Present Research and Future Directions of the Batteries for Advanced Transportation Technologies (BATT) Program

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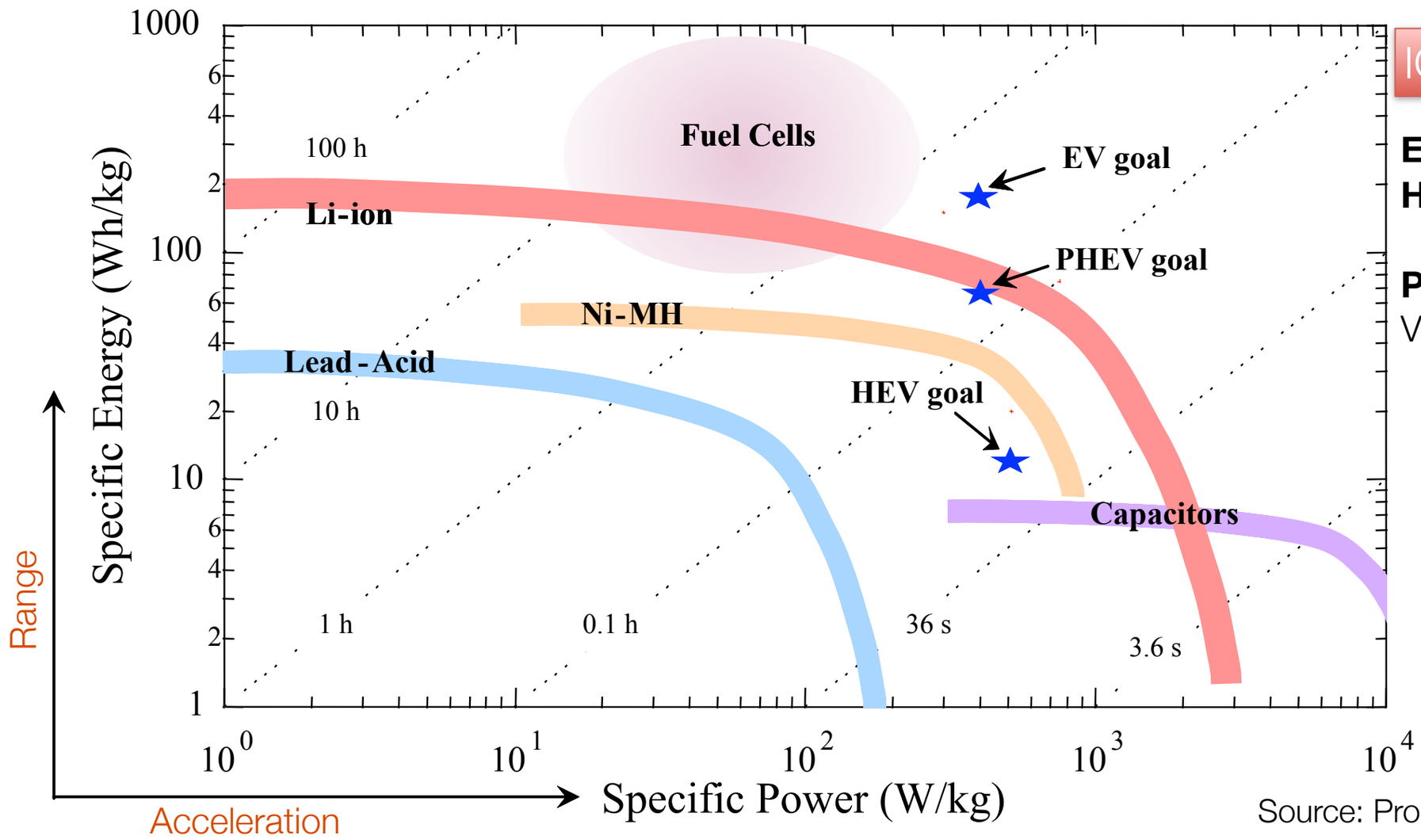
Lawrence Berkeley National Lab

ORNL Meeting
October 7, 2010

Requirements for vehicle batteries



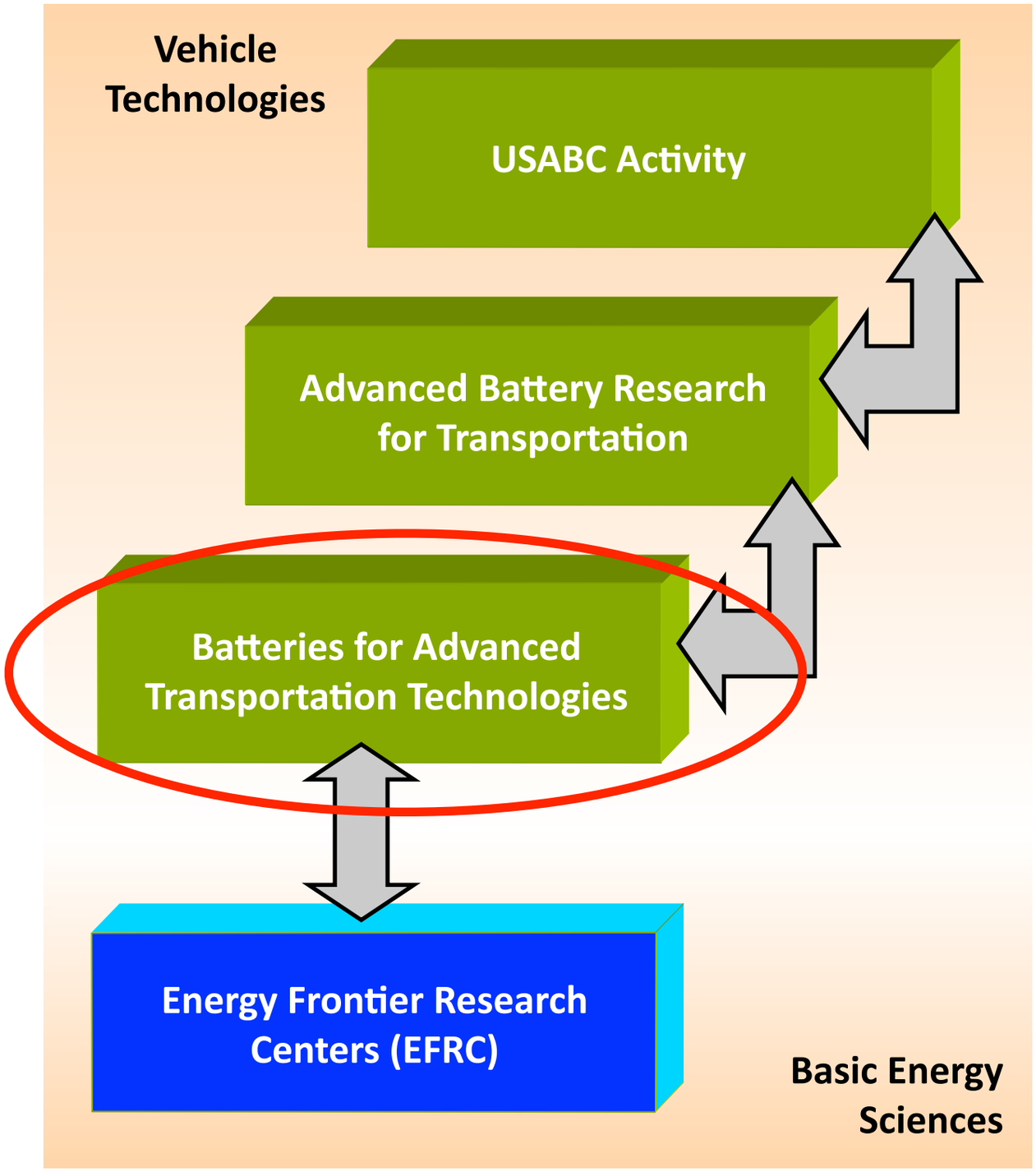
IC Engine=2500 Wh/kg

EV – Electric Vehicle
HEV – Hybrid-Electric Vehicle
PHEV– Plug-in Hybrid- Electric Vehicle

Source: Product data sheets

- For PHEVs to be commercial, need batteries with **lower cost ($/kWh)**
- For battery EVs to be commercial, a **doubling of energy density** needed
- In addition, safety and life (cycle and calendar) of Li-ion batteries remain a challenge

DOE battery research portfolio



- ❑ Cost-shared development activity with industry leading to full battery systems
- ❑ Benchmark and assess existing and candidate battery technologies

- ❑ Assist battery developers to overcome barriers for high power Li-ion batteries

- ❑ Innovative, cutting-edge long-term research to understand and solve life and performance limitations of next-generation batteries

- ❑ High-risk, high-reward research to identify new battery chemistries

The BATT Program

- Focus on the fundamentals to solve the performance, safety, life, and cost challenges that limit use of batteries in plug-in hybrid and electric vehicle applications
- Present emphasis is predominantly on Li-ion batteries
- Consists of 34 projects in universities, national labs, and one company
  - 4 additional projects expected to start in January 2011
- DOE Program Manager: Tien Duong
- Participants represent some of the best-known (battery) researchers in North America
  - Chosen using a highly-competitive proposal review process

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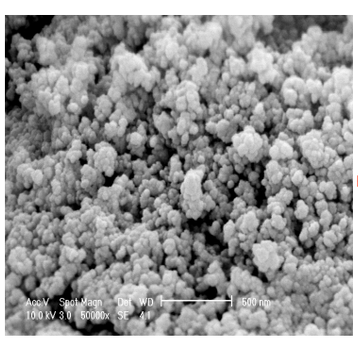
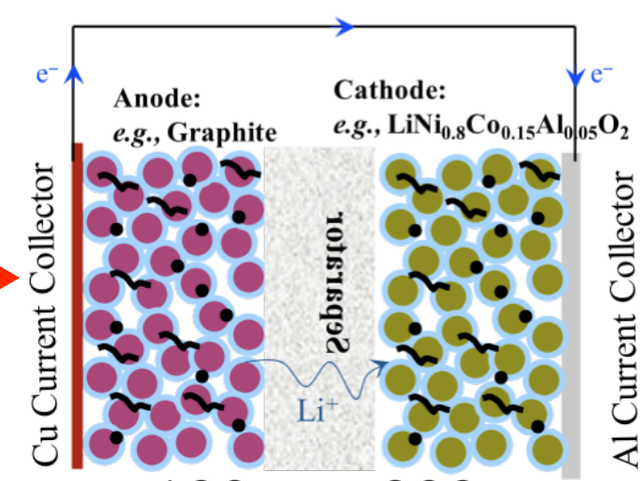


10 nm-10 μm

Length scales of interest



100 μm-300μm

Program participants

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Massachusetts Institute of Technology

University of Pittsburgh

THE UNIVERSITY OF RHODE ISLAND

BINGHAMTON UNIVERSITY
State University of New York

ARIZONA STATE UNIVERSITY

BERKELEY LAB

STONY BROOK UNIVERSITY

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Penn State 1855

Stanford University

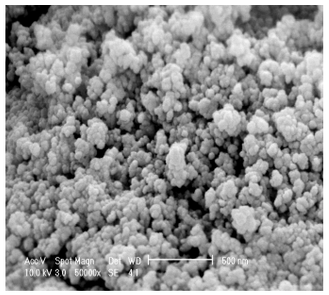
Drexel University

SwRI

BATT brings together experts from across the country and solves problems in a coordinated manner

Solving applied problems using a fundamental approach

Potential battery material identified



New battery developed for a PHEV

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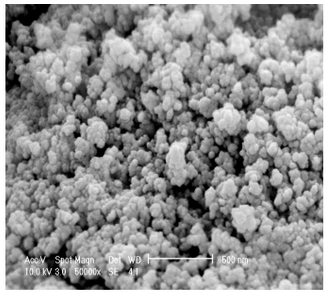
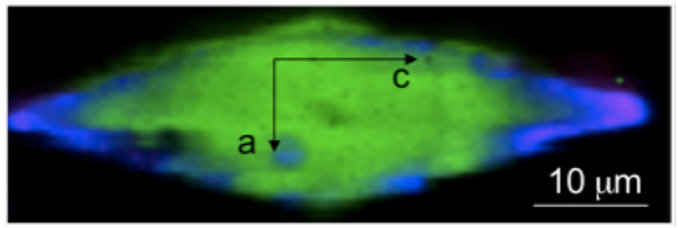
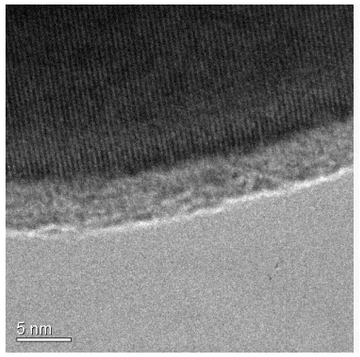


Understand limitations in the electrode



Modify material/electrode to alleviate limitations



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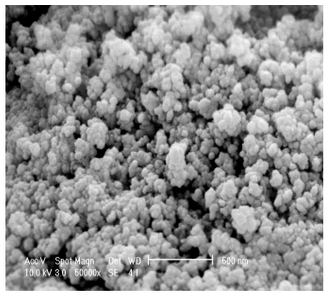

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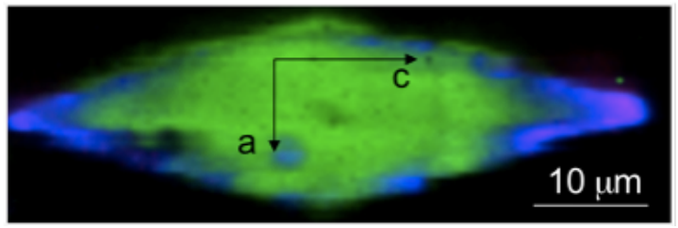

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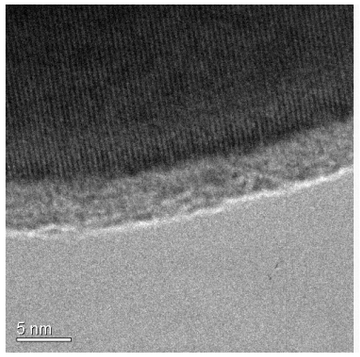


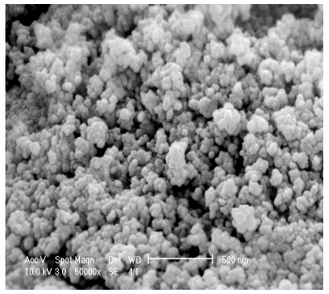
Assess ability of system to perform under real world

New battery developed for a PHEV

Solving applied problems using a fundamental approach

Commercialization Roadmap

Potential battery material identified



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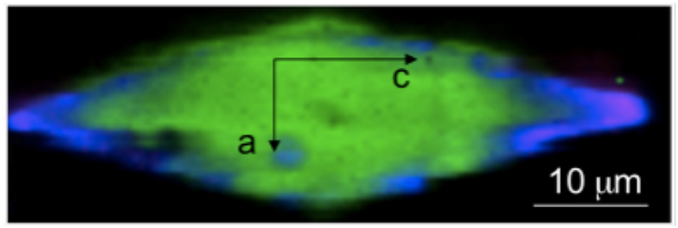

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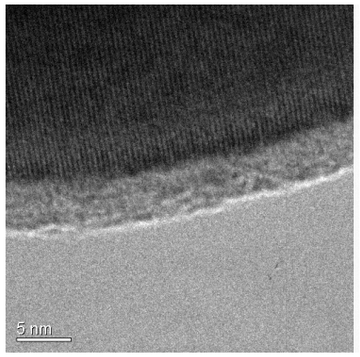

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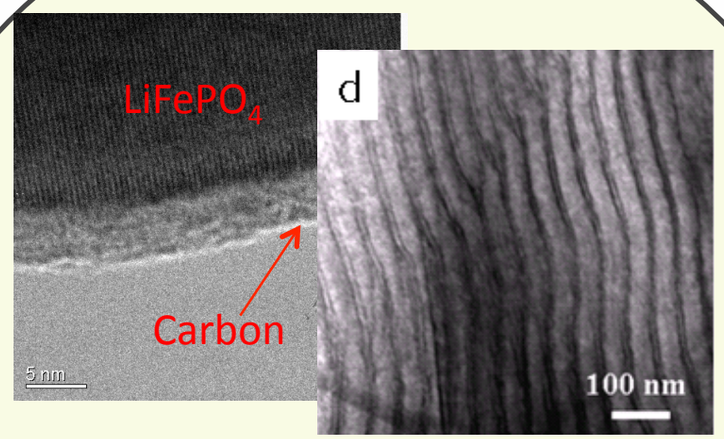
Expertise in the BATT Program



Material synthesis/ modifications

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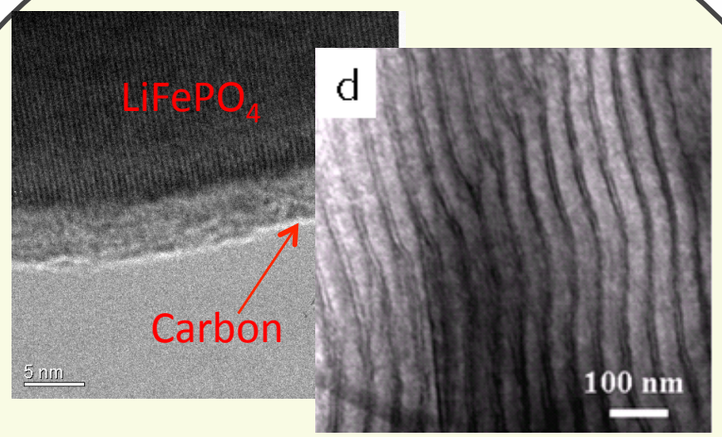

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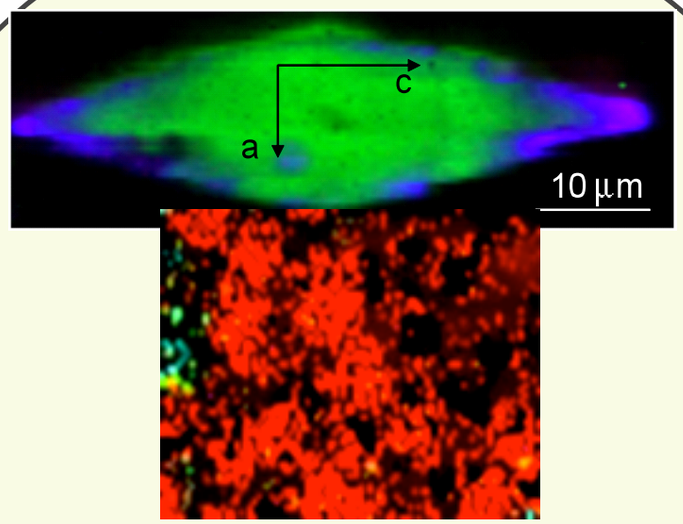

Diagnostics

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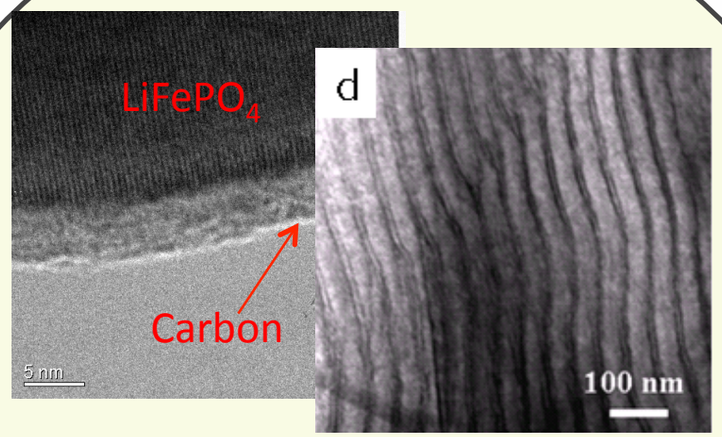

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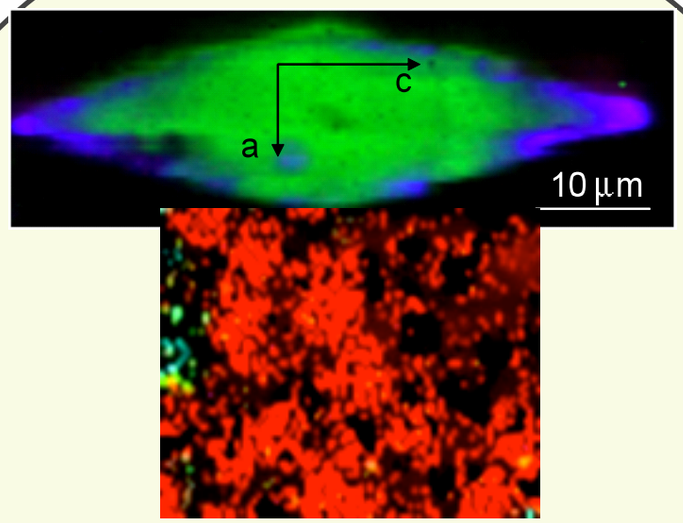

