High-Voltage Solid Polymer Batteries for Electric Drive Vehicles

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Project #: ES129

Overview

Timeline

- Start October 2011
- End September 2014
- 10% complete

Barriers

- Barriers addressed:
  - A. Battery cost
  - C. Performance: Energy Density
  - E. Lifetime
- Targets – prototype cells exhibiting:
  - >515 Wh/l, >325 Wh/kg
  - >1000 dd cycles,15 yr calendar life

Budget

- Total funding
  - DOE share: $4.9M
  - Contractor share: $2.1M
- Funding received in FY11: $0K
- Funding for FY12: $1.3M

Partners

- Hydro-Québec (IREQ):
  - Li anode development
    - For baseline, interim & final deliverable cells
    - Supports commercialization plan
  - Safety & Abuse Testing

Relevance: Project objectives

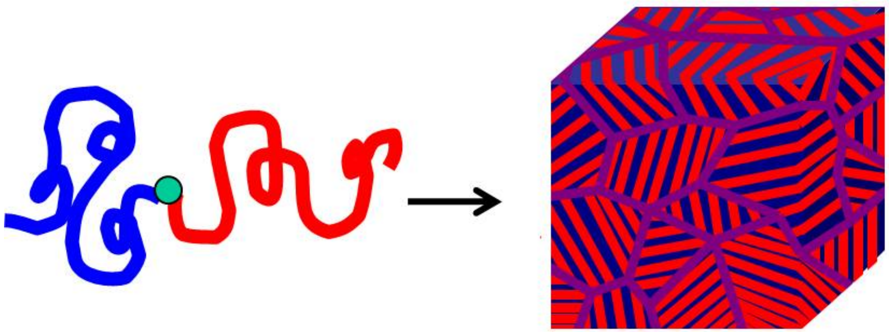
- Delivery of baseline low-voltage cells to demonstrate the safety, stability and performance of Seeo’s nanostructured polymer electrolyte (NPE) using high capacity Li anodes
- Delivery of advanced high energy cells utilizing a layered solid electrolyte, Li anode and high-voltage cathode material
- Full performance evaluation and validation of specifications, with results from USABC safety and performance testing
- Analysis of the commercial and manufacturing potential and impact of advanced high energy cells

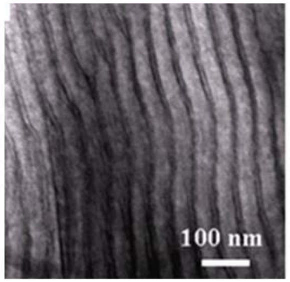
Relevance: Project milestones

Phase I: Baseline Evaluation and Material Synthesis	
Deliver baseline cell specifications and test parameters to DOE	May 2012
DOE Review: Voltage Stability and Structural Design	Jan 2013
Phase II: Material Formulation and Scale-Up	
Catholyte polymer synthetic method design completed	May 2013
DOE Review: Cathode-Catholyte Polymer Couples	Jan 2014
Phase III: Cell Fabrication and Testing	
Catholyte polymer large scale batches to specification	May 2014
Final Cells Delivered to DOE for validation testing	Sep 2014
Manufacturing and commercialization plan completed	Sep 2014
DOE Review: Final Cell Design and Testing Review	Sep 2014

