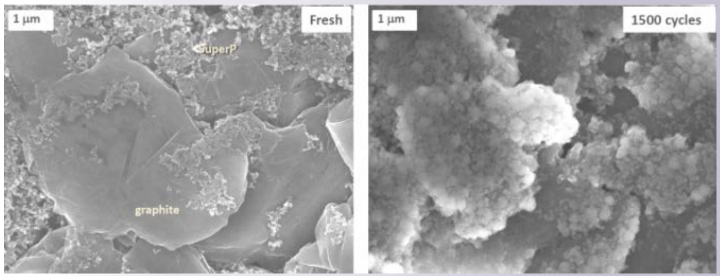
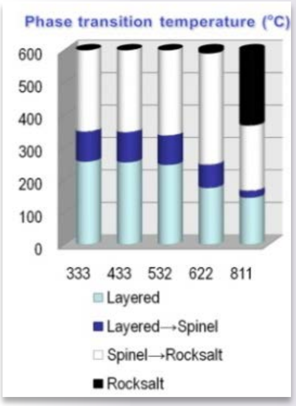
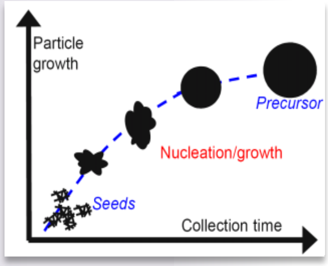
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

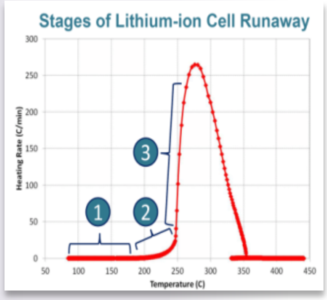




Overview and Progress of Applied Battery Research (ABR) Activities



Peter Faguy
Energy Storage
Hybrid and Electric Systems Team
Vehicle Technologies Office
Department of Energy



Tuesday, May 14, 2013
Project ID: ES014

ABR Program Goals

By 2014, develop a PEV battery that can deliver a 40-mile all-electric range and costs $3,400.

Timeline

- Start - October 2008
- ABR-phase I finished – September 2014
- ABR-Phase II – starting October 2014

Objectives

- Understand/develop solutions for issues with existing active electrode materials.
- Develop electrolyte systems that allow access to higher cell capacity.
- Significantly improve cycle & calendar life.
- Improve battery safety by reducing the consequences of a cell runaway or failure event, improving thermal stability of cell materials, and reducing the physical hazards under abusive conditions.

Barriers

- Need active electrode materials to achieve 200 Wh/kg at the cell level for 40-mile PHEV.
- Need higher voltage electrolytes that are stable in the presence of high-V cathodes.
- Need cell chemistries with high inherent stability to achieve life and abuse tolerance goals.

Battery R&D Budget

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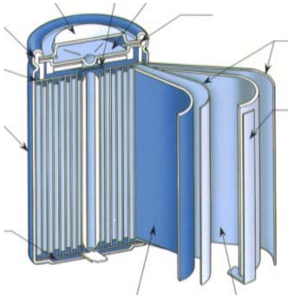
Battery/Energy Storage R&D Funding ($, M)	
FY 2012* Enacted	$90
FY 2013 Full Year CR**	$88
FY 2014* (request)**	$170.5

*FY 2012 SBIR/STTR removed.
**FY 2013 full year CR inclusive of SBIR/STTR.
*** FY 2014 budget request inclusive of SBIR/STTR.

FY 2013 Energy Storage R&D Budget** ($88M)