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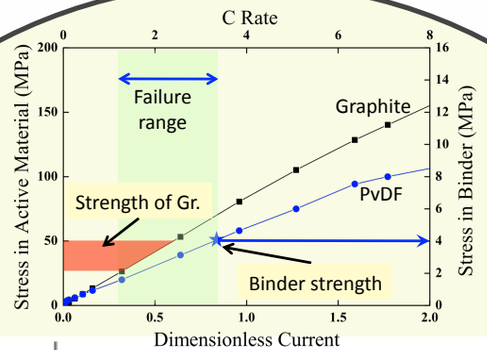
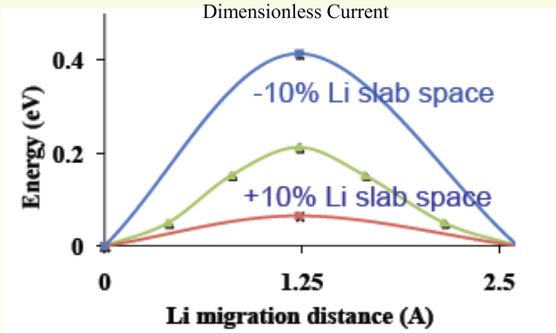
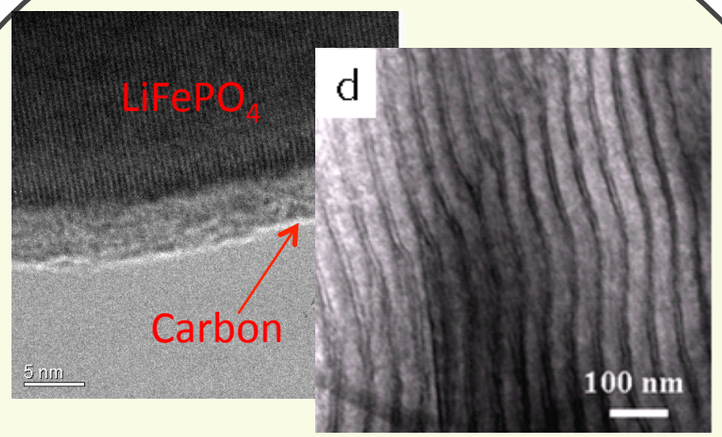




Theory

Expertise in the BATT Program



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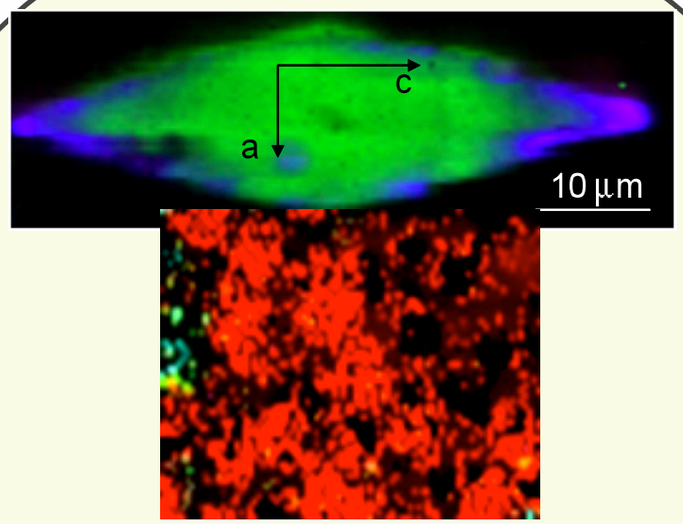

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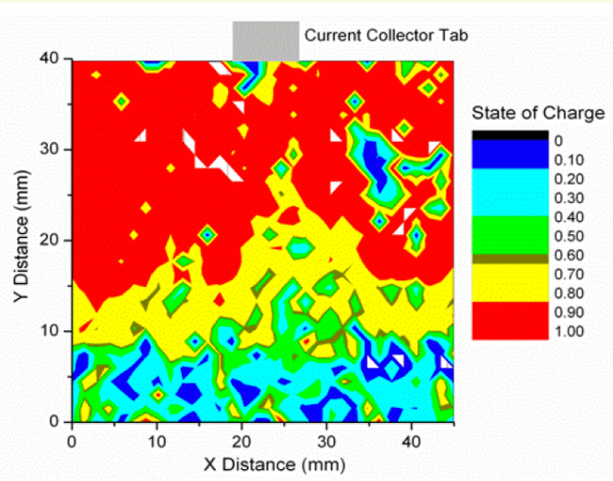
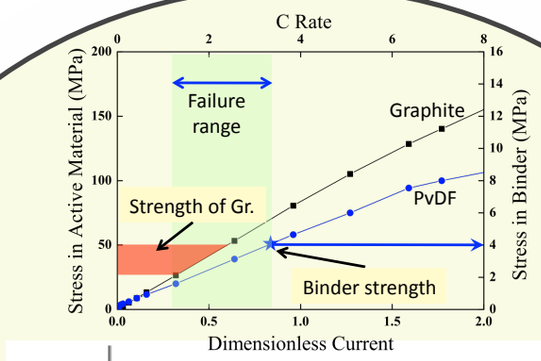
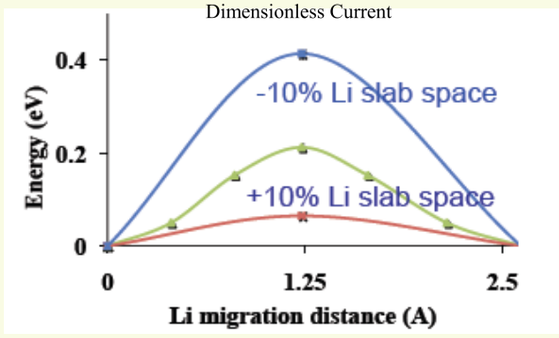


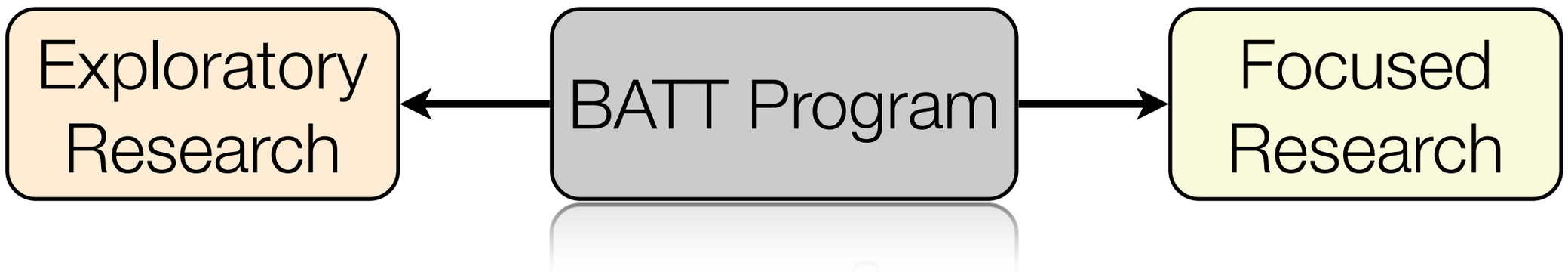
Electrochemistry





Theory

Structure of BATT



Unique structure allows us to focus on issues that limit present-day batteries while also performing cutting-edge long-term research

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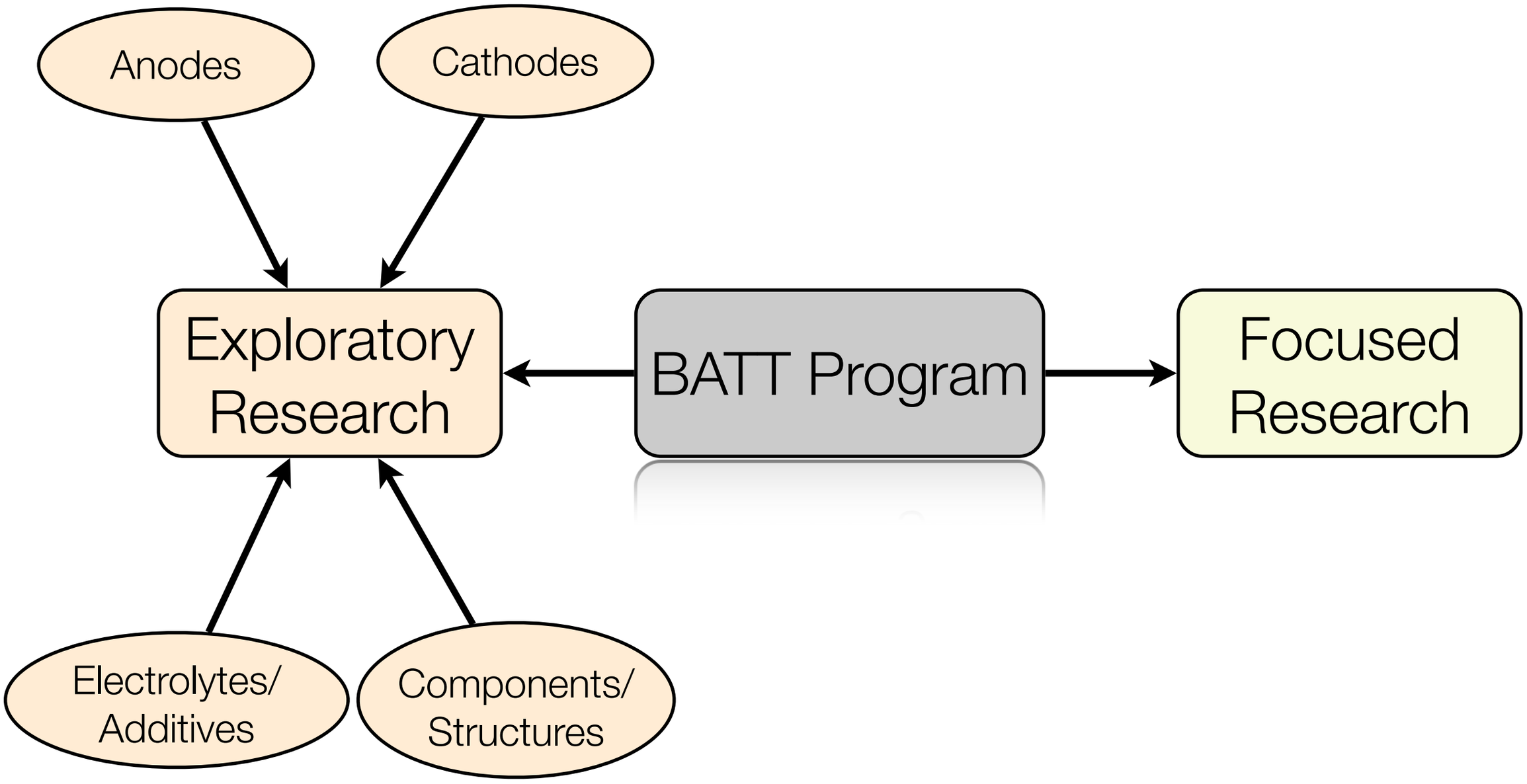

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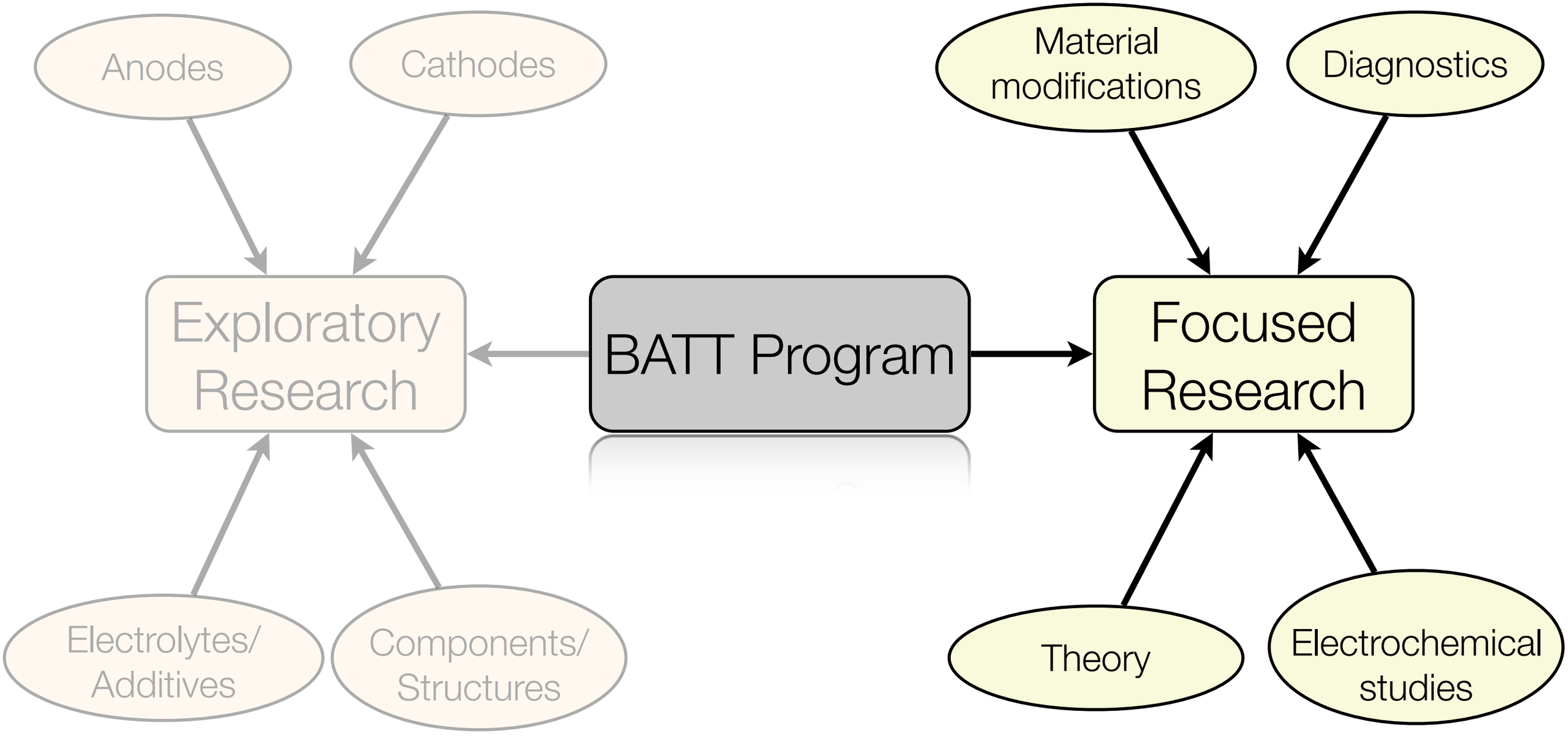

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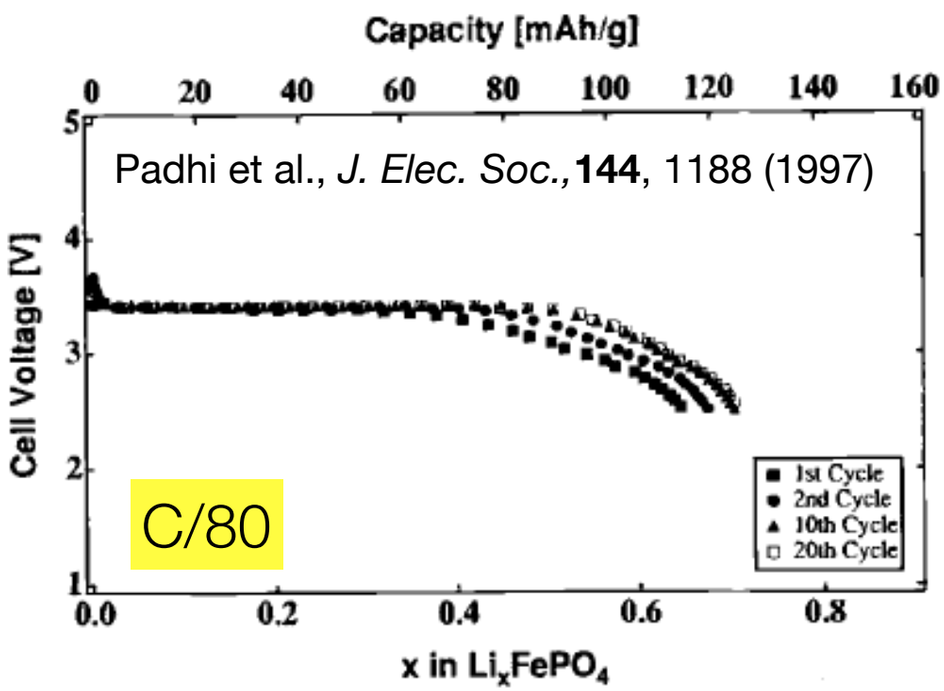
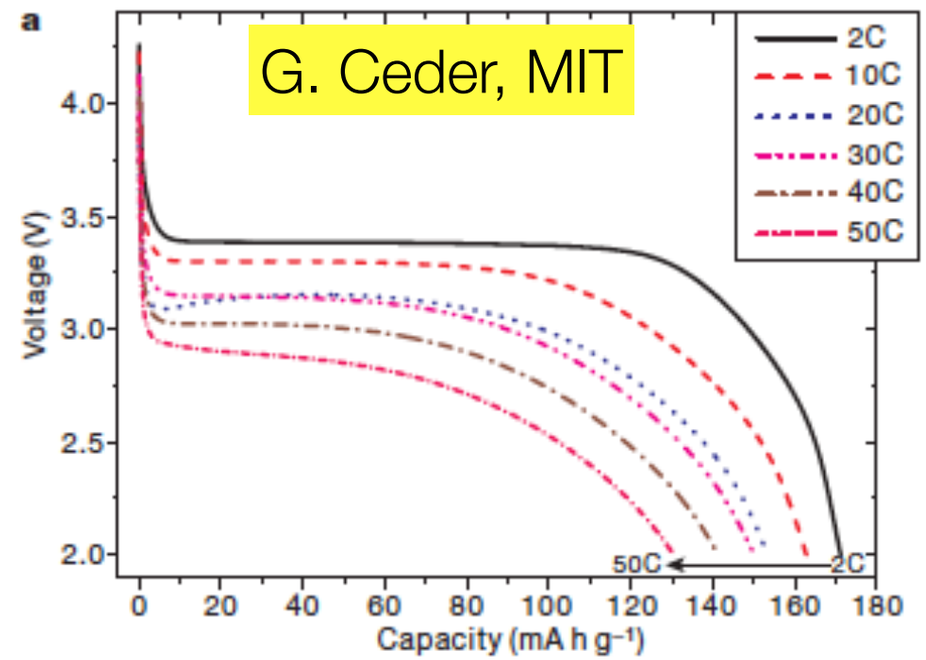
The $LiFePO_4$ Story





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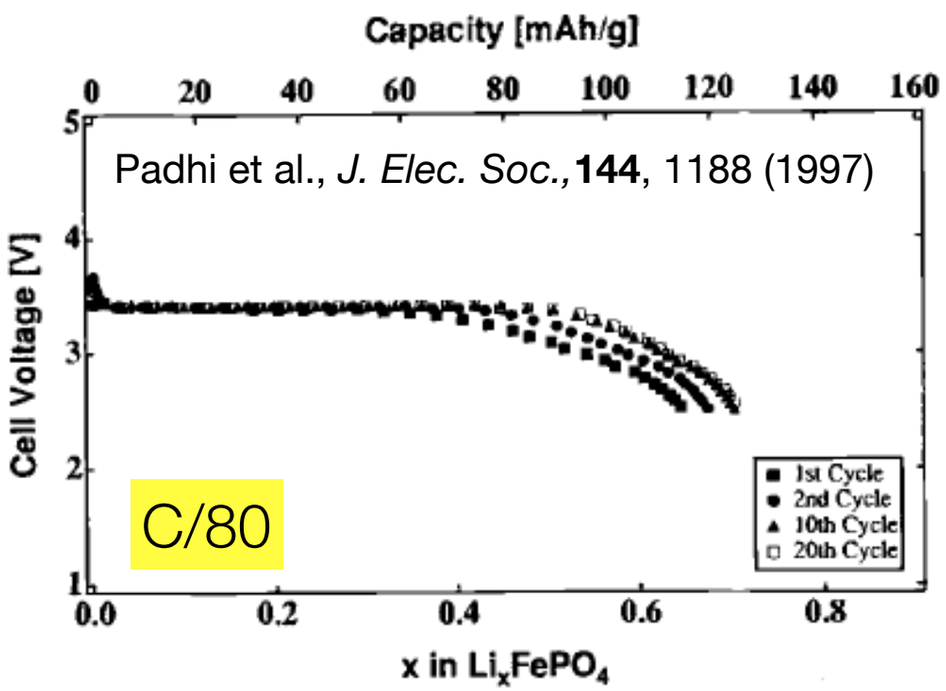