Approach: Nanostructured electrolytes

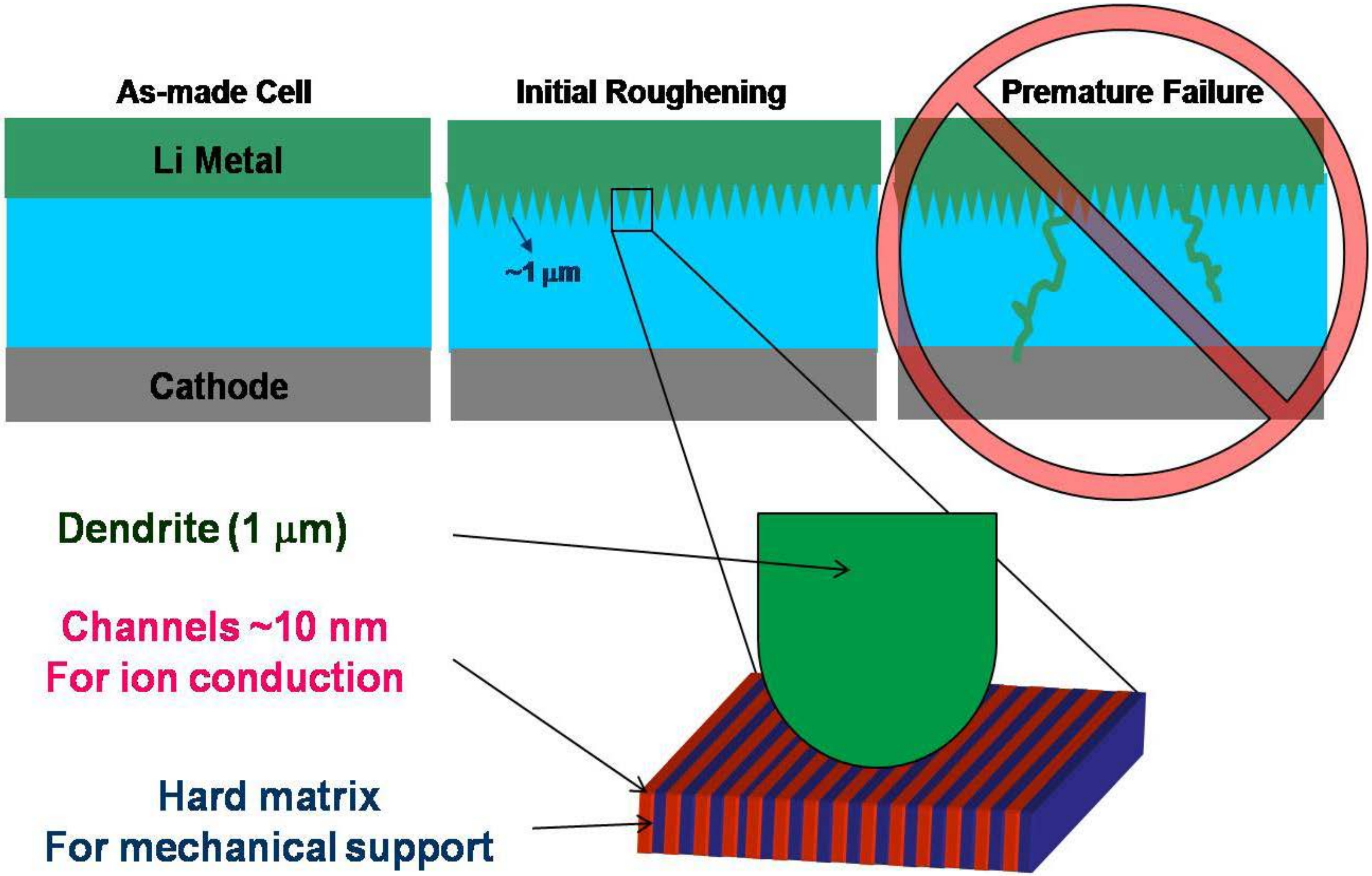
Well-established principles of block copolymer self-assembly ensure that channels of the two phases are created with dimensions on the nm-scale.





Self-assembly of block copolymer electrolytes and TEM of nanostructured electrolytes.

