High Energy Novel Cathode / Alloy Automotive Cell

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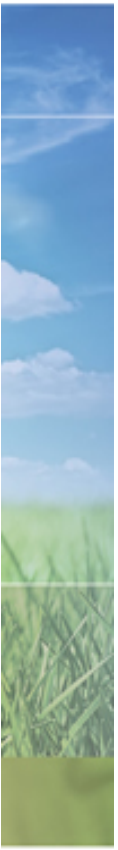
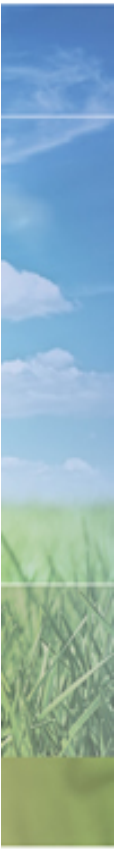
Overview



- Timeline
  - *Start: 10/01/2011*
  - *Finish: 1/15/2015*
  - *~77% complete*
- Budget
  - *Total project funding*
  - *DOE share: $4,577,909*
  - *Contractor share: $1,961,961*
  - *Funding received in FY11: $ 0*
  - *Funding for FY12 : $1,746,279*
  - *Funding for FY13 : ~$1,164,808*
  - *Funding for FY 14 : ~$1,000,000*
- 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*

3M

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% (1.4 X 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*

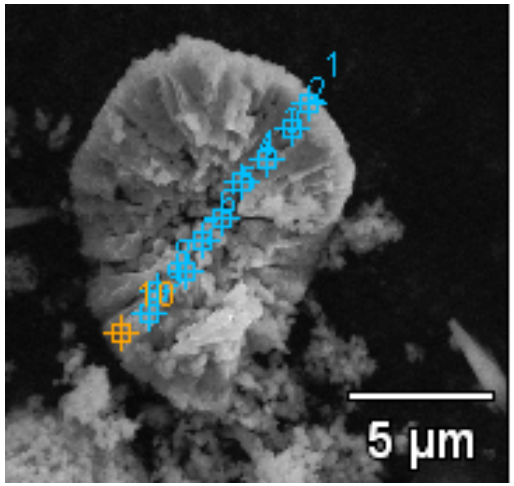
Milestones

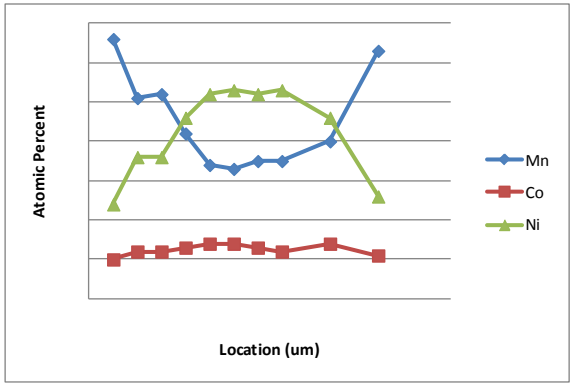
Month/ Year	Milestone	Status
Apr-12	▪Complete the synthesis of advanced materials in quantities to build cells	✓
July-12	▪Complete the prototype large cell build with baseline material	✓
Sep-12	▪Finalized 18650 as the relevant format ▪Demonstrated advanced materials capability to meet targets ▪Demonstrated baseline materials performance per EV test protocol	✓ ✓ ✓
Sep-13	▪Electrode coating procedures for advanced materials ▪Baseline materials data package ▪Preliminary 18650 with advanced materials to meet program goals ▪Deliver baseline cells ▪Deliver intermediate cells	✓ ✓ ✓ ✓ ✓

Approach: High Energy NMC Cathode Development

Core-Shell Concept

- *High Mn Shell: Cycle-Life*
- *High Ni Core: Capacity*
- *Combined: Stable High Energy*



