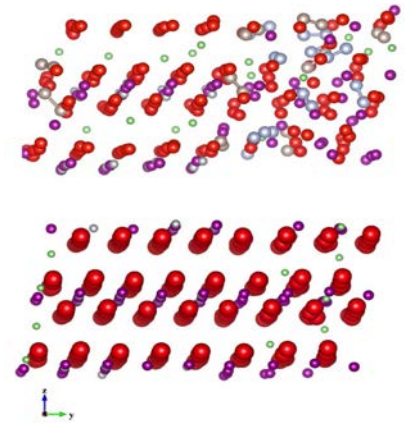
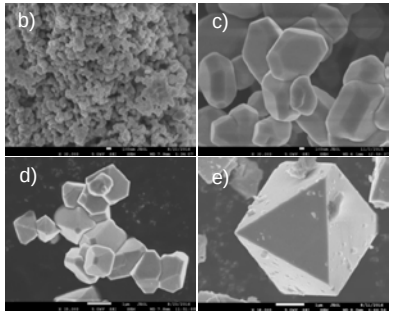
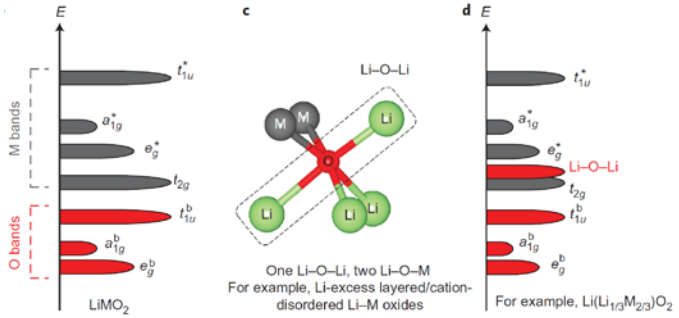
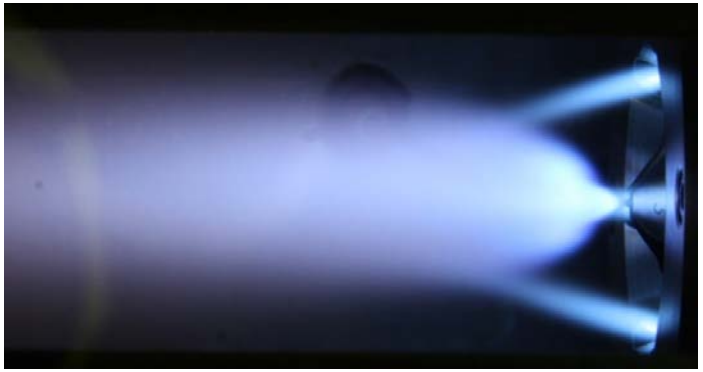
Vehicle Technologies Office