Program Strategy

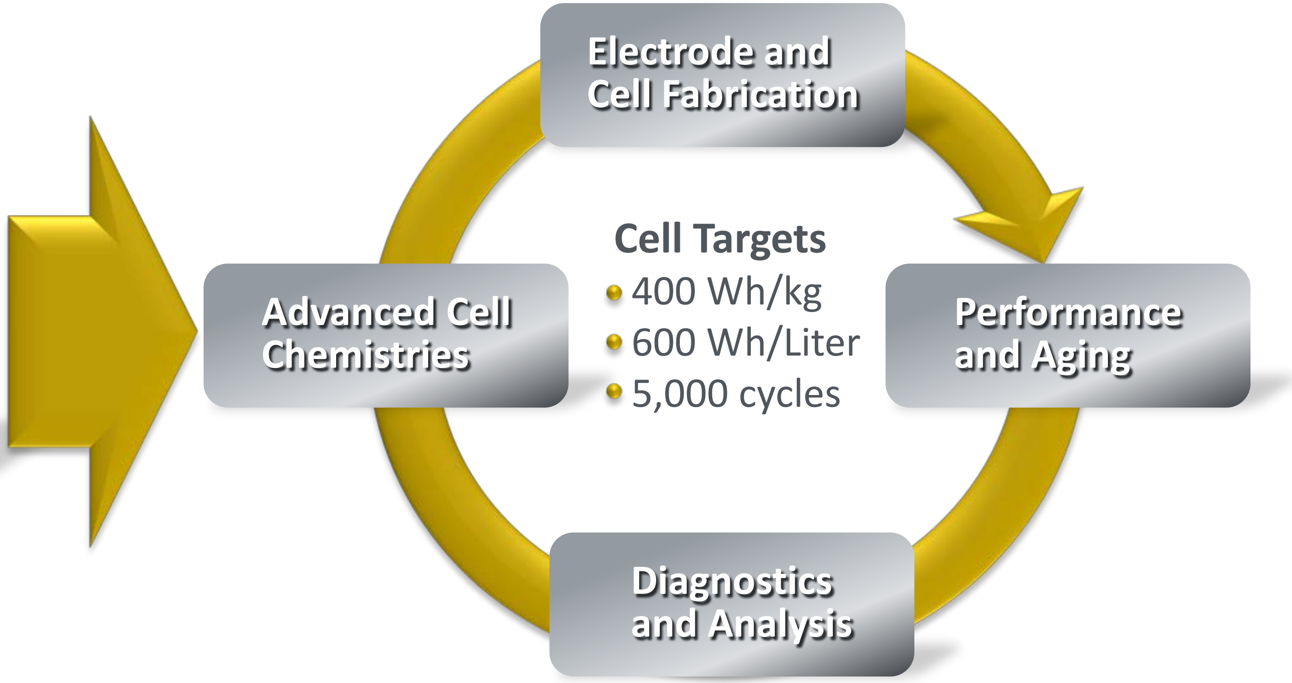


Expedite commercialization of advanced cell chemistries, cell compositions, and cell processing for transportation based lithium-ion batteries

Advanced Anodes
(600 mAh/g)

Advanced Cathodes
(300+ mAh/g)

Next Generation Electrolytes
(5 volt)



Work at the National labs is supported by R&D with industry partners

Current and Near-Term Cell Chemistries

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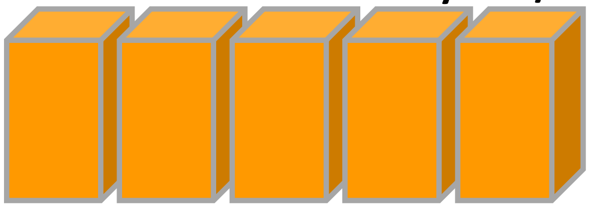
Current PHEV-40 Battery Size/Cost



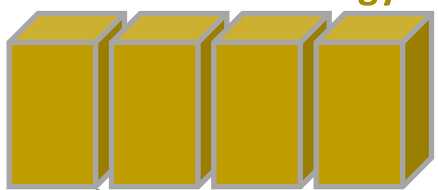
Graphite / $LiMn_2O_4$ + LiNi-Mn-Co Oxide

300 Cells, ~$10,000/Battery

Develop advanced cell chemistries using next-generation materials:

- 400 Wh/kg, 600 Wh/L cell goals
- 5,000 cycles, 10+ year life
- $300/kWh at the pack level

Next-Gen Technology Battery Size/Cost

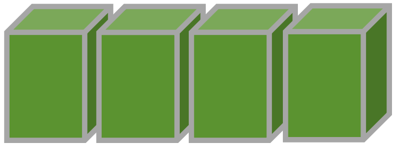


Graphite / $xLi_2MnO_3 + (1\text{-}x)LiMO_2$

200 Cells, ~$5,000 – $6,000/Battery

Major Issues:

- High-voltage stability
- Cycleability (power and energy fade)
- Electrode and cell fabrication



Nano-Silicon / $xLi_2MnO_3 + (1\text{-}x)LiMO_2$

100 Cells, ~$3,000/Battery

Program Evolution

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FY2012 ABR portfolio

27 projects
- 4 core projects
- 23 ABR-I (phase 1) projects

9 national labs
- 7 DOE facilities
- 1 JPL/NASA
- 1 Army

Significant changes at mid-year
- Voltage Fade project created
- 9 ANL projects down-selected

FY2013 ABR portfolio

14 ABR-I projects
- All to complete FY2013

4 core projects

1 ABR-II project
- Voltage Fade
  (2 oral & 11 poster presentations)

VTO-wide Funding Opportunity
- AOI 7 ≡ ABR-II projects

FY2014 ABR portfolio

4 core projects

4 to 6 ABR-II projects (FOA 793*)

* FOA 793 (AOI 7)

"Applied Battery Research for Improvements in Cell Chemistry, Composition, and Processing "

$12M total funding, 4 – 6 two year projects with Oct. 2013 start dates.

