Room Temperature Na-ion Battery Development

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Pacific Northwest National Laboratory

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Energy Storage Program

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Project Overview

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 in FY16

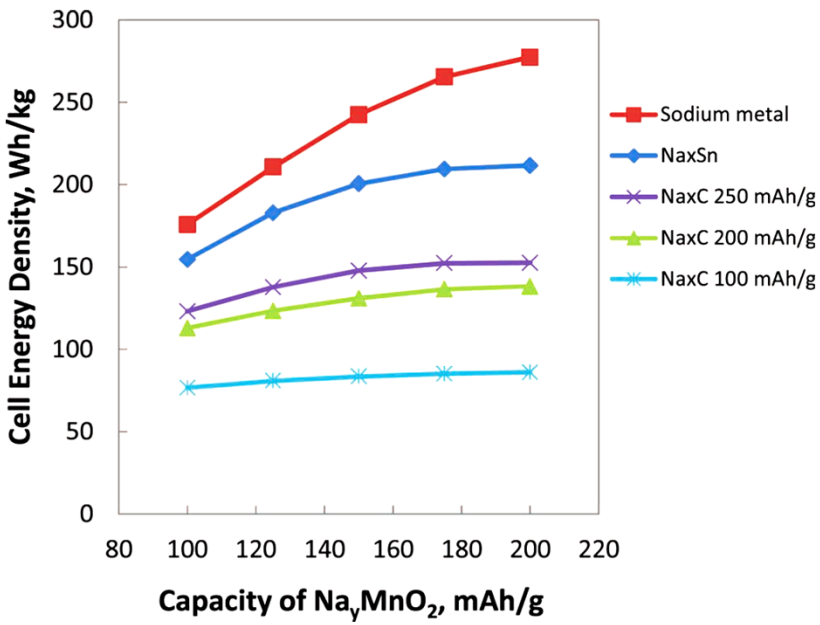
- Elucidated the critical role of hard carbon solid electrolyte interphase (SEI) layer on anode performance.
- Tuned the SEI with advanced electrolyte to enable high Coulombic efficiency and good rate performance of hard carbon
- Demonstrated high capacity and long cycling stability hard carbon nanowire anodes
- 3 papers published and 1 paper under review

Why Na-ion Batteries

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

Advantages:

- High energy density[1]
- Na sources are more abundant than Li and geographically uniformly distributed
- Operate at room temperature
- Al can be used as anode current collector
- Na-ion battery can be thermally more stable than Li-ion battery.[2]



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.

Current challenges:

Hard carbon currently is the most promising anode material in terms of overall electrochemical performance and cost. However, it has

- Limited Coulombic efficiency
- Poor rate performance at room and low temperature
- Mediocre specific capacity.

It is critical to improve the performance of hard carbon anode or develop other advanced anode materials.

