Construction of High Energy Density Batteries (DOE Phase II SBIR)

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Overview

Timeline

- Project Start (Phase I): June 9, 2014
- Project Start (Phase II): July 28, 2015
- Project End: July 27, 2017
- Percent Complete: 30%

Budget

- FY15-16 = $1000K (DOE)

Barriers Addressed

- **Performance:** The proposed technologies reduce the inactive mass in the cell increasing cell energy density.
- **Cost:** The PSI coating technology reduces cost by enabling increased active material loadings and operating voltages thus reducing the amount of cathode material and solvent required during cell production.

Project Partners

- Argonne National Laboratory
- SKC Powertech, Inc.

Relevance and Project Objectives

Overall Project Objective: Construct cells offering a 25% increase in cell energy density over the state of the art.

- Demonstrate the PSI high active (HA) coating technique allows for the production of high performance cathode electrodes with >98% active material that:
  - Deliver equivalent electrochemical performance to conventionally produced electrodes.
  - Require reduced amount of solvent during electrode production.
  - Enable stable, extended high voltage operation.
- Produce 2+Ah cells incorporating the PSI coated cathode material and demonstrate equivalent cycling performance to cells produced employing conventional electrode formulations.
- Demonstrate a novel composite film with <20% the mass of conventional copper foil can be used as the anode current collector to construct lithium ion cells with increased energy density.

Milestones

Date	Milestones	Status
January 2016	Cathode Electrode Scale-Up: Kg- scale coating of cathode material/ electrode production	Complete
February 2016	Pouch Cell Construction: Production of 3+Ah cells with PSI coated material	Complete
June 2016	Anode Current Collector Scale-up: Continuous production and demonstration in lithium ion cells. (Batch produced current collector demonstrated in lithium ion cell during quarter 2.)	On track to meet revised date.
June 2016	Cycling and Rate Testing: Confirmation of required pouch cell performance and cycle life.	On track
July 2016	Pouch Cell Construction: Production of high voltage 3+Ah cells with PSI coated material	On track
October 2016	Pouch Cell Construction: Production of 3+Ah cells with PSI cathode and anode current collector technologies.	On track
Mar 2017	Cycling and Rate Testing: Confirmation of required pouch cell performance and cycle life.	On track

