Room Temperature Na-ion Battery Development

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Energy Storage Program

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Project Overview

Energy Storage Challenge

- Na-ion battery has been regarded as a low cost high efficiency energy storage device and significant effort has been made on the development of electrode materials. However, demonstration of low cost long stability full-cell battery remains a significant challenge and limits further understanding and deployment of the technology.

Project Objective

- To develop low cost Na-ion batteries with similar performance to Li-ion batteries and to utilize the already existing facilities/capabilities for Li-ion battery manufacturing.

Accomplishments

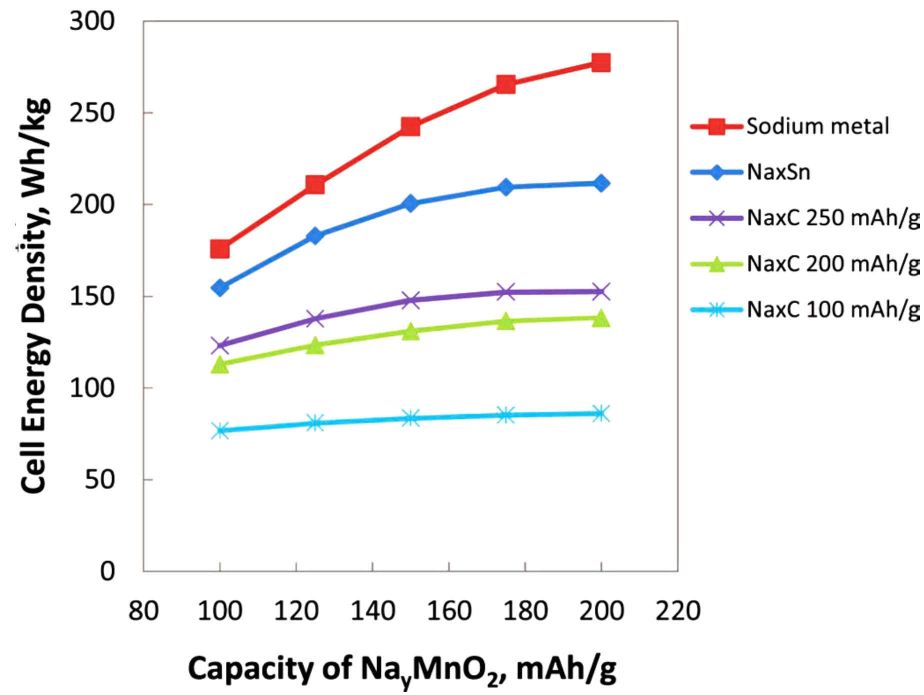
- Investigated key factors that enable long stability Na-ion battery full-cells including the cathode and anode stability and the solid electrolyte interphase (SEI) layer on electrode-electrolyte interfaces.
- Understand the Na-ion storage in hard carbon and develop advanced electrolyte to improve the rate performance and first cycle Coulombic efficiency of hard carbon anodes.
- 2 publications under preparation, 1 patent/application (to date)

Why Na-ion Batteries

Na-ion batteries are potentially low cost and high efficiency energy storage devices.

Advantages:

- High energy density[1,2,3]
  - e.g. >300 Wh/kg (material level estimation)
  - ~150 Wh/kg (cell level estimation)
- Na sources are more abundant than Li and geographically uniformly distributed
  - Li_2CO_3 (~$5000/ton) v.s. Na_2CO_3 (~$150/ton)
- Operate at room temperature
- Na-ion battery can be thermally more stable than Li-ion battery even though Na metal is more active than Li.[4]



Energy densities for various Na-ion systems
*Standard Li-ion cell energy density calculated with the same technique range from 160 to 210 Wh/kg.

Challenges:

- Similar problems to Li-ion batteries
  - e.g. cathode, anode, electrolyte, interface
- Na-ion is ~30% larger than Li-ion in diameter and ~2 times heavier.
- Na metal standard electrode potential is ~0.3V higher than Li.
- Full-cell demonstration

1. M. Slater, et al. Adv. Funct. Mater. 2013, 23, 947.
2. S. P. Ong, et al. Energy Environ. Sci.. 2011, 4, 3680.
3. N. Yabuuchi, et al. Chem. Rev., 2014, 114, 11636
4. J. Zhao, et al. J. Power Sources, 2013, 244, 752.