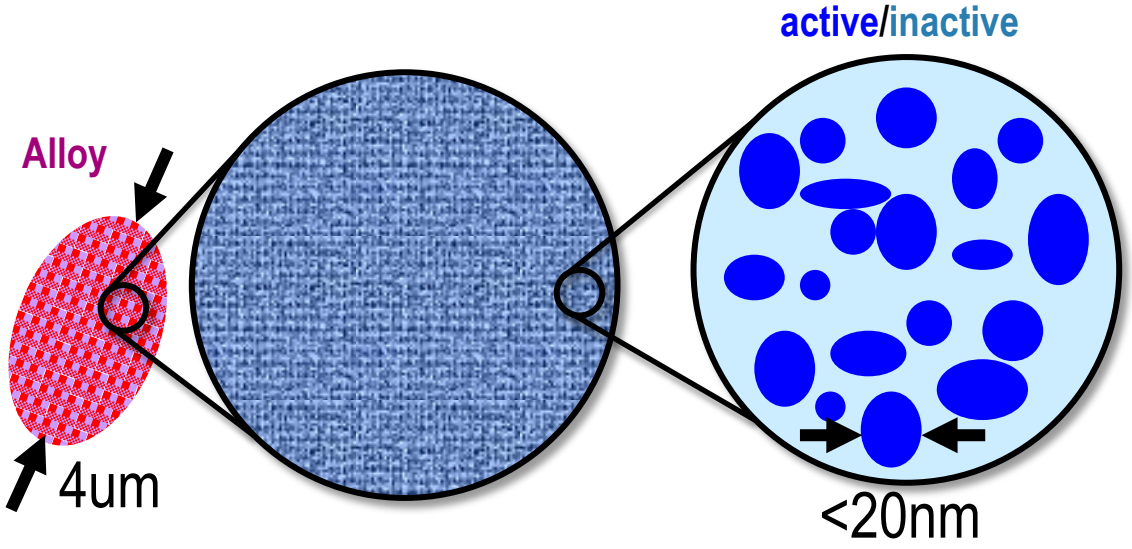


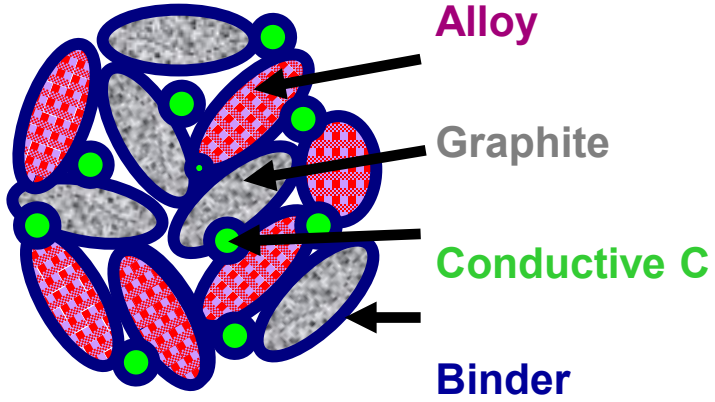
	Oxide	Capacity	X	Density	X	Voltage	X	Irrev Factor	=	Cathode Energy Factor
Electronics	LCO	0.179		3.75		3.99		0.95		2.54 (graphite)
	LCO	0.179		3.75		3.99		0.88		2.36 (alloy)
	NCA	0.196		3.5		3.78		0.97		2.51 (graphite)
Automotive	NMC	0.160		3.3		3.90		0.98		2.01 (graphite)
	NMC	0.160		3.3		3.90		0.95		1.96 (alloy)
Core-Shell	126M	0.230		3.4		3.84		0.95		2.85 (alloy)
	126T	0.220		3.4		3.88		1.00		2.90 (alloy)