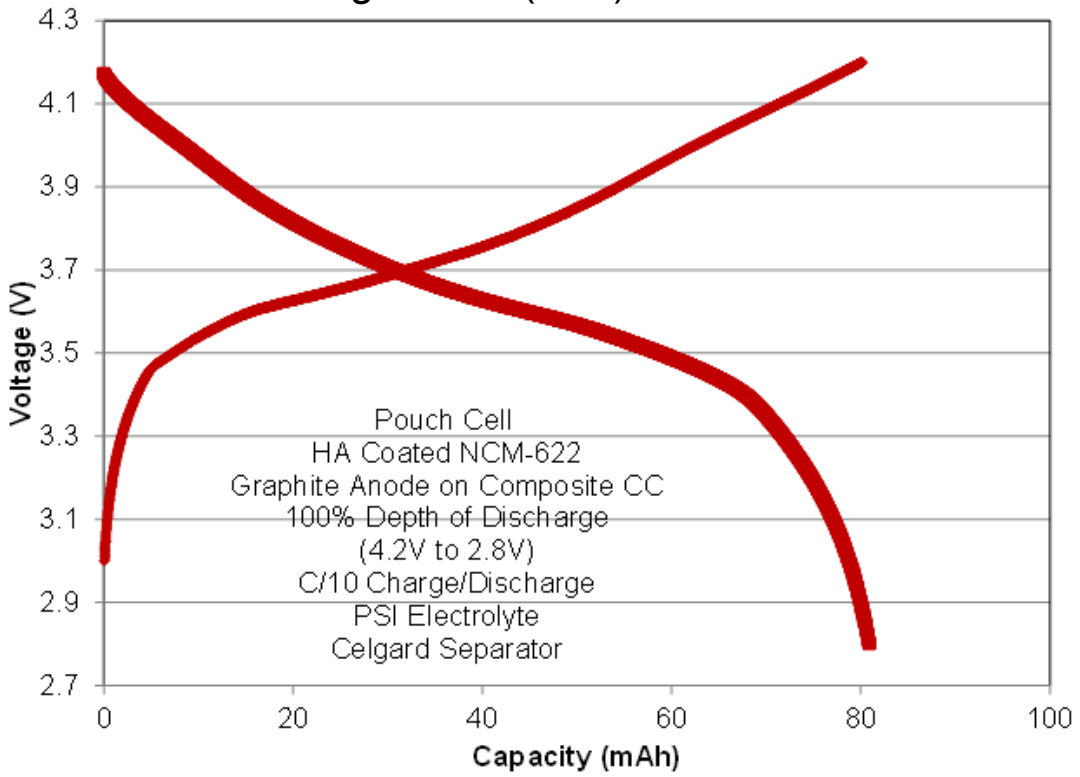
Program Approach/Strategy

Phase II efforts are focused on producing multi-amp hour cells.

- **Focus of Year 1 (July 2015 through July 2016):**
  - Novel Composite Anode Current Collector
    - Demonstrate performance of batch produced samples in 2 layer cells.
    - Transition to continuous production.
    - Confirm performance in multi-layer Ah sized pouch cells.
  - Cathode Coating/Electrode Scale-Up
    - Apply PSI HA coating to multiple active cathode materials and demonstrate targeted electrochemical performance.
    - Scale-up coating and electrode production together with SKCP to support construction of cells with capacity >2Ah.
    - Evaluate performance of PSI and SKCP produced cells to demonstrate the required performance for use in electrode vehicles.
    - Work with scientists at ANL's CAMP facility to characterize the electrodes formed with multiple active materials using the PSI coating and electrode formulation techniques.

Successful Pouch Cell Construction with Composite Current Collector

- A composite substrate was prepared at PSI with a mass of 2.55mg/cm^2 or <30% of the copper foil typically used at PSI.
  - Double sided anodes were prepared on the composite using standard procedures.
- Pouch cells were built with the double sided anode and 2 single sided PSI HA cathodes.
- Extended cycling of half and full cells demonstrated robust electrical connection.
- Scale-up is in process to build larger cells (>Ah).



HA Coating Successfully Applied to Multiple Cathode Chemistries

Coating applied to commercially available $LiCoO_2$, NCA, NCM-111, NCM-523, and NCM-622.

- Electrodes prepared with 98.5% active material delivered equivalent performance to standard electrodes.
- Solvent required during casting reduced by 50% or more.
- Electrode density increased due to reduced binder/conductor fractions.