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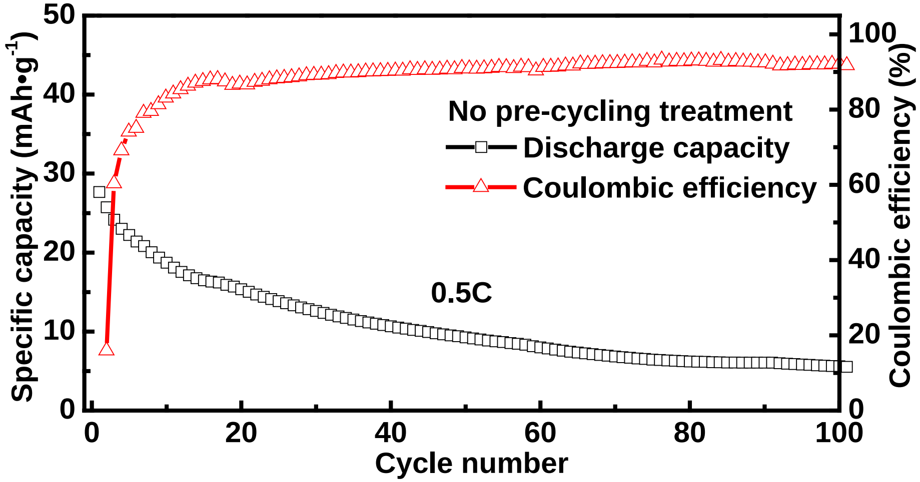
Our challenge

Without pre-treatment of the cathode and anode, $Na_{0.44}MnO_2$ – hard carbon full-cell shows low capacity and fast capacity fade.



- ➢ Our work is to understand the key factors that enable a long stability and to figure out how to get it work for pristine materials.

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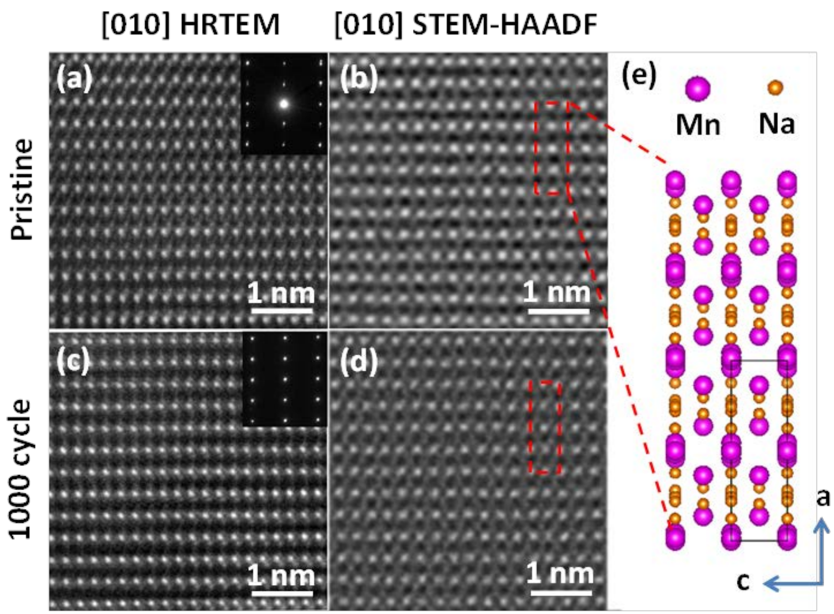
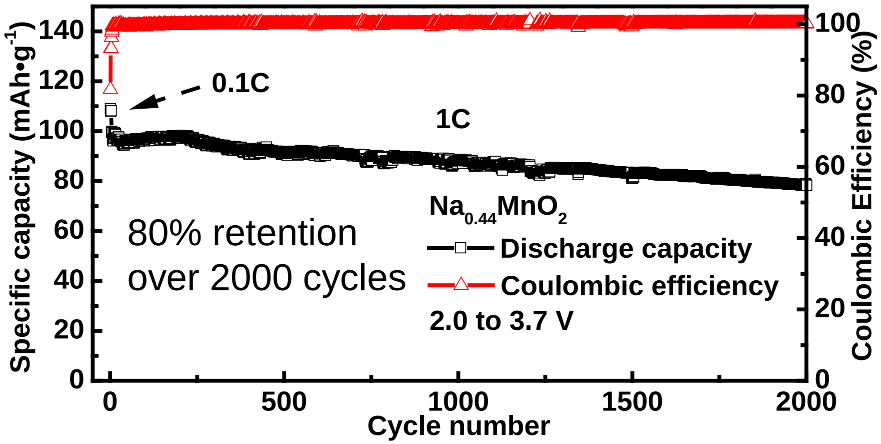
Cathode stability

The $Na_{0.44}MnO_2$ cathode structure is very stable.