ABR II

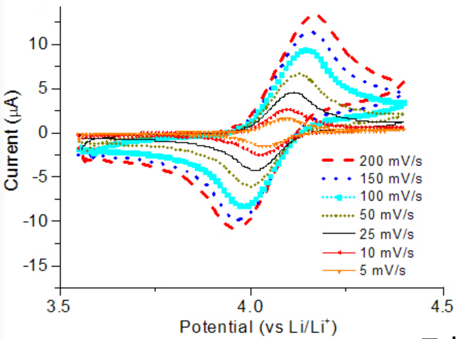
- ❑ Address barriers for next-generation Li-ion batteries for EDVs.
- ❑ Collaborative, iterative, multi-mode applied R&D processes that move materials and advanced chemistries through design, fabrication, performance testing, and diagnostics.

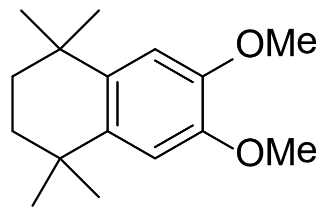
Highlights – Core Programs: Materials Scale-up

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

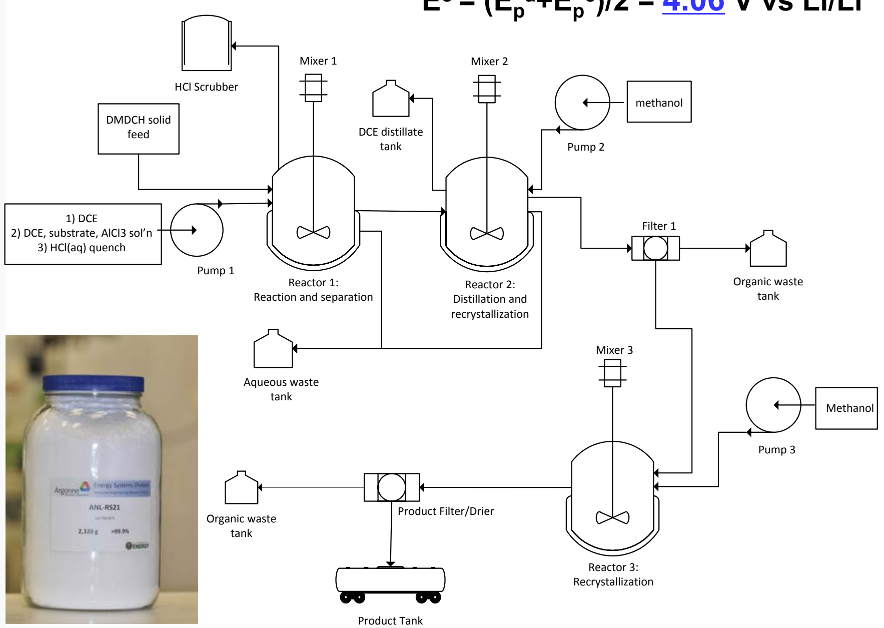
Materials Engineering Research Facility (MERF)