1. M. Slater, et al. Adv. Funct. Mater. 2013, 23, 947.
2. J. Zhao, et al. J. Power Sources, 2013, 244, 752.

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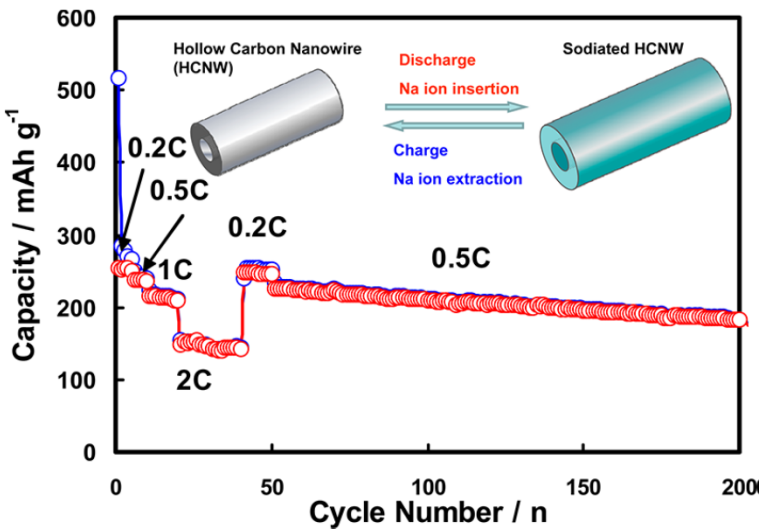
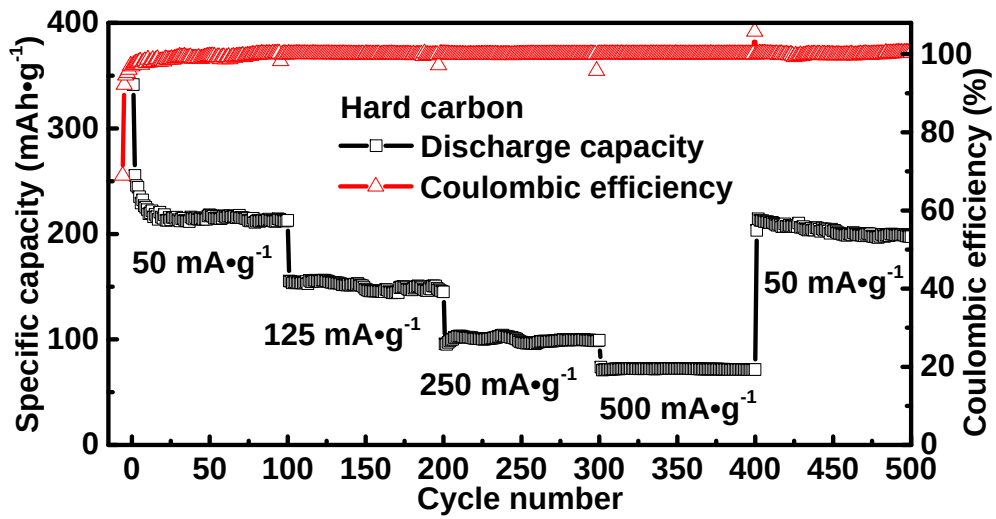
Overview of our previous work on hard carbon anode

Hard carbon nanowires



Commercial hard carbon



- We prepared hard carbon nanowires and demonstrated improved specific capacity (~250 mAh/g) and good cycling stability over 200 cycles.
- We tested different commercial hard carbon anodes and obtained good performance in terms of specific capacity (~250 mAh/g) and cycling stability.

1. Y.L. Cao, et al. Nano Lett. 2012, 12, 3783.
2. X.L. Li, et al. Nano Energy 2016, 27, 664.

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The challenge

- How to obtain high Coulombic efficiency for hard carbon anodes?
- How to deliver good rate performance?
- How to improve the low temperature performance?

What are the critical pieces missing?

Our work

- is to understand the key factors that enable a long stability and to figure out how to make it work for pristine materials.
- Investigate the effect of the SEI layer on hard carbon anode performance.
- Tune the SEI to enable high Coulombic efficiency and good rate performance at both room and low temperature conditions
- Demonstrate high capacity and long cycling stability hard carbon anodes