- The structure of $Na_{0.44}MnO_2$ doesn't change much even after 1000 cycles.
- It has very good half-cell performance with a specific capacity of ~100 mAh/g and capacity retention of ~80% over 2000 cycles at 1C rate (1C = 120 mA/g).

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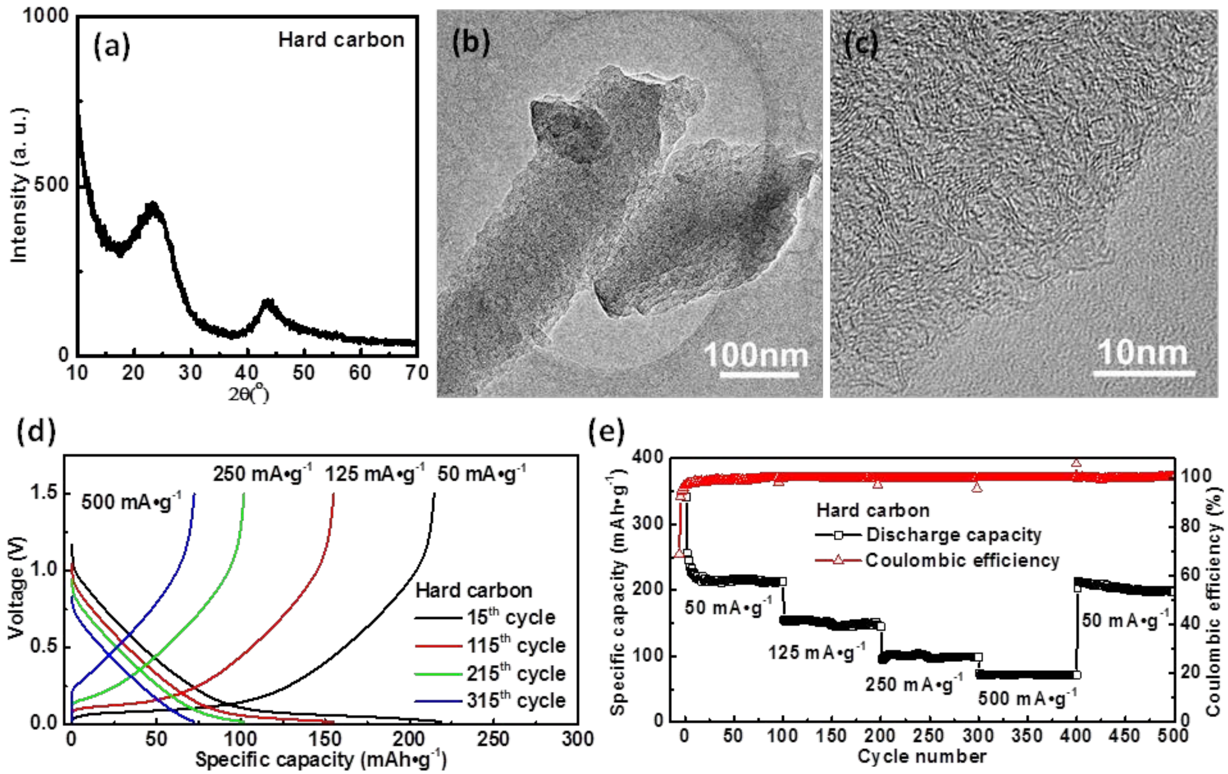
Anode stability

The hard carbon anode structure is also very stable.



- Hard carbon has a stable structure of highly disordered few-layer graphene stacks.
- It has good half-cell performance with a specific capacity of ~218, ~155, ~102, and ~72 mAh/g at different current densities of 50, 125, 250 and 500 mA/g.

