Pacific Northwest NATIONAL LABORATORY

Sodium-ion Battery Development

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Presentation 406

DOE-OE Peer Review
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U.S. DEPARTMENT OF ENERGY BATTELLE

Project overview

The time for Na-ion batteries

c&en TOPICS MAGAZINE COLLECTIONS VIDEOS JOBS

Sodium comes to the battery world

Sodium-ion technology is ready, cheap, and safe, but can it oust lithium ion?

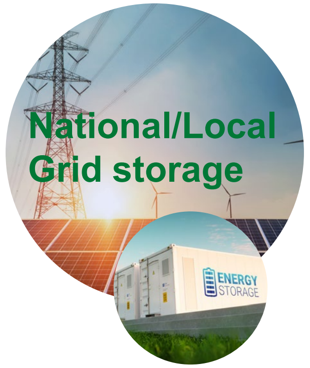
After lithium-ion batteries: sodium-ion batteries

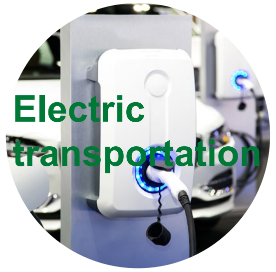
Government investment

NAIMA ~8M €, Dec. 2019 - Dec. 2022

THE FARADAY INSTITUTION
NEXGENNA
The next generation in sodium-ion batteries ~11.5M £, Oct. 2019 - Sep. 2023

SIMBA SODIUM-ION AND SODIUM METAL BATTERIES ~8M €, Jan. 2021 - Jun. 2024





Sodium-ion batteries go mainstream

Sodium-ion batteries are emerging as a viable alternative to lithium-ion technology. Industrial heavyweights CATL and Reliance Industries, following the acquisition of UK-based sodium-ion specialist Faradion, are bent on bringing the technology out of the lab and into mass production. Against a backdrop of soaring prices and predicted shortfalls of lithium-ion battery materials, sodium-ion chemistry has never been more tantalizing.

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Industry manufacturing

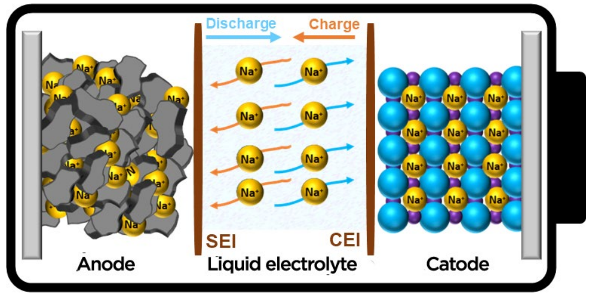
Company name	Website	Country
Faradion Limited (Bought by Reliance Industries)	https://faradion.co.uk/	UK
AMTE POWER	https://amtepower.com/energy-storage/	UK
Contemporary Amperex Technology Ltd. (CATL)	https://www.catl.com/en/	China
HiNa Battery Technology Co.Ltd	https://www.hinabattery.com	China
TIAMAT Energy	http://www.tiamat-energy.com/	France
Natron Energy Inc.	https://natron.energy/	US
Altris	https://www.altris.se/	Sweden
Natrium Energy	http://www.natriumenergy.cn/	China
Nanjing Nasco Energy Technology Co. Ltd.	http://www.nasico.cn/	China

https://cen.acs.org/business/inorganic-chemicals/Sodium-comes-battery-world/100/i19?ref=search_results
https://www.pv-magazine.com/magazine-archive/sodium-ion-batteries-go-mainstream/
https://www.biobasedpress.eu/2022/06/after-lithium-ion-batteries-sodium-ion-batteries/

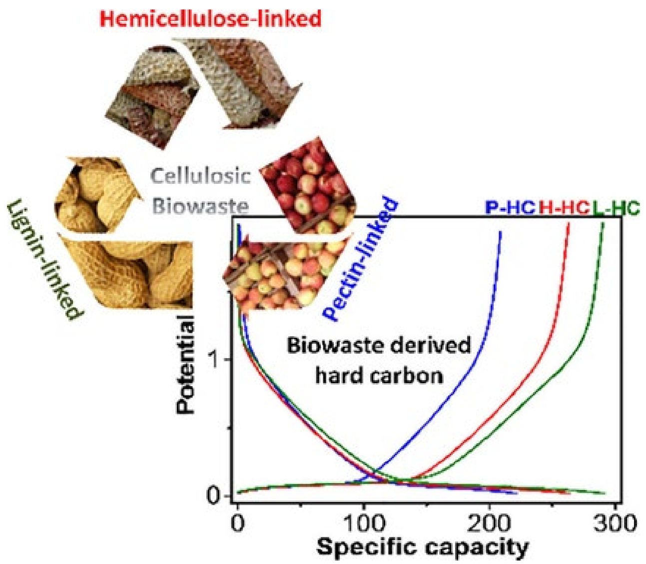
https://naimaproject.eu/
https://simba-h2020.eu/
https://www.nexgenna.org/