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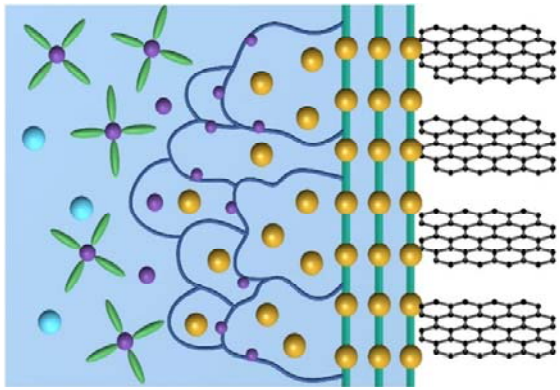
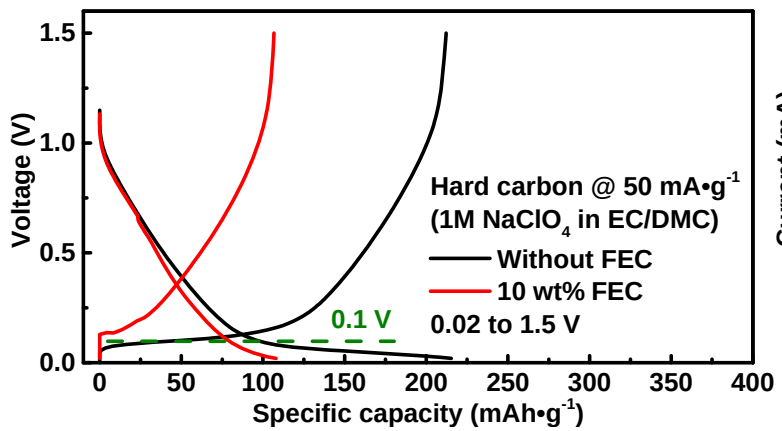
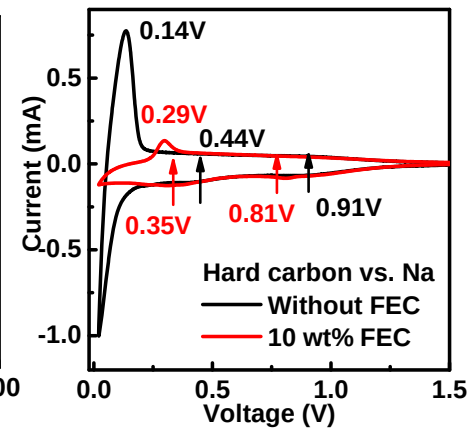
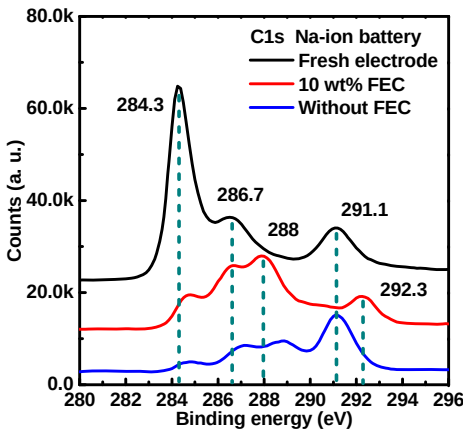
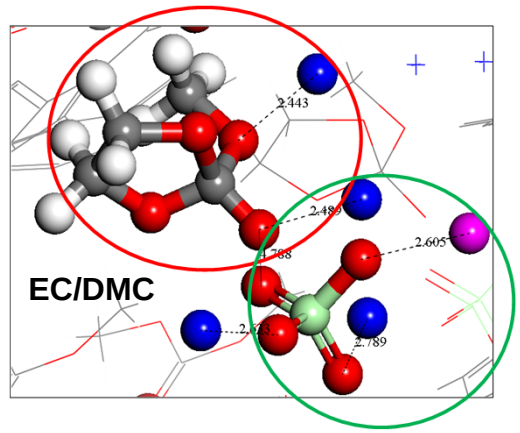
Na-ion transfer -- the anode SEI layer

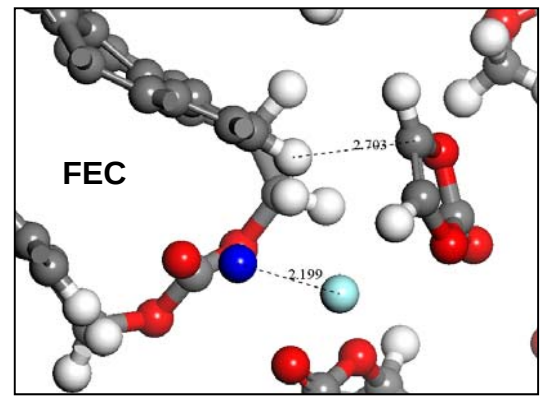












- Na-ion transfer is sensitive to the SEI layer at hard carbon surface.
- The SEI can be tuned by electrolyte or electrolyte additive and hence affects the Na-ion transfer properties and subsequent hard carbon anode performance.

X.L. Li, et al. submitted.

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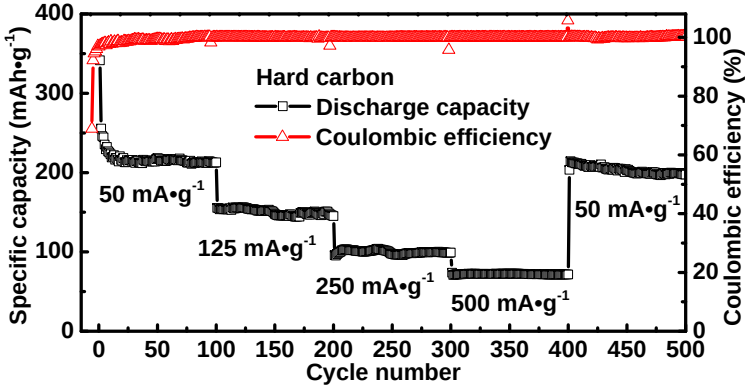
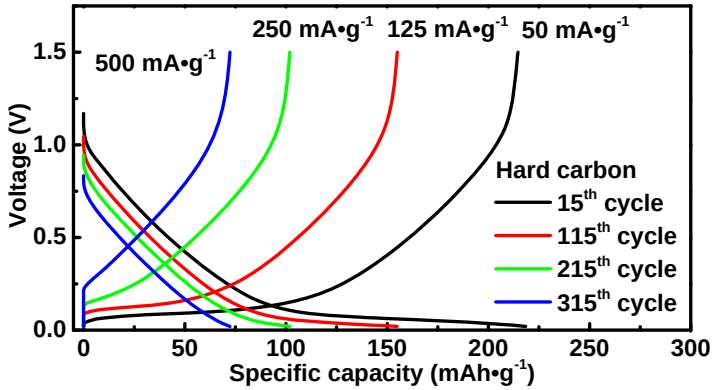
Tuning the SEI -- Rate performance