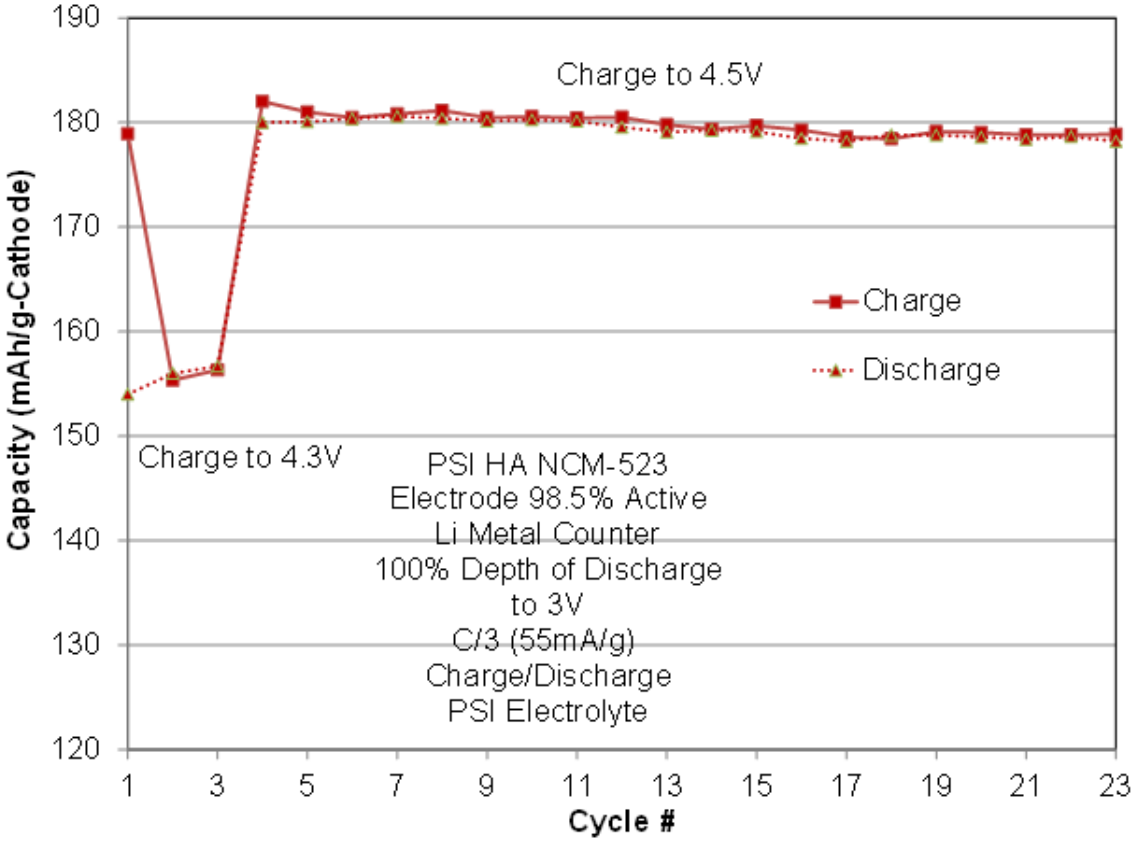
Example performance of HA electrodes:

- NCA: (4.3V) >185mAh/g-active material;
  (4.4V) >195mAh/g-active material
- NCM-523: (4.3V) 160-165mAh/g-active material;
  (4.5V) 180mAh/g-active material
- NCM-622: (4.3V) 168-170mAh/g-active material;
  (4.5V) >190mAh/g-active material

Stable Cycling of HA NCM-523 at 4.5V

Half-cell tests were performed at C/3 charge/discharge rates to demonstrate HV performance of HA NCM-523 electrode with 98.5% active material.