Project overview

Na-ion battery structure

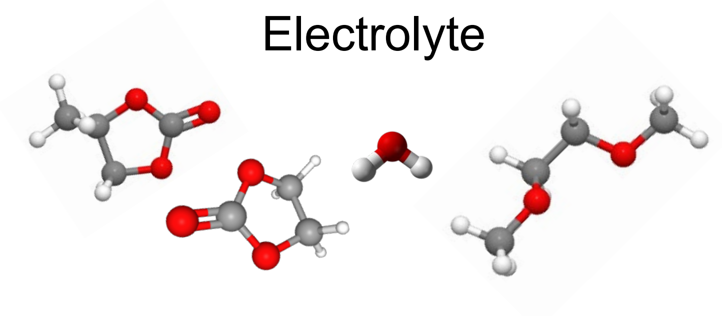


Anode



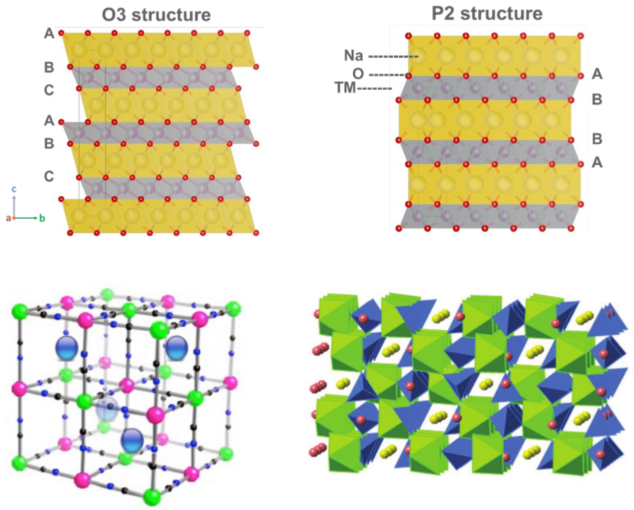
Carbonaceous anodes from biomass/biowastes; other anode choices

Electrolyte



Carbonate/ether/H_2O

Cathode



Diverse material choices using abundant elements

Na-ion battery has intrinsic advantages on material sustainability.

X.W. Dou, et al. ChemSusChem 2017, 10, 2668
https://www.euchems.eu/euchems-periodic-table/

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Project objectives

- Develop cost competitive, high-performance Na-ion batteries through thorough understanding of battery fundamentals.
  - Understand the mechanisms of battery fading in bulk structures and at interphases across time scales.
  - Develop Co-free layered cathode materials with reduced amount of Ni.
  - Develop high-performance hard carbon anodes
  - Materials scale up
  - Pouch cell fabrication and evaluation.

Project milestones in FY22

- **Milestone 1.**

  Develop a spray drying process for the synthesis of hard carbon (03/31/2022)
- **Milestone 2**

  Develop at least one low-cost sustainable cathode material (e.g., Mn-rich, Co-free) that can deliver > 140mAh/g specific capacity and > 80% retention over 200 cycles (06/30/2022)
- **Milestone 3.**

  Demonstrate Na-ion battery pouch cell of ~300 mAh using Co-free cathode and hard carbon anode (09/30/2022)
- **Milestone 4.**

  Publish 2 high impact journal articles on advanced Na-ion battery materials (09/30/2022)

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Achievements summary in FY22

Research highlights

- Hard carbon by spray drying biomaterial precursors can deliver a specific capacity of ~350 mAh/g and 1st cycle Coulombic efficiency of ~91%.
- Modified Gen-3 (Ni-low, Co-free) cathode material can deliver a specific capacity of ~150 mAh/g and > 80% retention over 200 cycles.
- Pouch cell with a capacity of ~300 mAh has been fabricated.