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







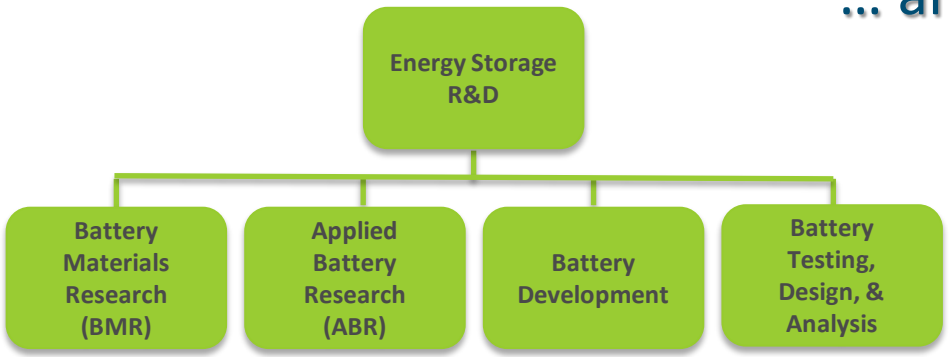


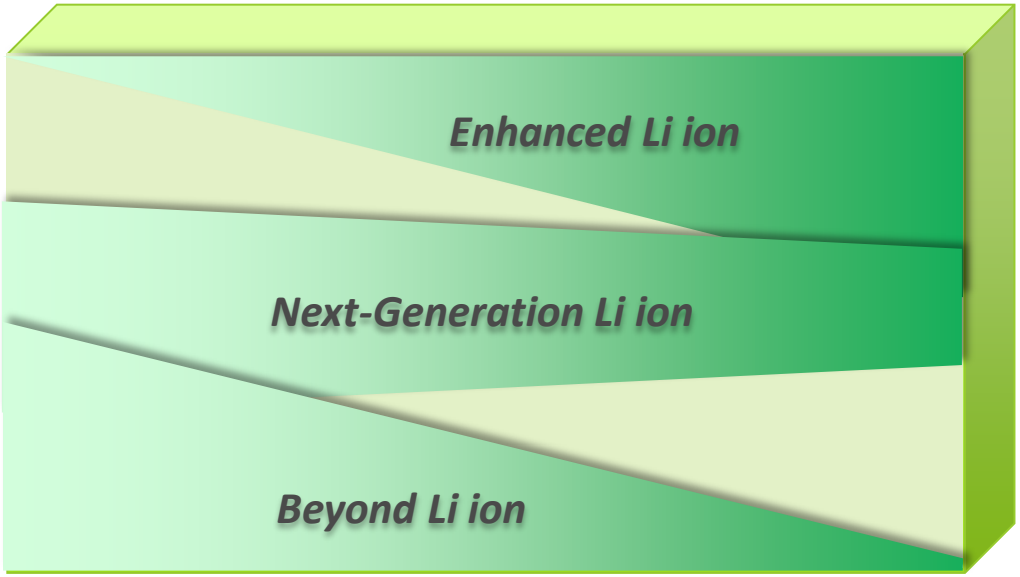
BAT337: Next-Generation Lithium-Ion Batteries: Electrode Architecture and Cell Materials Research Projects

Peter Faguy (DOE)

EERE-VTO Advanced Battery R&D Portfolio

… an evolving portfolio structure





EXAMPLE PROJECTS

- Performance and Safety Testing
- USABC
- XFC

- Silicon Projects
- TMO Cathode Projects
- Advanced Processing

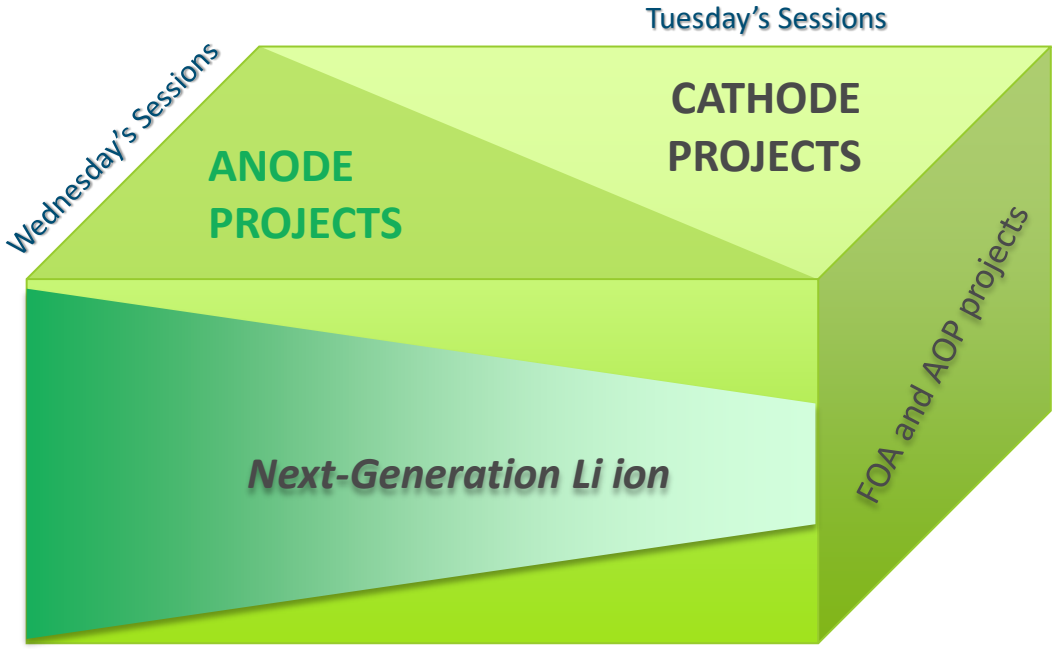
- Battery 500
- Li-S
- Solid State Electrolytes

~110 oral and poster presentations

Advanced Battery R&D: NG LiB Cathodes

"Next-Generation Cathodes"

- Early TRL Use-Inspired R&D on Cathode Materials and Interfaces
- Consortium directed at enabling NG-LiB ACMs
- Cell Optimization, Support Services, and Electrode Architecture
- Advanced Processing Science and Engineering



- Enabling High-Energy, High Voltage LiBs
  3 oral presentations
- Frontier Research: NG Cathode Materials
  6 posters
- Advanced Processing of Cathode Materials
  3 oral presentations, 12 posters
- Cell Optimization and Testing
  9 posters

TUESDAY, June 19 Poster Presentations
5:00 PM - 7:00 PM Salon IV-V-VI

Advanced Processing Projects

- Seven FOA projects and five projects at the National Labs
- Six materials projects and six electrode processing projects

