High Energy Novel Cathode / Alloy Automotive Cell

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Project ID #
ES131

Overview

- Timeline
  - *start: 10/01/2011*
  - *finish: 1/15/2015*
  - *15% complete*

- Budget
  - *Total project funding*
  - *DOE share: $4,577,909*
  - *Contractor share: $1,961,961*
  - *Funding received in FY11: $ 0*
  - *Funding for FY12 : $1,700,000*

- Barriers

  Cycle Life, Energy, Cost and Thermal Stability

- Targets
  - *Increase in energy density > 40%*
  - *Reduce Cost > 25 %*
  - *Maintain thermal stability and cycle life*

- Partners
  - *Argonne National Laboratory*
  - *Dalhousie University*

Project Objectives

To develop a high-performance battery cell for electrical vehicle with high energy density and low cost by integrating advanced chemistries

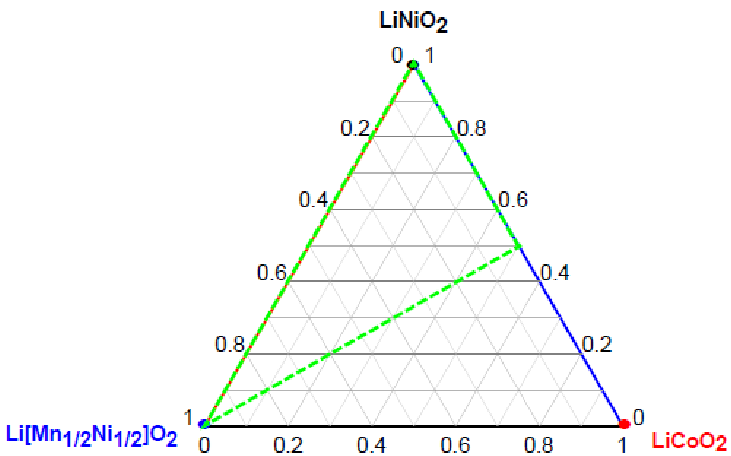
- *at least 40% (1.4X base Wh/l) increase in energy density compared to baseline cell performance (NMC111 and Graphite)*
- *35% increase in energy for advanced high voltage cathode*
- *70% increase in volumetric capacity for alloy anode*
- *at least 25% lower cost per unit energy at cell level for a comparative integrated advanced materials cell to a baseline materials one*

Milestones

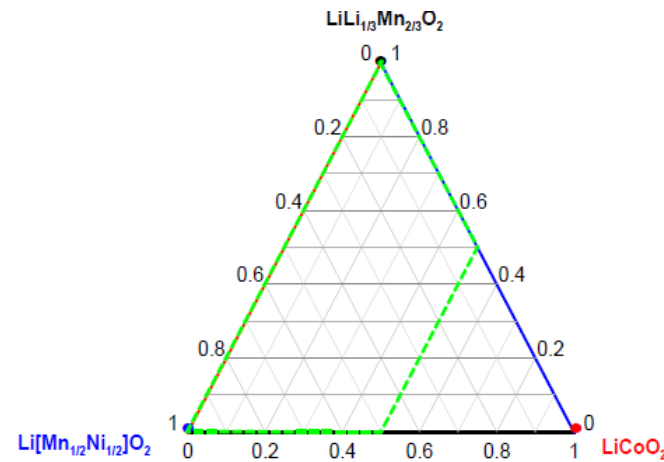
Month/Year	Milestone or Go/No-Go decision
Apr-12	**Milestone** : Complete the synthesis of advanced materials in quantities to build cells
July-12	**Milestone** : Complete the prototype large cell build with baseline material
Sep-12	**Go/No-Go Decision** : ▪ Demonstrate advanced cathode with composite density of 2.57Wh/cc or high and 95% capacity retention after 50 cycles ▪ Demonstrate advanced anode composite with > 760 mAh/cc (70% increase over graphite) and 95% capacity retention after 50 cycles ▪ Data on one or more > 1.5Ah cell designs capable of supporting baseline and advanced materials testing under test guideline. Data enables down selection cell design for next phase ▪ Evaluation data of baseline materials in one or more relevant cell designs having > 1.5Ah capacity and less than 20% capacity fade after 500 cycles with a 60% swing in capacity at room temperature

Approach to Cathode Development

Approach 1 : NMC material with high Ni content (Ni ≥ ½)