Publications

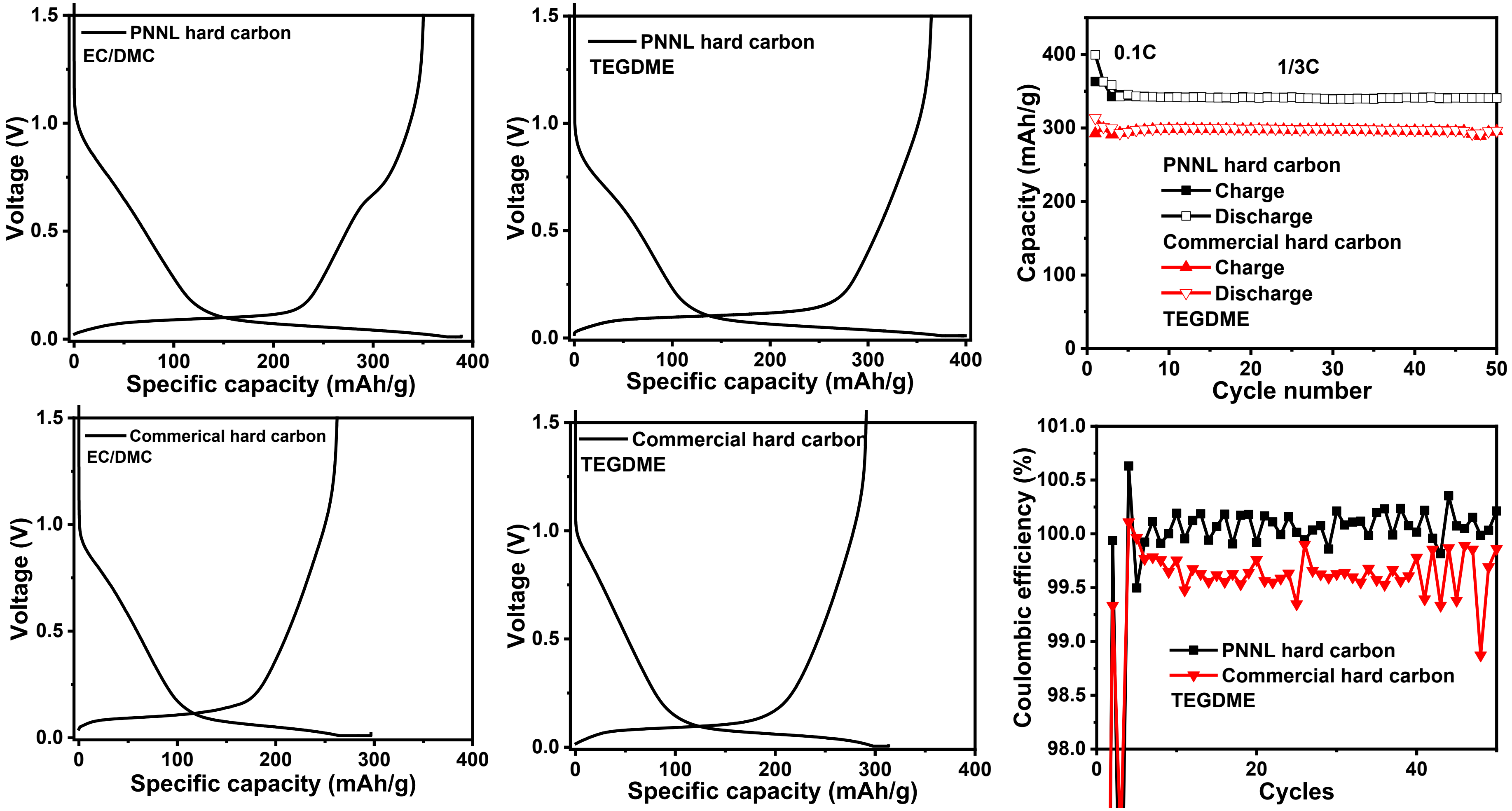
- B.W. Xiao, et al. Uncommon behavior of Li doping suppresses oxygen redox in P2-type manganese-rich sodium cathodes. ***Adv. Mater.*** 2021, 33, 2107141.
- Y. Jin, et al. Low-solvation electrolytes for high-voltage sodium-ion batteries. ***Nature Energy*** 2022, 7, 718
- Y. Jin, et al. Stabilizing interfacial reactions for stable cycling of high-voltage sodium batteries. ***Adv. Funct. Mater.*** 2022, 2204995.
- L.-J. Jhang, et al. Stable all-solid-state sodium-sulfur batteries for low-temperature operation enabled by sodium alloy anode and confined sulfur cathode. ***Under review***.

