Room Temperature Na-ion Battery Development

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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.\(^2\)

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.

Overview of our previous work on hard carbon anode

- 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.

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?

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.
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.

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Tuning the SEI -- Rate performance

- 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.

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

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

Tuning the SEI -- 1\textsuperscript{st} Coulombic efficiency (treatment with Li powder)

- Baseline electrolyte
  - OCV: ~790 mV
  - 1\textsuperscript{st} cycle Coulombic efficiency: ~93%
  - Good cycling stability
  - ~50% capacity of that without treatment

- Advanced electrolyte
  - OCV: ~622 mV
  - 1\textsuperscript{st} cycle Coulombic efficiency: ~92%
  - Good cycling stability
  - Similar capacity to that without treatment

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

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).
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.
Future work

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