Core shell materials enable higher Cathode Energy Factor

Approach: Si Alloy Anode Development

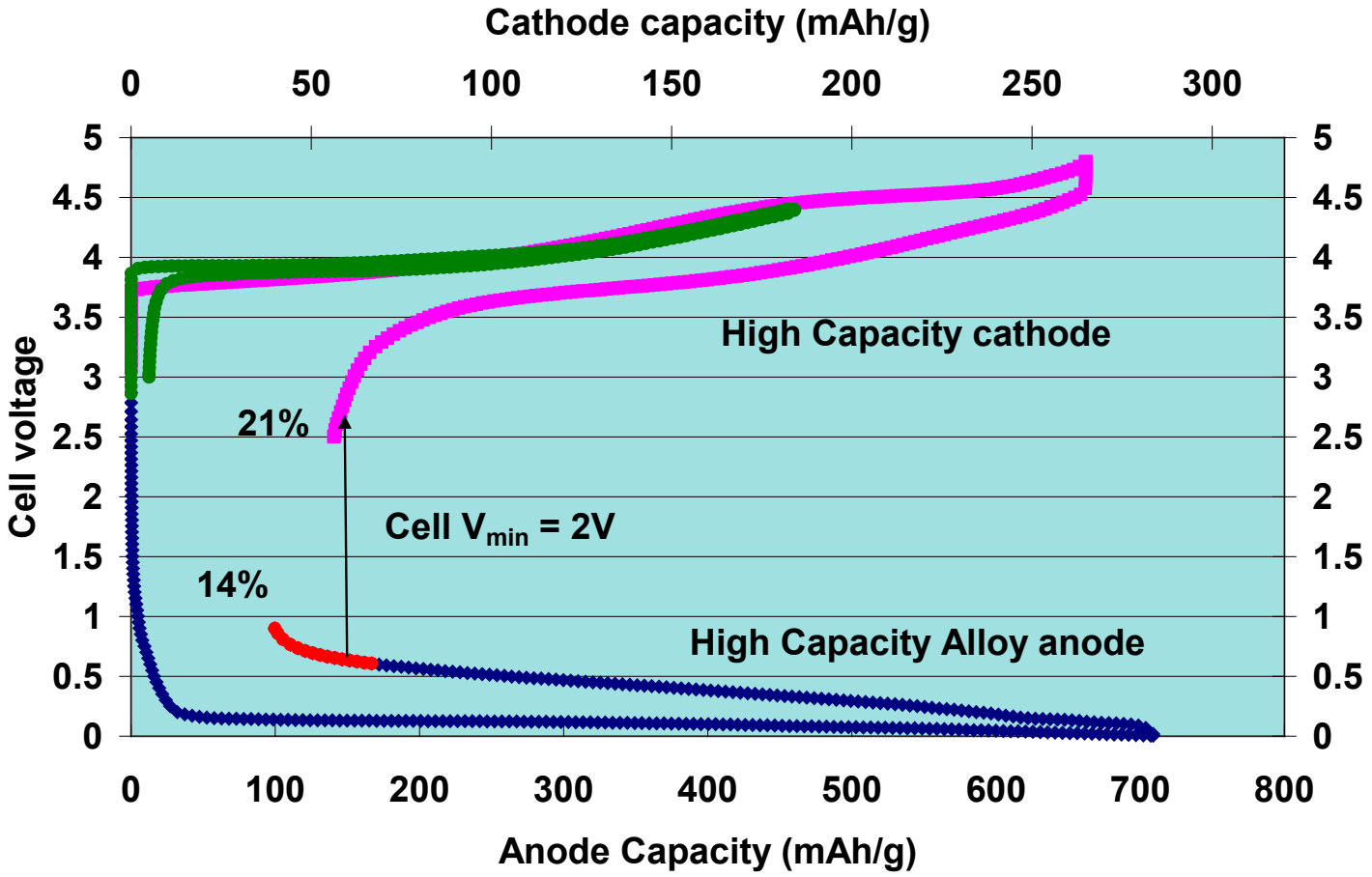
- Alloy Level
  - *Composition*
  - *Microstructure*
- Electrode Level
  - *Graphite*
  - *Conductive Carbon*
  - *Binder*
  - *Dispersion Quality*
- Cell Level
  - *Matching Cathode*
  - *Electrolyte*





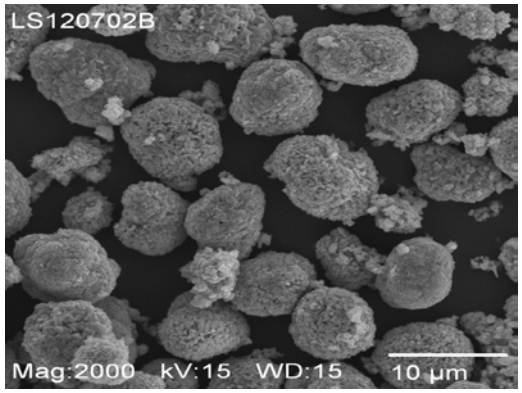
Multi-faceted approach to optimize energy, cycle life and composite thickness change