Approach 2 : "Oxygen-release" cathode materials

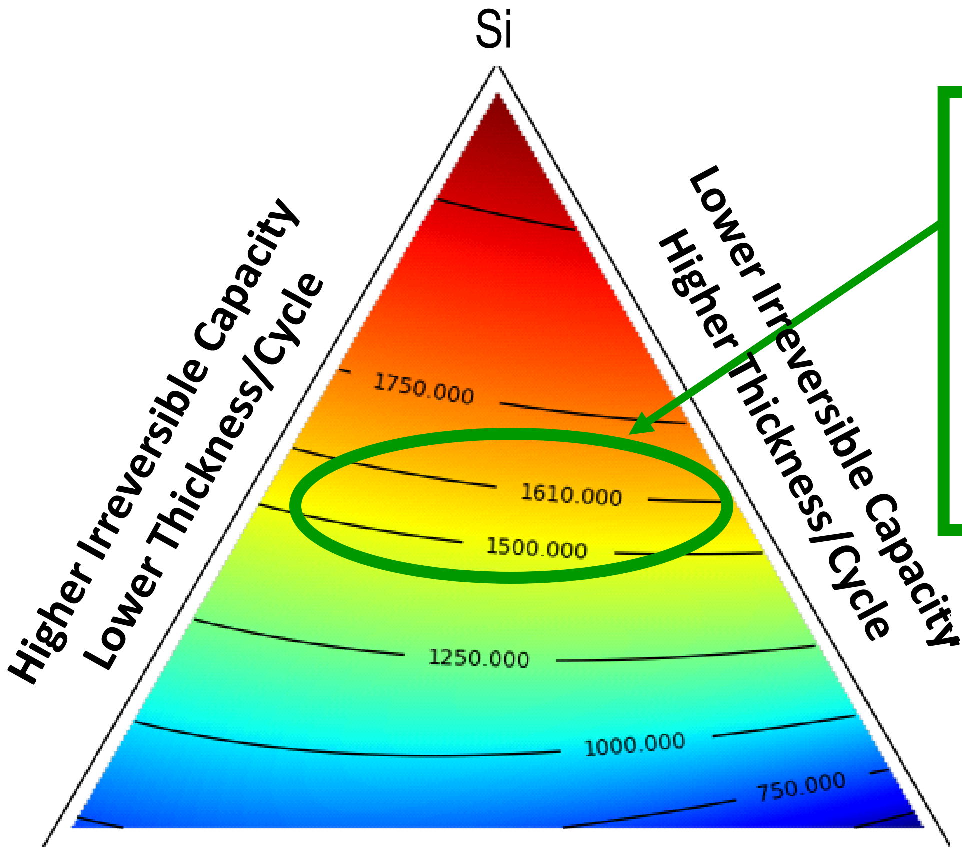


Based on the above phase diagrams, we explored compositions by the following experiment design (without morphology control) Factor 1: Ni/Mn, Factor 2: Co, Factor 3: Li/M, Factor 4: Temperature

Response: Energy between 2.5-4.7V, Cycle life, Crystal density (All at 30°C)

- **Explore the compositions in two composition triangles**
- **Enable the high voltage cycle by engineering the particle**

Approach to Anode Development

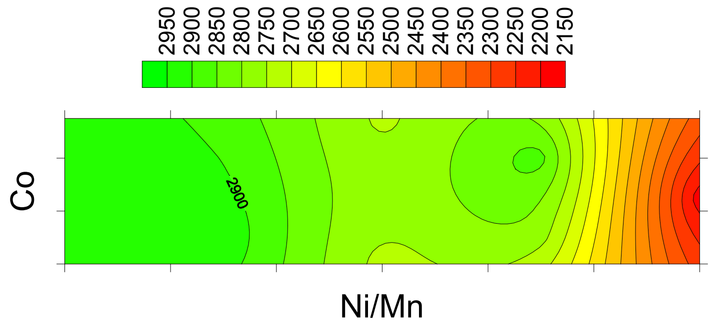


In Region of Interest, Optimizing
- Composition
- Morphology
- Surface

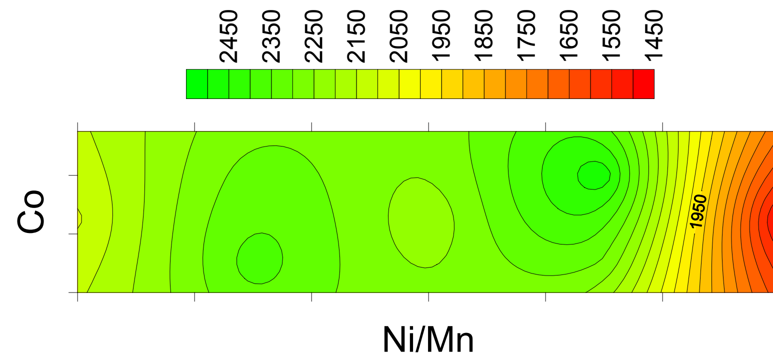
- Explored trade-off between low irreversible capacity and low thickness per cycle
- Optimizing Composition, Morphology, Surface