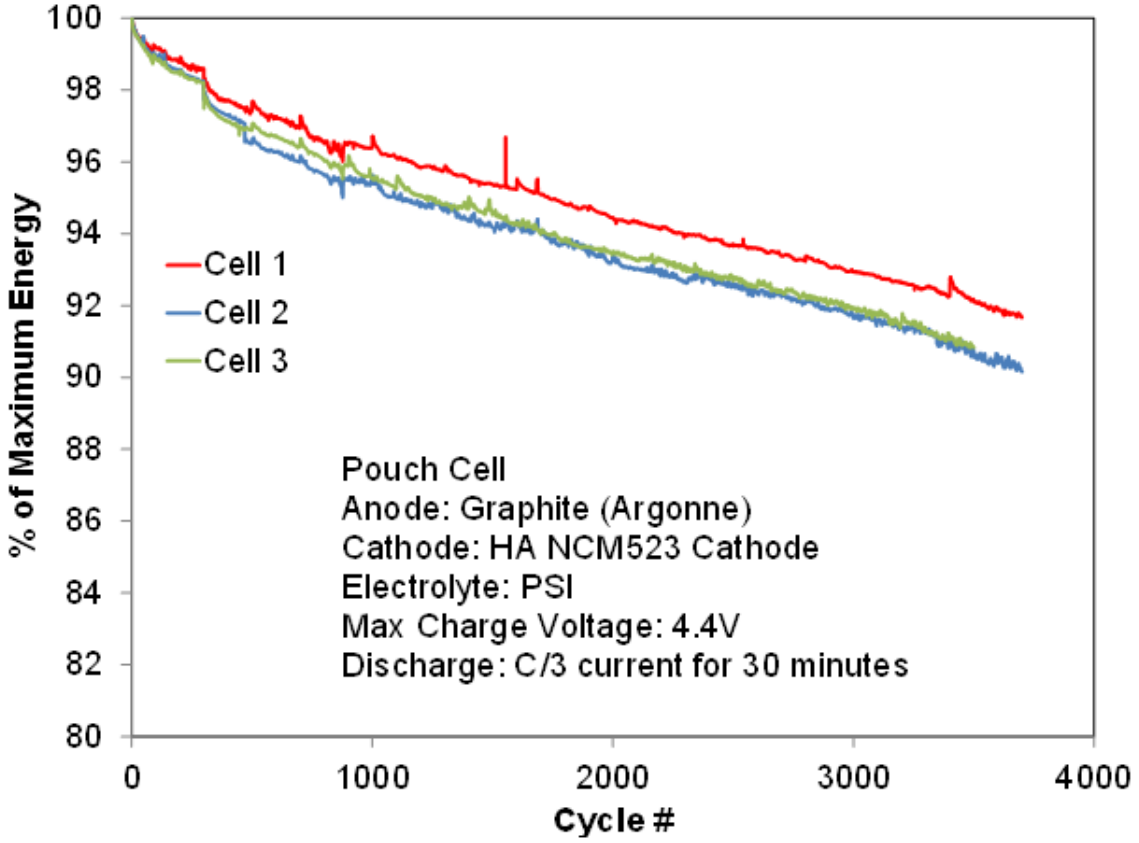
- The performance is steady with only ~1% fade over 20 cycles.



Pouch Cell
High Voltage Cycling at 20% DOD

150+mAh Pouch cells were built with PSI's HA NCM-523 cathode.

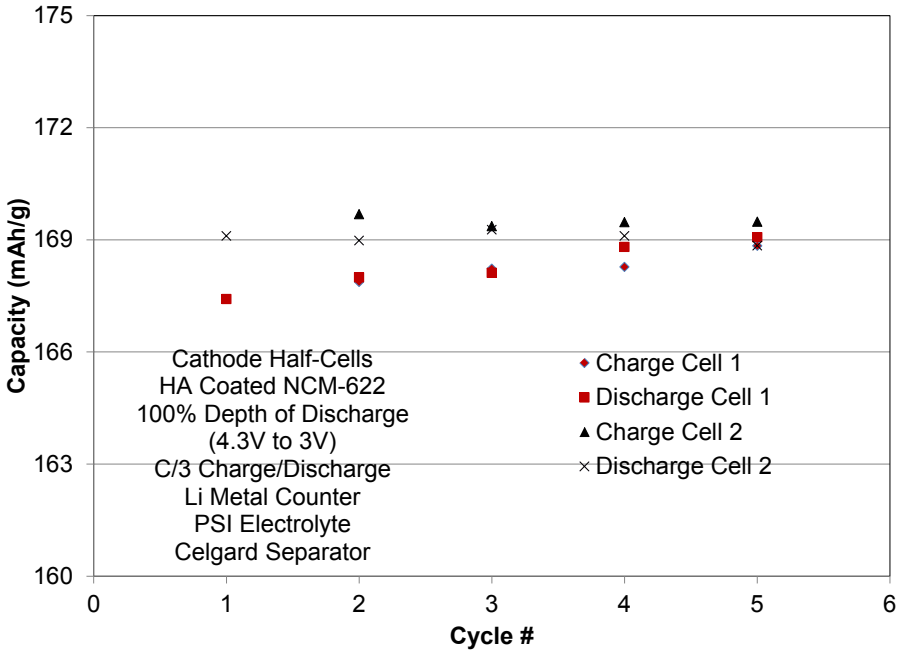
- Cycling performed from 80 to 100% SOC to accelerate testing.
- Each cell shows less than 10% fade over >3500 cycles.

