TOWARDS ROOM TEMPERATURE SODIUM BATTERIES: PROGRESS IN HIGH CAPACITY SODIUM ION BATTERIES

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Outline

- Motivation and background
- Objective
- New high capacity storage mechanism for cathode
- Progress in anodes
- Summary and future work
Significant challenges for meeting the low term low cost and reliability requirement for stationary energy storage.

Alternative, low cost technologies are desired!


Guest editor: Jun Liu, Khalil Amine, Venkat Srinivasan
Biology stores energy with Na, K, Ca ions, not Li ions (electrical eels).


Can we develop high capacity Na-ion batteries like Li-ion batteries?
Objective

Develop new room temperature Na storage mechanisms with capacity and stability close to Li-ions
Many groups have explored Na-ion storage materials, but the capacity and stability remain a challenge.

F. Sauvage, L. Laffont, J.-M. Tarascon, and E. Baudrin

PNNL’s breakthrough in both cathode and anode materials: demonstrated that high capacity Na-ion battery is possible with long cycle life.

PNNL research: Y. Cao et al, Advanced Materials, 2011
The nanowire based Na-ion battery has good capacity and long cycle life.

However, in general the cathode capacity is limited as compared with Li-ions.
New monolith carbon electrode materials as the cathode for Na-ion Batteries

Before

After

No change in morphology

PNNL unpublished research
Specific capacity of functionalized carbon = 155 mAh/g, double that of KOH activated carbon

Discharge/charge
Rate and cycling stability: significantly exceeded the targets in FY12 milestone.

Very small capacity fading for over 100 cycles

>80% capacity retention in 10000 cycles

PNNL unpublished research
Surface chemistry

Reversible reaction of carbon-oxygen double bonds and single bonds

Na content increases significantly after discharge and turns back to ~0 after charge

Na energy storage mechanism: Surface redox reaction between Na+ and >C=O

PNNL unpublished research
Hypothesis:
Surface redox reaction between Na\(^+\) and oxygen-carbon functional groups

\[ \text{Na}^+ + \text{C}=\text{O} + \text{e}^- \leftrightarrow \text{C-O-Na} \]

Surface-confined redox reaction

No intercalation reaction

[Double layer capacitance not excluded (~1/4)]

PNNL unpublished research
The storage capacity of the new mechanism could be comparable to what can be achieved for Li-ions

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PNNL unpublished research
High capacity and long cycling stability have been achieved with nanostructured carbon for anodes.
First demonstration of reversible Na ion storage in high capacity alloys

Summary

- Significant progress has been made in both cathodes and anodes with capacities and stabilities close to Li-ions.

Future Work

- Understand and explore the new storage mechanisms in simple inexpensive inorganic and organic materials;
- Design new full cells to demonstrate the full cell performance.

Some new cell concepts have already been successfully tested in other batteries and will be tailored and explored for Na storage.

Collaboration with Prof. Y Cui, Stanford University

Prediction?
Professor JM Tarascon: “High capacity Na ion batteries will be commercially available in about five years.”