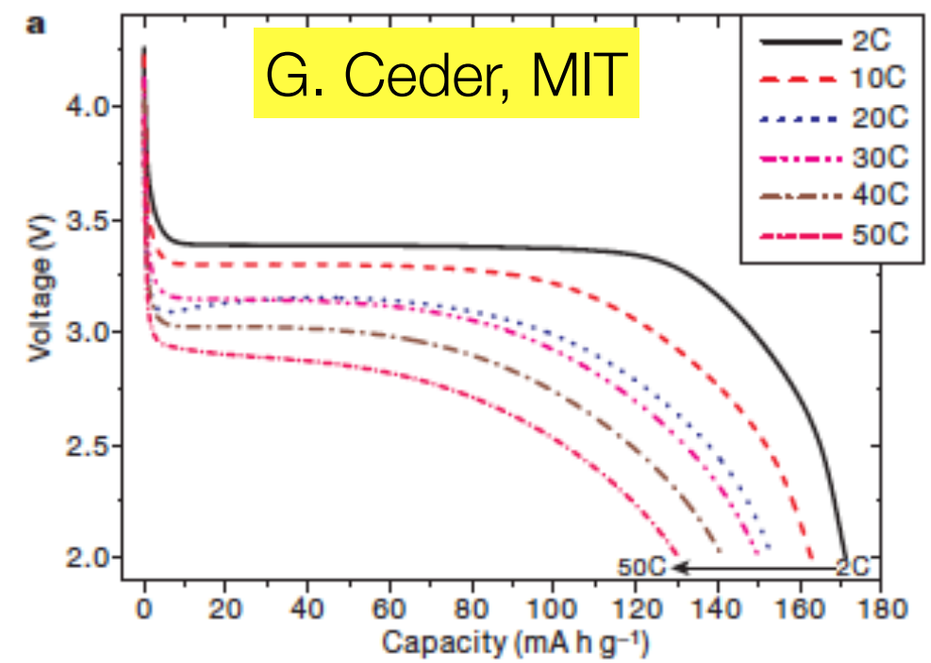

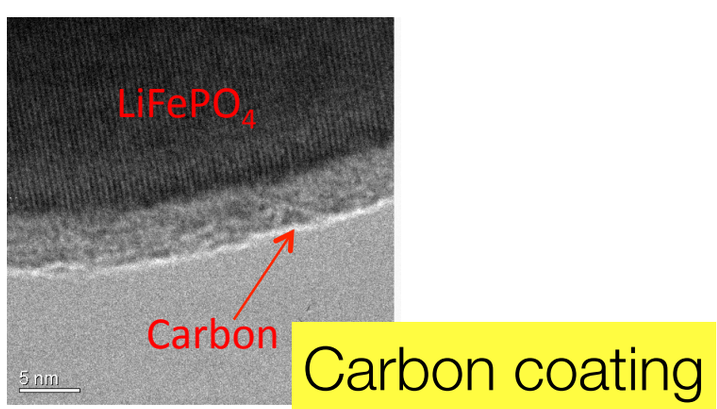

Carbon coating

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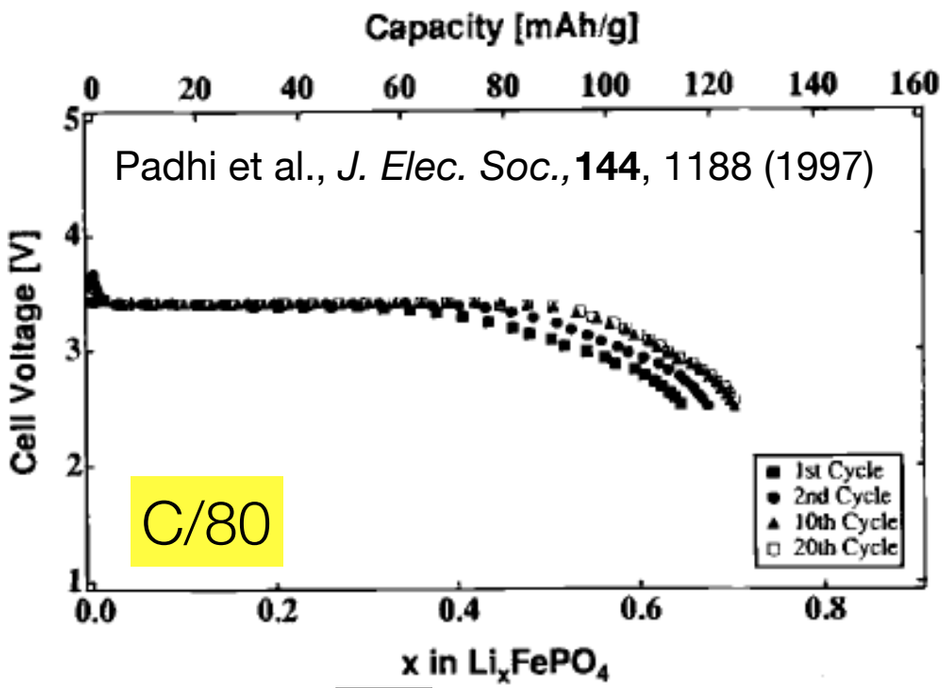

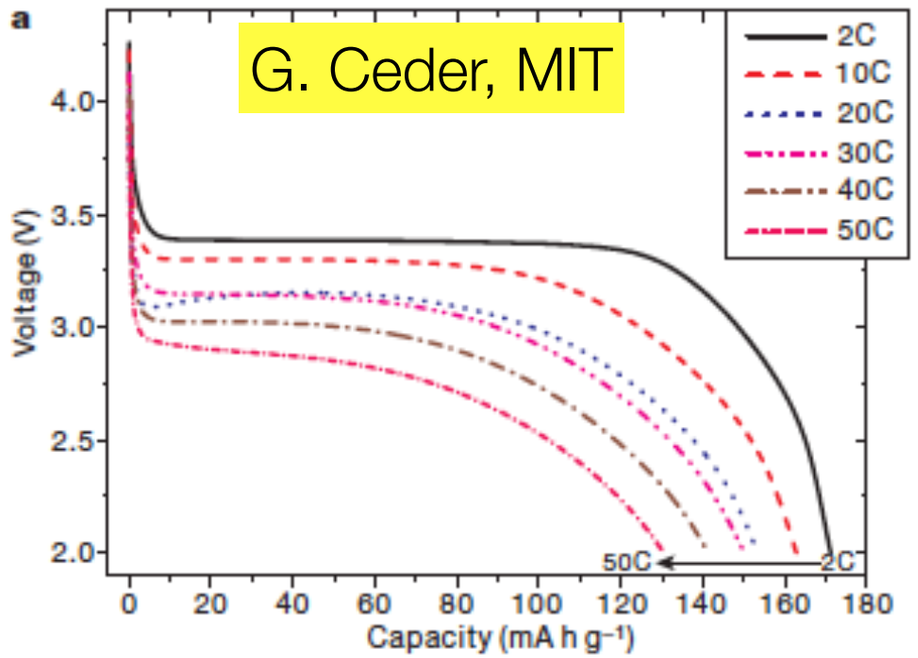

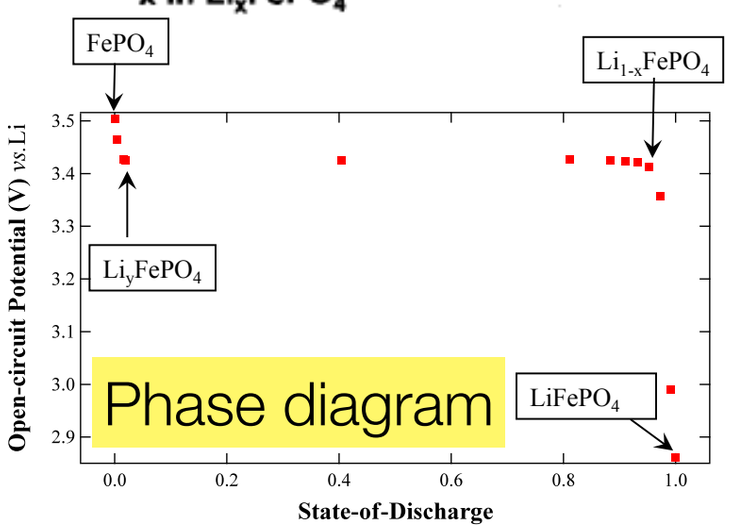

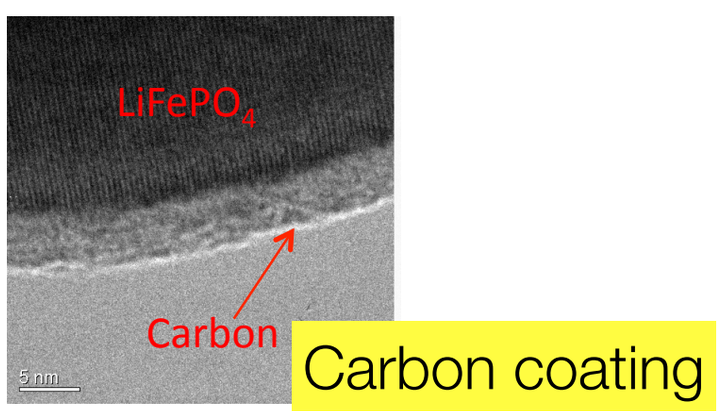

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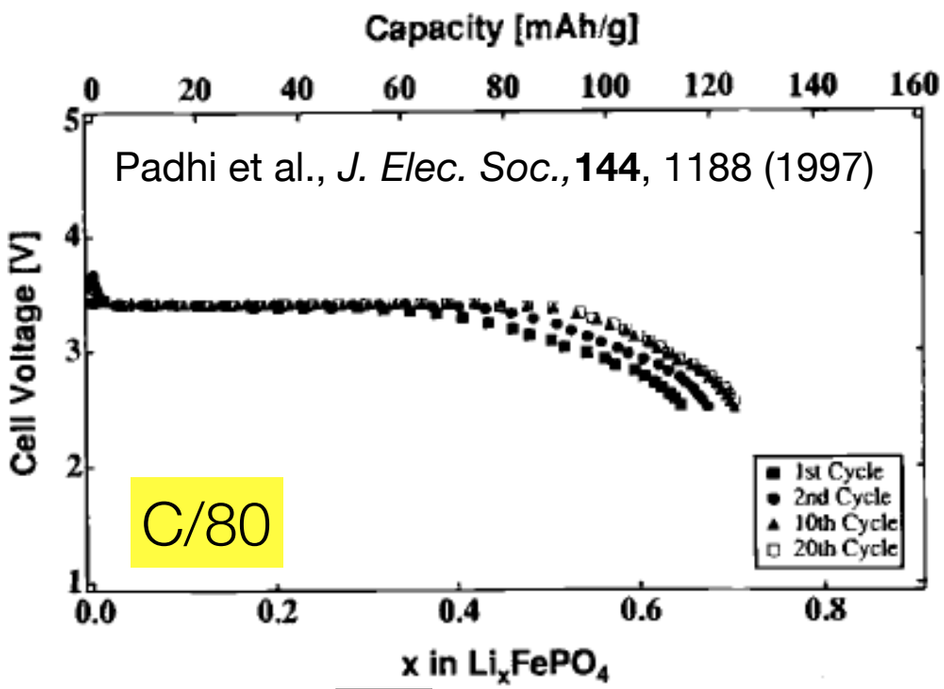

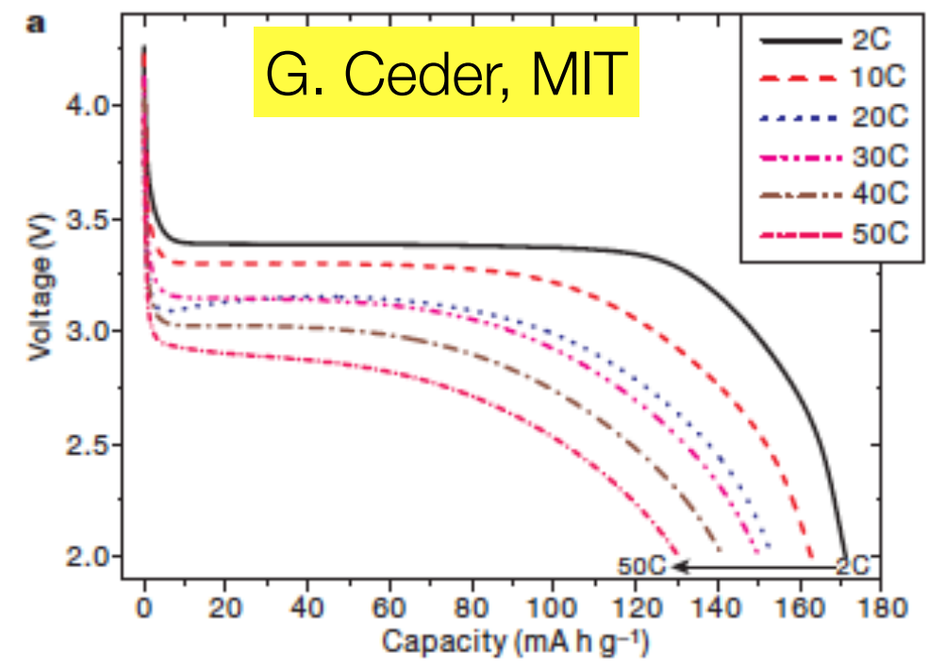

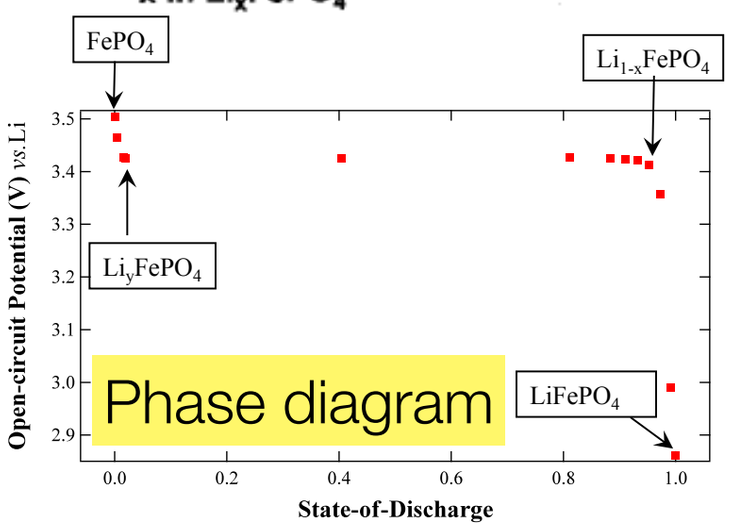

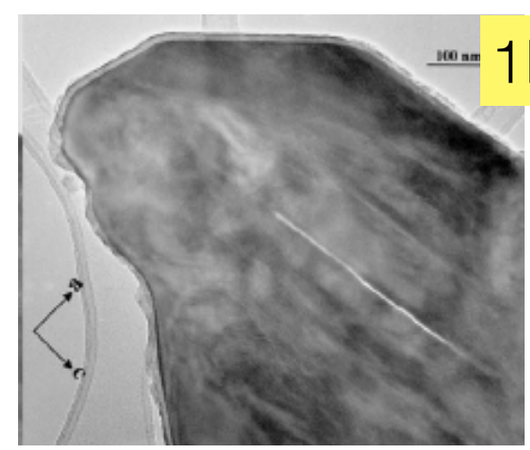

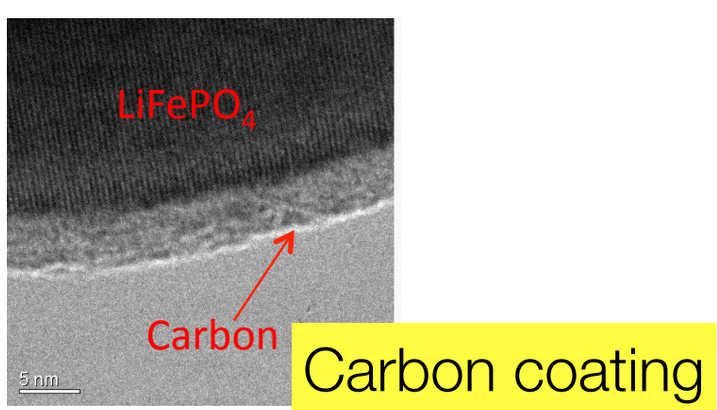

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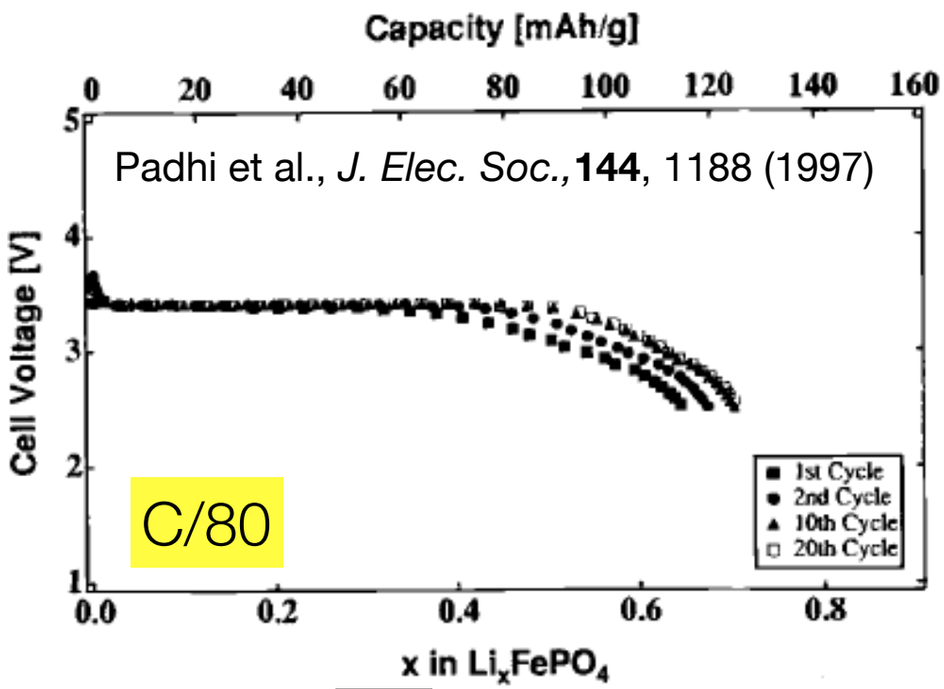
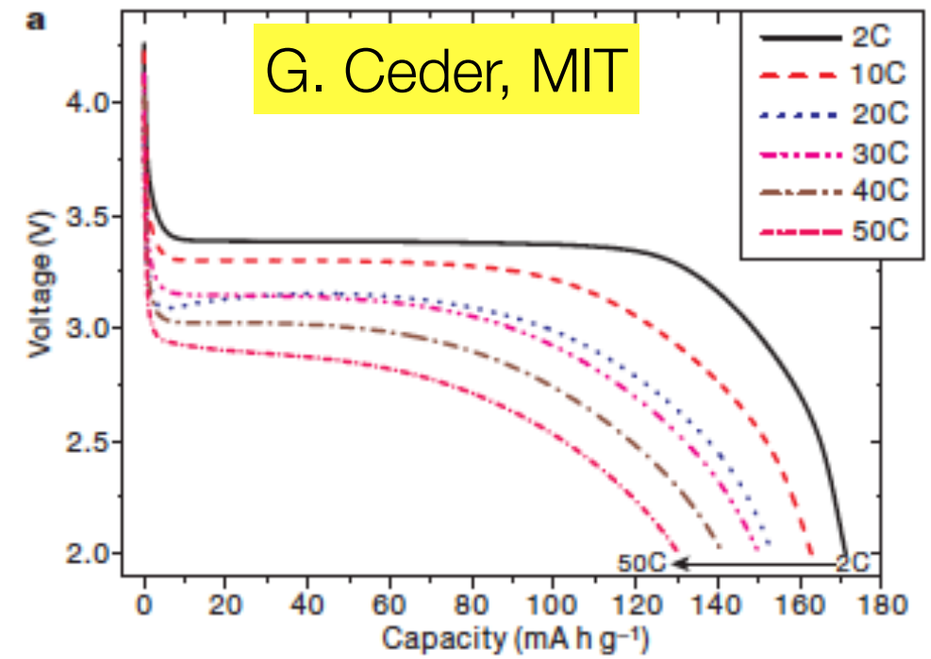
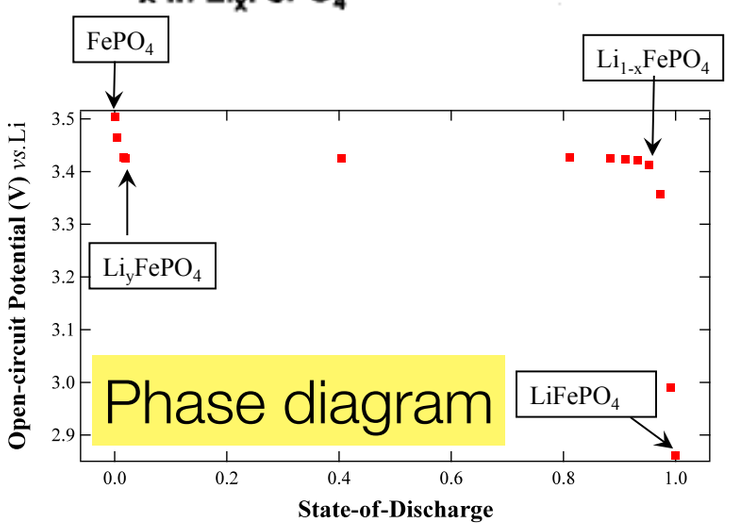
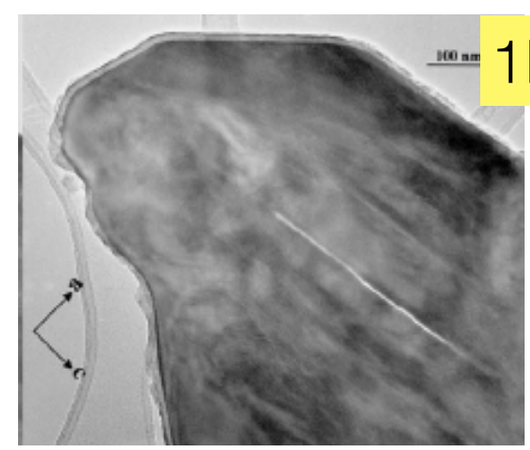
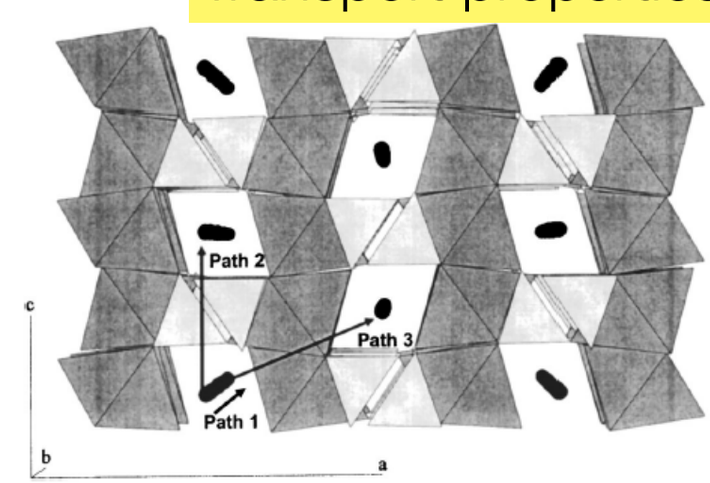