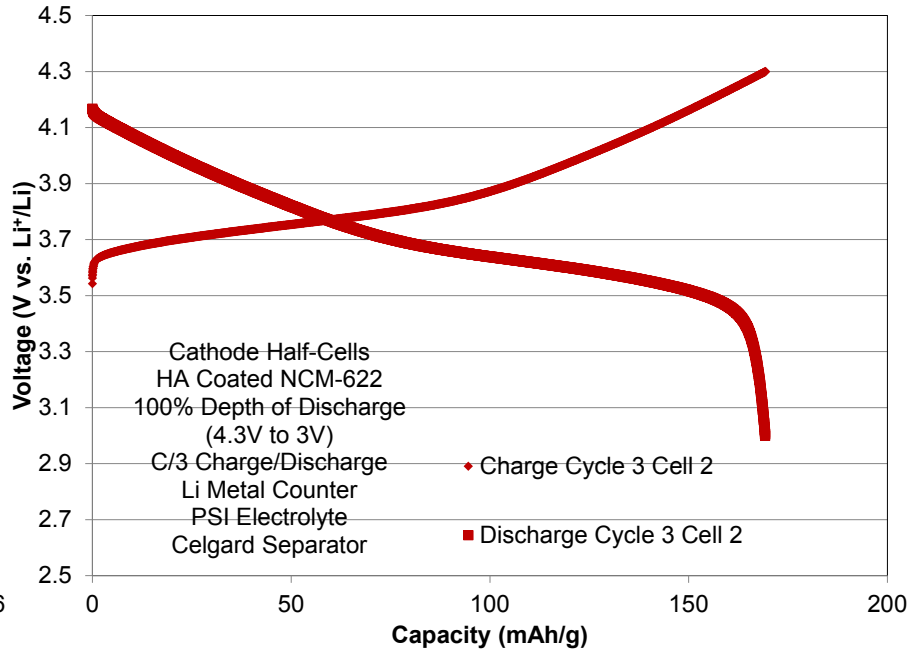


HA Coating of NCM-622 Used in 3+Ah Scale-up Cells

HA coating was applied to NCM-622 material for scale-up cell production.

- Baseline SKCP 3+Ah pouch cells have an energy density of ~197Wh/kg.
- The HA cathode (98.5% coated active material) delivers the targeted capacity of 169mAh/g at C/3 charge/discharge between 4.3 and 3V.
- Consistent performance observed on cycling.