Baseline electrolyte

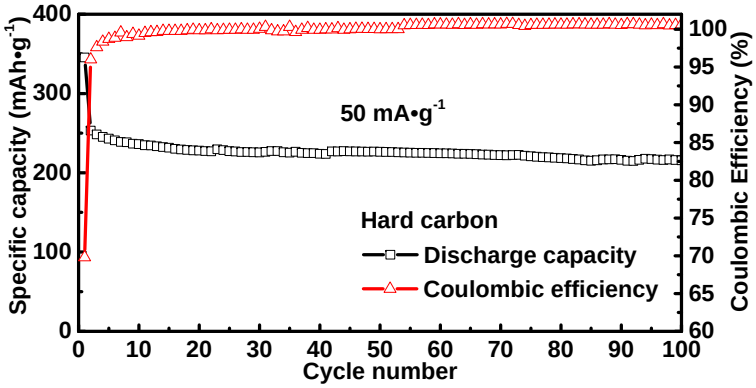


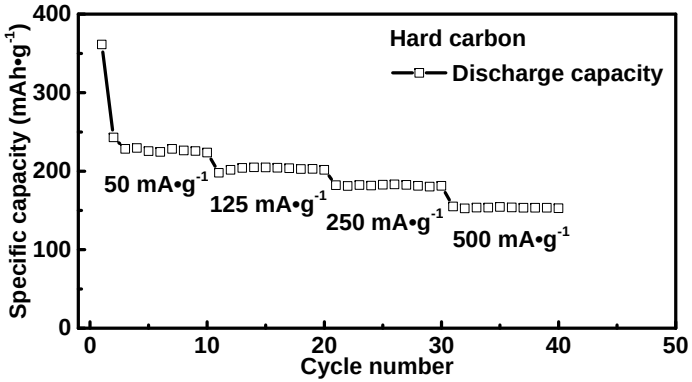


- High specific capacity
- Good cycling stability
- Poor 1st cycle Coulombic efficiency
- Poor rate performance

Poor rate performance between 0 to 0.1 V
Good rate performance between 0.1 and 1.5 V but decreased specific capacity.

Advanced electrolyte





- High specific capacity
- Good cycling stability
- Poor 1st cycle Coulombic efficiency
- Greatly improved rate performance

~180 mAh/g at 250 mA/g (1C rate).

X.L. Li, et al. Nano Energy 2016, 27, 664.

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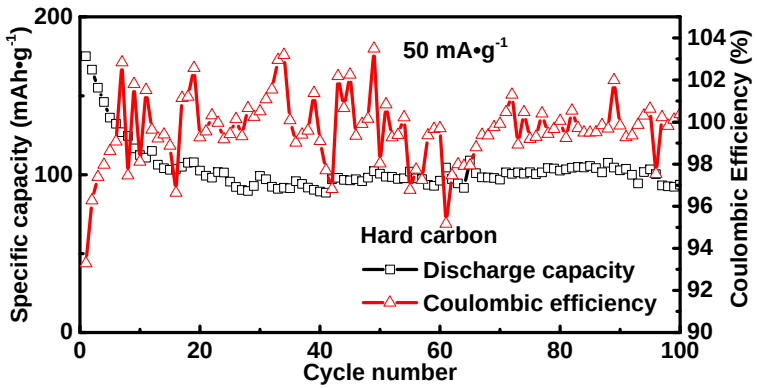
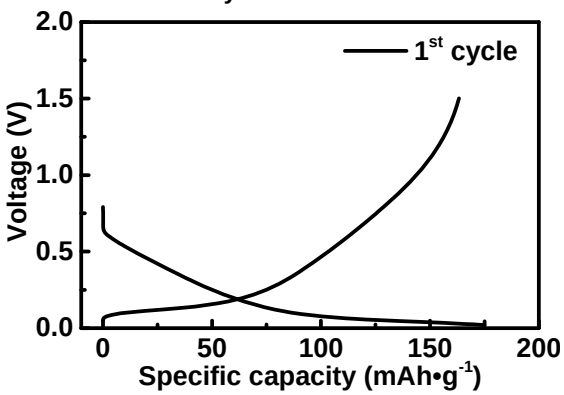
Tuning the SEI -- 1st Coulombic efficiency