Accomplishments - Cathode

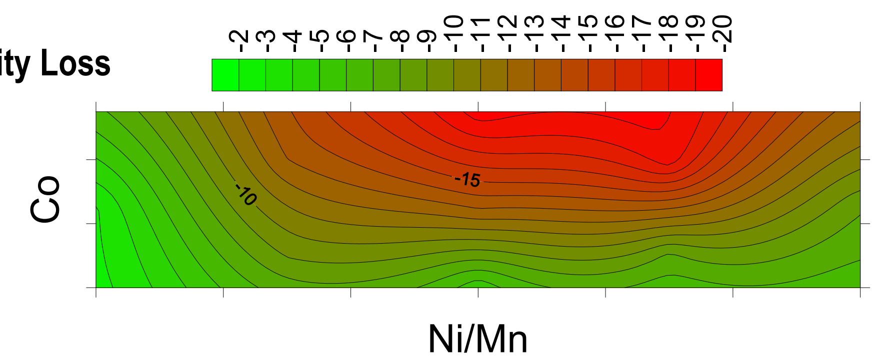
Composite Energy at C/16 rate



Composite Energy at 1C rate



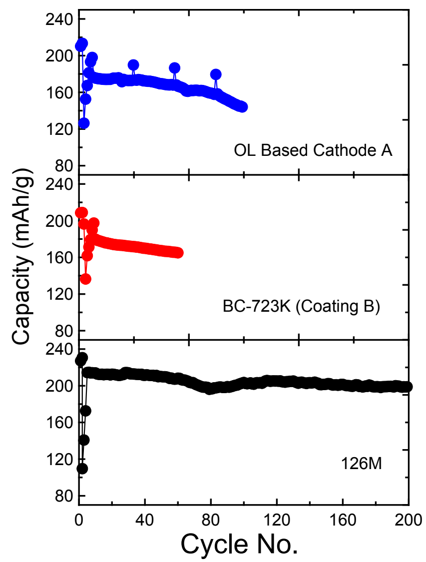
Capacity Loss



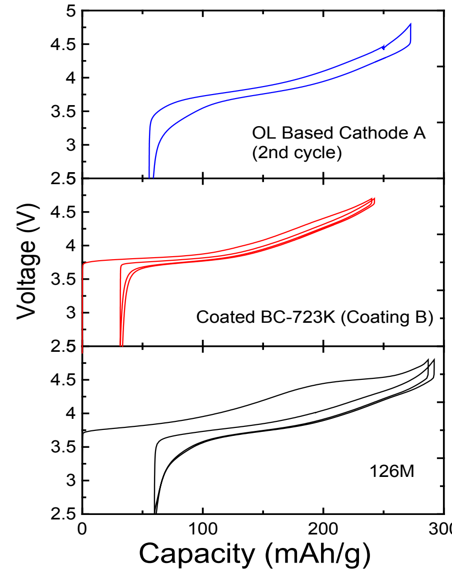
Compositional exploratory study shows that low Ni/Mn ratio with low cobalt region is most promising in meeting the project goal