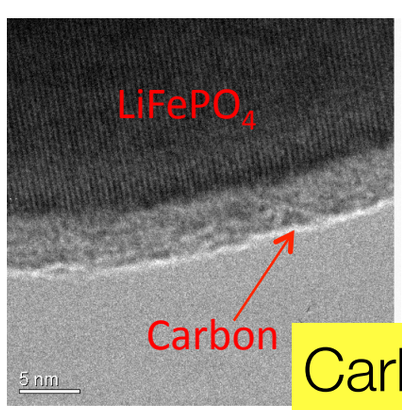






Transport properties





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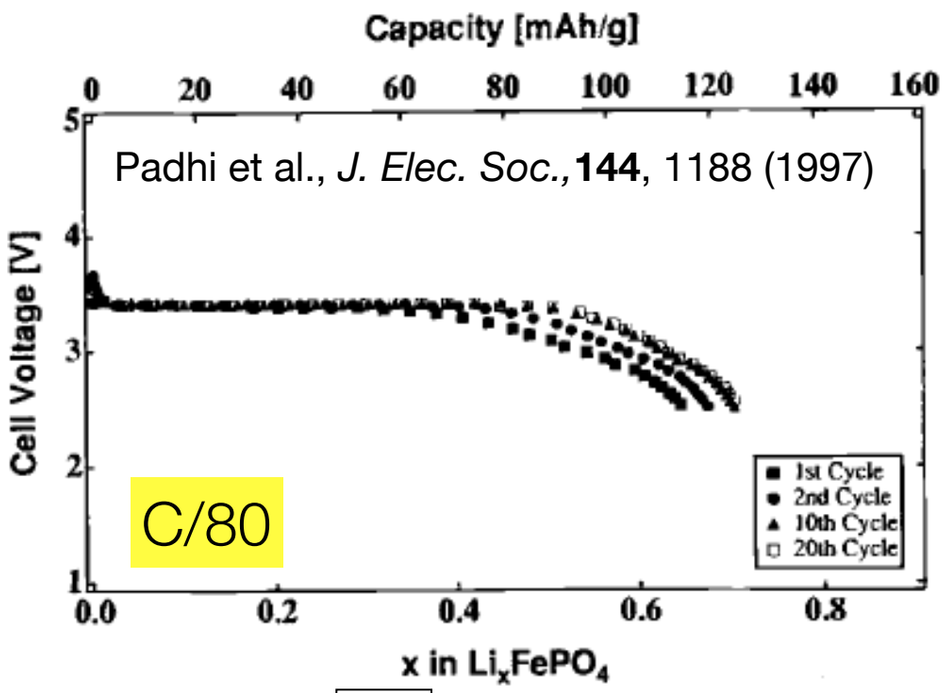
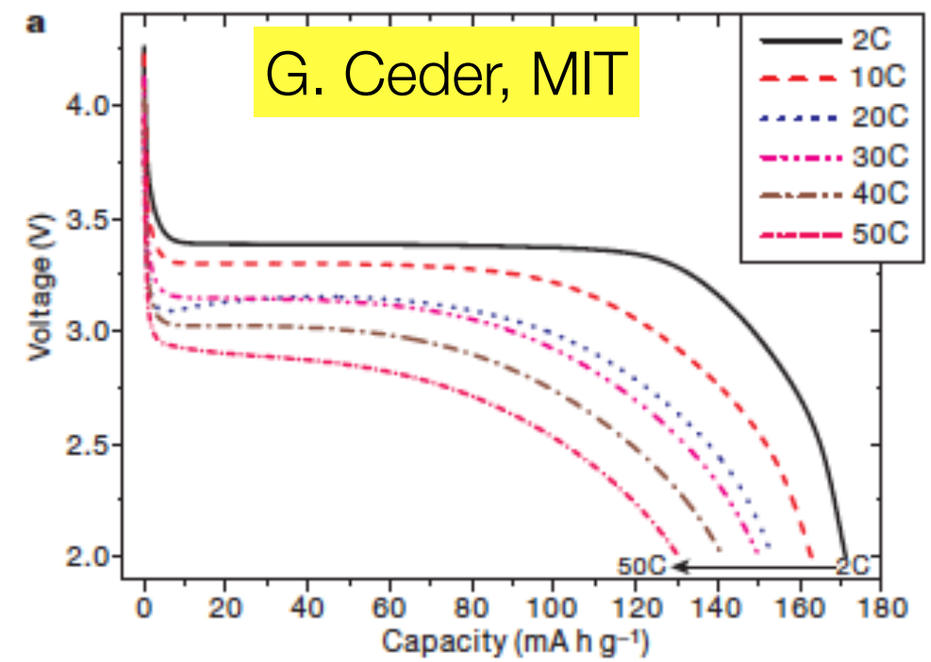
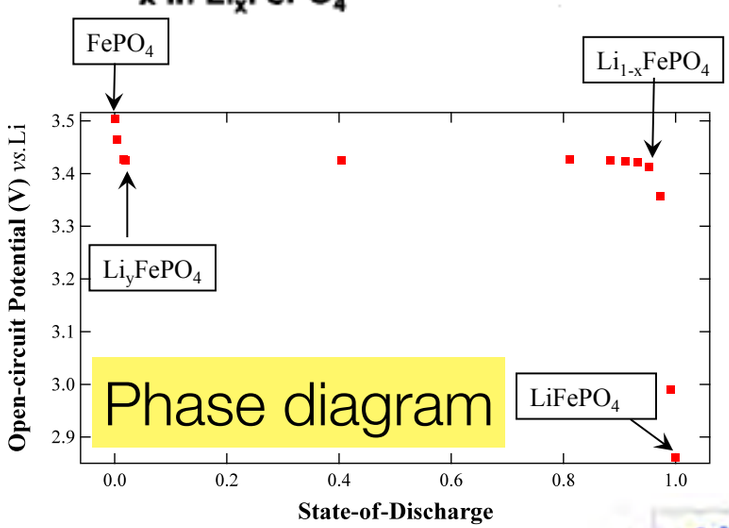
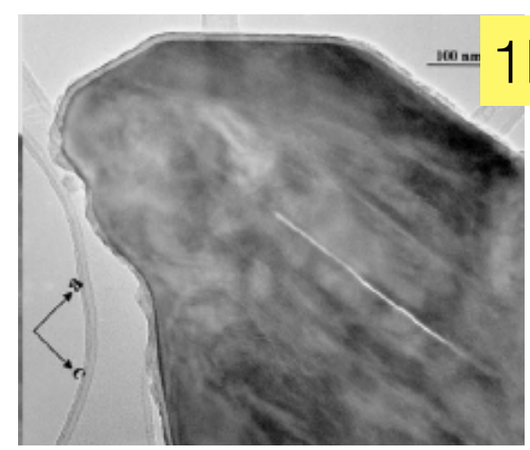
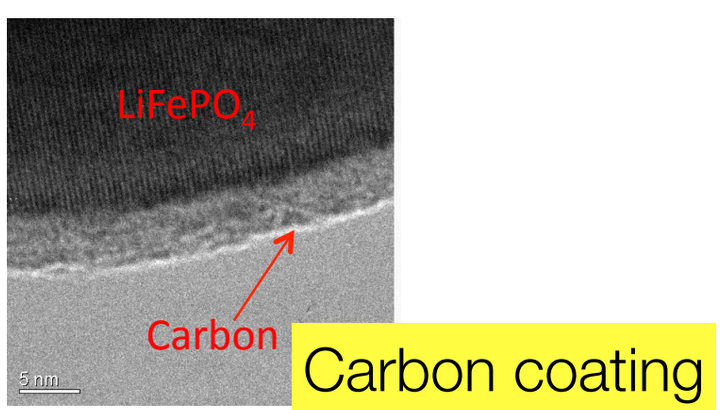
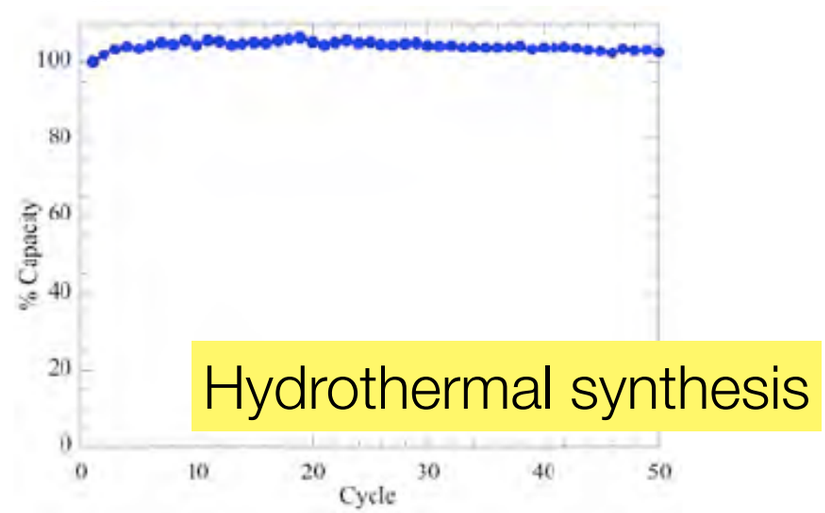


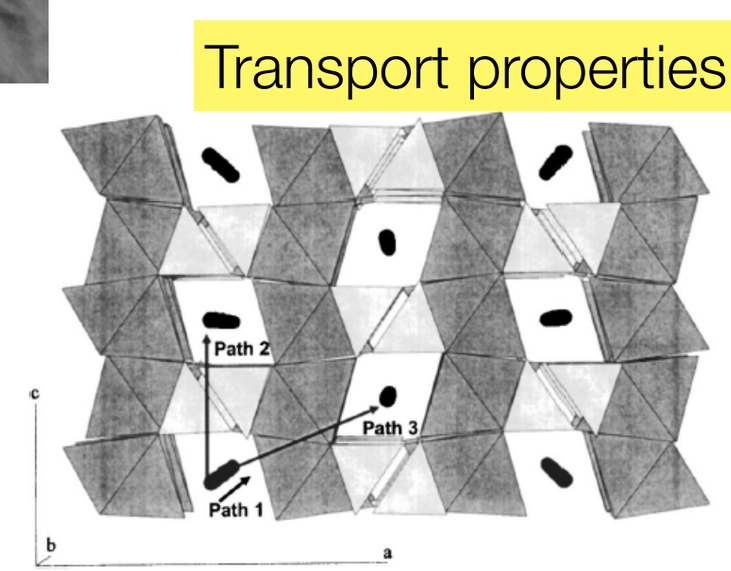




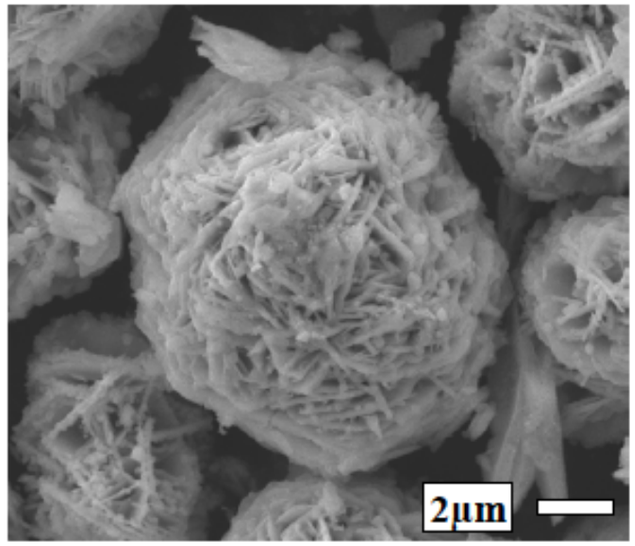








Finding new high-energy materials



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New, high-capacity / high-energy materials with improved cycling ability through doping and coatings

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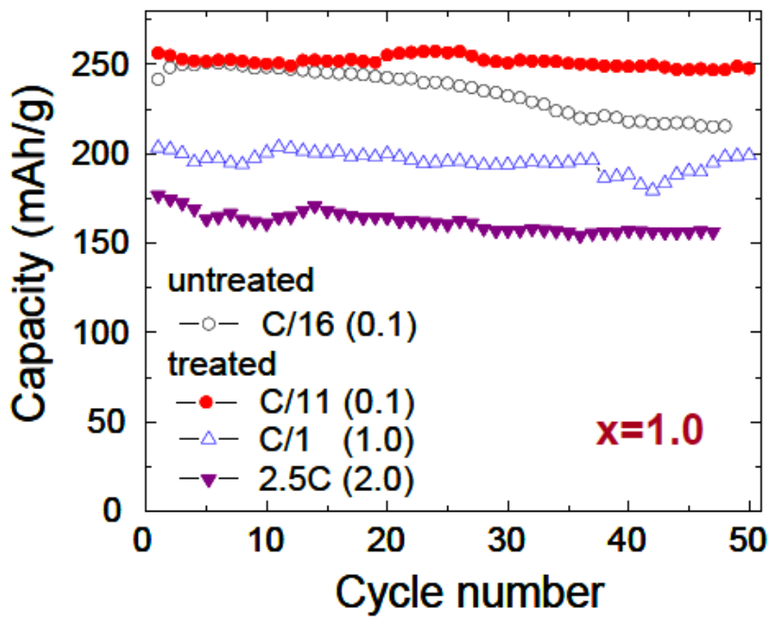

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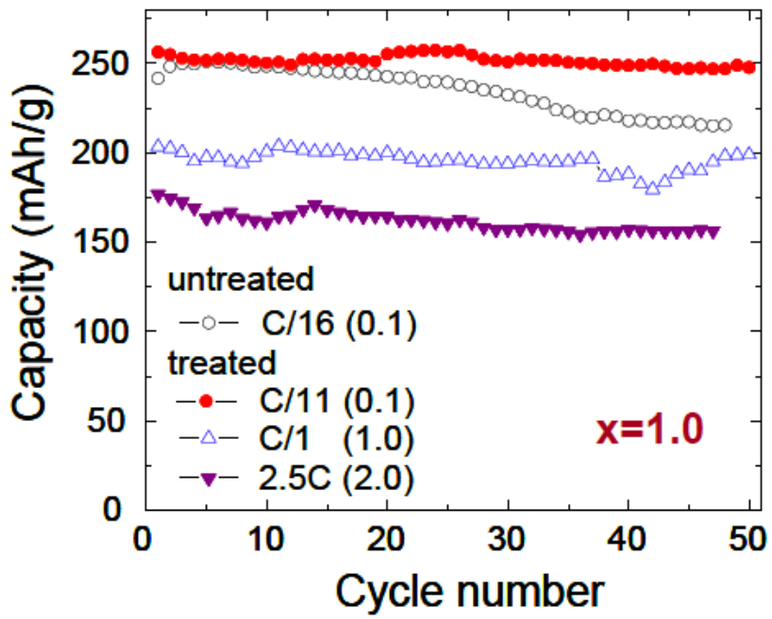

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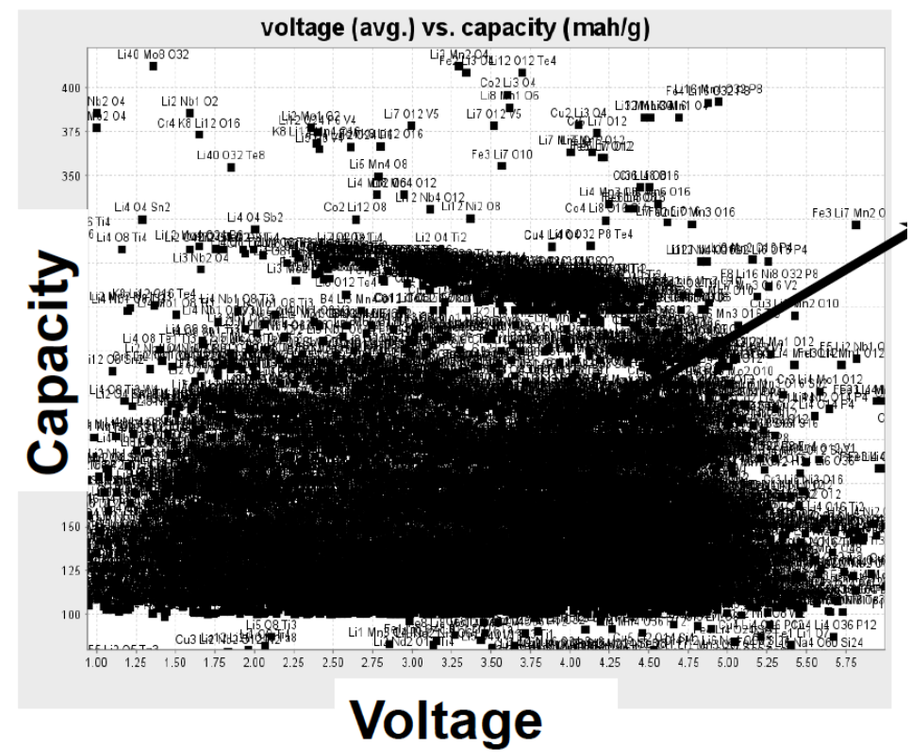

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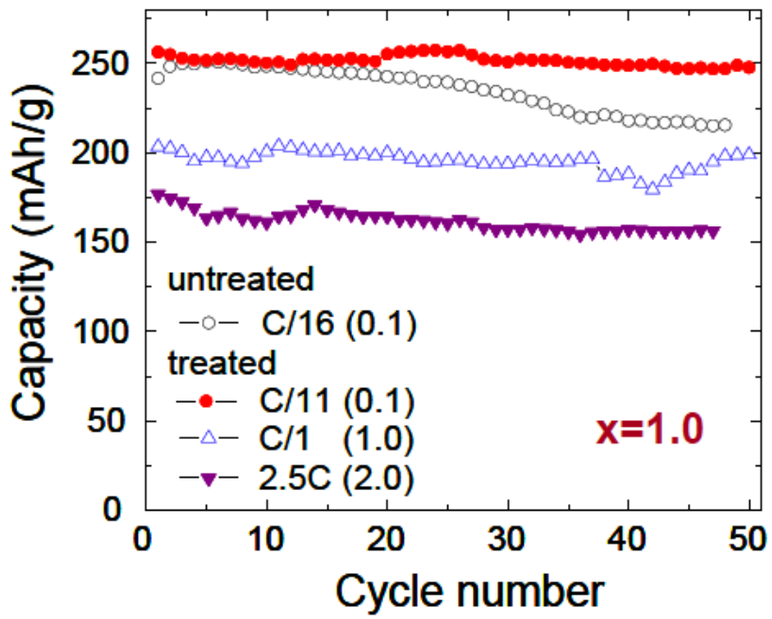