Professional activities

- An invited talk at the *International Workshop on Na-Ion Battery*
- A poster presentation at *Gordon Research Conferences*
- Organized the symposium of “*Advanced materials and chemistries for low-cost and sustainable batteries*” for the *2021 MRS fall meeting*

Project achievements in FY22 (1)

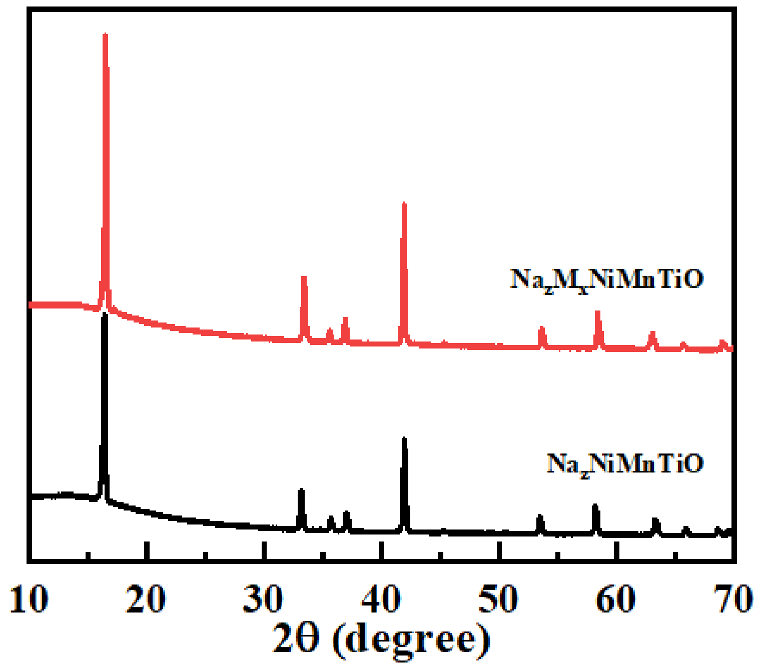
PNNL hard carbon vs. commercial hard carbon