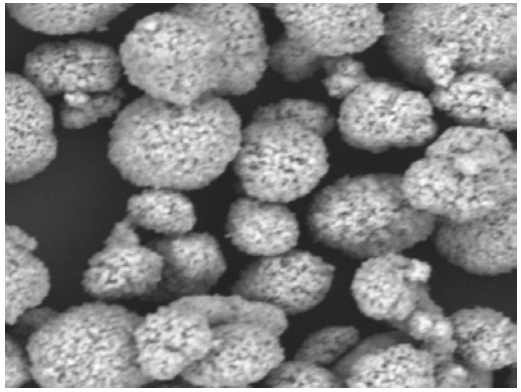
Approach: Cell Integration (HE NMC || Si/Graphite)

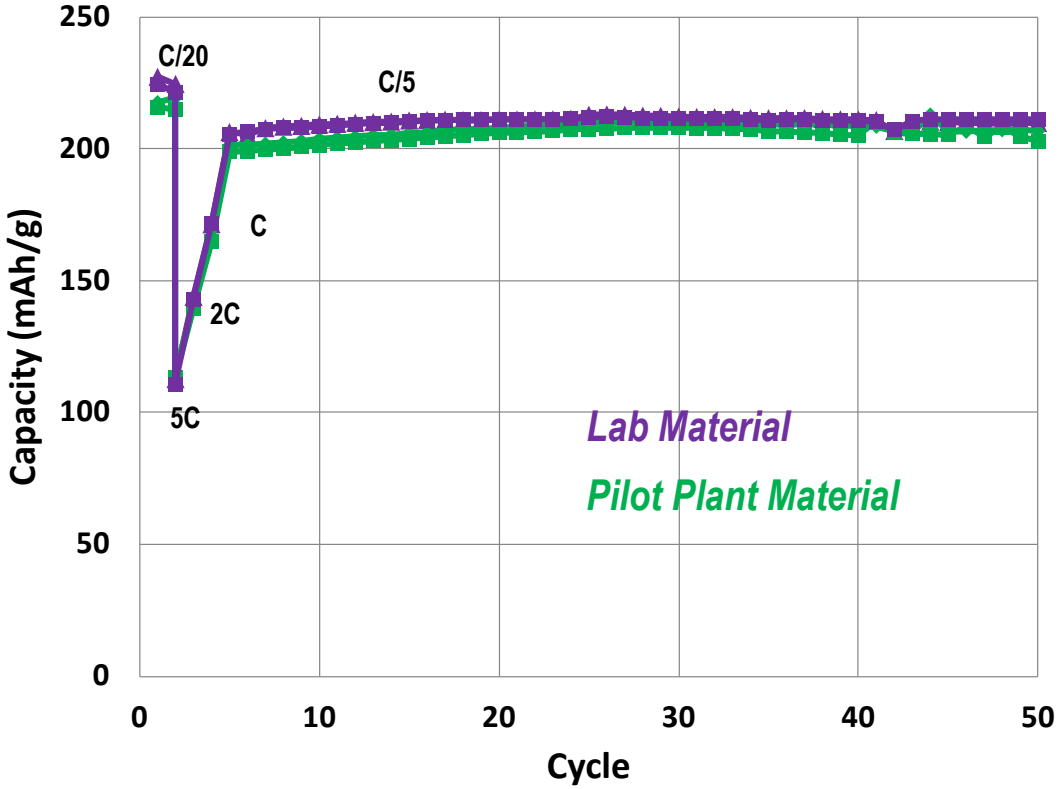


Matching 1st cycle efficiency maximizes benefit of both materials

Accomplishment: High Energy NMC Cathode Scale Up







Similar Performance from scaled up materials

Accomplishment: Si Alloy Anode Scale Up

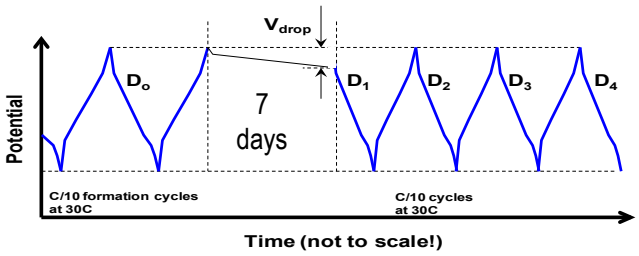
- *Cost effective scalable process for commercially viable Si Alloy Anode materials*
- *Capability to manufacture commercial level quantities*
- *>100 kg of advanced material manufactured*