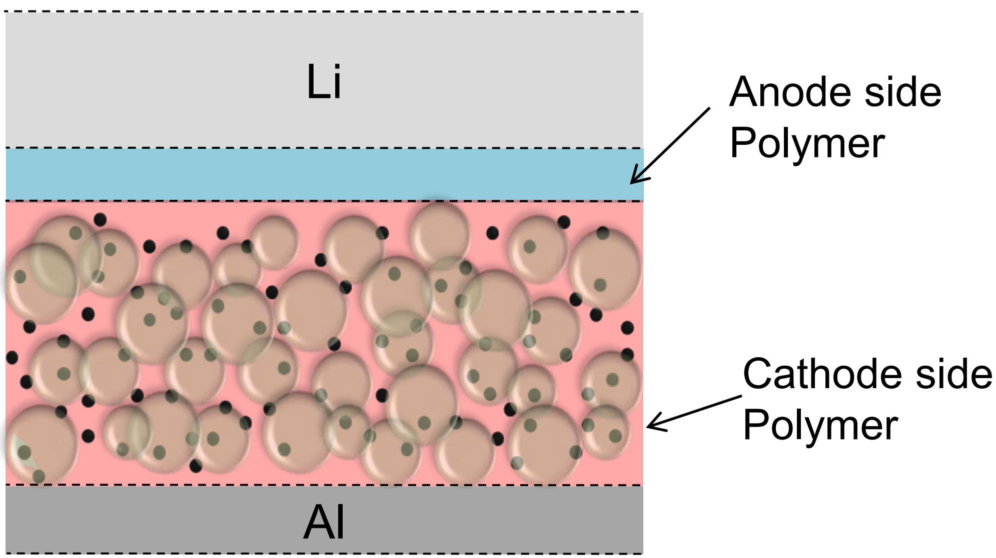
Approach: Dendrite suppression



Schematic of the mechanism of dendrite growth inhibition by Seeo's solid polymer electrolyte

Approach: Decoupling through solid-state

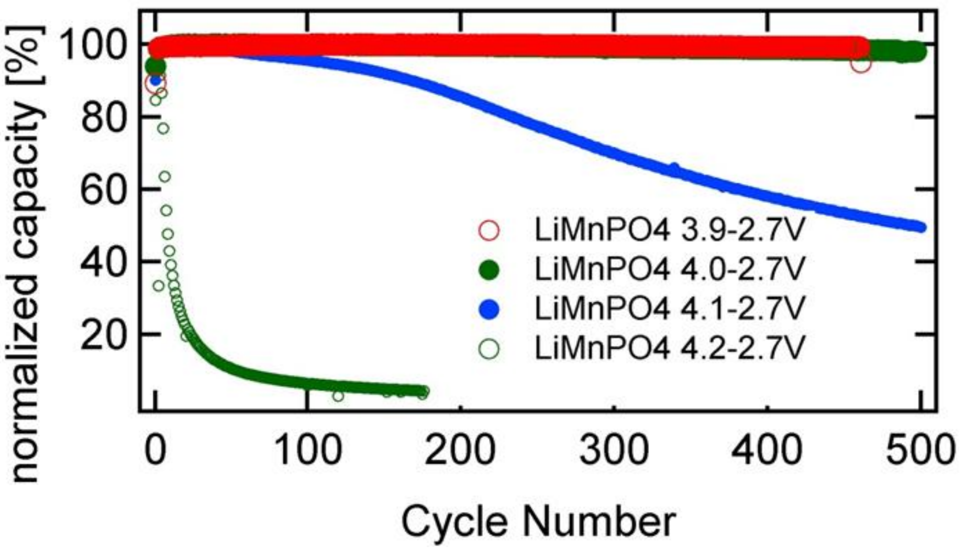
Liquid electrolytes must be stable across a voltage window.
Solid electrolytes needs to be stable at a particular potential.



Cell component	Conventional Li-ion	**Proposed Technology**
Anode	Graphite	**Thin Li Foil**
Electrolyte	Organic liquid	**Solid Polymer**
Separator	PE/PP porous membranes	**Solid Polymer**
Cathode	Nominal voltage <3.7	**Nominal voltage >4.0**