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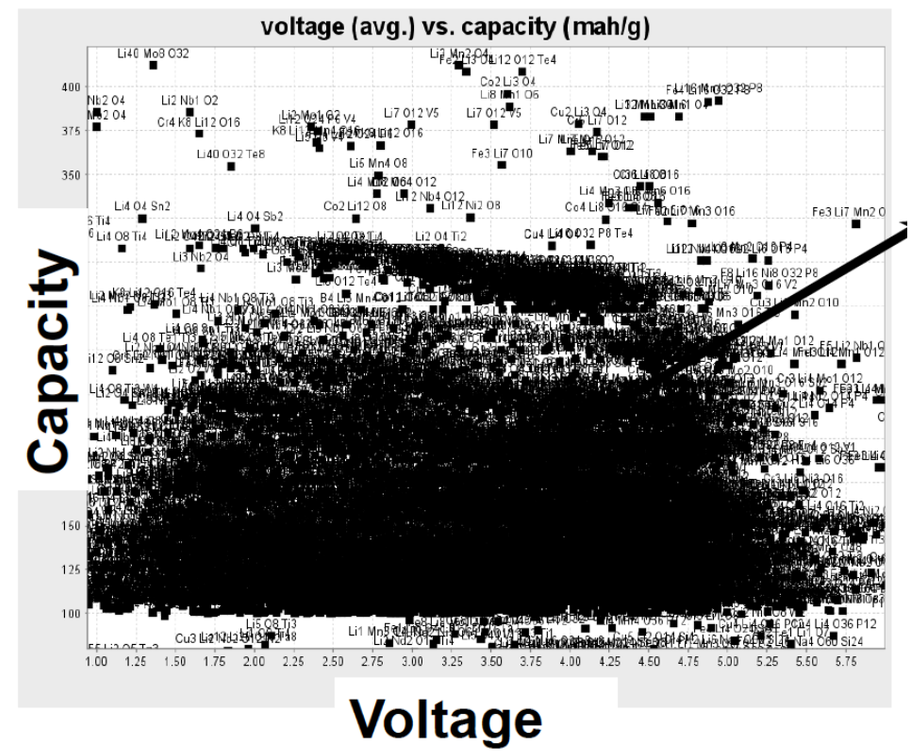

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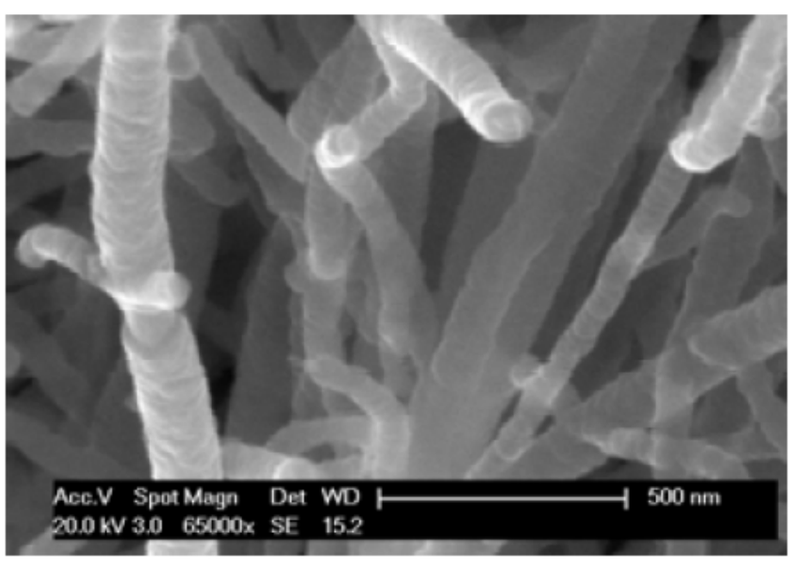

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High capacity, cycleable Si in the form non-crystaline Si on carbon nanotubes

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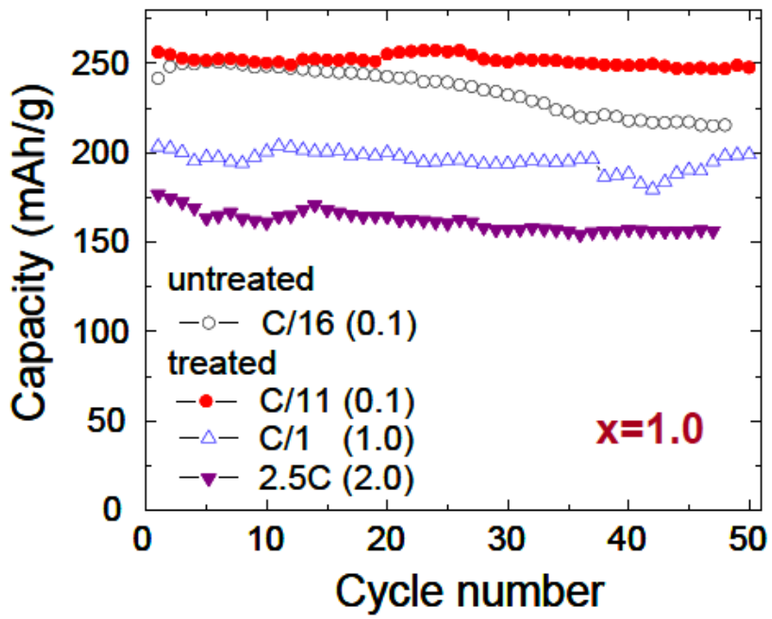

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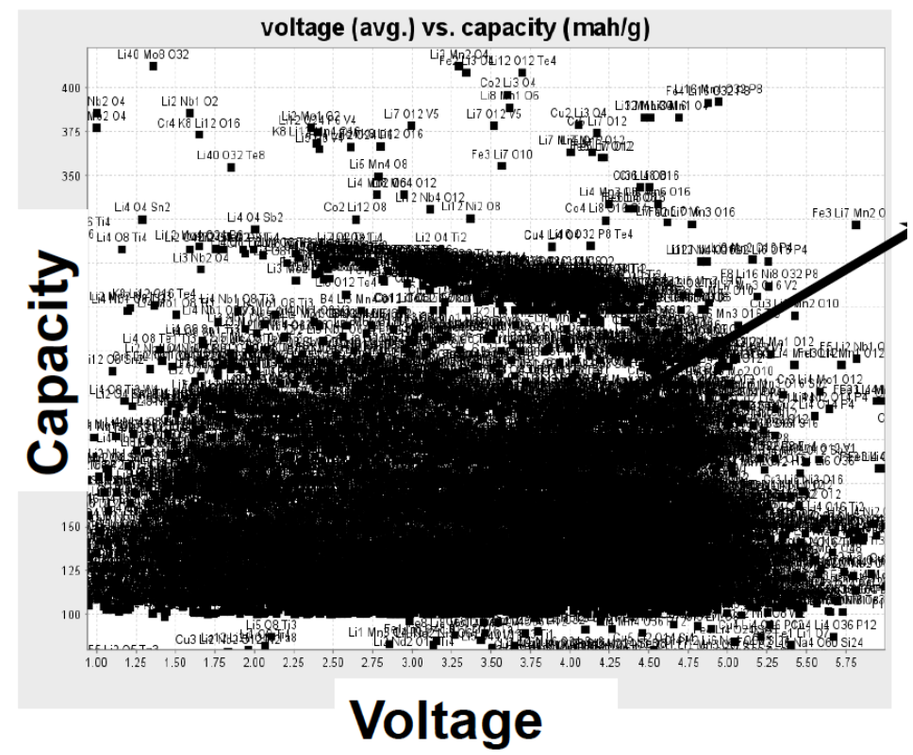

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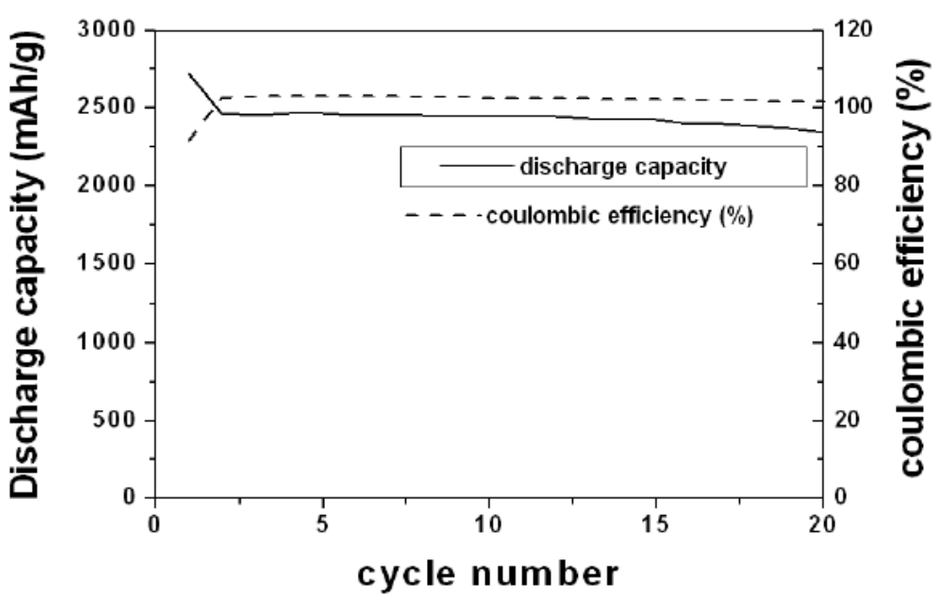

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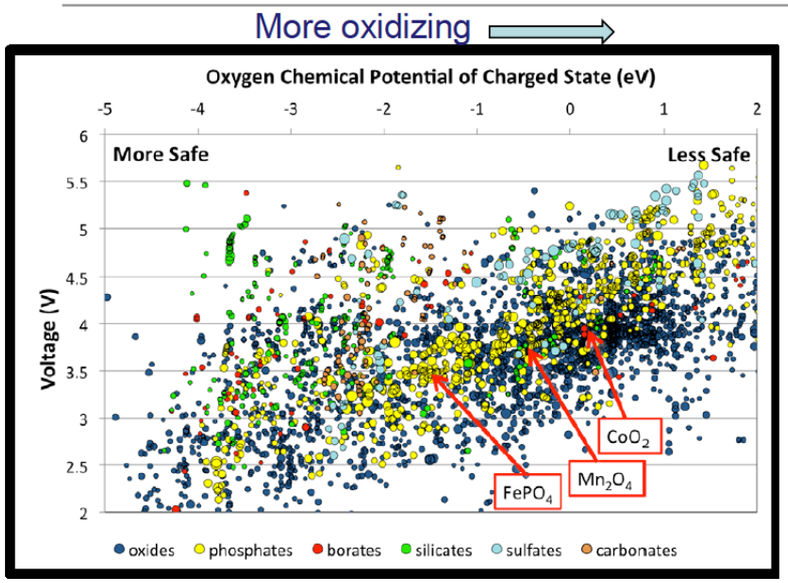

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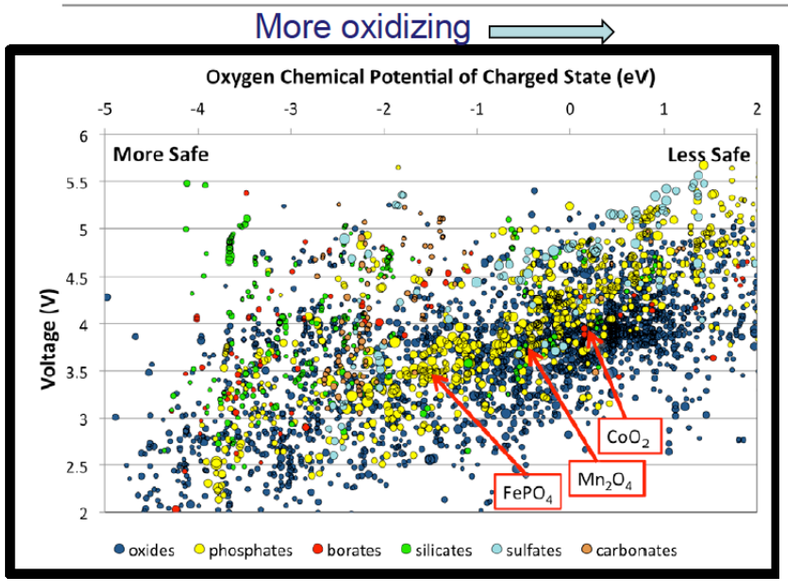

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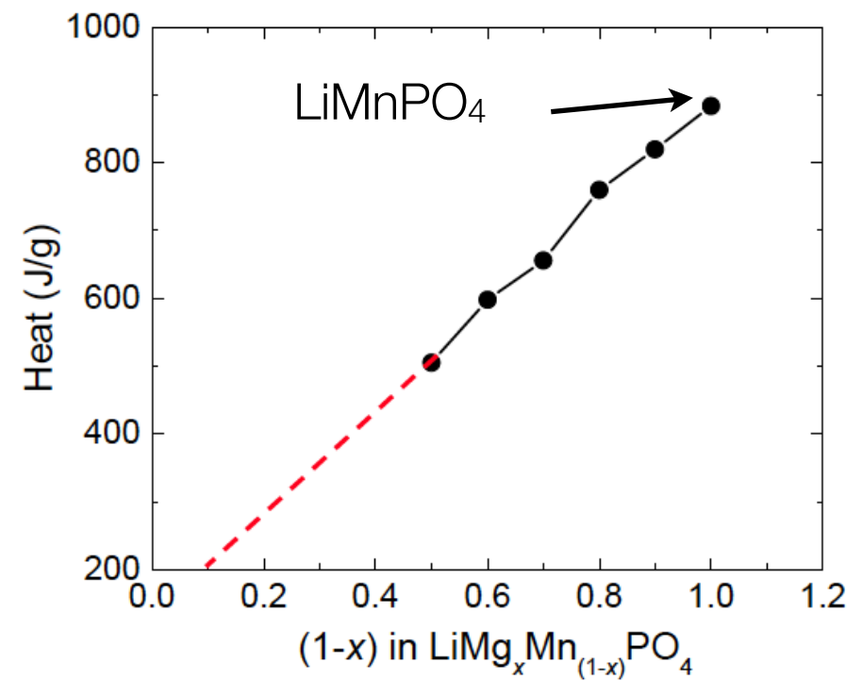

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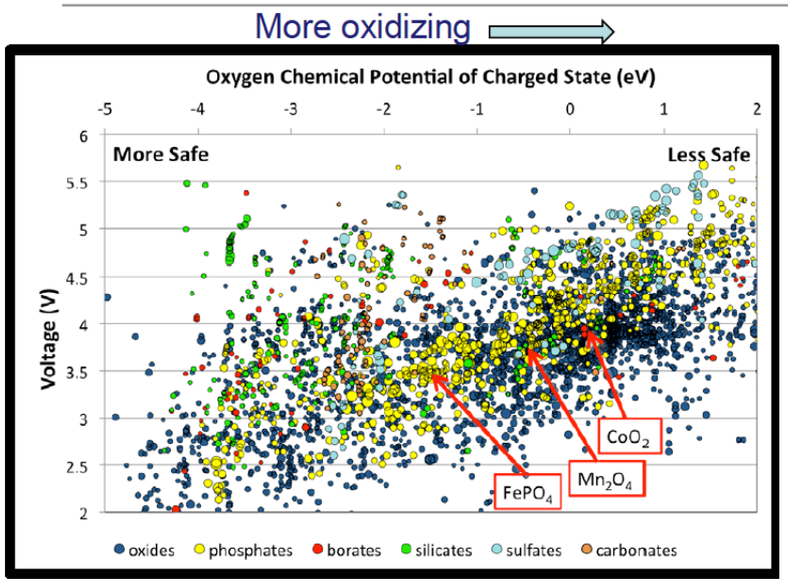

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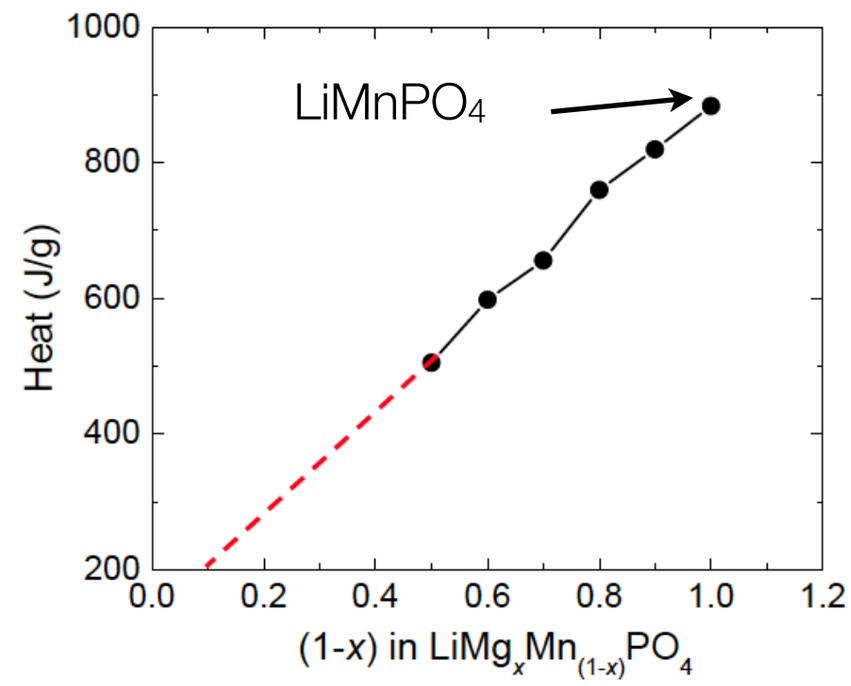

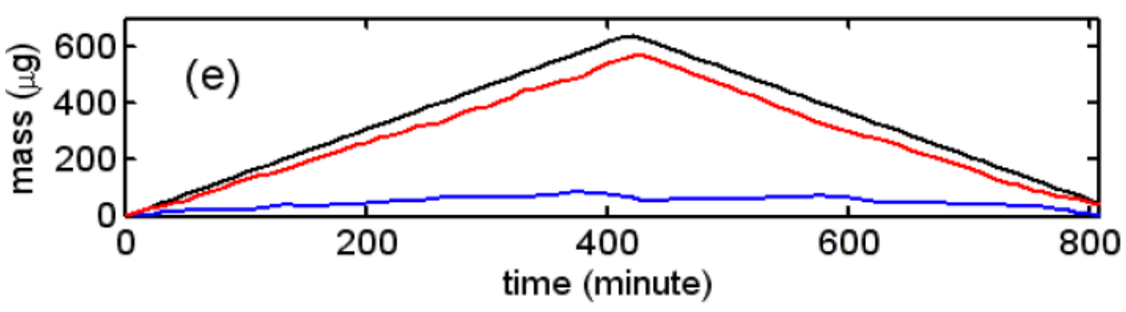

C. Grey (SUNY):
NMR used as a tool to identify signature for Li deposition

The Commercial side of BATT

- Block copolymer electrolytes for Li-metal batteries (Balsara) being commercialized by Seeo Inc.