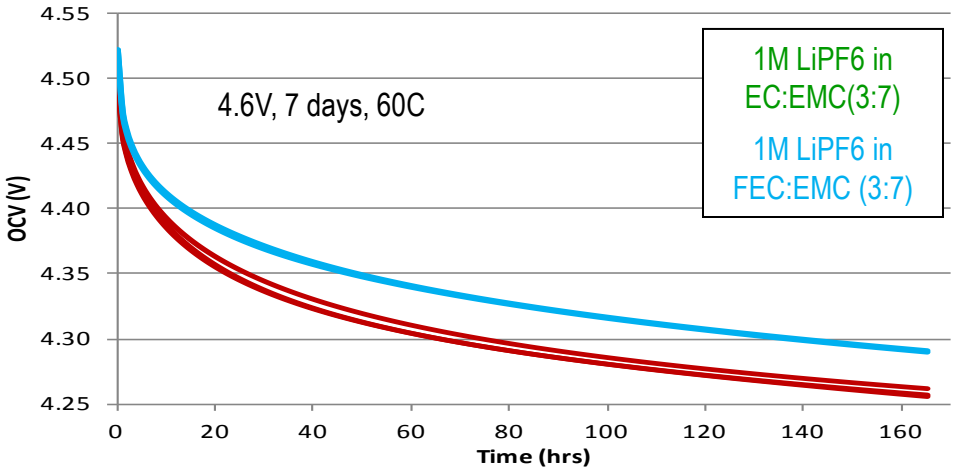
Material Type	Specific Capacity (mAh/g)	1st Cycle Efficiency (%)	Scalability	DOE Support
L-20772	860	89.6%	No	
C-L-20772	850	88.2%	No	EE-000650
V4	1250	76.4%	Yes	
V5	1004	83.5%	NA	
V6	1060	85.0%	Yes	EE-005449
CV6	837	84.1%	Yes	

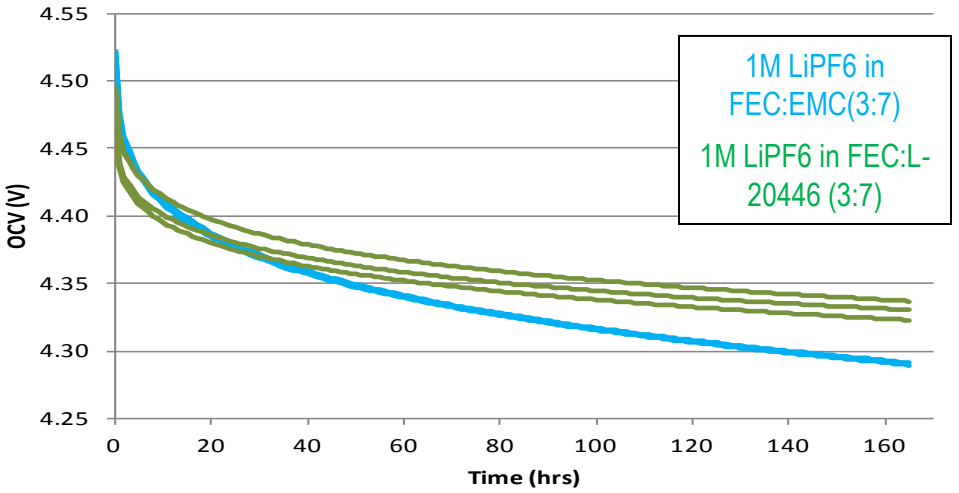
CV6 material scaled up for cycle life optimization

Accomplishment: High Voltage Electrolyte Evaluation

- *Cathode*
  - *NMC:PVDF:Sp:KS6 = 94:3.5:1.25:1.25*
- *Anode*
  - *Graphite:SBR:CMC =96:2.2:1.8*
- *Coin cells Torr sealed*
- *Storage Testing Protocol*