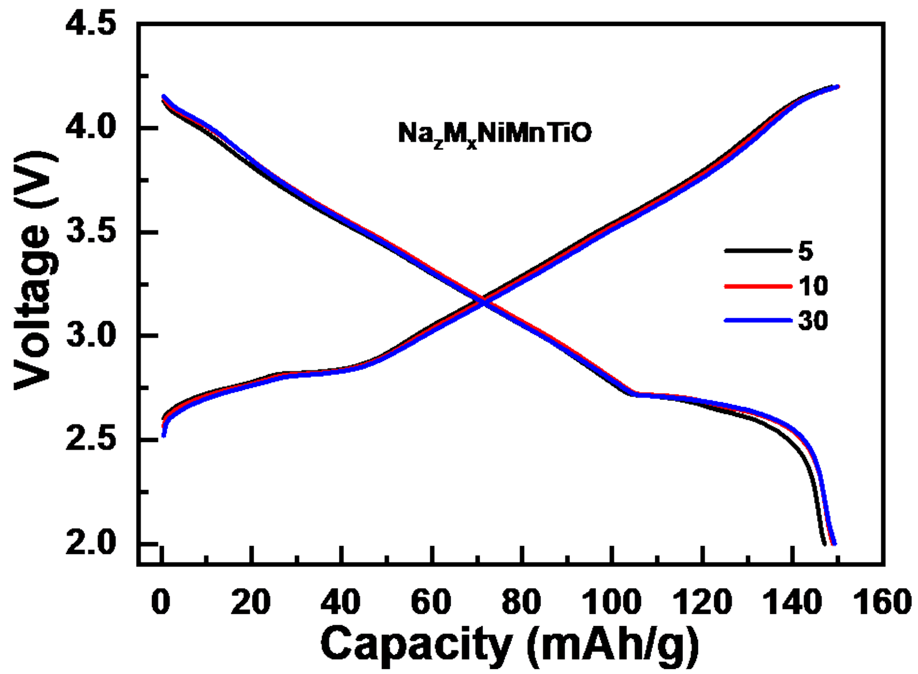


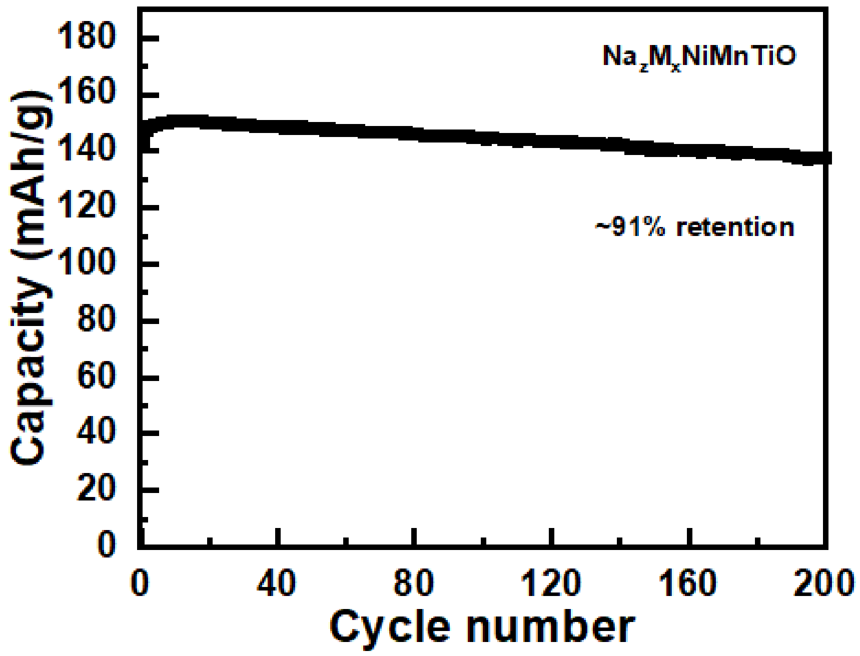
- PNNL hard carbon by spray drying can deliver a specific capacity of ~350 mAh/g in EC/DMC and TEGDME electrolytes.
- The 1st cycle Coulombic efficiency (CE) in both electrolytes can be >90%, higher than commercial hard carbon.
- PNNL hard carbon by spray drying shows good cycling stability and the CE at stable cycling reaches >99.8%.

Project achievements in FY22 (2)

Modified Gen-3 cathode



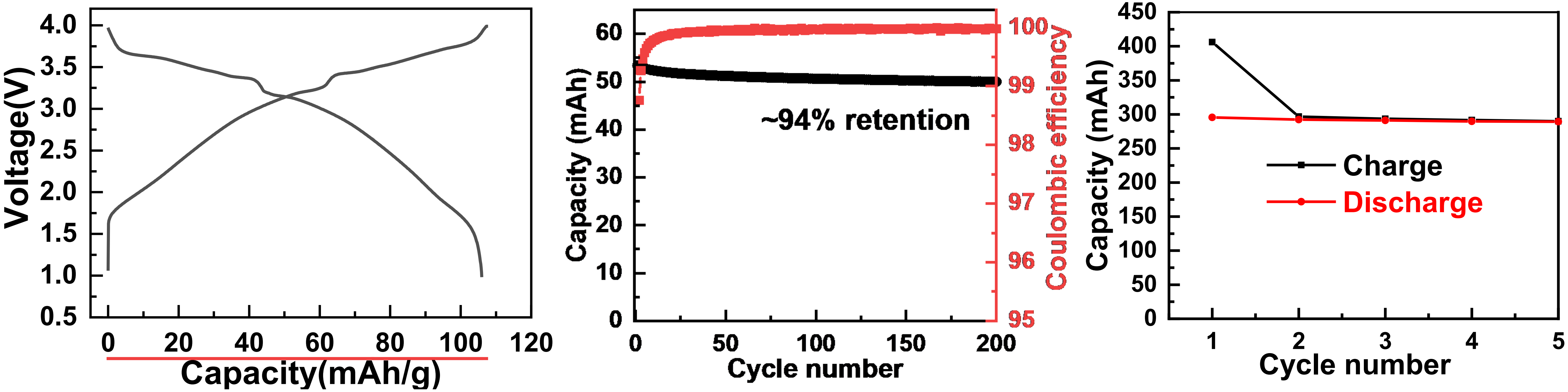




- Gen-3 cathode with further element doping can deliver a high specific capacity of ~150 mAh/g between 2-4.2 V.
- The half cell capacity retention can reach ~91% over 200 cycles.