Accomplishments - Cathode

Cycle Life



Charge Discharge Profile

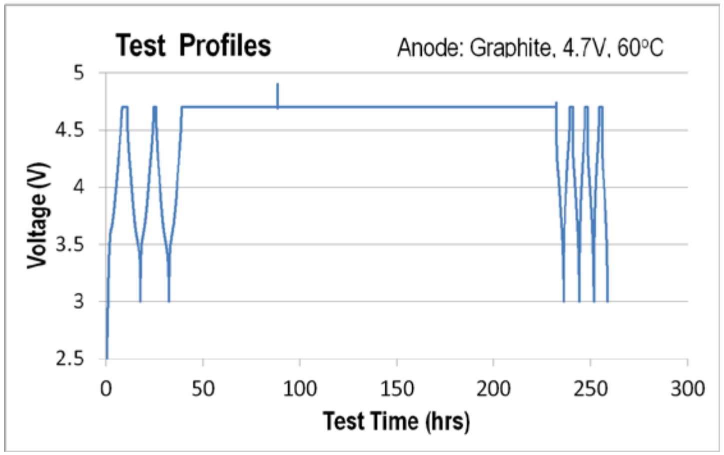


Sample_description	Voltage	C1 (mAh/g)	D(mAh/g)	D_Energy (mWh/g)	Electrode density (g/cc)	Energy density (Wh/cc)	Capacity Retention
OL_based Cathode A	4.8V	272	211	807	3.35	2.70	0.98
3M BC-723K (Coating B)	4.7V	237	205	810	3.45	2.8	0.96
	4.8V	246	215	848	3.45	2.9	
Engineered Cathode 126M	4.8V	287	230	871	3.40	3.0	0.98

- **Several potential candidates have been scaled up and meet goal.**
- **More sintering process optimization and composition exploring are on going.**

Accomplishments - Cathode

Floating Test Profile



Capacity Loss Comparison

Sample	Reversible Capacity (mAh/g)		Capacity Loss (%)
	Before Floating	After Floating	
3M BC-723K (No Coating)	198	0.08	99.9
3M BC-723K (Coating A)	206	69.7	66.2
3M BC-723K (Coating B)	199	116.8	41.3

The surface treatment has a clear benefits for the capacity retention at high voltage and high temperature

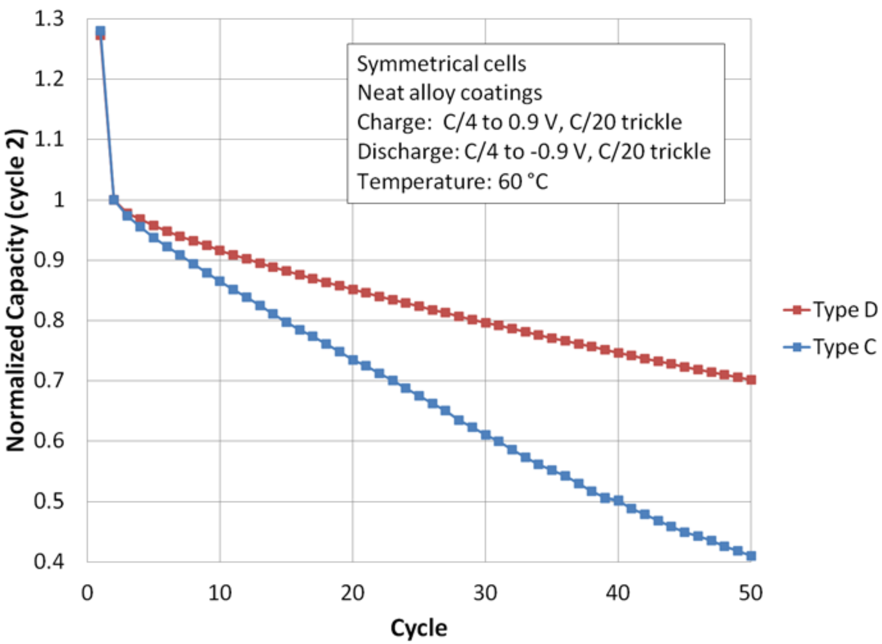
Accomplishments - Anode

*Composite Vol-Cap calculated for 63:30:2:5 wt%, Alloy:Graphite:SuperP:LiPAA, with 25% porosity **at full expansion/lithiation**.*