- Advanced cathode materials (Manthiram) being commercialized by ActaCell. Company has recently licensed an anode material developed under BATT

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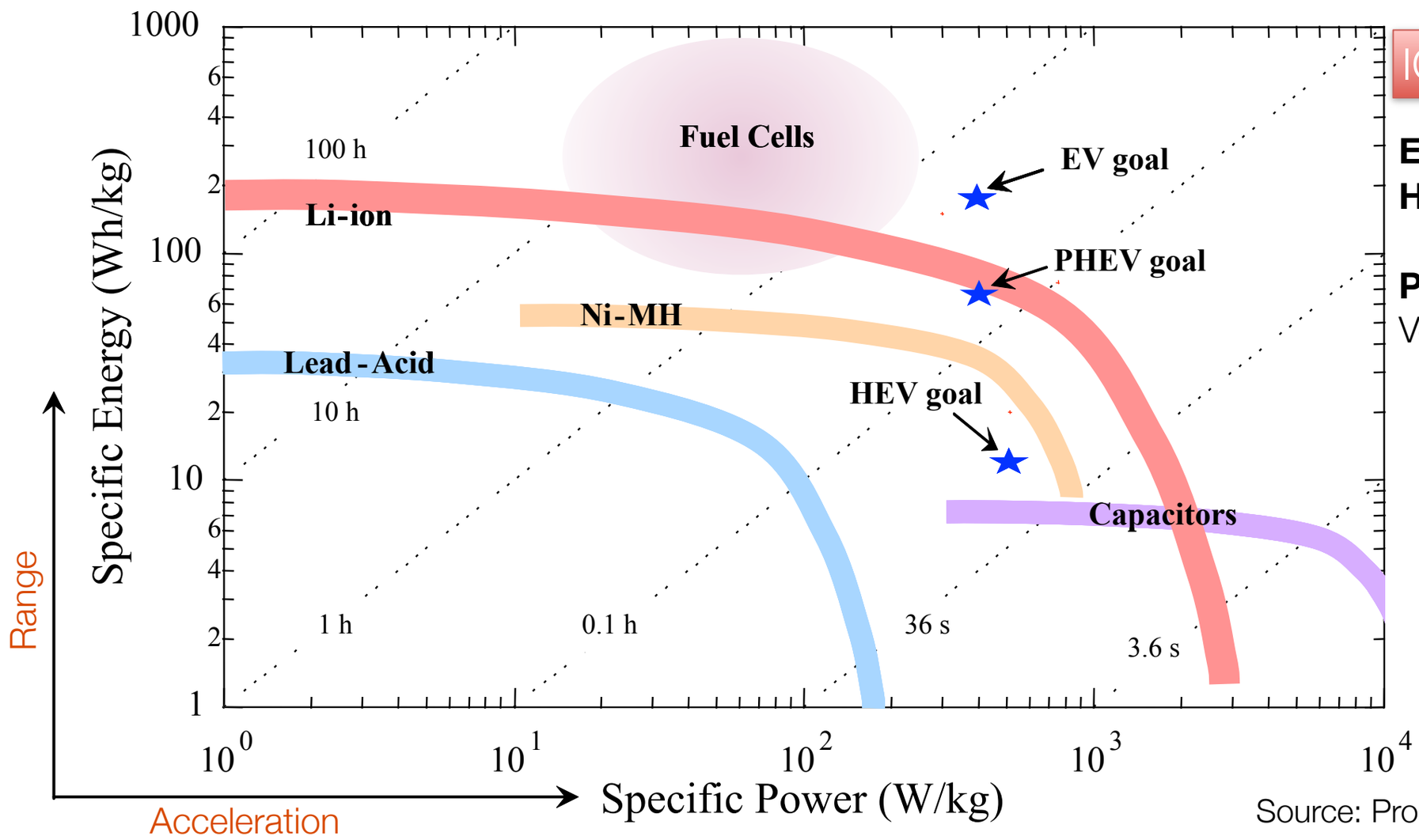
- Numerous patents have resulted over the years, with some licensed to companies for commercialization
  - *e.g.,* ANL “composite” material, MIT nanotube material

Requirements for vehicle batteries



IC Engine=2500 Wh/kg

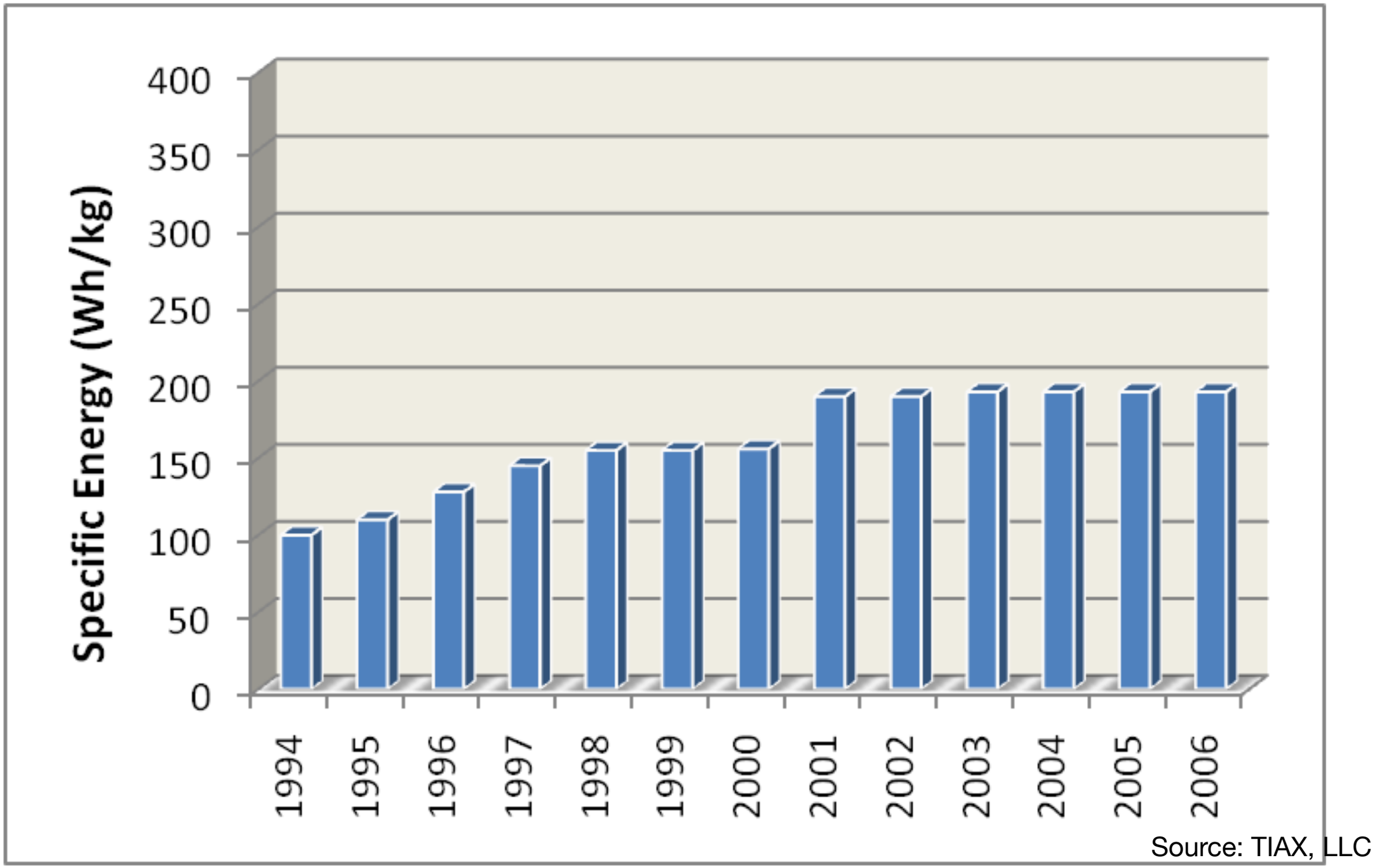
EV – Electric Vehicle
HEV – Hybrid-Electric Vehicle
PHEV– Plug-in Hybrid- Electric Vehicle

Source: Product data sheets

- For PHEVs to be commercial, need batteries with **lower cost ($/kWh)**
- For battery EVs to be commercial, a **doubling of energy density** needed

How do we increase the energy density of batteries?

Energy density of Li-ion batteries



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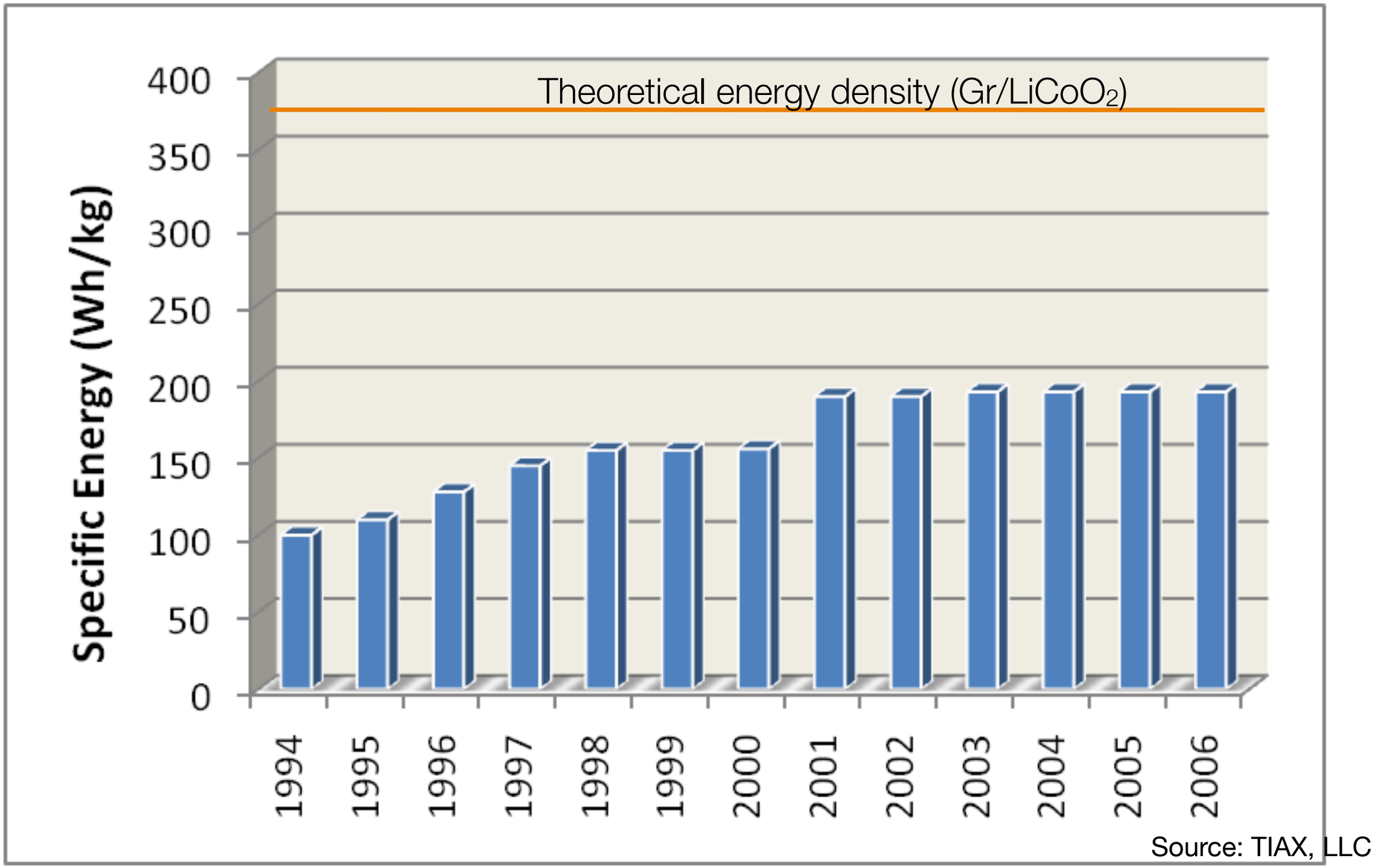


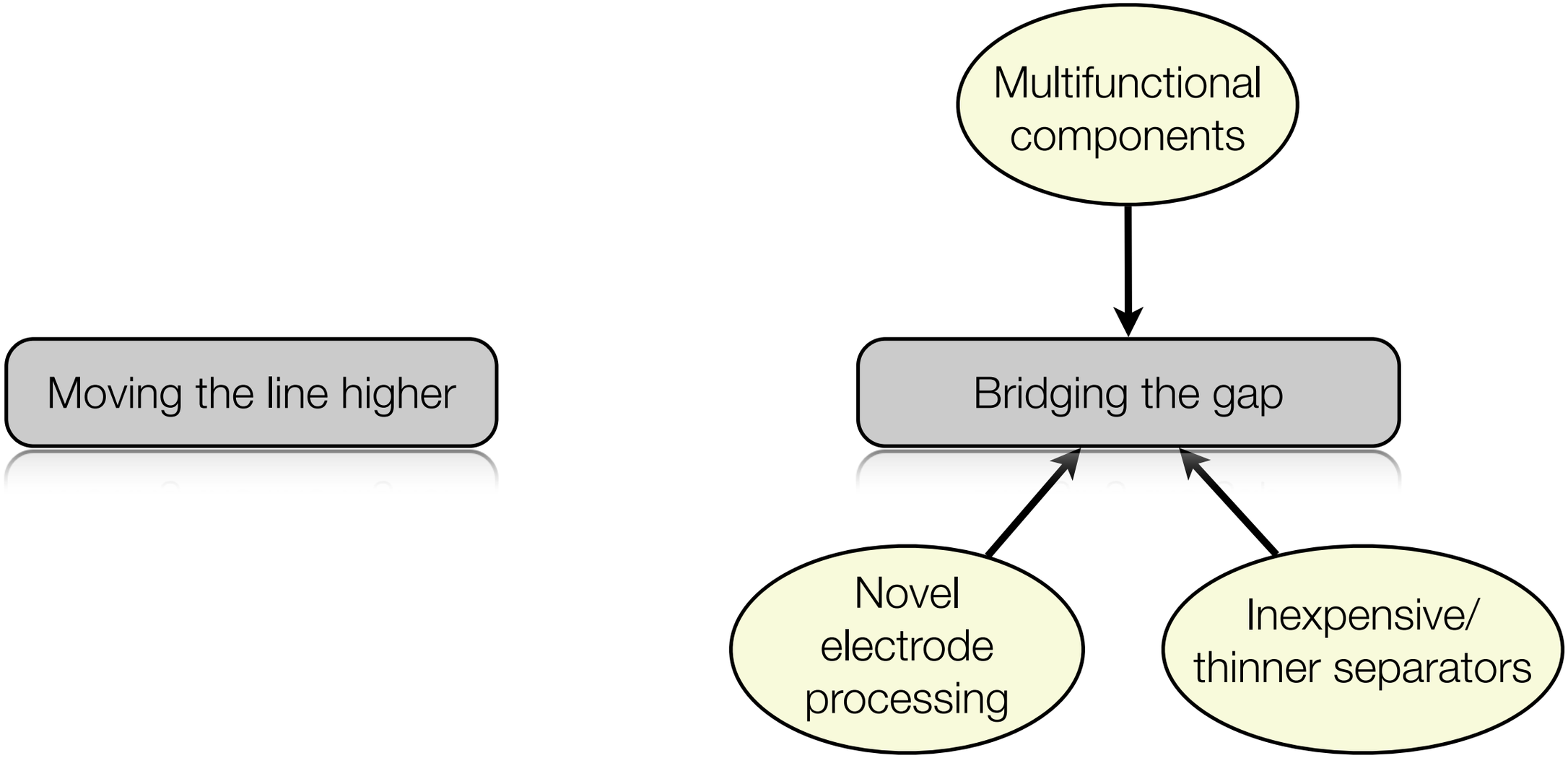
Two approaches (i) find new materials to increase theoretical energy and (ii) make a more “efficient” battery

Approaches to improve energy density/reduce cost

Moving the line higher

Bridging the gap

Approaches to improve energy density/reduce cost



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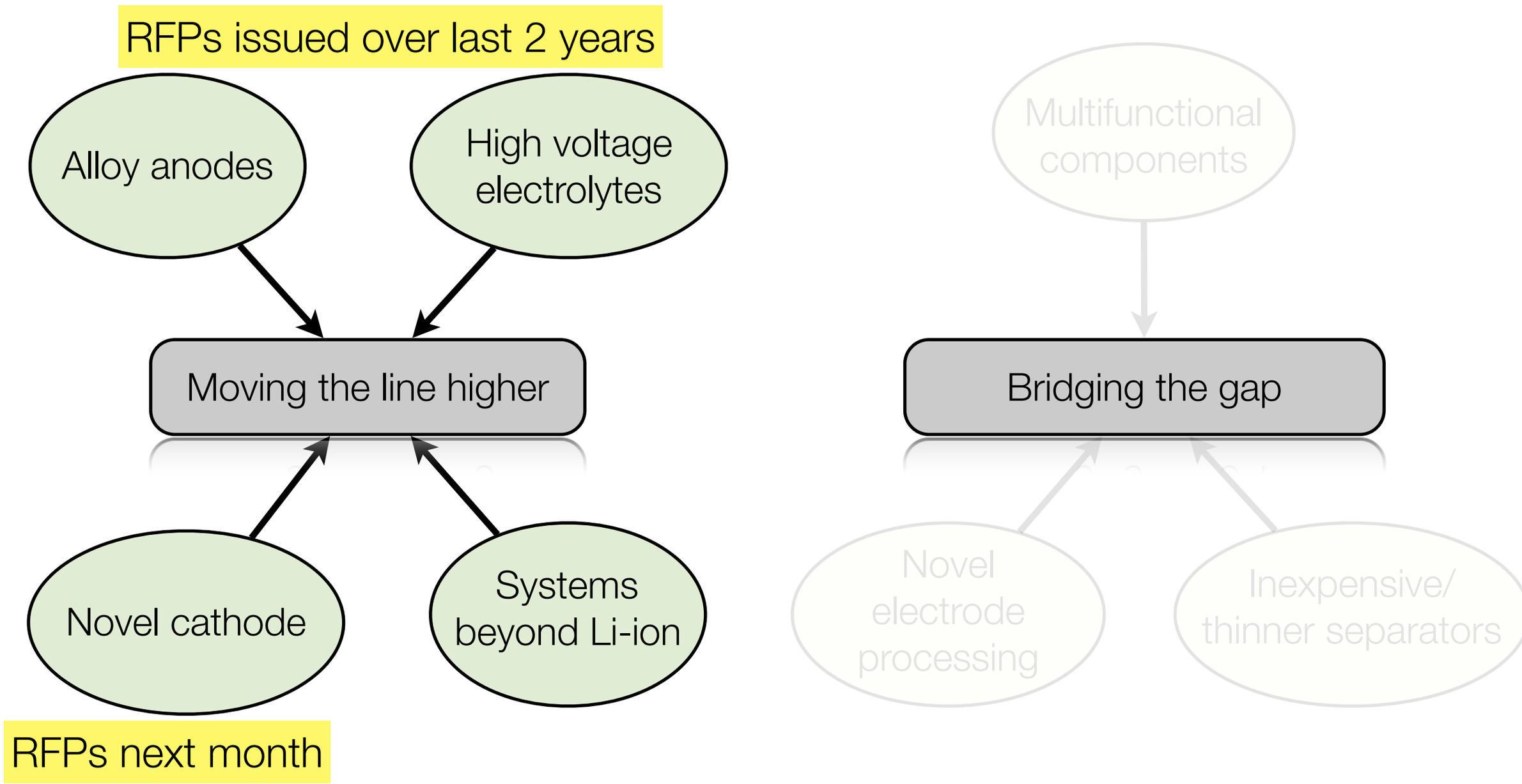