Electrolyte Component Processing

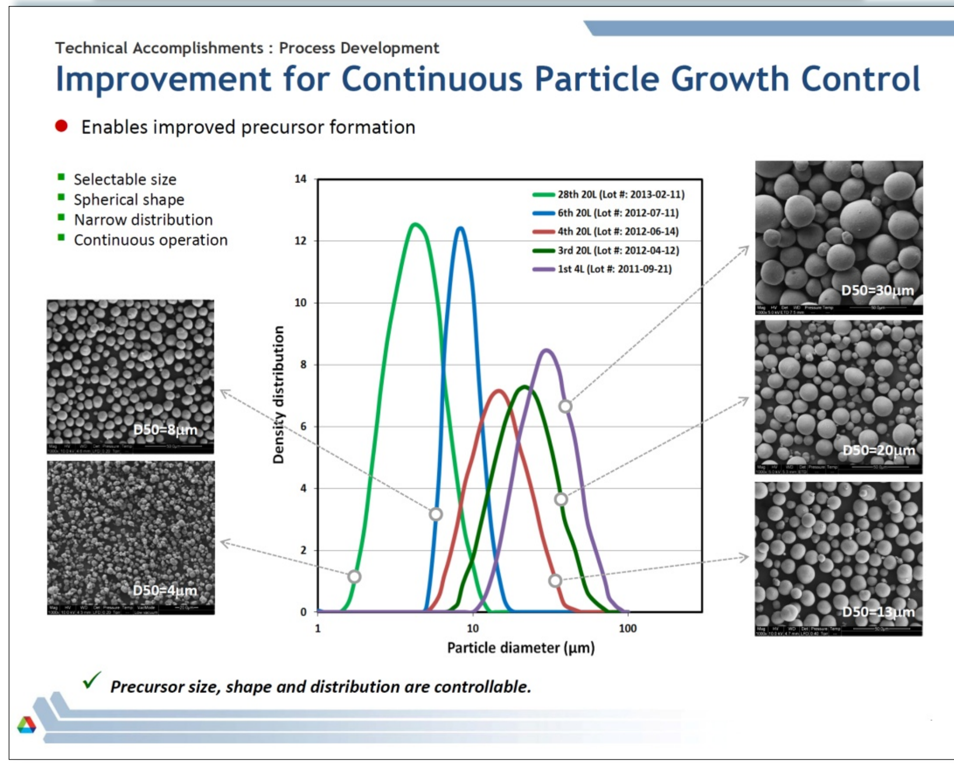




$E^{o\prime} = (E_p^a + E_p^c)/2 =$ 4.06 V vs Li/Li^+



Active Cathode Material Processing



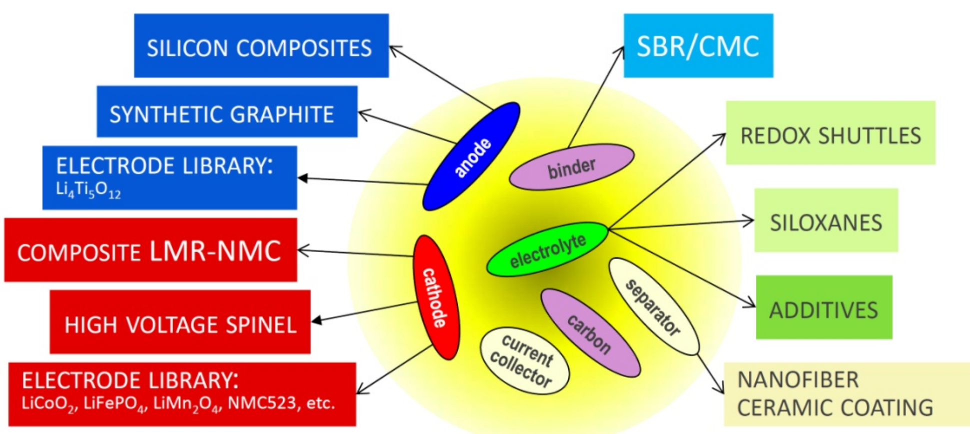
Argonne NATIONAL LABORATORY

Highlights – Screening / Benchmarking

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

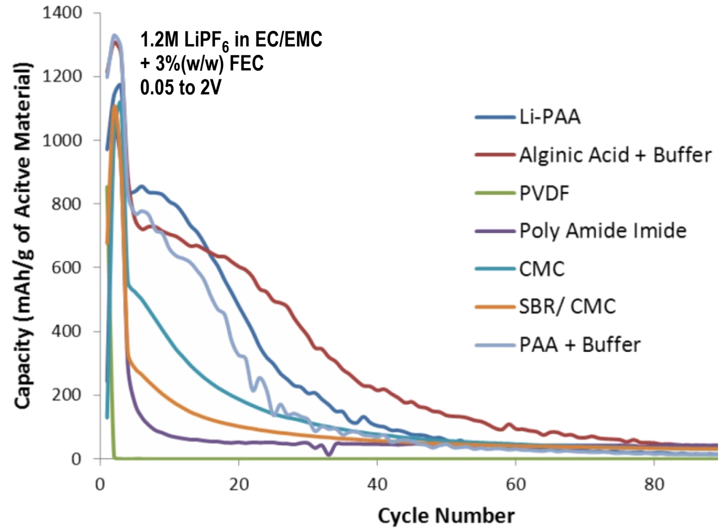
Materials Screening

- Several high energy cathode materials of two major chemistries—composite cathode and high voltage spinel-have been identified and studied.
- Several silicon morphologies and Si-composite materials have been identified. The material validation work on these Si-based negative electrode materials has been incorporated with the binder investigations.
- Other cell components, such as electrolyte solvents and additives, conductive additives, binders, etc., have also been investigated.



Silicon Electrodes & Binders

- Silicon-based negative electrodes have a better chance to meet the PEV energy requirements due to their adjustable high capacities.
- Their utilization, however, still waits on developing the high capacity, stable active anode material PLUS developing non-active components (additives & binders), establishing testing protocols, and optimizing electrode engineering.