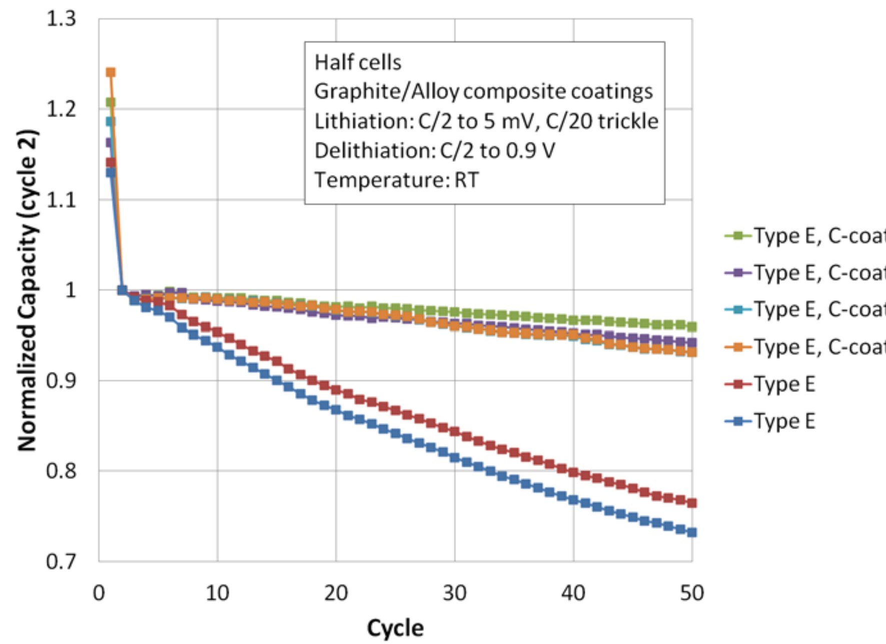
	Material Type	Specific Capacity (mAh/g)	1st Cycle Efficiency (%)	Density (g/cc)	Composite Vol-Cap (mAh/cc)	PSD D50 (um)	SSA (m^2/g)
2011	A	840	85%	4.1	1230	3	5
	B	840	85%	4.1	1230	7	3
2012	C	860	90%	4.1	1260	8	3
	D	850	88%	4.0	1230	8	4
	E	1250	76%	2.7	1290	8	9
	F	1000	84%	3.4	1270	10	4
	G	1100	85%	3.3	1340	14	5

- **In previous DOE program developed A and B**
- **In current DOE program improved efficiency and developed range of lower expansion materials**
- **All meet performance goals**

Accomplishments - Anode



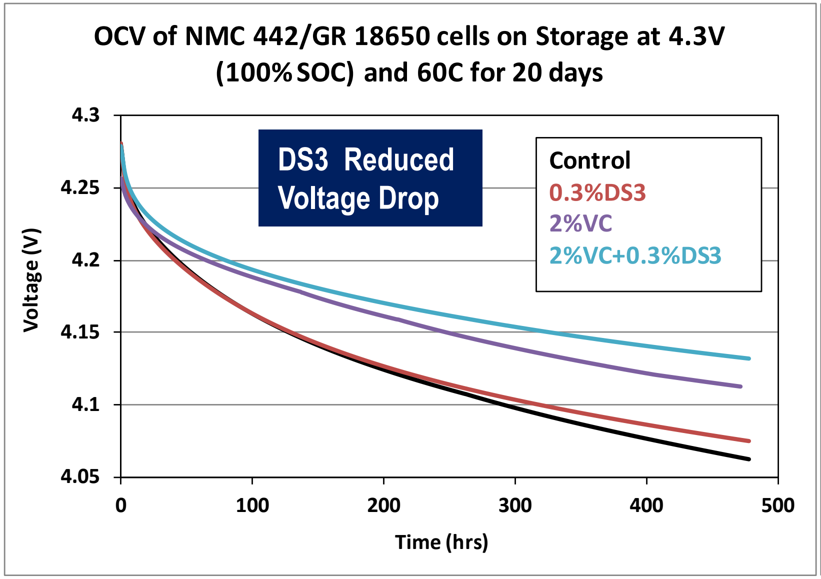
Increased capacity retention with Type D material compared to Type C material in symmetrical cells at high temperature.