Project achievements in FY22 (3)

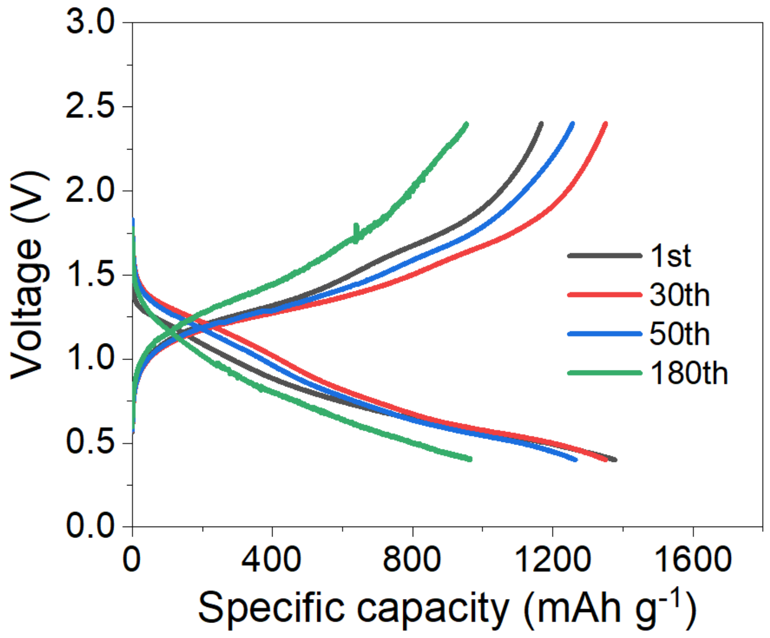
Gen-3 cathode - hard carbon pouch cell

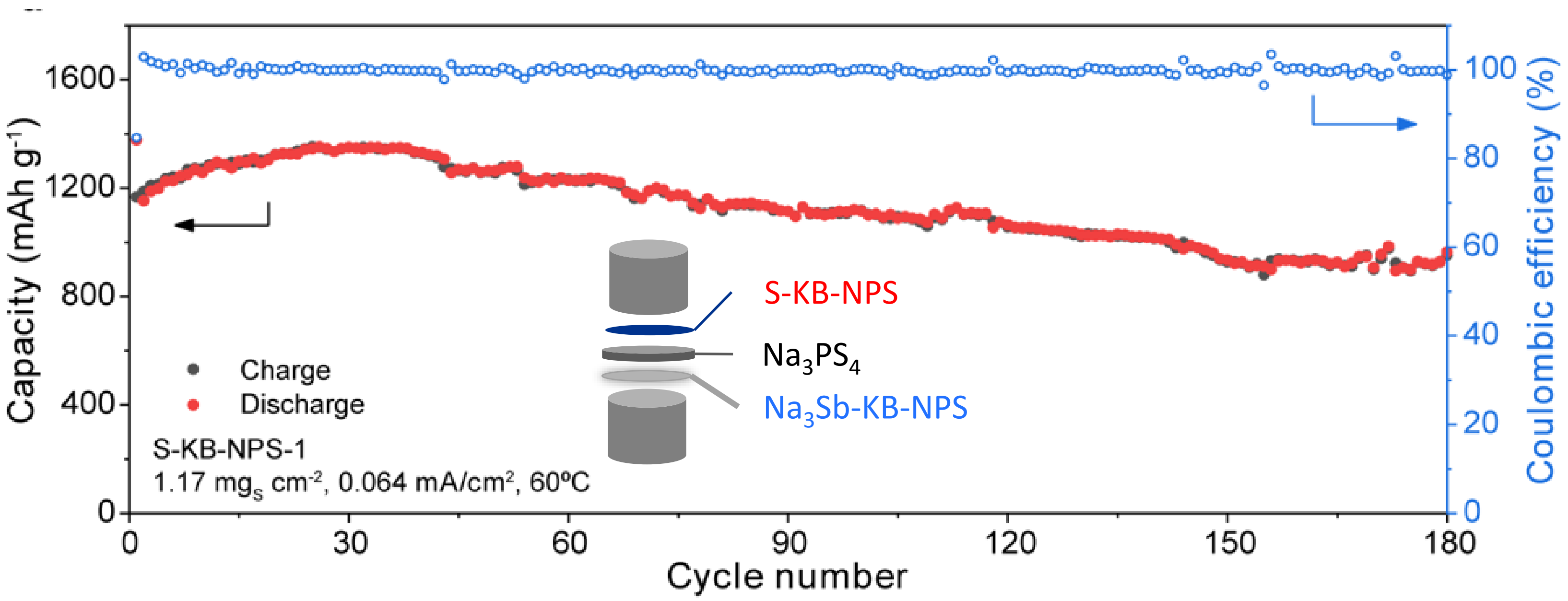


- The specific capacity based on the cathode material is ~ 108 mAh/g.
- Single-layer pouch cell with a capacity of ~50 mAh has ~94% retention over 200 cycles.
- Pouch cell with a capacity of ~300 mAh demonstrated good stability in the initial cycling.

Project achievements in FY22 (4)

All-solid-state sulfur-sodium alloy batteries





- The all-solid-state batteries using sodium alloy anodes, sulfur cathodes and sulfide-based solid electrolyte are expected have reduced material cost and improved safety.
- The full cell demonstrated high sulfur utilization degree and good cycling stability at low operation temperature of 60 °C.

L.-J. Jhang, et al. Stable all-solid-state sodium-sulfur batteries for low-temperature operation enabled by sodium alloy anode and confined sulfur cathode. *Under review*.

Proposed work for FY23