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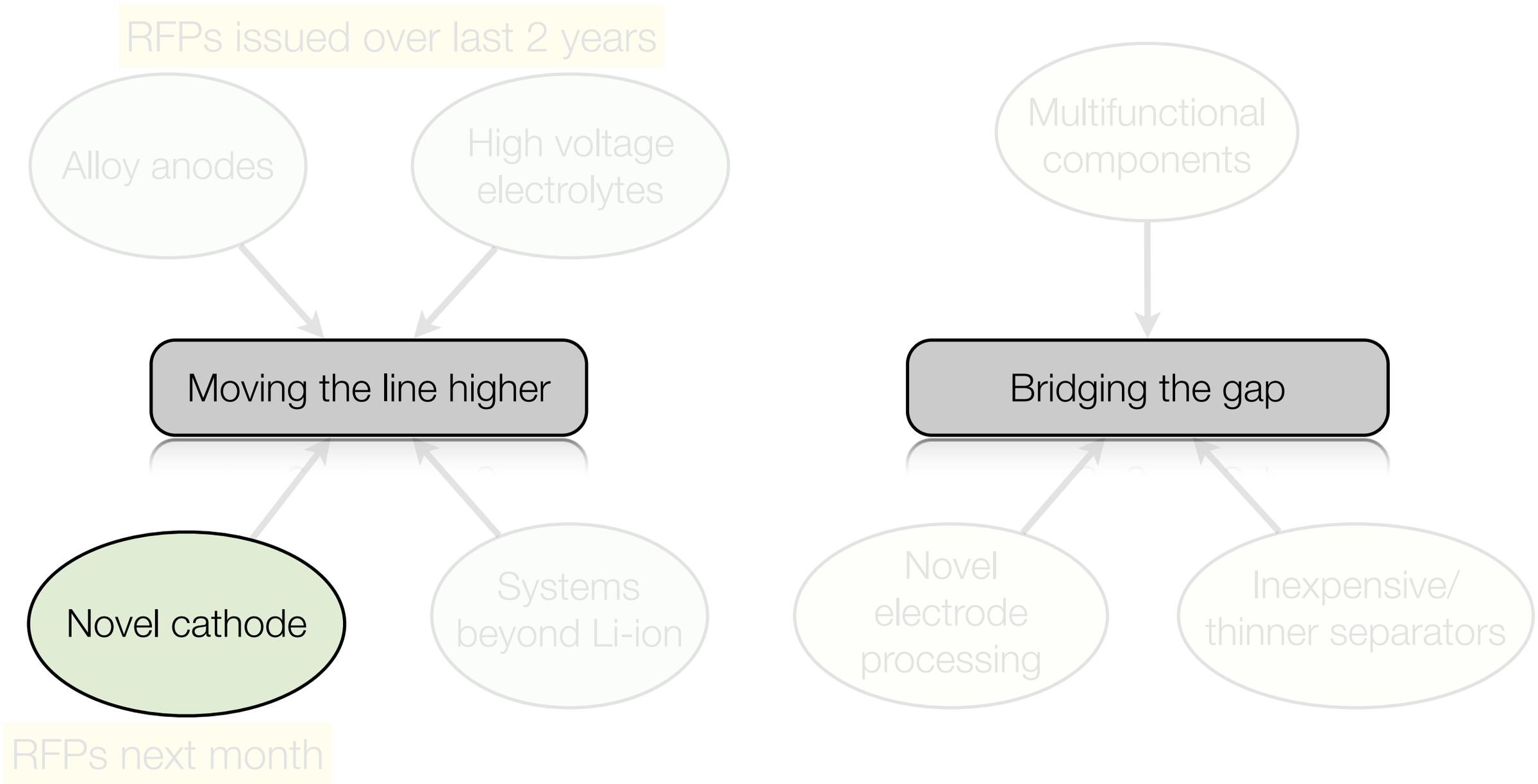
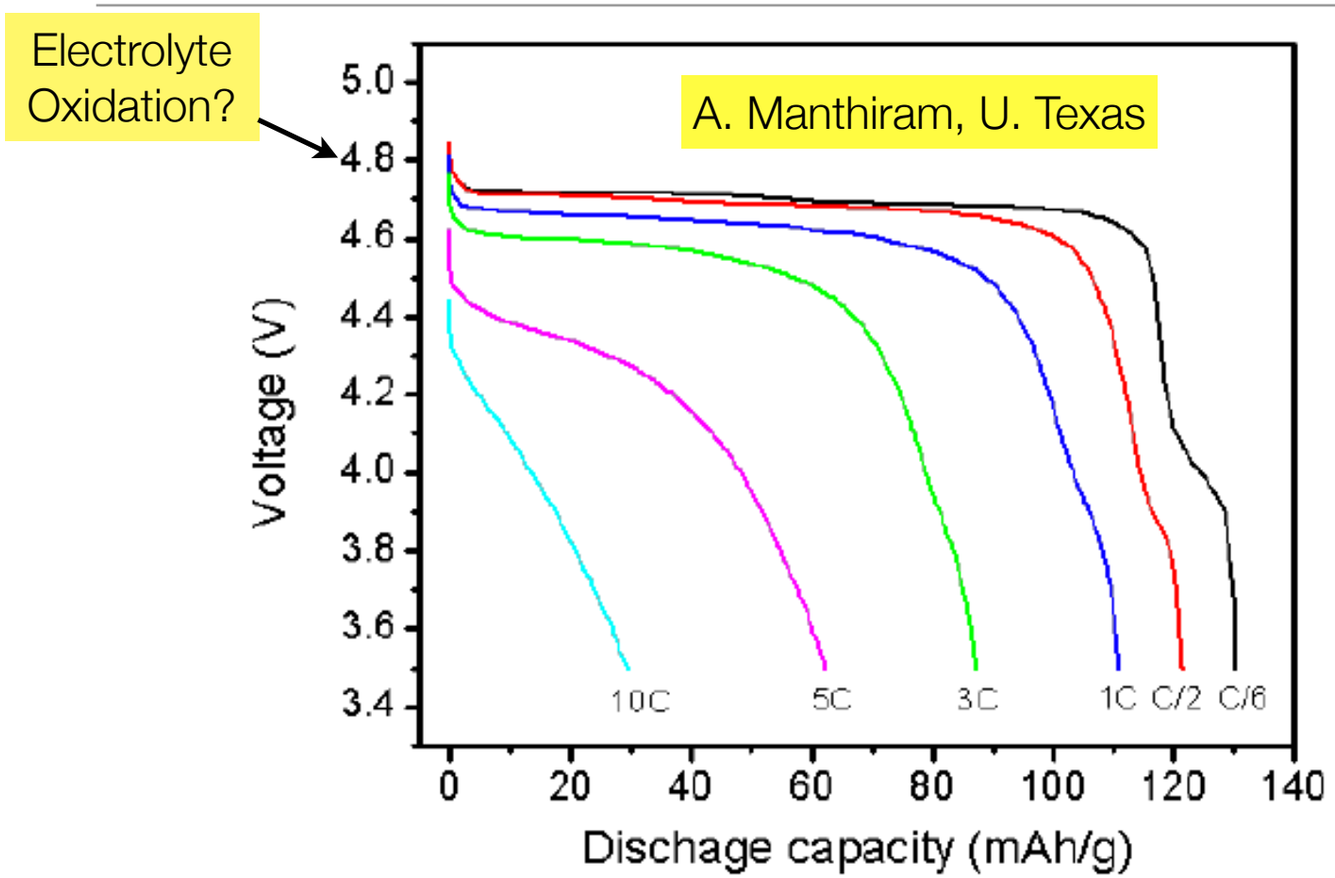
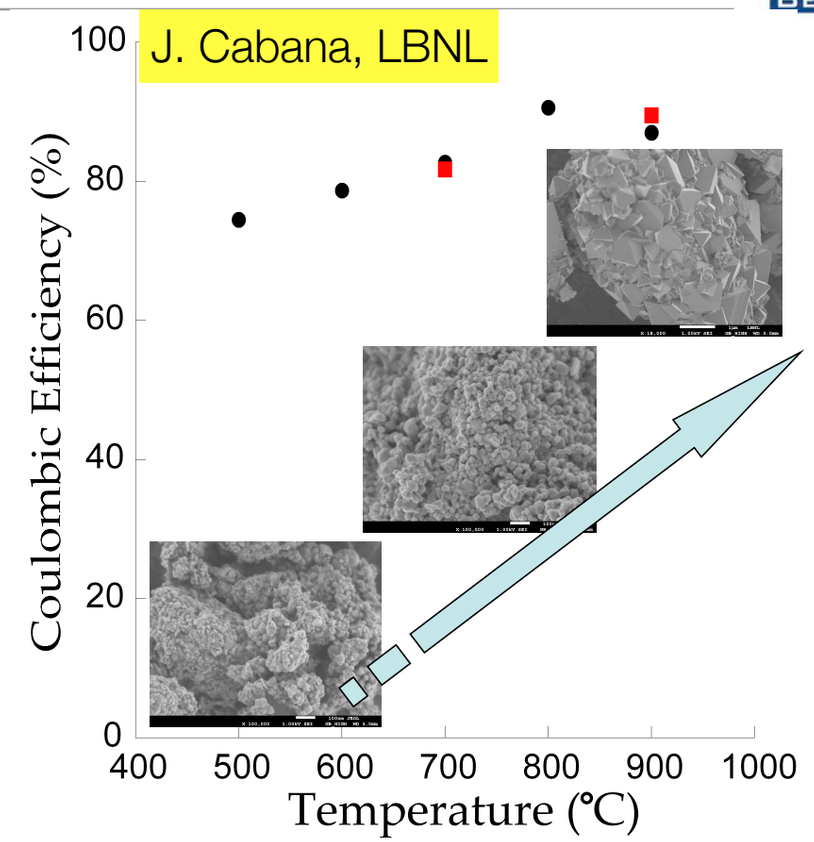


In addition to exploratory research, BATT has identified a new focus area in cathodes

Activities on the $LiMn_{1.5}Ni_{0.5}O_4$ spinel system





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  - An ideal test bed for studying high voltage operation

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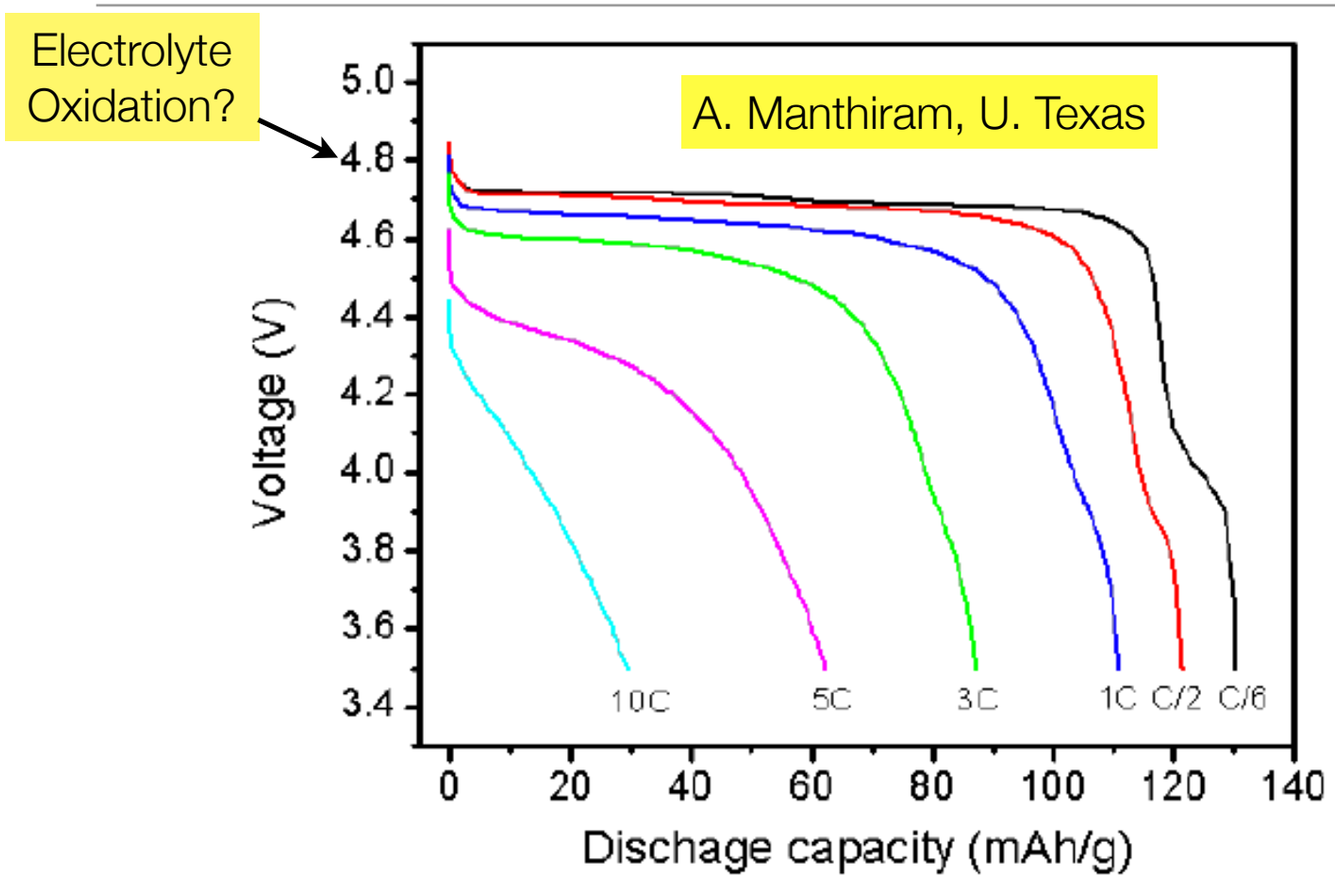

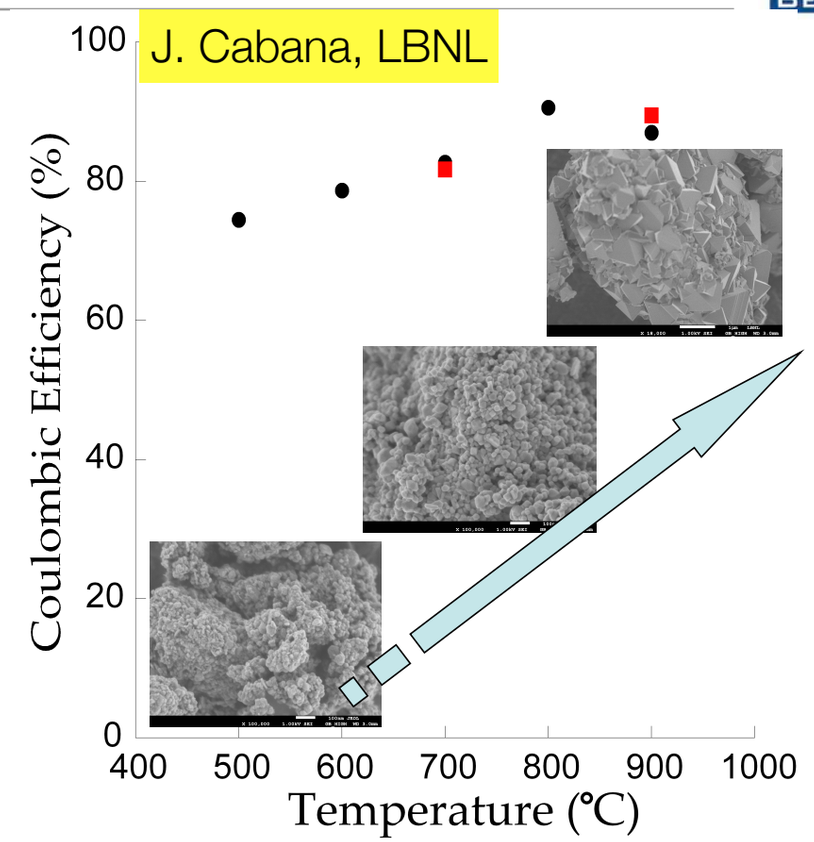

- Very stable cathode that results in ~15% improvement in energy over Gr./NMC
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- BATT Management will oversee two program-wide milestones:
  1. What are the side reactions in this system and how do we mitigate them?
  2. What is the optimal particle size to minimize side reactions and achieve PHEV rates?

BATT will be focus on answering these two questions over this fiscal year

Ni/Mn spinel focus area

- Are there any side reactions and if so what are they?

1. Quantify side reaction rate and mechanism

    - Team consisting of electrode studies (Battaglia), diagnostics (Kostecki), and theory (Smith/Borodin)

2. Propose and test techniques to decrease rate of side reactions

    - Techniques include surface modification (Zaghib, Zhang, Manthiram), new electrolytes (Kerr, Lucht, Angell), modifications to morphology of cathode (Chen, Zhang, Manthiram), and using binder/carbon free electrodes (Chiang)

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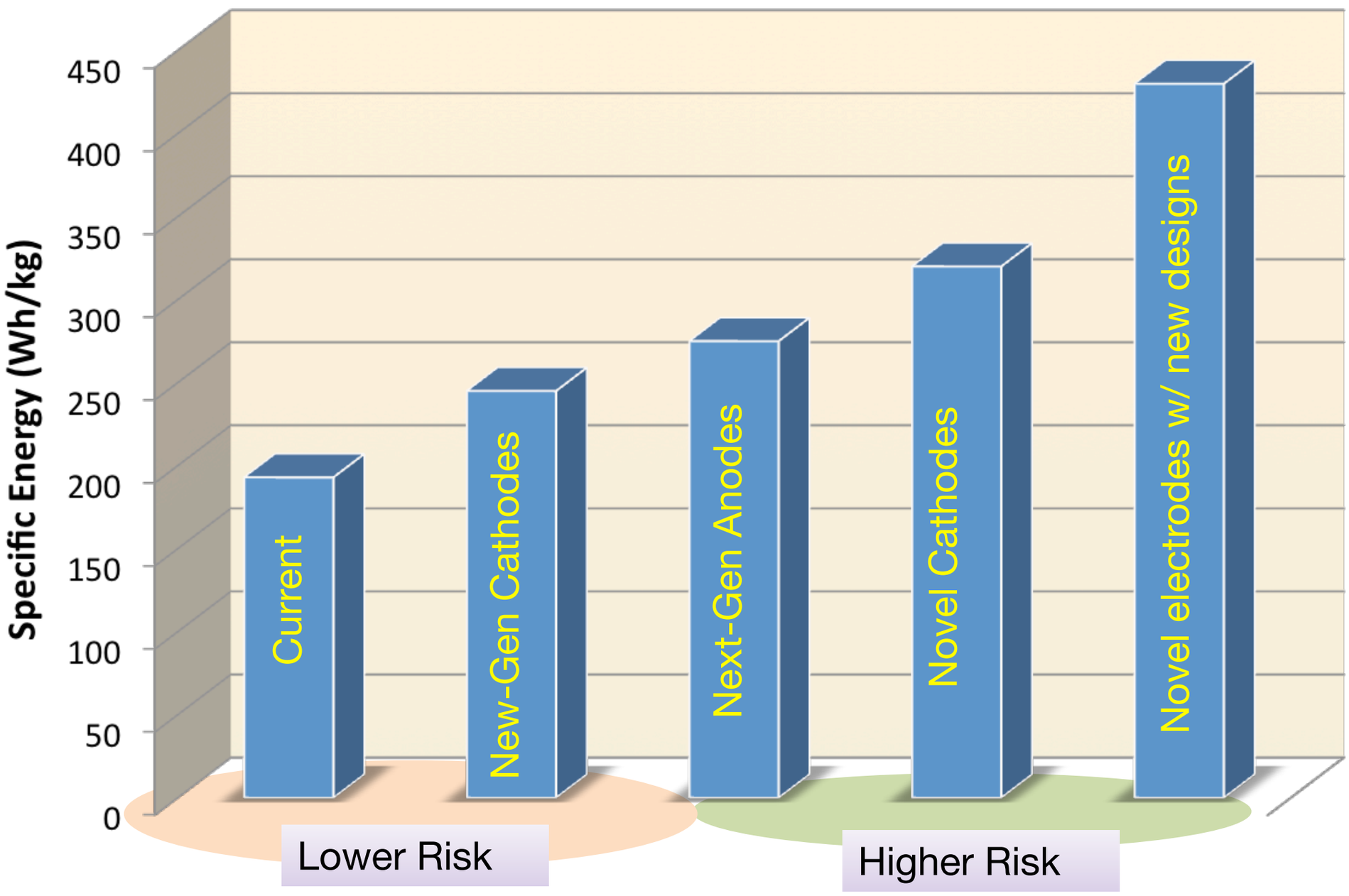
- Identify the optimum particle size to meet PHEV power requirements while minimizing side reactions.

  - Team consisting of material synthesis (Manthiram, Cabana, Ceder, Chen), theory (Ceder, Persson, Srinivasan), diagnostics (Grey), and electrode studies (Battaglia, Chiang)

BATT expects to use this team as a means of understanding high voltage operation

Impact of BATT Li-ion research



- Li-ion has potential to change the energy landscape
- More research needed

Beyond Li-ion

- BATT views solving the Li metal problem (rate and dendrites) as a critical first step to enabling Li-S and Li-O_2
- BATT has had a portfolio in Li metal systems for 2 decades
  - Pioneering research at LBNL has led to different methods of protecting lithium metal

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  - Pioneering research at LBNL has led to different methods of protecting lithium metal
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  - Project interacts with industrial partners to help enable use of Li metal at rates relevant to vehicle operation at room temperature

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  - Project interacts with industrial partners to help enable use of Li metal at rates relevant to vehicle operation at room temperature
- In addition, BATT has nucleated projects in both sulfur and oxygen
- Focus on the sulfur cathode: Can we contain the soluble polysulfides and recharge the insoluble ones?
- Focus of the oxygen cathode: Can the oxygen reaction be made reversible in a non-aqueous media?

