such as primary particle size, carbon coating, or agglomeration can be essential towards the development of practical batteries.




- $Na_3V_2(PO_4)_3$ has average voltage of ~ 3.4V and long cycling stability. Graphene coated $Na_3V_2(PO_4)_3$ demonstrated improved rate performance and cycling stability with ~97% capacity retention over 1500 cycles.

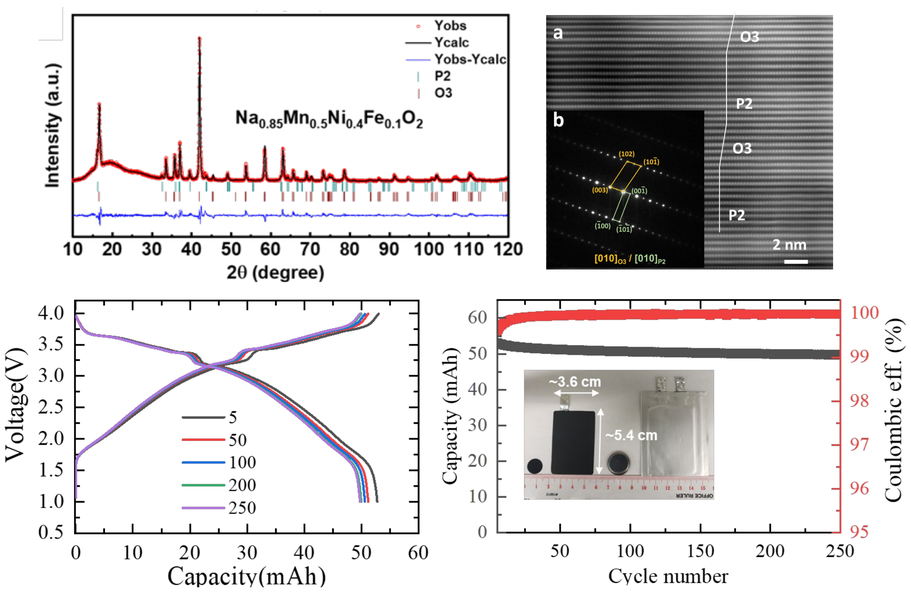
### Layered Oxide Cathodes

### Viability by $NaNi_{0.6}Mn_{0.2}Co_{0.2}O_2$ cathode material




- The O3 $NaNi_{0.6}Mn_{0.2}Co_{0.2}O_2$-hard carbon pouch cells (~300 mAh) delivered ~88% retention over 700 cycles. The viability of sodium-ion battery was demonstrated.

### $Na_{0.85}Mn_{0.5}Ni_{0.4}Fe_{0.1}O_2$ Cathode




- The single layer pouch cell of P2/O3 $Na_{0.85}Mn_{0.5}Ni_{0.4}Fe_{0.1}O_2$-hard carbon (~50 mAh) has demonstrated ~94% retention over 250 cycles.

## Summary and Future Work

- ❑ Various chemistries including layered oxide and polyanion cathodes have been developed for high-performance, sustainable sodium-ion batteries.
  - ✓ Pouch cells of long cycle life have been demonstrated.
- ❑ Future work will focus on large cell demonstration and further advancing the material sustainability and performance.

## Acknowledgements

This work is supported by the U.S. Department of Energy (DOE) Office of Electricity under contract No. DE-AC05-76RL01830 through Pacific Northwest National Laboratory Project No. 70247.

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