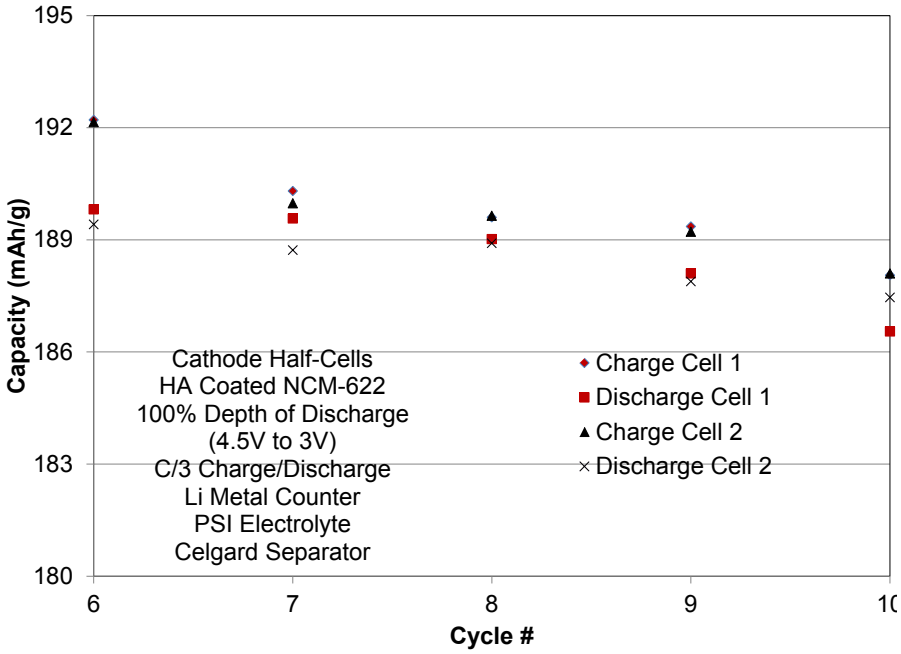


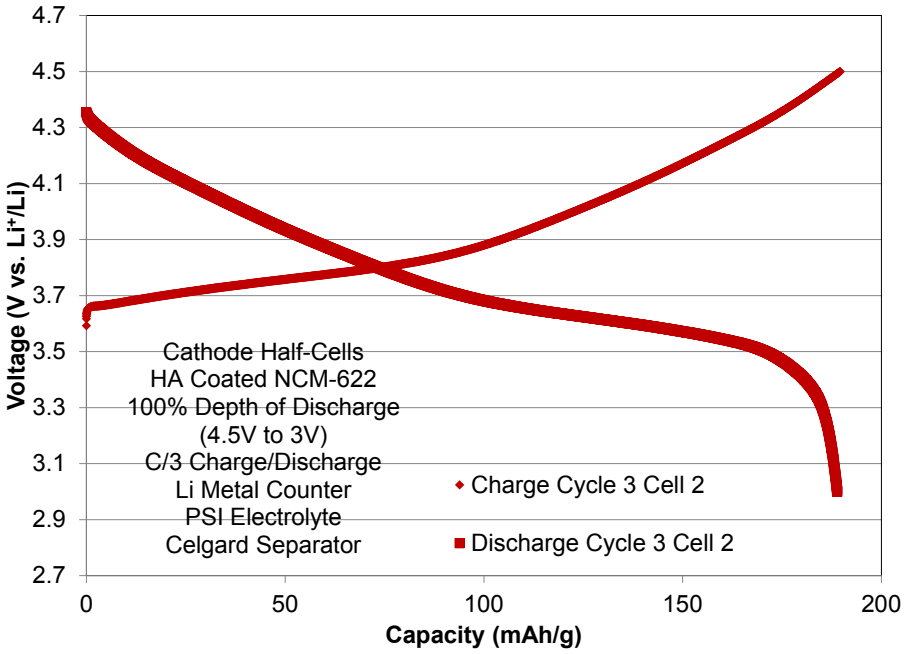


HV Performance of HA Coated NCM-622

Cycling to 4.5V was performed following 5 cycles to 4.3V.

- The cathode delivers >185mAh/g on charge/discharge between 4.5 and 3V.
- Cycling efficiency is >99.4%.
- After half-cell demonstration, the effort transitioned to PSI pouch cell construction and scale-up at SKCP.