Proposed layered cell configuration

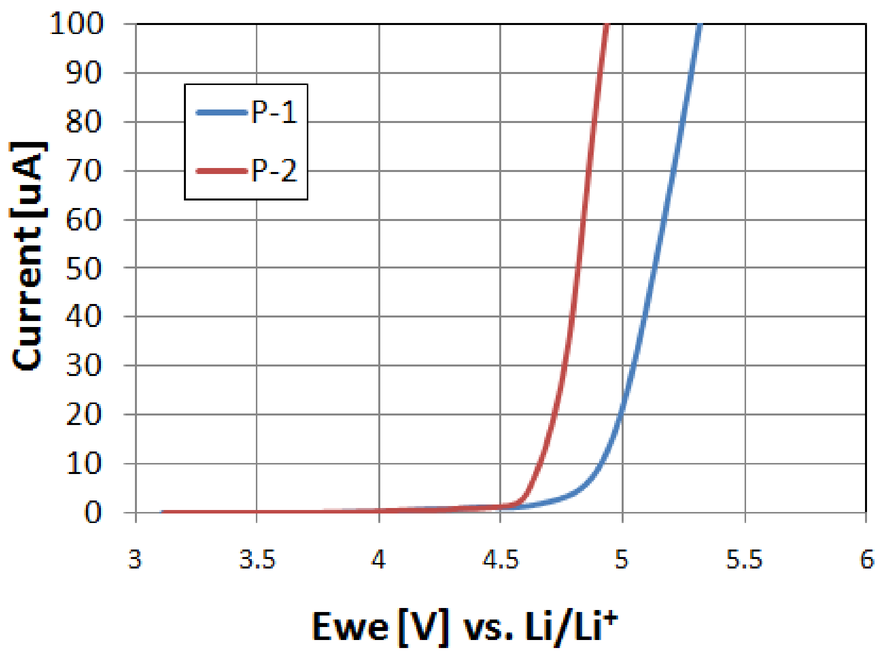
Progress: Need for higher-voltage stability



At high voltages with LMP, capacity fades rapidly using current polymer electrolytes

Progress: Catholyte candidates

High voltage catholytes that have been synthesized are polymeric versions of small molecule electrolytes that have shown stability at high potentials.



Cyclic Voltammetry of catholyte polymers P-1 and P-2. Carbon working and counter electrodes used with Li metal reference

Collaborations: Technical partners

- Institut de recherche d'Hydro-Québec (IREQ):
  - Provide Li foil for baseline, interim and final cell deliverables
  - Assess manufacturing costs for high capacity anodes
  - Lead safety, abuse and performance testing for final cells
- Cathode suppliers
  - Working with 2 commercial suppliers of high-voltage cathode materials for testing with candidate catholyte materials

Future work: Project phasing

Project plan (high-level)

			2012				2013				2014		
		Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3
Phase I	**Baseline Evaluation and Material Synthesis**												
1	Baseline Cell Delivery												
2	Cathode Sourcing and Characterization												
3	Mechanical Stabilization of HV Catholyte												
4	Anolyte-Catholyte Interfacial Stability												
Phase II	**Material Formulation and Scale-Up**												
5	Small-Area Cell Validation												
6	Polymer Scale-Up												
Phase III	**Cell Fabrication and Testing**												
7	Large-Area Cell Validation												
8	Stacked Cell Design Iterations												
9	Cell Fabrication & Manufacturability Assessment												
10	Safety and Performance Testing												

Phase I: Establish a baseline level for project evaluation and commence major research activities. Identify and develop high-voltage polymer and cathode materials.

Phase II: Optimize polymer and cathode mechanical and electrochemical properties. Develop volume synthetic techniques, comparing cost and performance.

Phase III: Test and construct prototype cells, validate cell design, establish final specs, and deliver a commercialization plan

Future work: FY12 focus

- Baseline Cell Delivery
  - Specify baseline cell properties & test parameters
  - Deliver baseline cells to DOE for independent verification
- Cathode & Catholyte Development
  - Optimize material properties & composition
  - Tune interfacial performance between layered electrolytes

Summary

- Polymer electrolytes offer a fundamentally safe and reliable medium for efficient transport of Li ions
- Seeo has developed a proprietary nanostructured polymer electrolyte (NPE) that is stable against high capacity anodes
- Focus of this research project is to develop an NPE-based platform that is stable with high-voltage cathode materials and build prototype cells to demonstrate the potential of this system
- Solid-state, high-energy cells represent a distinct opportunity for the United States to build a viable battery manufacturing industry
  - Solid-state cells require reduced capital (e.g. formation equip.)
  - High-energy, long-life materials reduce cost/delivered kWh
- With support from DOE, Seeo has commitment from our private investors for the full duration of this project