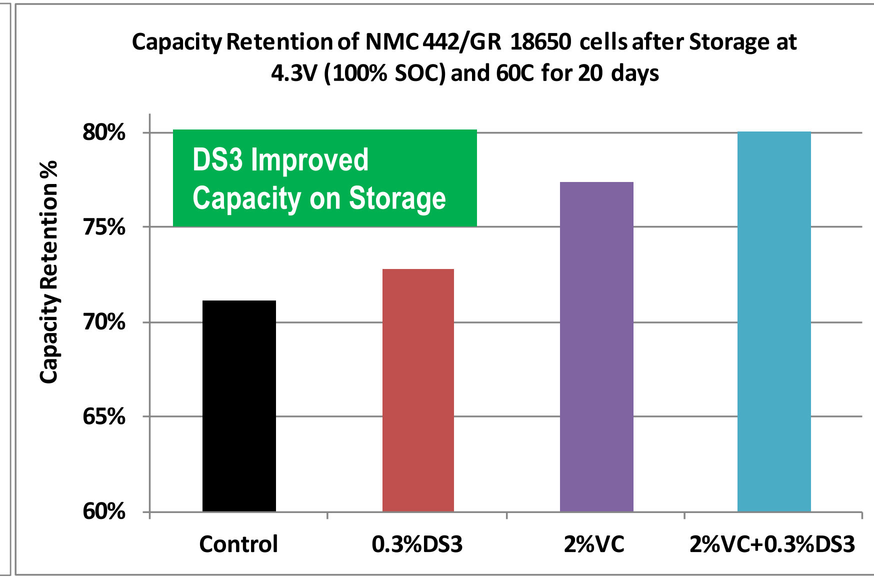


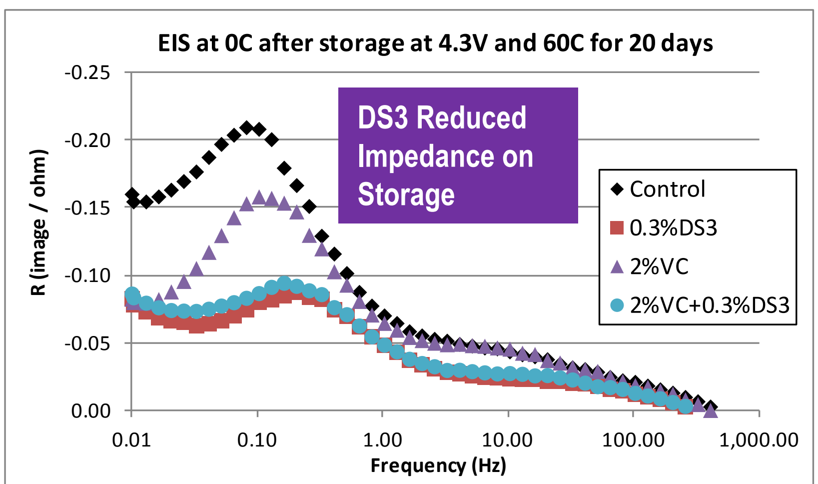
Carbon coating improves the performance of Type E materials in composite electrodes with high rate cycling.

- **Identified new type of Si material (Type D) with improved cycle life**
- **Carbon coating improves the cycling performance of Si material (Type E)**

Accomplishments - Electrolyte



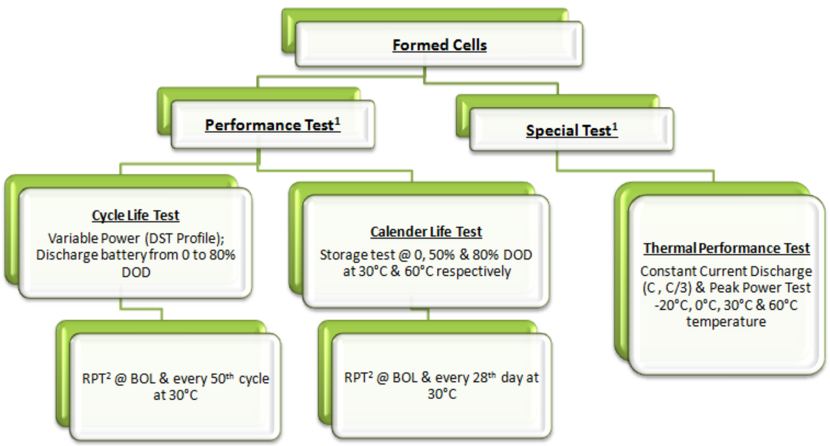




- 3M new DS3 electrolyte additives improved storage performance of NMC 18650 cells at HT and HV.
- Synergy observed - combination of DS3 and VC works best.