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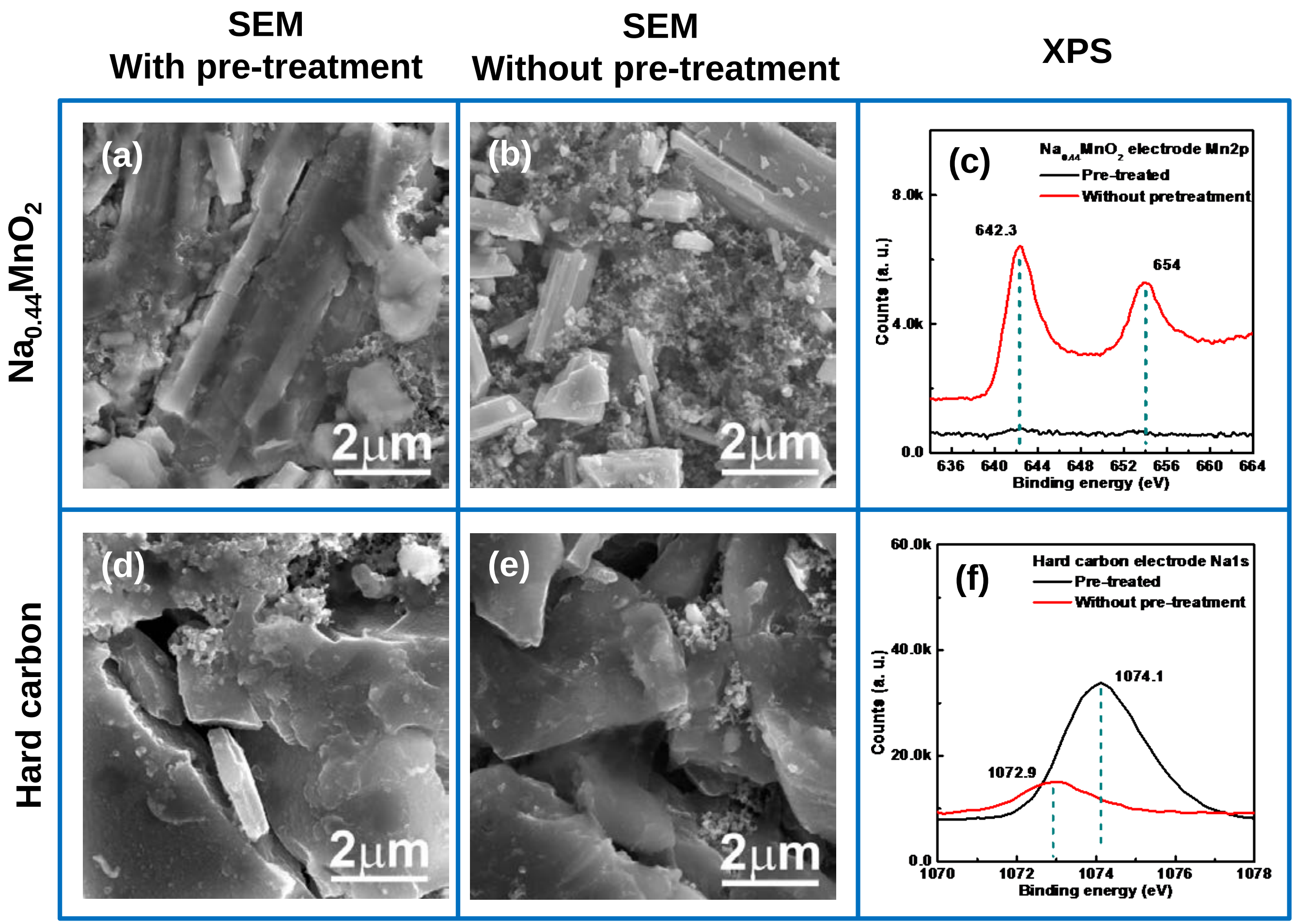
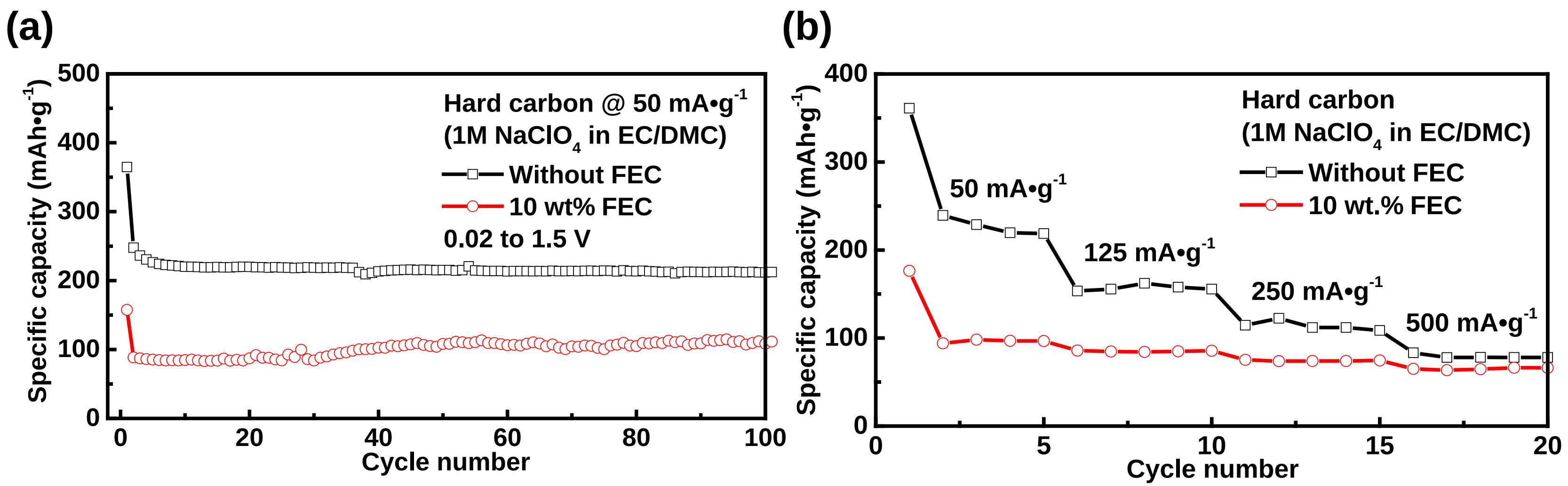
SEI on electrode/electrolyte interface