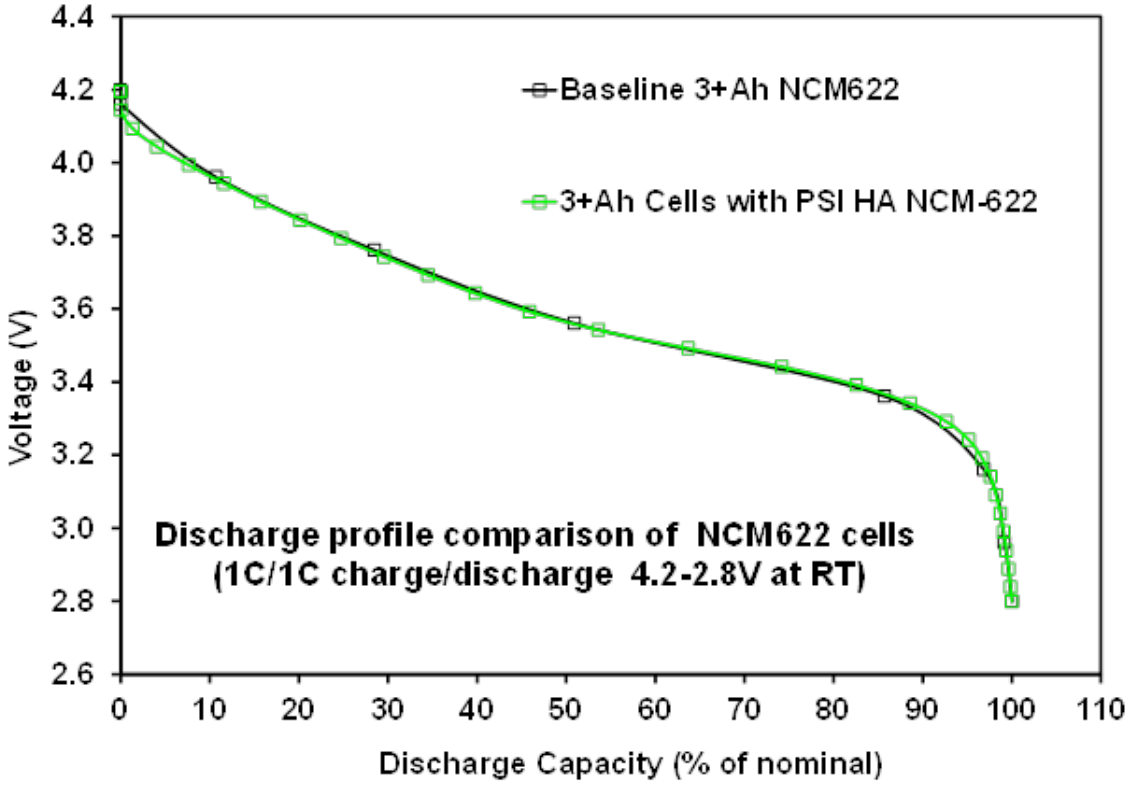




Rate Performance of HA NCM-622 in 3+Ah Cells

SKCP successfully built 30+ pouch cells with capacity >3Ah using the PSI coated NCM-622 cathode material and electrode formulation.

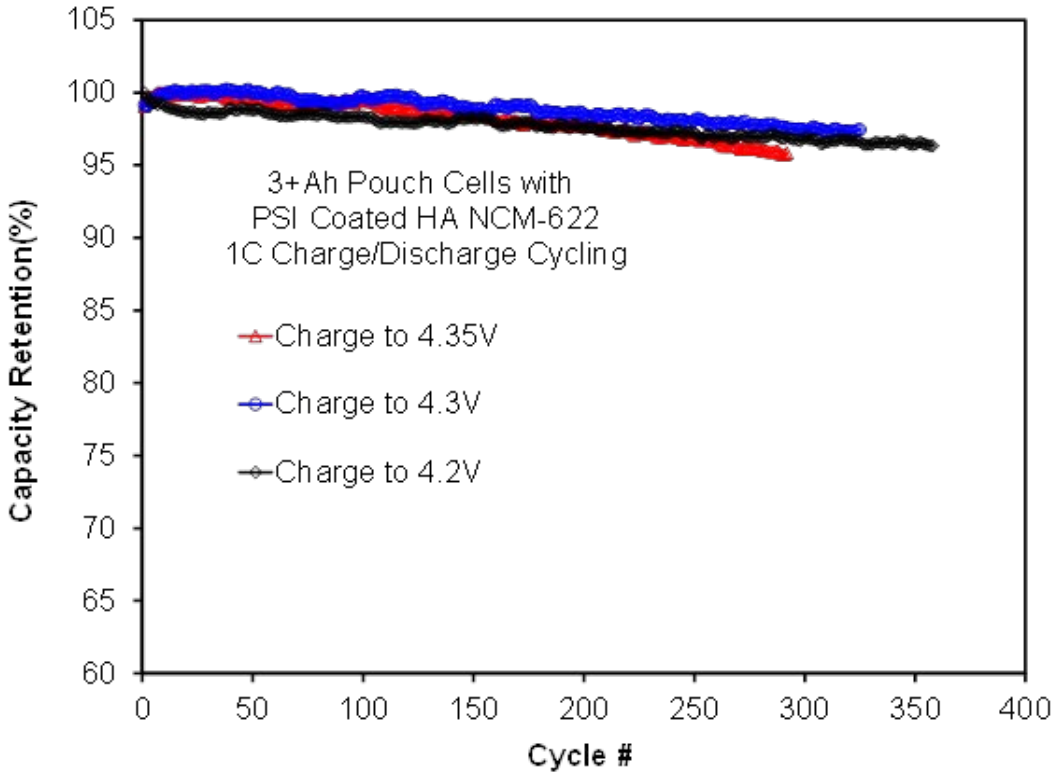
- The measured low rate capacity was 168-169mAh/g as targeted.
- The measured voltage profiles at 1C charge/discharge rates of the cells is consistent with that measured for the baseline cells.