(treatment with Li powder)

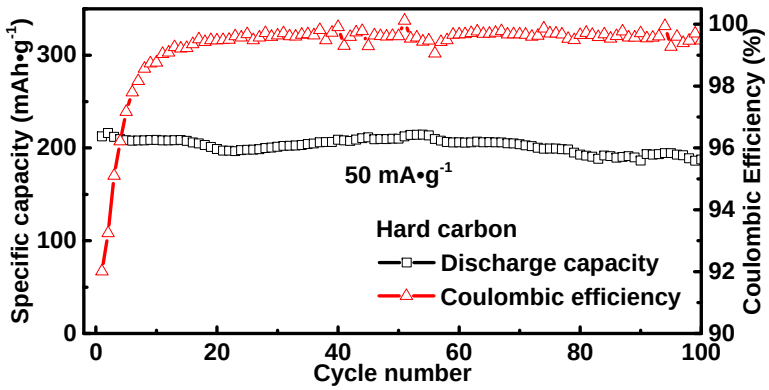
Baseline electrolyte

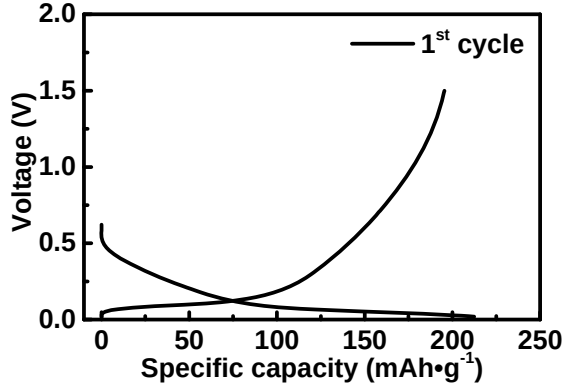




- OCV: ~790 mV
- 1st cycle Coulombic efficiency: ~93%
- Good cycling stability
- ~50% capacity of that without treatment

Advanced electrolyte





- OCV: ~622 mV
- 1st cycle Coulombic efficiency: ~92%
- Good cycling stability
- Similar capacity to that without treatment

X.L. Li, et al. under preparation.

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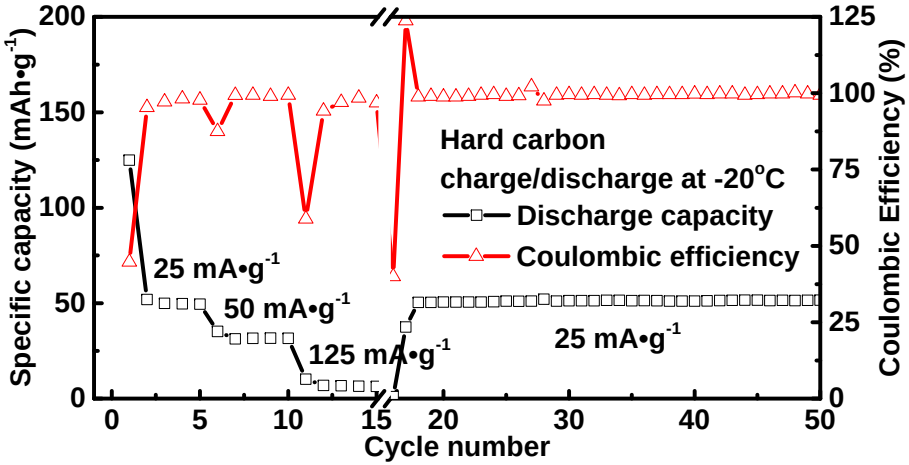
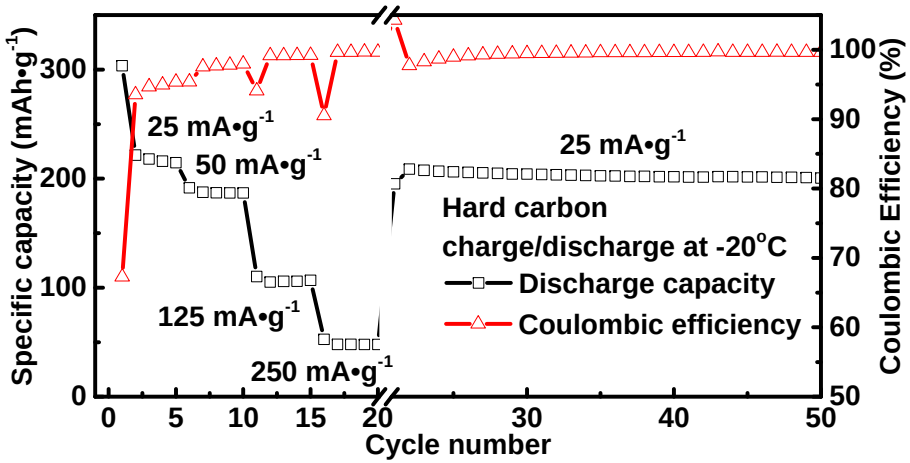
Tuning the SEI -- Low temperature performance