- A layer of solid electrolyte interphase (SEI) is formed on the surface of pre-cycled cathode and anode. It enables long stability full-cells together with the stable cathode and anode.

Electrolyte effect on Na-ion storage in hard carbon

Na-ion storage in hard carbon is very sensitive to the electrolyte composition.



- The Na-ion capacity in hard carbon becomes half with the addition of 10 wt% fluoroethylene carbonate (FEC) additive in the electrolyte. The rate performance also is affected.
- Electrolyte not only serves as ion transfer media, but also determines the SEI property at the electrode/electrolyte interface. Hence, it is important to understand/control the electrolyte composition and SEI formation.

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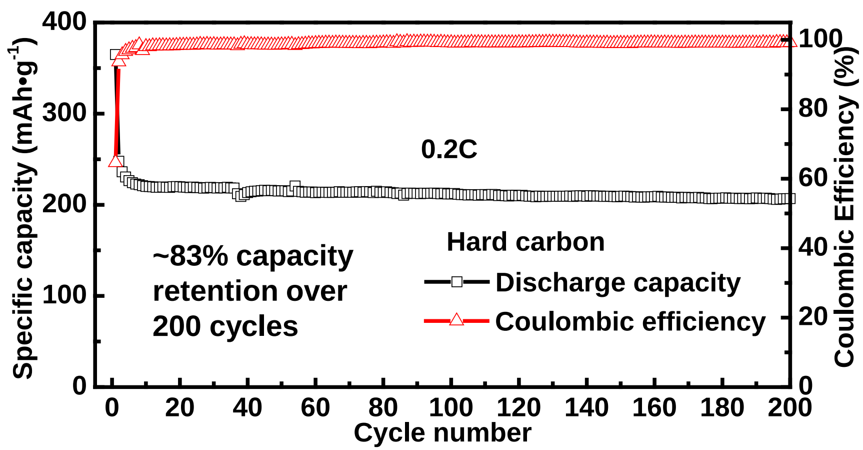
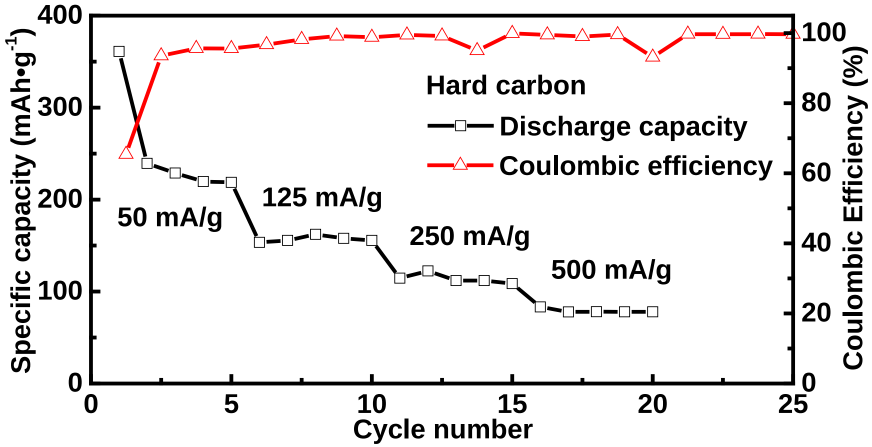
Hard carbon in baseline electrolyte