Extended Cycling of HA NCM-622 3+Ah Pouch Cells

1C full DOD charge/discharge cycling was performed to 3 different charge voltage levels (4.2, 4.3 and 4.35V) with minimal fade.

- The fade on cycling to 4.2 and 4.3V is ~1% per 100 cycles.
- The fade on cycling to 4.35V is <1.5% per 100 cycles. This is due to the cell reaching the maximum cathode to anode ratio.



Responses to Previous Year Reviewers' Comments

This project is a new start that was not reviewed last year.

Partners/Collaborators

- CAMP Facility at Argonne National Laboratory:
  - Role: Characterization and Evaluation
  - Description: In the coming year, scientists at ANL will assist in characterizing the physical structure and electrochemical performance of electrodes formed with multiple active materials using the PSI coating and electrode formulation techniques.

- SKC Powertech, Inc.:
  - Role: Cell builder/scale-up partner
  - Description: SKCP has produced and delivered 3+Ah with the PSI coated cathode materials and electrode formulation techniques using their standard cell designs and construction procedures. These production efforts highlighted the reduced amount of solvent required when using the PSI coated materials. In the coming year, additional cells will be built with coated cathode material and the composite anode current collector.

Future Work: Upcoming Project Work and Challenges

Key Challenges

- **Challenge:** Demonstrate the targeted rate performance in Ah sized cell using the novel composite as the anode current collector.
  - Semi/continuous production of the composite is necessary to perform the required testing in multilayer cells.
- **Challenge:** Demonstrate the targeted cycle life performance in 2+Ah sized cells on operation to 4.4V or higher.
  - Electrodes at a reduced loading will be produced to allow 3+Ah pouch cells to be constructed with the same anode as in the initial build effort.

Future Work

- Demonstrate continuous production of the novel composite anode current collector.
  - Construct multi-layer cells at PSI.
  - Transition to pilot anode production with the current collector at SKCP.
- Apply HA coating to multiple active cathode materials and characterize impact on porosity and electrochemical performance.
- Scale-up coating to 5+kg size to support construction of additional 3+Ah pouch cells.
  - Fully characterize the cycle life and rate performance of the pouch cells to demonstrate targeted 25% increase in energy density and required cycle life.

Summary

- Demonstrated HA coating enables production of electrodes with >98% active material that deliver equivalent performance as standard commercial electrodes.
  - The electrode increases cell energy density by >5%.
  - Demonstrated 50% reduction in the amount NMP required during electrode production.
  - Successful scale-up and production of >2kg of coated material at coating cost <$0.2/kg.
  - Demonstrated with $LiCoO_2$, NCA, and multiple NCM chemistries.
  - 3+Ah pouch cells demonstrate less than 1.5% fade per 100 cycles on cycling at up to 4.35V when using PSI coated material/electrode formulation.
- Successfully demonstrated stable high voltage operation increasing cell energy by 12-15% when using HA coated material.
  - Pouch cells showed stable cycling at 4.4V, compared to 4.1V for conventional cells.
- Successfully prepared a composite anode current collector with <30% the mass of conventional copper foil.
  - Constructed 2 layer (80mAh) pouch cells demonstrating the ability to prepare the anode electrode and establish a robust electrical connection.

The targeted 25% increase in energy will be achieved by combining the lightweight anode current collector with the HA coating.