Binders tested:

- poly(vinylidenefluoride) (PVDF)
- poyacrylic acid (PAA)
- sodium alginate
- poly(amine imide) (PAI)
- carboxymethyl cellusoe (CMC)
- styrene-butidiene rubber (SBR)

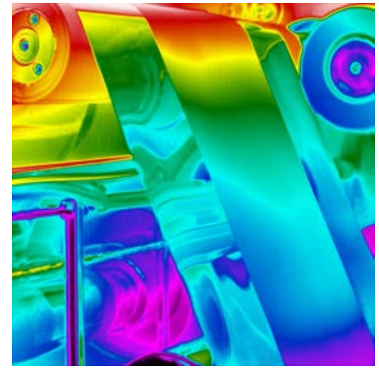
Argonne NATIONAL LABORATORY

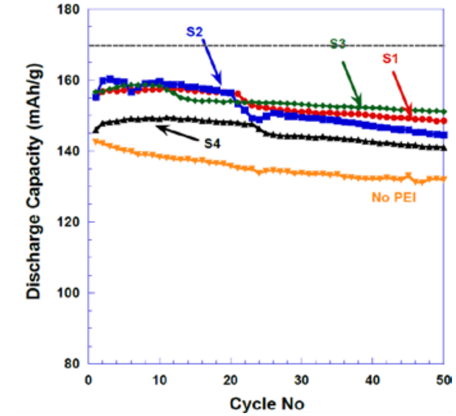
Highlights – Process-based R&D

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Oak Ridge National Laboratory

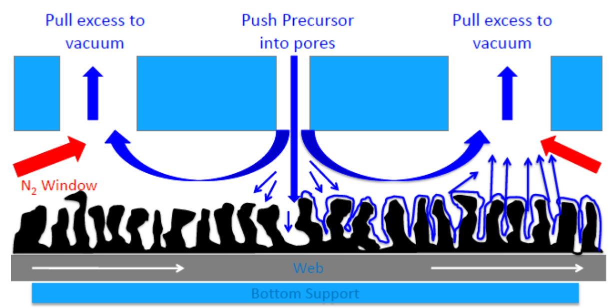
- Overcoming Processing Cost Barriers of High-Performance Lithium-Ion Battery Electrodes
- Roll-to-Roll Electrode NDE and Materials Characterization for Advanced Lithium Secondary Batteries

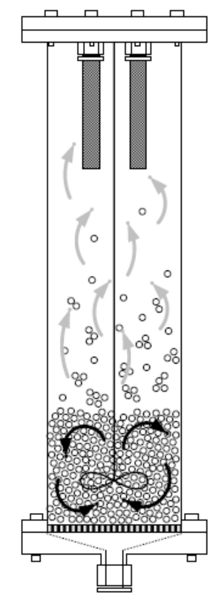




NREL
National Renewable Energy Laboratory

- Development of Industrially Viable Electrode Coatings
- Impact of ALD Coating on Mn-rich Cathode Materials





Highlights – Electrolyte Development

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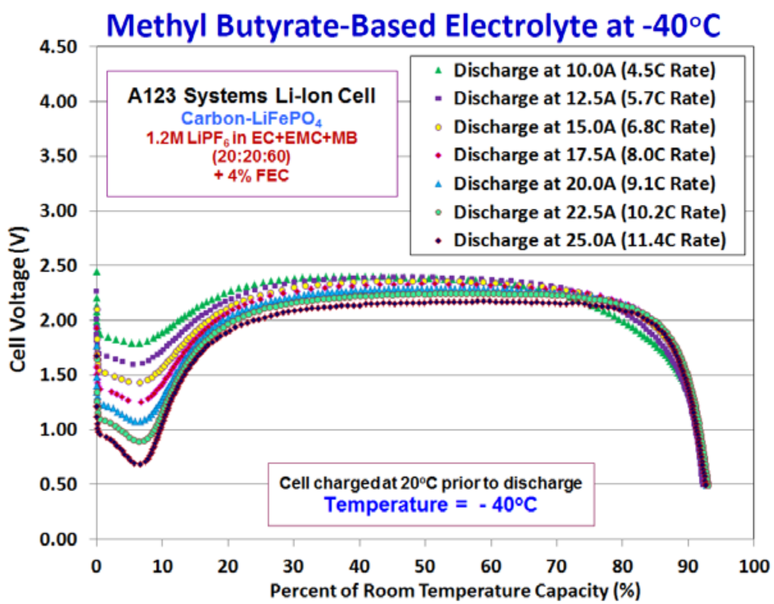
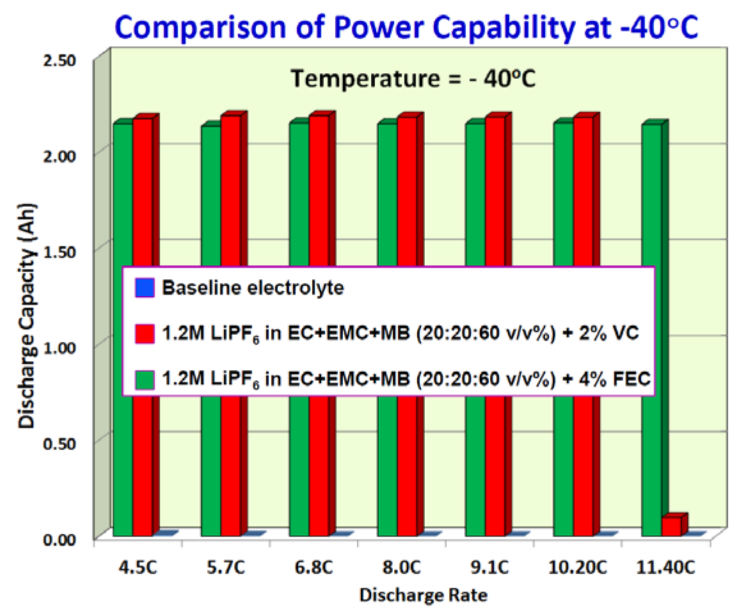
JPL