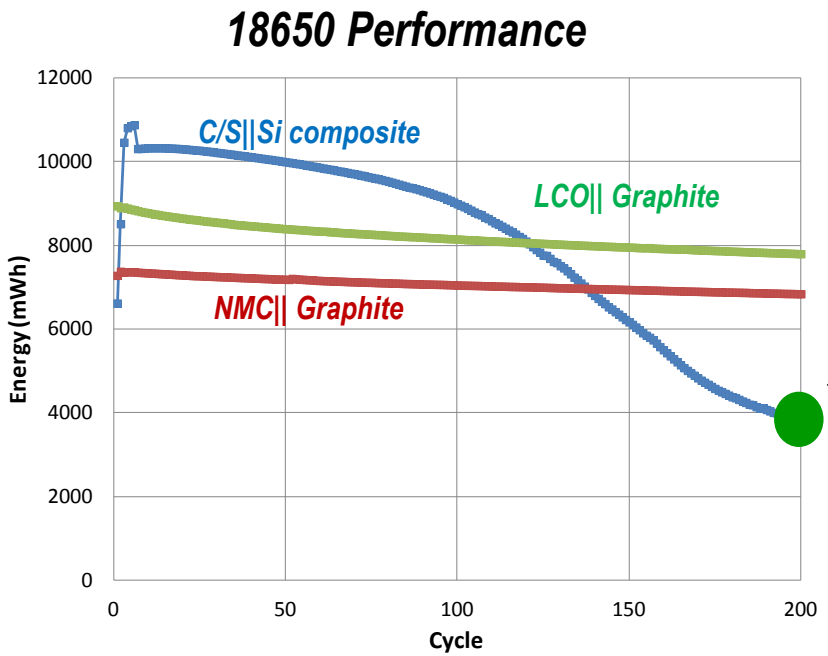


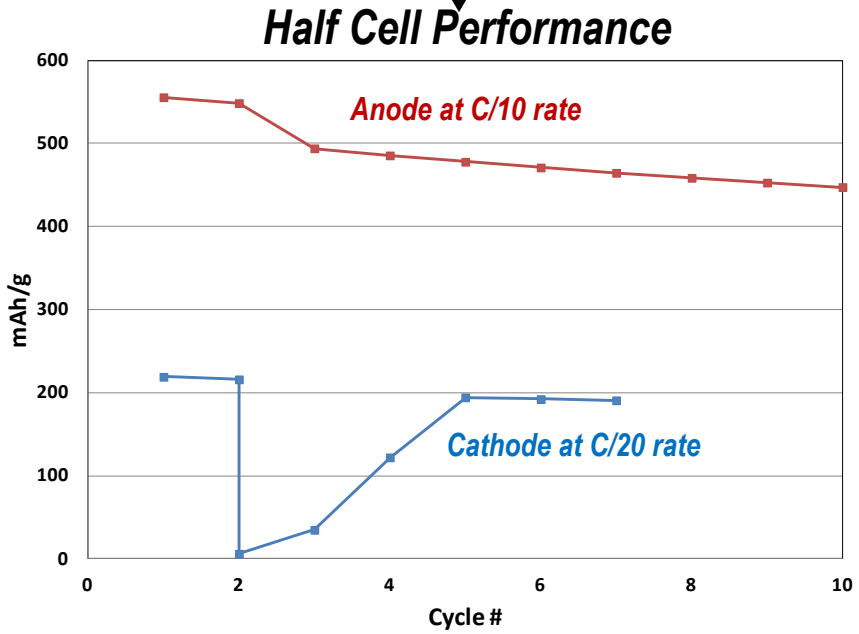




FEC and L-20446 Demonstrate better Stability at High Voltage

Accomplishment: Fade Determination

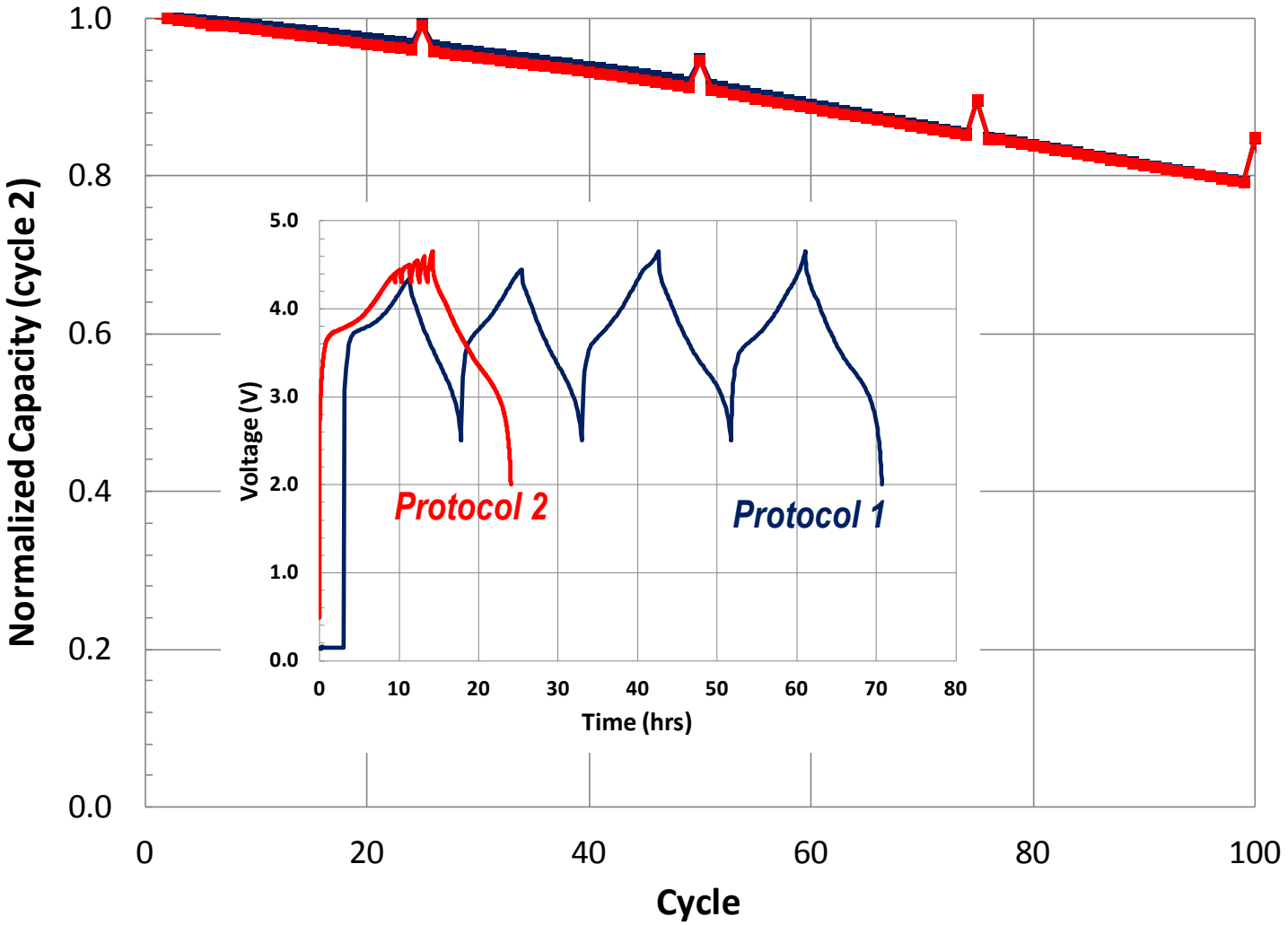




C/S||Si composite design shows >40% energy improvement over NMC||Graphite design

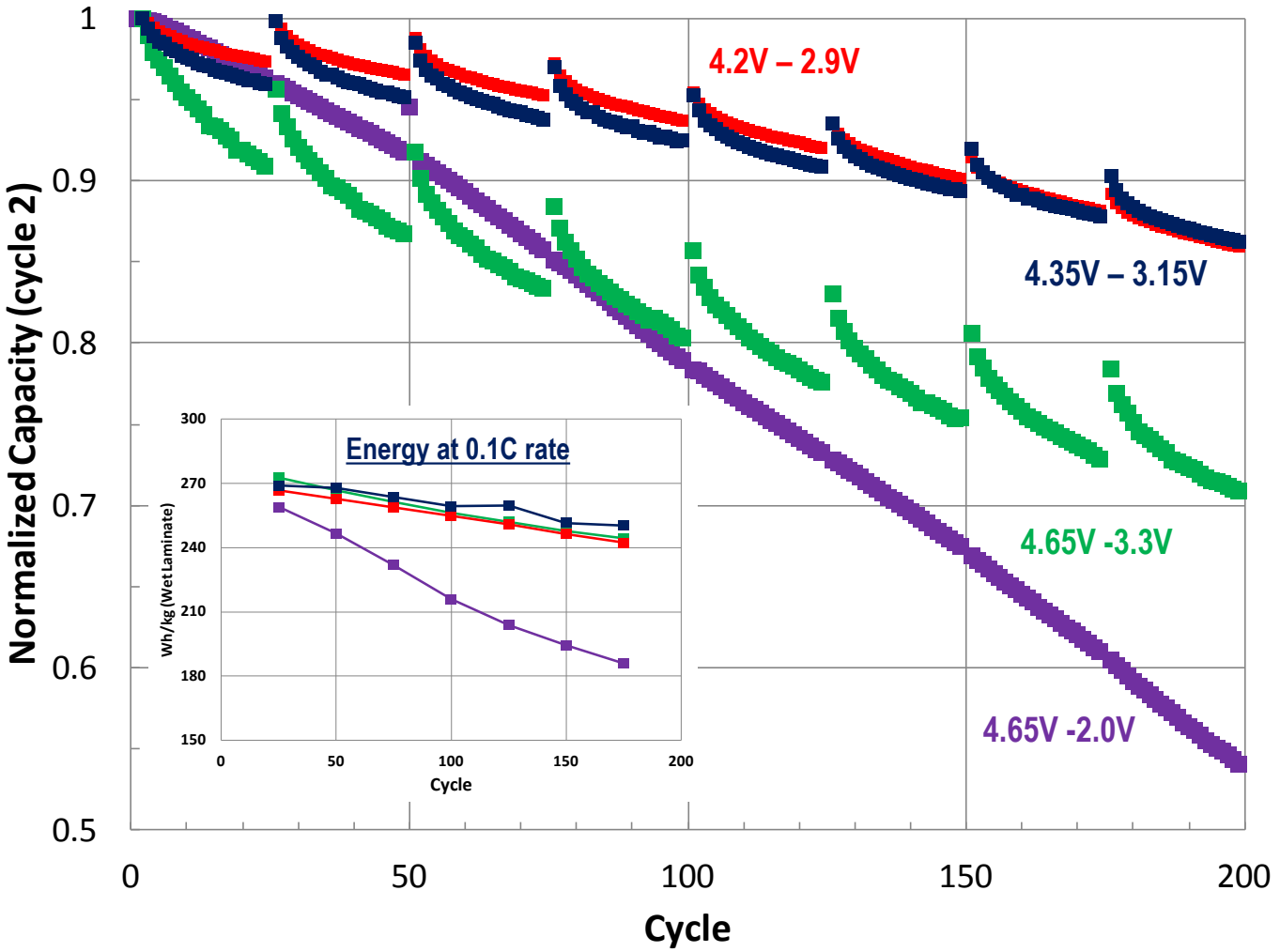
Stable high voltage electrolyte key to long term performance

Accomplishment: Formation Time Reduction



Reduced formation time with similar cycle life performance

Accomplishment: Cycle Life Optimization



Improvements in cycle life in progress.

Collaborations

- Dalhousie University (Jeff Dahn and Mark Obrovac)
  - *Technical discussions related to Lithium ion battery*
- Argonne National Lab (Ira Bloom and David Robertson)
  - *Testing procedure (EV protocol) discussion*
  - *Deliverable testing and discussion*

Summary

- Demonstrated Materials Scale up
  - *Viable High Energy NMC cathode*
  - *Si Alloy anode*
- Demonstrated 18650 performance
  - *≥40% energy improvement*
  - *Cycle life improvement in reduced voltage windows*
  - *Reduced formation time with similar performance*
- Stable high voltage electrolyte key to long term performance

Proposed Future Work

- Phase III
  - *EV testing of HE NMC || Si Anode 18650 cells*
  - *Develop and test electrolytes for cycle life improvement*
  - *Thermal stability testing*
  - *Deliver 24 final cells to DOE designated National Lab*