- Hard carbon in baseline electrolyte shows good specific capacity and cycling stability. However, the first cycle Coulombic efficiency and rate performance are poor.

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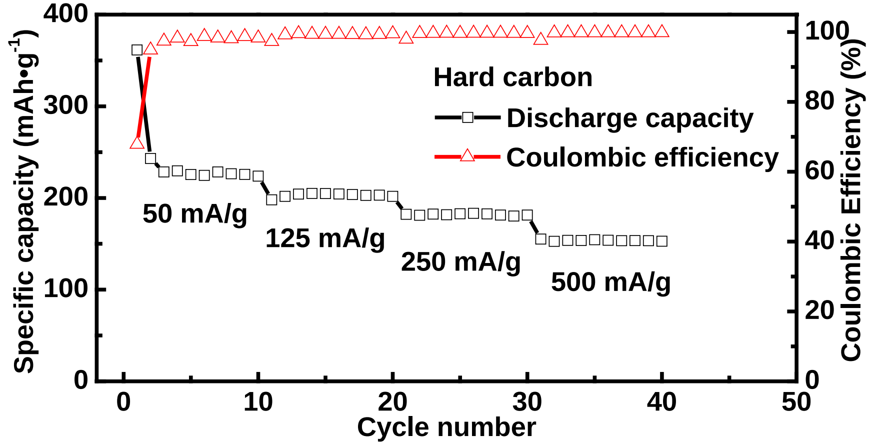
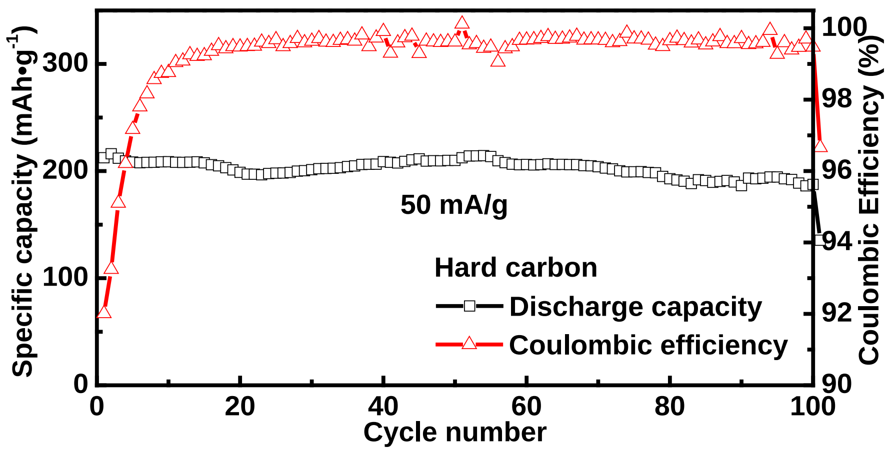
Hard carbon in advanced electrolyte





- Initial results show that hard carbon in advanced electrolyte has Improved first cycle Coulombic efficiency (from ~70% to ~92%) and rate performance (from ~100 to ~180 mAh/g at 1C rate) (1C= 250 mA/g).
- The specific capacity and cycling stability remain similar to it obtained in baseline electrolyte.

Summary

- The key factors for long stability Na-ion battery full-cells are investigated. In addition to the stable cathode and anode materials, the SEI is found important to ensure long life Na-ion batteries.
- The Na-ion storage in hard carbon anodes was investigated, particularly the electrolyte effect. With the advanced electrolyte, the rate performance and first cycle Coulombic efficiency of hard carbon anodes are improved greatly while the specific capacity and cycling stability remain similar.

Future work

- Development of high performance Na-ion battery anode materials.
- Demonstration of high performance Na-ion battery full-cells
- Material scale up for pouch cell fabrication
- Conduct long term testing for large scale materials
- Safety (heat generation) assessments and cost estimation (component cost).

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