A123 2.20 Ah High Power Lithium-Ion Cells with JPL Electrolytes

Discharge Capability at -40°C

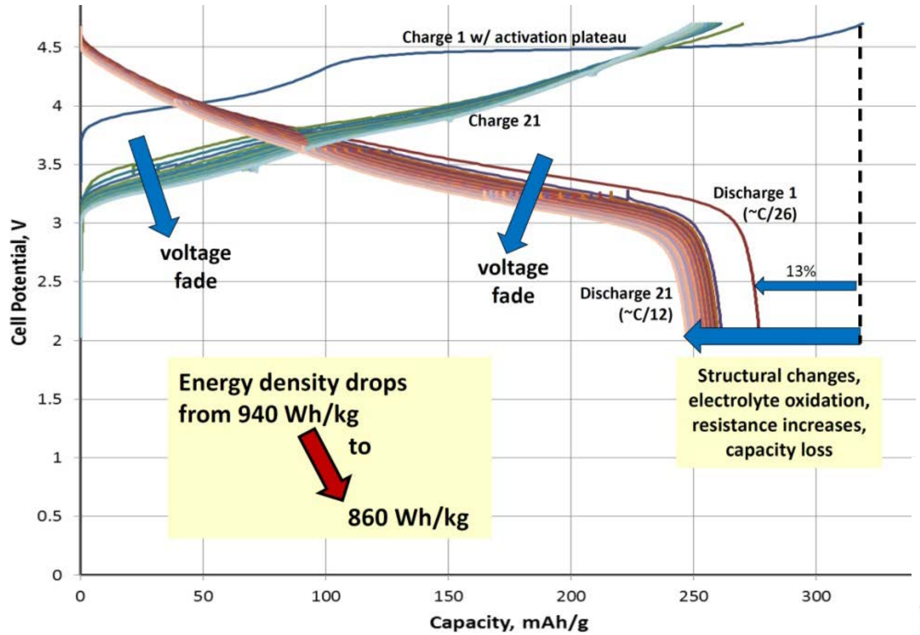




- A123 cells (2.20 Ah) containing JPL MB-based electrolytes were demonstrated to support greater than 11C discharge rates at -40°C, with over 90% of the room temperature capacity being delivered. (1.2M $LiPF_6$ in EC+EMC+MB (20:20:60) + 4% FEC shown above).
- The cells were also observed to perform well down to -60°C, with 80% of the room temperature capacity being delivered using a C/10 rate.