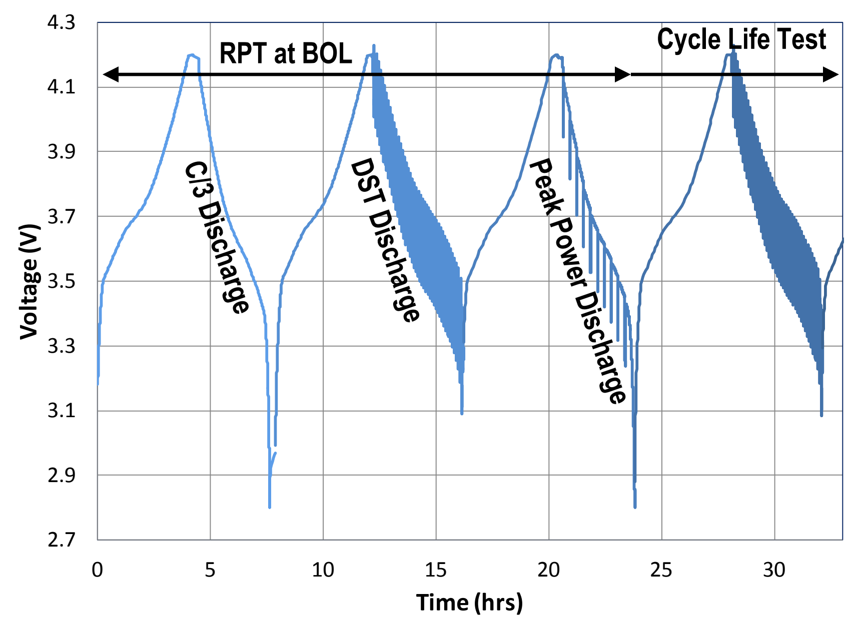
Accomplishments - Cell Integration

Establish Test Protocol



- Testing Protocol, Data Acquisition & Reporting will be performed in conformance to USABC's 'Electric Vehicle Battery Test Procedures Manual'; Rev 2; Published January 1996.
- RPT (Reference Performance Test) - Constant Current Capacity (C/3); DST (Dynamic Stress Test) discharge Capacity; Peak Power Capability

Preliminary Cycle Life Testing



Test Protocol established and preliminary testing initiated

Accomplishments - Cell Integration

Old Mixer

- Single Rectangular Planetary Blade
- Single Disperser Blade

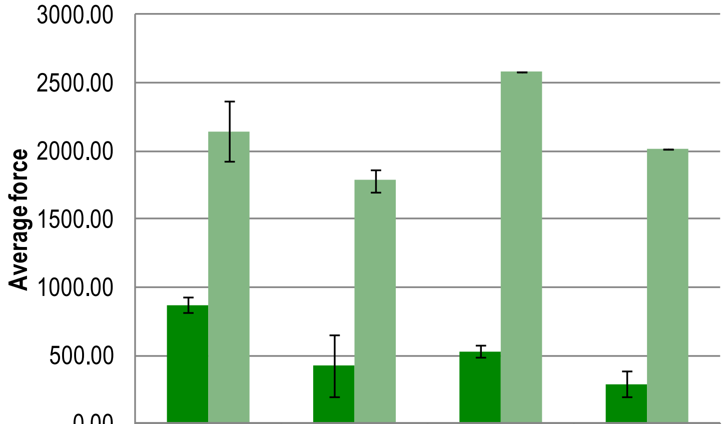
New Mixer

- Double Helical Planetary Blade
- Double Disperser Blade (with bottom scraper)
- Side wall scrapper
- Sanitary fitting in discharge port for easy Filtering

New mixer provides better mixing for superior performance

Accomplishments - Cell Integration

Pouch Sealing Study

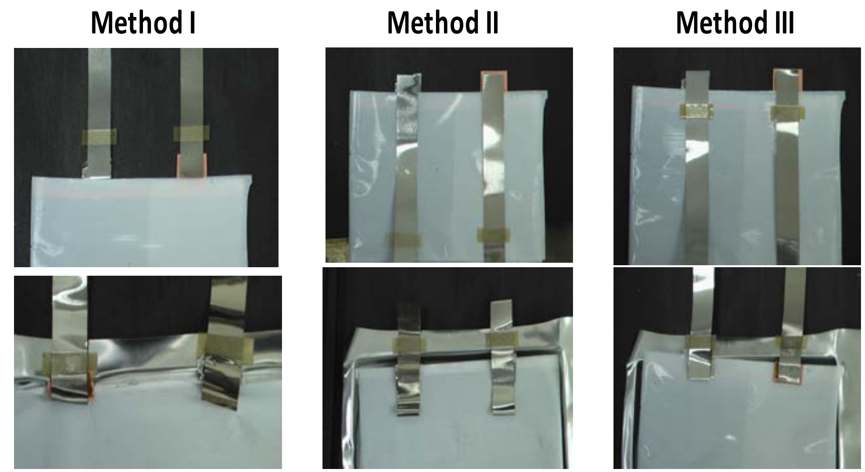


	pouch w/ tape	pouch w/o tape	tab w/ tape	tab w/o tape
140C	871.60	427.24	530.13	288.83
180C	2146.05	1786.53	2581.83	2018.10