Low temperature carbonate electrolyte



Advanced electrolyte



- Greatly improved low temperature performance with advanced electrolyte
- Specific capacity: ~200 mAh/g at 25 mA/g vs. ~50 mAh/g at 25 mA/g
- 1st cycle Coulombic efficiency: ~65% vs. 44%
- Rate performance: ~50 mAh/g at 250 mA/g vs. ~50 mAh/g at 25 mA/g

X.L. Li, et al. under preparation.

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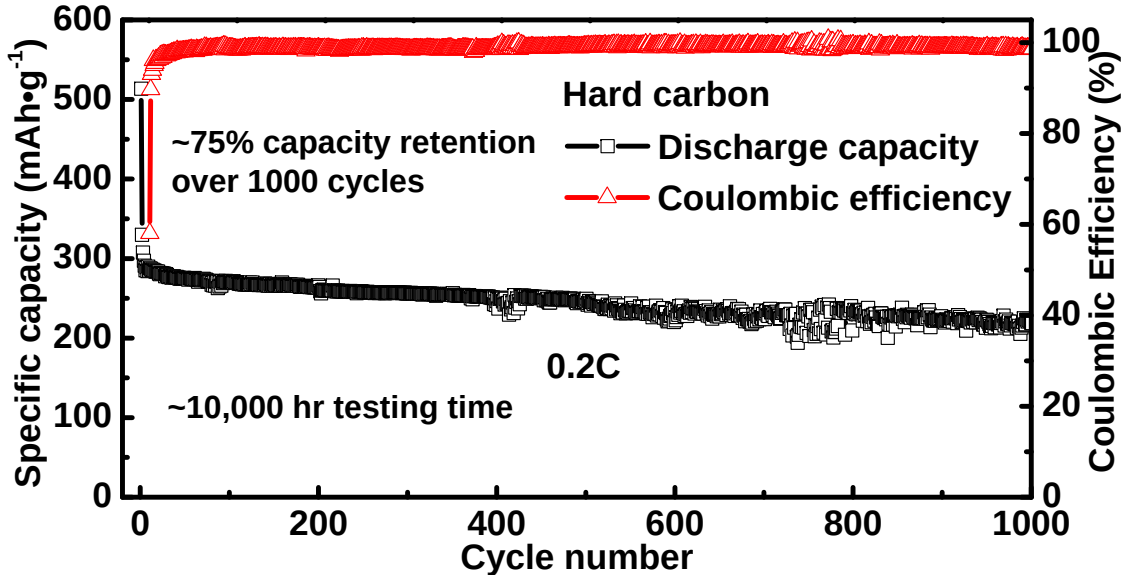
High performance hard carbon nanowire anodes



- The hard carbon nanowires prepared demonstrated very good specific capacity (~290 mAh/g) and cycling stability (~75% retention over 1000 cycles).

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Summary

- Elucidated the critical role of the SEI layer on hard carbon anode performance.
- Developed advanced electrolyte that enables high Coulombic efficiency and good rate performance of hard carbon anodes at both room and low temperature conditions.
- Demonstrated high capacity and long cycling stability hard carbon nanowire anodes.

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Future work

- Development of high performance Na-ion battery anode materials.
- Material scale up for pouch cell fabrication

Acknowledgements

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