Non-conventional Electrode Manufacturing

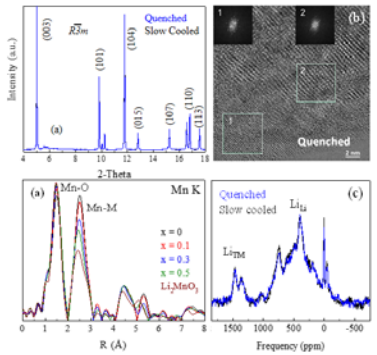
Powder Processing

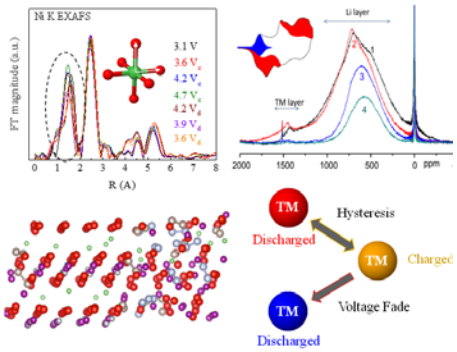
Next-Generation Li-ion Battery Cathode Materials

Lab-based Consortium = "***deep-dive***"

ACM R&D 2012 -- 2015

Voltage Fade Deep-Dive: Structure-Property Relationships of Li/Mn-Rich Cathodes



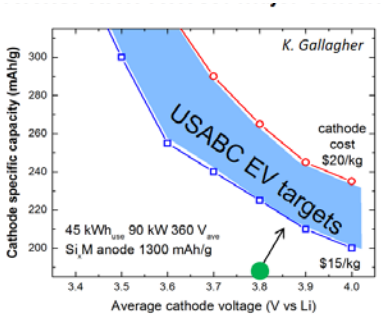


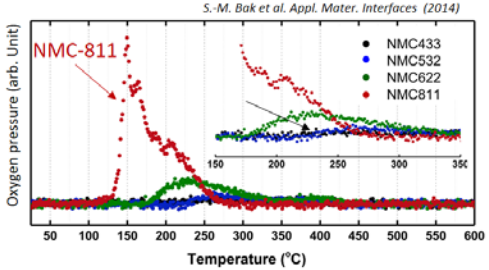
HR-XRD, TEM, XAS, and NMR combined to give an unprecedented look at the local structures that dictate the degradation mechanisms of complex, high-capacity, Li-ion cathode materials

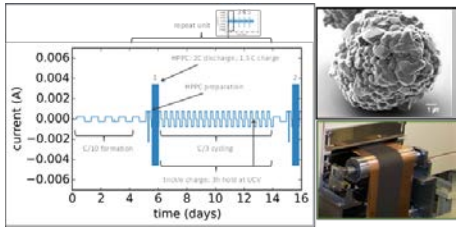
Advanced characterization of working electrodes, combined with electrochemistry and simulation, uncovered, for the first time, the atomic-scale mechanisms governing macroscopic electrode behavior

ACM R&D 2015 -- 2018

Enabling High-Voltage NMCs Deep-Dive: Nickel-Rich NMCs







ACM R&D 2019+

ANL + 3 to 5 other national labs

Realizing Next Generation Cathodes for Li-ion Batteries:
Low Co to Co-free ACMs

- Understanding the critical roles of cobalt in $Li_{1+x}Ni_aMn_bCo_cO_2$ oxides
- Implementing effective replacement strategies in $Li_{1+x}Ni_aMn_bCo_cM_rO_2$ oxides
- Engineering particle surfaces and electrolyte formulations to greatly mitigate or eliminate phenomena associated with oxygen activity, surface reconstructions, electrolyte degradation, and the detrimental effects of electrode crosstalk

Detailed diagnostics and characterization for modified and augmented existing TMOs

low Co

Next-Generation Li-ion Battery Cathode Materials

NEW! Lab-based Consortium == "***disordered rocksalt***"

ACM R&D 2019

LBNL + 3 to 5 other national labs

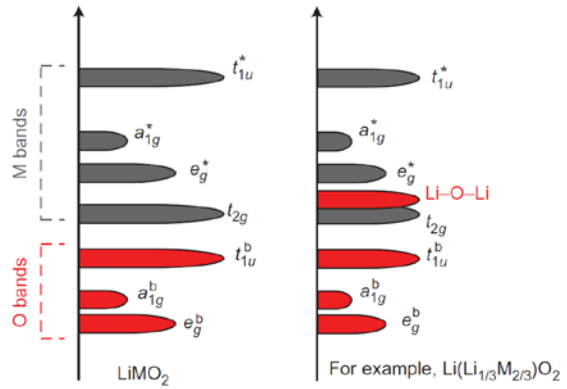
Cation Disordered Rocksalts as Active Cathode Materials

- Disordered Li-excess rocksalts (DRX) are a new chemically diverse class of compounds with significant potential as high energy density, inexpensive, cobalt-free cathode materials.
- Li transport is achieved by percolation through a cation-disordered but high-density crystalline rocksalt structure.
- The utility (necessity) of cobalt in traditional Li excess TMO intercalation compounds: density, potential, surface stability, etc., does not exist for DRX materials.
- Excess Li in DRX materials provides reversible oxygen redox states that yields high capacity.
- Very promising modeling results, but only demonstration systems, proof-of-principle, and unoptimized ACMs synthesized to date.