Key to pouch cell seal

- Sealing Temperature
- Thermo polymer tape

Tab welding to Electrode MFZ



- Method III gives max yield
- Method I gives tears in MFZ
- Method II gives drop in cell OCV during formation

Preliminary data tends to indicate more robust stacked pouch cell design

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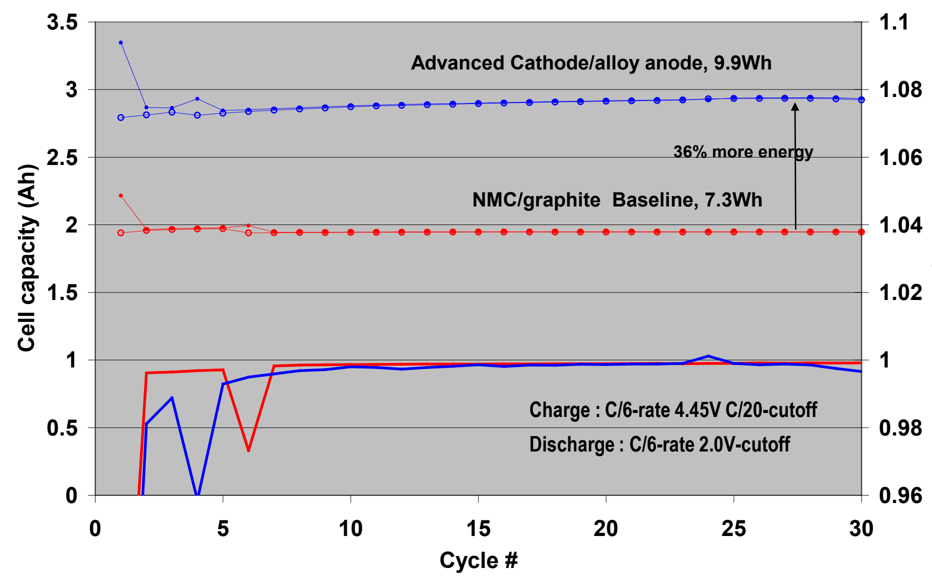
Accomplishments - Cell Integration

Cell Design

		Reference cell	Advanced cell A
Cell Design	Cathode	NMC 723	C-S 126M
	Anode	Graphite	65%Alloy/35% graphite
	Composite density (C)	3.3g/cc	3.3g/cc
	Separator	25□	25□
	Cycling range	2.8V to 4.25V	2V to 4.45V
	Capacity	1.97Ah	2.90Ah
Test Results	Energy	7.30Wh	9.89Wh (+35%)
	Wh/L	445	600
	Wh/kg	184	225
	Capacity fade @30	0%	Slight increase
	Capacity fade @200	2%	-

18650 cell capacity and cycling data



> 30% energy improvement from baseline chemistry by integrating 3M HE cathode and alloy anode

Collaborations

- Dalhousie University (Jeff Dahn and Mark Obrovac)
  - *Technical discussion for most of lithium ion battery related areas.*
- Argonne National Lab (Ira Bloom and David Robertson)
  - *Testing procedure (EV protocol) discussion.*

Summary

- Demonstrated multiple cathode concepts which can meet the project goal.
- Identified several new Si anode materials with improved efficiency and reduced expansion, which can meet the project goal.
- Identified new electrolyte additive which improved the performance of baseline materials at high voltage and high temperature test condition.
- Optimization of stack pouch cell is still on-going : critical issues of sealing and table welding studied.
- Test protocol (EV) was established and preliminary data were generated using large cell test vehicles.
- Achieved > 30% increase in energy compared with that of baseline chemistry by integrating new high energy cathode and Si alloy materials in 18650 formats

Proposed Future Work

- Continue to optimize the composition and planning to initiate the morphology control.
- Initiate the experiments to find new electrolytes based upon fluorochemical chemistry enabling high voltage cycling.
- The exploration of composition spaces for new Si alloys will be continued in tandem with optimization of coating methods and coating chemistries in next quarter.
- Continue to focus on stack cell process validation and build 18650 & pouch cells using baseline material and generate complete set of data package using established EV test protocol.
- Continue to build and monitor the cycling performance of high capacity large cells using advanced cathode and anode materials