- Scale up the Co-free and low Ni Gen-3 cathode material and the spray drying hard carbon material.
- Systematically evaluate the material cost and performance of the pouch cells using Gen-3 cathodes and hard carbon anodes.
- Improve the performance of modified Gen-3 cathode materials.

Project team

❑ **PNNL contributors**

- Fredrick Omenya*
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- Hyungkyu Han
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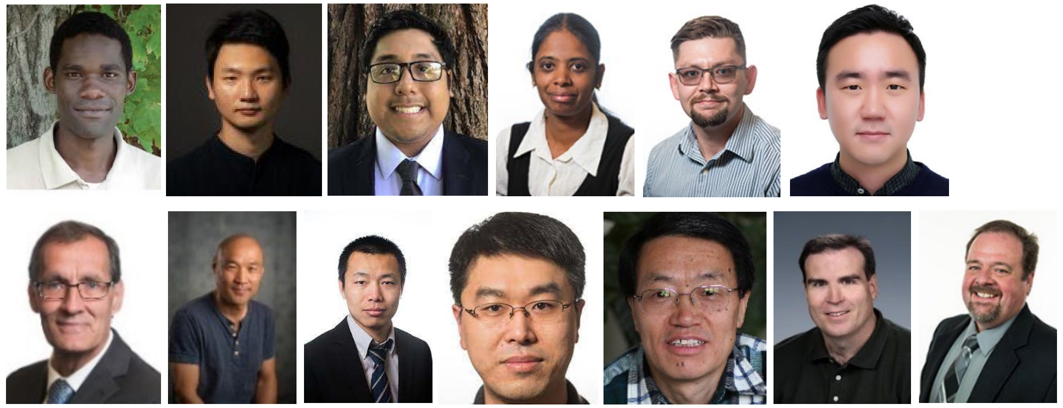
- Kee Sung Han
- Yaobin Xu
- Peiyuan Gao
- Chongmin Wang
- David Reed
- Vincent Sprenkle



❑ **External collaborators**

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PennState

- Prof. Perla Balbuena

TEXAS A&M UNIVERSITY

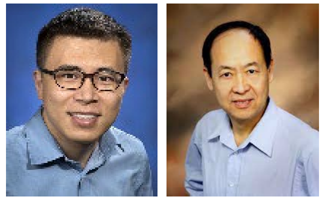
- Dr. Guiliang Xu & Khalil Amine

Argonne NATIONAL LABORATORY

- Dr. Wanli Yang

BERKELEY LAB Lawrence Berkeley National Laboratory

- Dr. Enyuan Hu & Xiaoqing Yang



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Thank you!