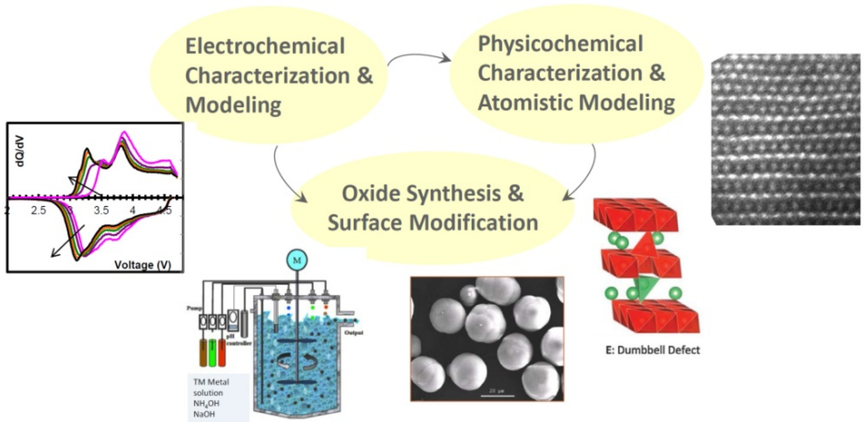
ELECTROCHEMICAL TECHNOLOGIES GROUP

Highlights – Voltage Fade



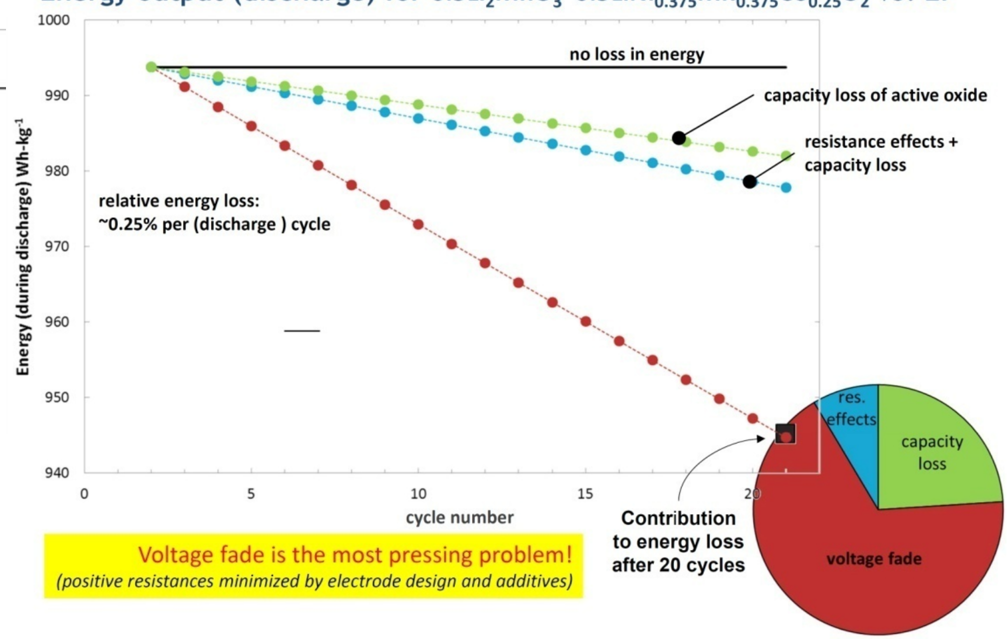
Approach

Multi-institution effort to identify factors that contribute to voltage fade in Li- and Mn-rich NMC oxides (LMR-NMC**)**



Suggest/implement approaches to mitigate voltage fade

Energy output (discharge) for $0.5Li_2MnO_3 \bullet 0.5LiNi_{0.375}Mn_{0.375}Co_{0.25}O_2$ *vs.* Li