As systems evolve, BATT will periodically evaluate need to increase emphasis

Beyond Li

- BATT has been periodically evaluating the need to start research into systems beyond lithium

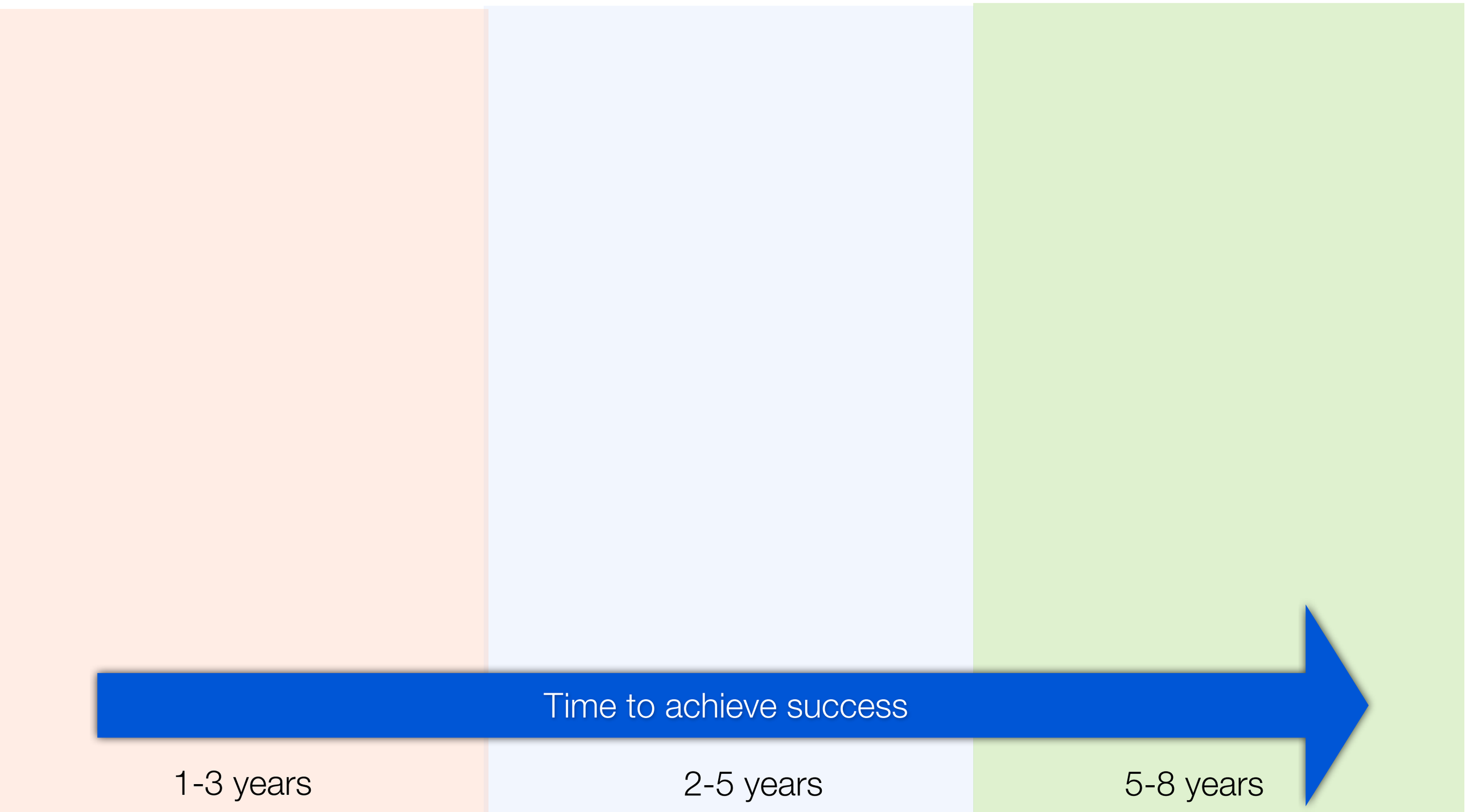
- Justification for moving away from lithium still controversial
  - Difficult to see sodium being higher energy than lithium or being lower cost
  - Justification for sodium: “its not lithium”!

- BATT has nucleated one small theory/synthesis project on sodium batteries
  - Hope is to see if materials exist that can react with sodium reversibly

- Research expected to inform BATT if further effort is appropriate

As system evolves, BATT will periodically evaluate need to increase emphasis

The BATT portfolio in FY2011



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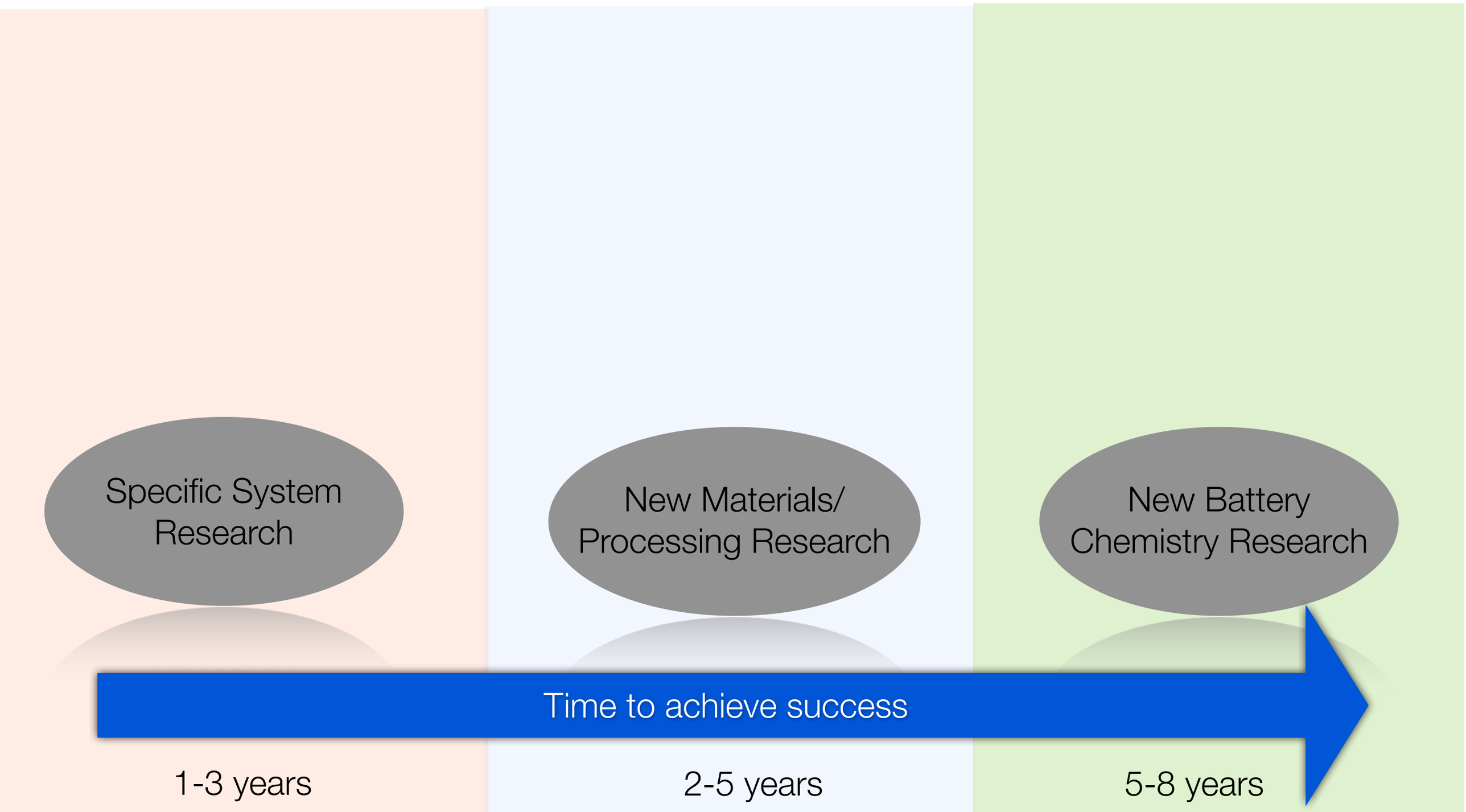

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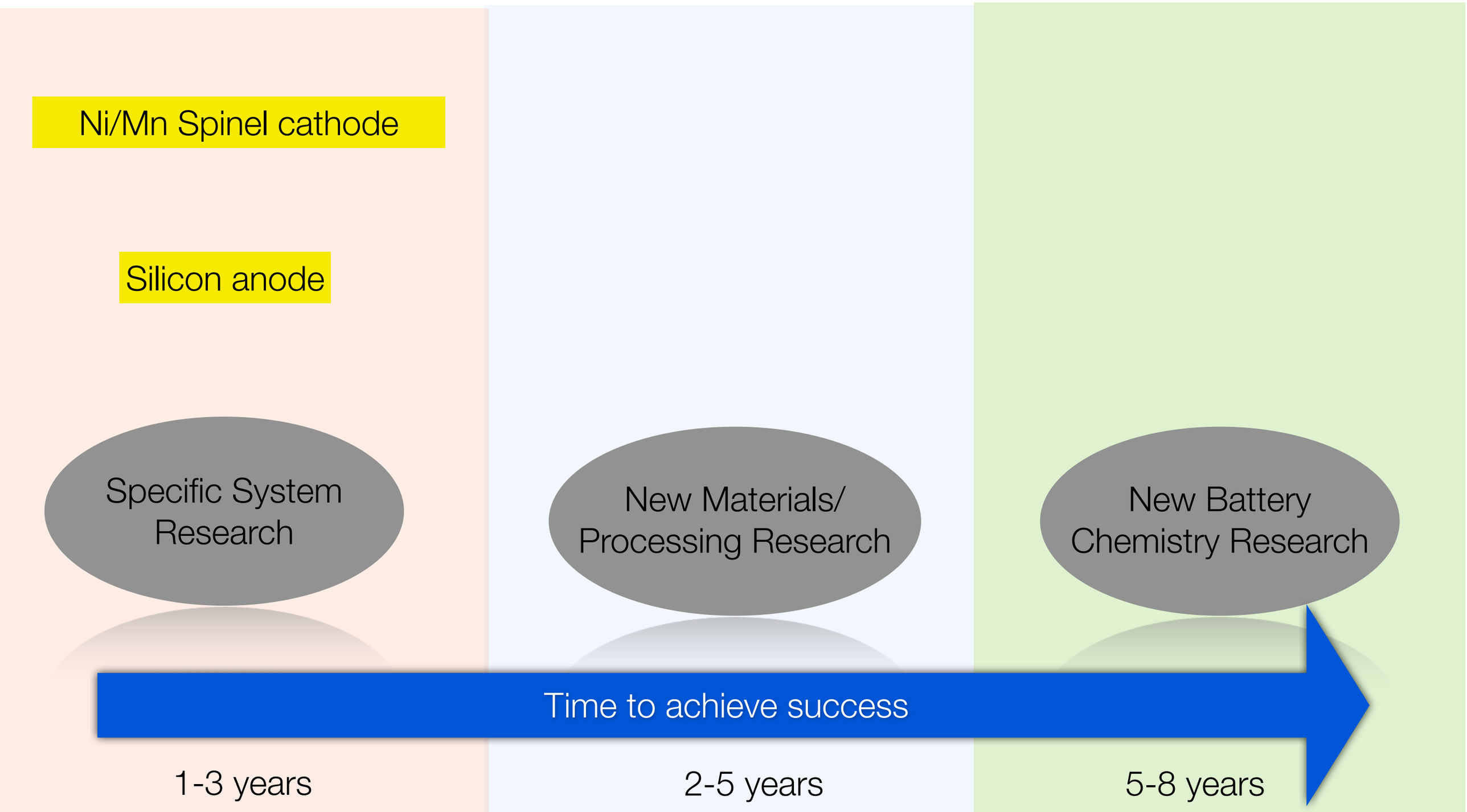

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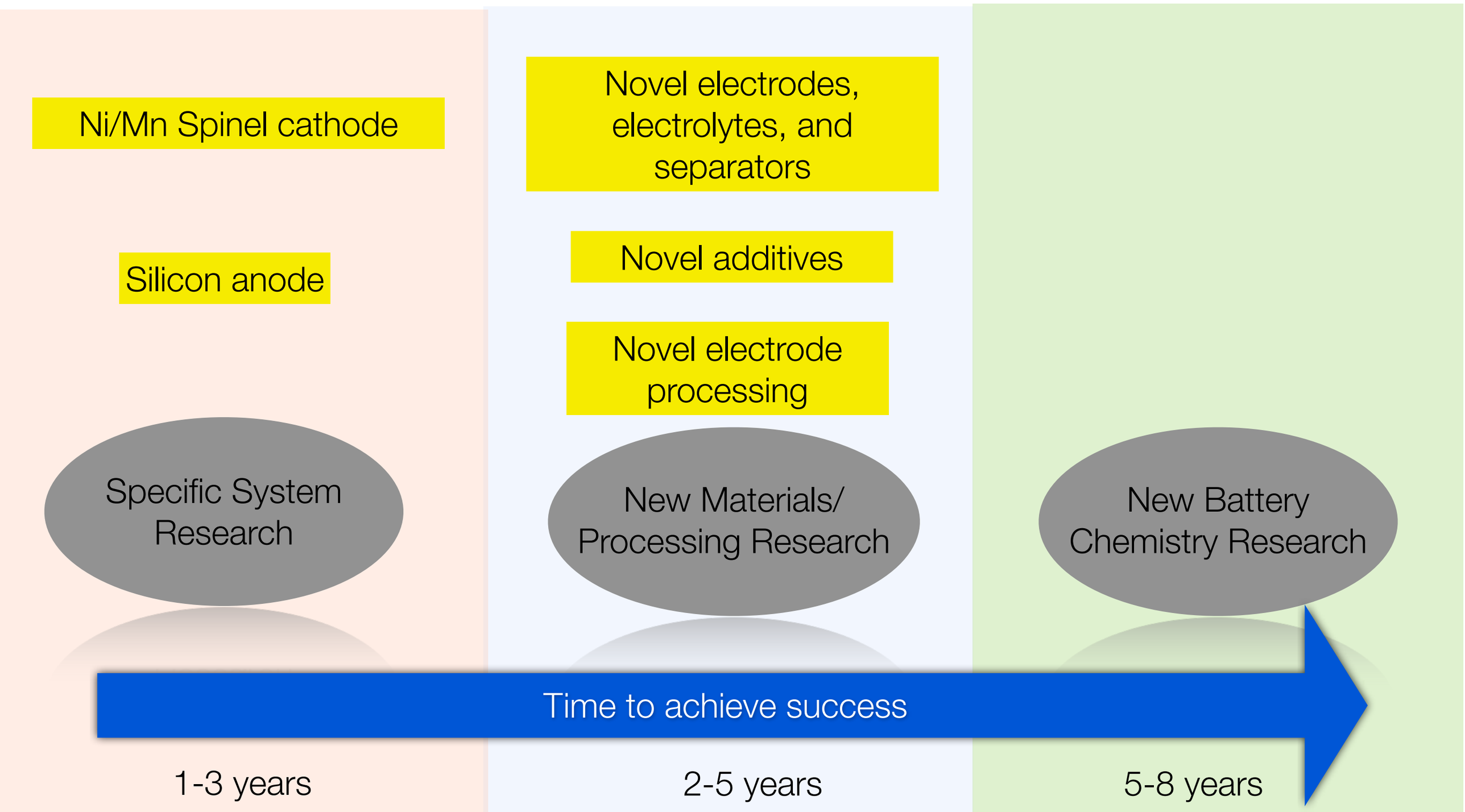

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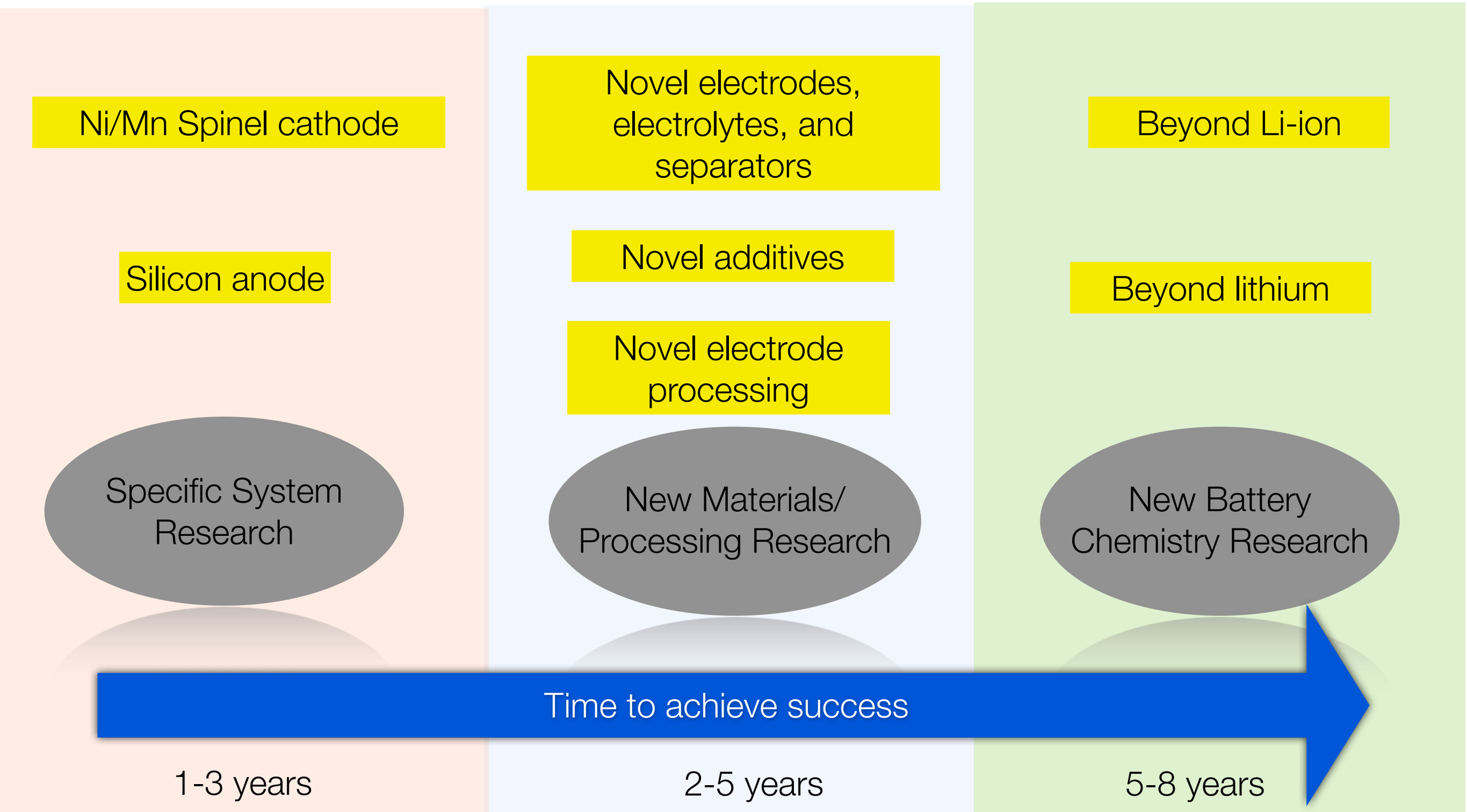


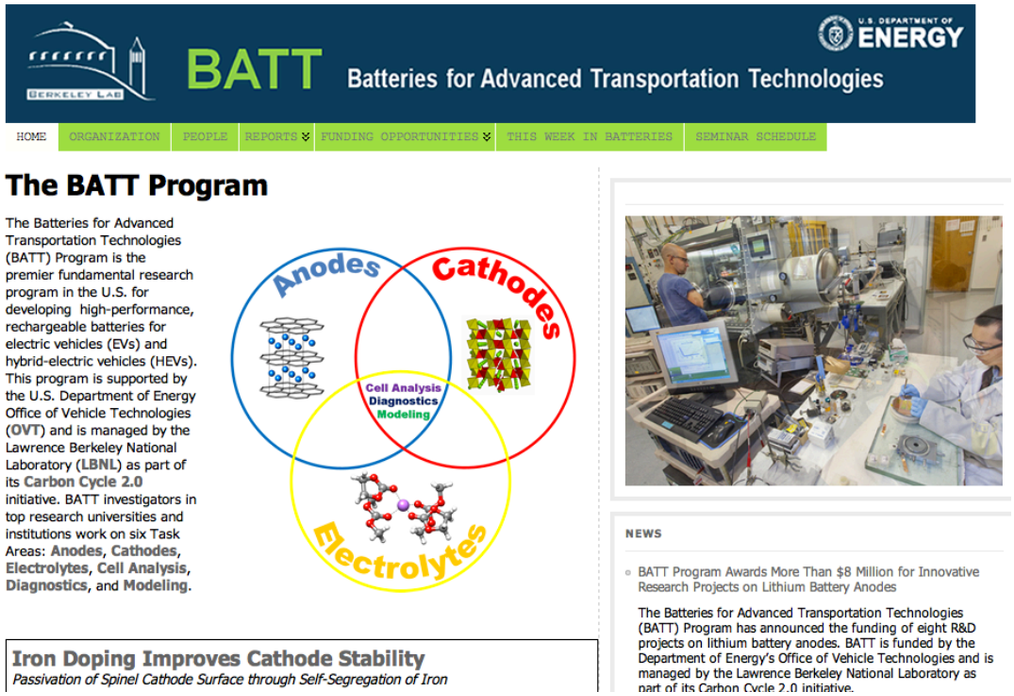
Cathode request for proposals (RFP)

- All projects in BATT have a 4 year term after which they are officially stopped
  - Applies to Universities, Industry, and National Labs
- RFP is issued in November of each year
  - 1 page white paper is requested. White paper is reviewed and full proposals are requested from a paired-down list. Full proposals are subjected to a "consensus review" process
    - ★ Anode RFP in 2009: BATT received 88 white papers of which 27 were asked to submit full proposals. 8 projects are being funded
- In 2010, focus will be on novel cathode materials for lithium batteries
- More specifics will be provided next month
- BATT also accepts "unsolicited" proposals for consideration outside the RFP cycle

We encourage you to participate in the RFP process

For more information...

BATT website: http://batt.lbl.gov/



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