Accelerated push to realize the promise of DRX intercalation materials.

DRX Consortium Focus

1. **Cycling Stability** … **and how can it be improved?**
2. **Rate Capability** … **how can it be improved?**
3. **Voltage Slope** … **how can it be reduced?**



Co-free

Year	Compound	Capacity (mAh/g)
2014	$Li_{1.211}Mo_{0.467}Cr_{0.3}O_2$ [1]	280
2015	Li_2VO_2F [3]	320
2015	$Li_{1.3}Nb_{0.3}Mn_{0.4}O_2$ [4]	300
2015	$Li_{1.25}Nb_{0.25}Mn_{0.5}O_2$ [5]	290
2016	$Li_4Mn_2O_5$ [9]	350
2016	$Li_{1.3}Nb_{0.3}V_{0.4}O_2$ [10]	190
2017	$Li_{4/3}Mo^{6+}_{2/9}Mo^{3+}_{4/9}O_2$ [11]	330
2017	$Li_{1.15}Ni_{0.45}Ti_{0.3}Mo_{0.1}O_{1.85}F_{0.15}$ [12]	250
2017	$LiMoO_{2-x}$-LiF $(0 \le x \le 2)$ [13]	320
2018	Li_2MnO_2F [14]	280
2018	$Li_2Mn_{2/3}Nb_{1/3}O_2F/Li_2Mn_{1/2}Ti_{1/2}O_2F$ [2]	320

Table 1. Recently reported Li-excess DRX cathodes.

Next-Generation Li-ion Battery Cathode Materials

NEW! FOA Topic: AOI1a – Developing Low-Cobalt ACMs for NG LiBs

DE-FOA-0001919_1A

Low-Co NG LiBs

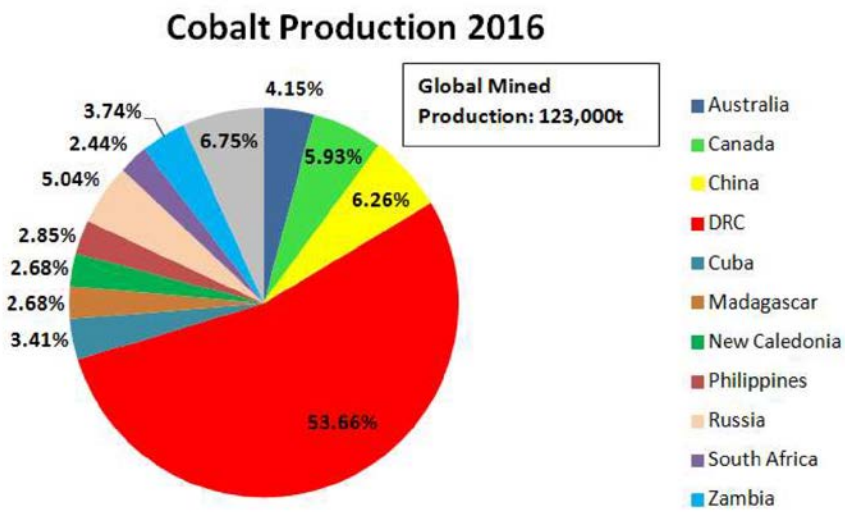
Concept papers reviewed and full proposals due end of July.

- Team-based projects, corporations, universities, and national labs, with full cell deliverables showing high risk/reward innovation specific to achieving a very low Co level.
- Research, develop, and qualify next-generation lithium ion batteries capable of achieving DOE's cell performance and life targets, with a target cobalt loading of less than 50 mg cobalt per Whr, and an ultimate goal of producing Co-free next-generation lithium ion batteries.
- 24 – 36 month projects, $1M – $2.5M projects, 5 – 7 projects funded, 20% cost share.

Accelerated push to reduce Co demand in EV energy storage.

This focus arises now because of the confluence of soaring cobalt costs, the real possibility of a global critical material shortage, and the very real ethical dilemma of child labor involvement in artisanal cobalt ore mining.

Demand for cobalt is dramatically increasing due both to the proliferation of consumer electronic devices relying on cobalt-only LiB cathodes, and to the growing electrification of the consumer vehicle fleet.



low Co → Co-free

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