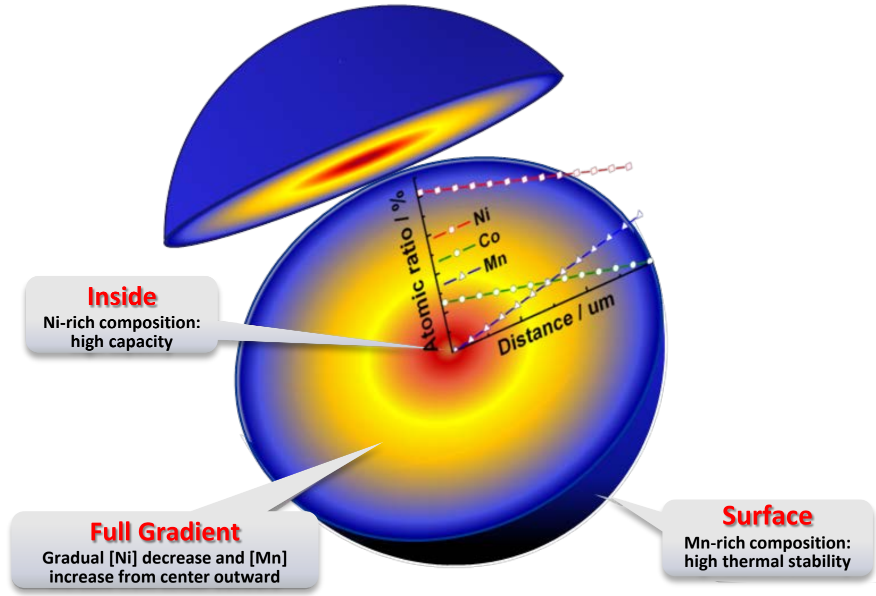


Technology Transfer

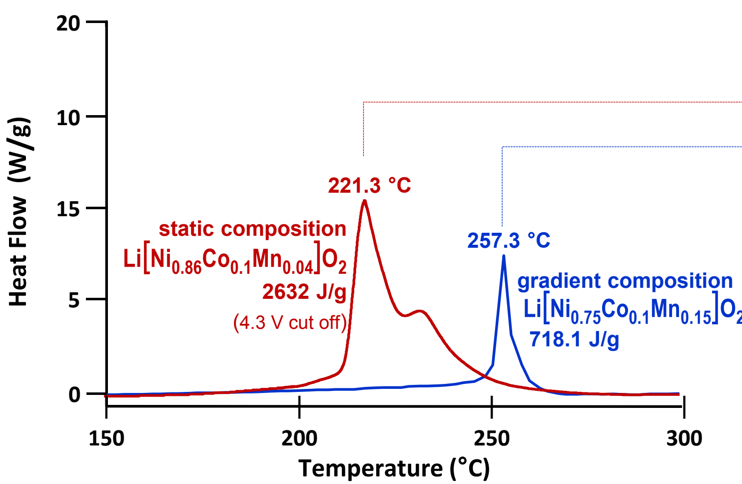
High-Energy Concentration-Gradient Cathode Material for Plug-in Hybrids and All-Electric Vehicles

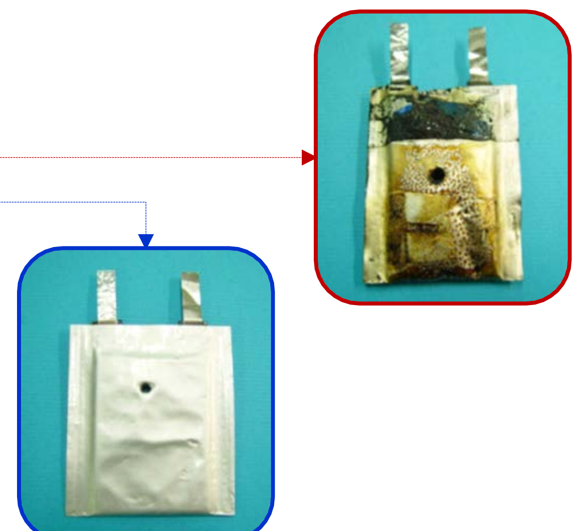
"A new, layered manganese-nickel material, developed by Argonne National Laboratory, Hanyang University, South Korea, and ECOPRO Co. Ltd., South Korea, addresses this problem by providing higher energy and longer life…"

2012 R&D 100
50th ANNIVERSARY



Khalil Amine, Ilias Belharouak Argonne National Laboratory





Corporate Stakeholders

APPLIED MATERIALS

Dow

GM

TODA AMERICA

NAVITAS

NEI Corporation

DURACELL BATTERIES

CABOT

DreamWeaver

ZEON

PHILLIPS 66

DOW KOKAM

QUALLION

DAIKIN

nanosys

XG sciences THE MATERIAL DIFFERENCE

Silatronix

SAFT

DUPONT The miracles of science

plextronics

umicore

Hanwha

SOLVAY

DOW CORNING

BASF

JSR Micro MATERIALS INNOVATION

ConocoPhillips

Johnson Controls

FMC

CELGARD

Summary

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- Translational (benchtop-to-prototype) R&D in next-generation PEV battery cell composition and construction strongly supports the growth of the commercial vehicle electrification in the United States.
- Comprehensive suite of applied R&D activities:
  - full cell calendar, cycling, and abuse performance testing
  - electrode and cell modeling and design
  - materials scale up
  - cell building
  - cell & component diagnostics)
- Continues to enable a flexible, design of experiments approach to resolving issues with high energy couples.
- ABR re-focus at ANL
  - Voltage fade results from multiple investigator, multiple research thrust collaborative effort lead to the following
  - Go/No-Go for post treatment/system level fixes
  - 'Working tools' established (test protocols, database, performance metrics)
  - Omnibus peer-reviewed paper in preparation, over 15 authors from > six organizations.
- Seven electrolyte materials/additives produced in high purity and under scalable procedures.
- >150 m^2 of electrode material distributed to US researchers for ABR-relevant study
- Initial projects in process R&D indicate fertile territory
- A major portion of the ABR program will now be competitively awarded.

For more information …

Contact me

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