# Robust, Multifunctional and Low-Cost Battery System for Electric Vehicles: A Non-Electrochemical Approach

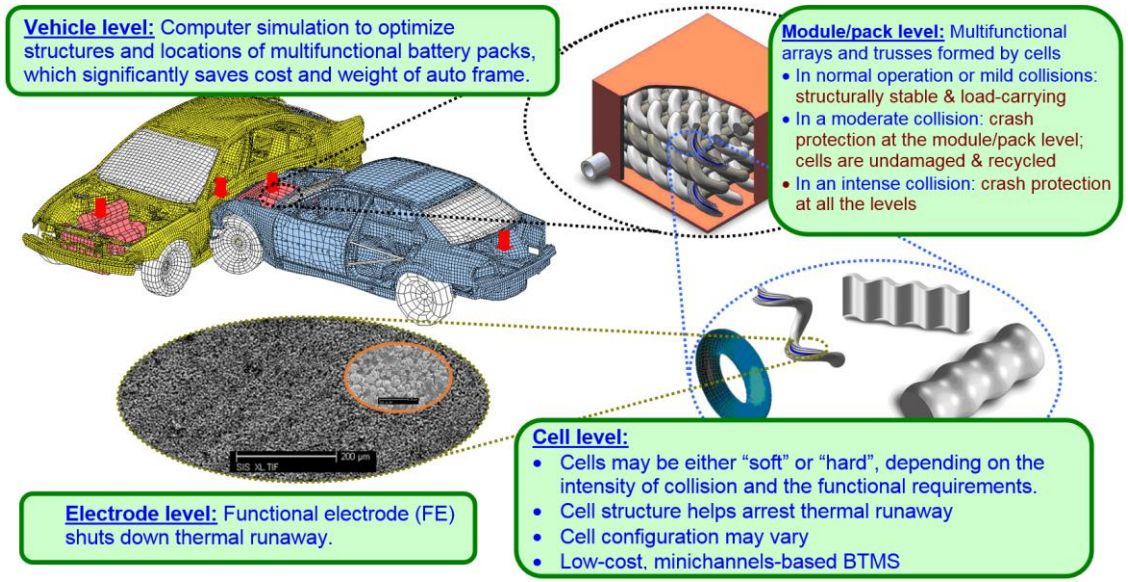

**TEAM:**

PI: Yu Qiao, UCSD (yqiao@ucsd.edu)

Team Members: Shirley Meng, John Fan, Yanbao Ma, Xi Chen


## Technology Overview

- Safety-first approach for light-weight, long-range electric vehicles
- Thermal-runaway-free structures inherent to battery electrodes
- "Negative mass" of battery packs of multifunctional design




## Current Status

- For fully charged high-energy Li-ion batteries that are subjected to mechanical or thermal abuse, thermal runaway is much suppressed; the peak temperature is reduced drastically.
- Technology has been proven in large pouch cells.
- We are looking for investors or customers to move the technology to mass production.

## Project Statistics

| | |
|---|---|
| Award Amount | $3.4M |
| Award Timeline | 02/19/2014-02/18/2017 |
| *Next Stage Target* | Commercialization |
| *Collaborations Sought* | TBD |

# Robust, Multifunctional and Low-Cost Battery System for Electric Vehicles: A Non-Electrochemical Approach (DE-AR0000396)

**PI: Yu Qiao (yqiao@ucsd.edu)**

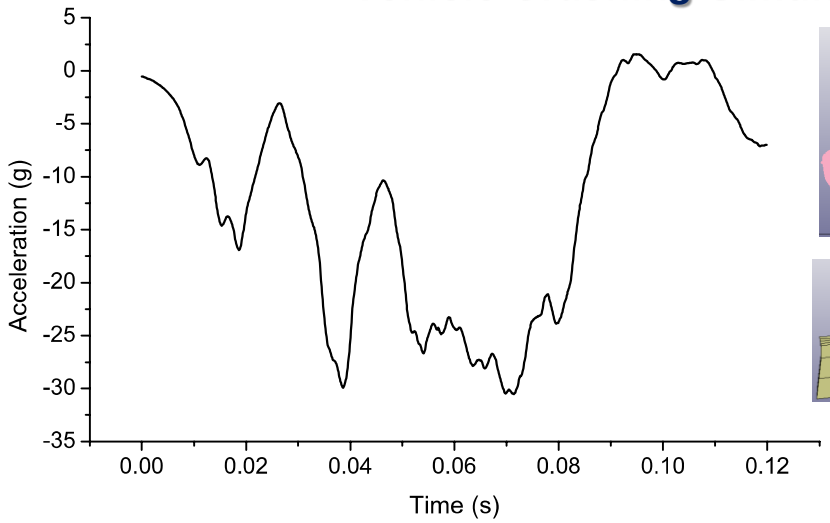
## In normal operation

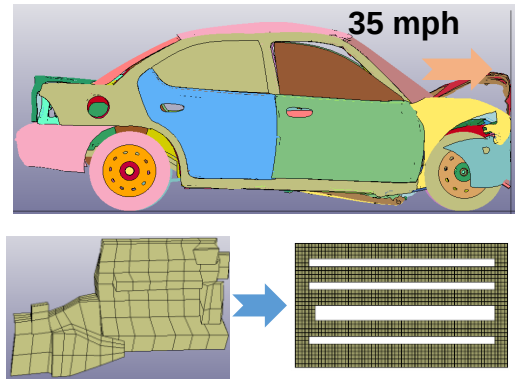
- Improved electrochemical performance

## In mild collision

- Battery modules/packs absorb energy and protect driver
- Battery cells do not deform and can be recycled

**Vehicle Crashing Simulation**




UC San Diego · Columbia University · University of California Merced · A.L.E.C. American Lithium Energy Corp

arpa·e CHANGING WHAT'S POSSIBLE

*Award# DE-AR0000396*

# Robust, Multifunctional and Low-Cost Battery System for Electric Vehicles: A Non-Electrochemical Approach (DE-AR0000396)

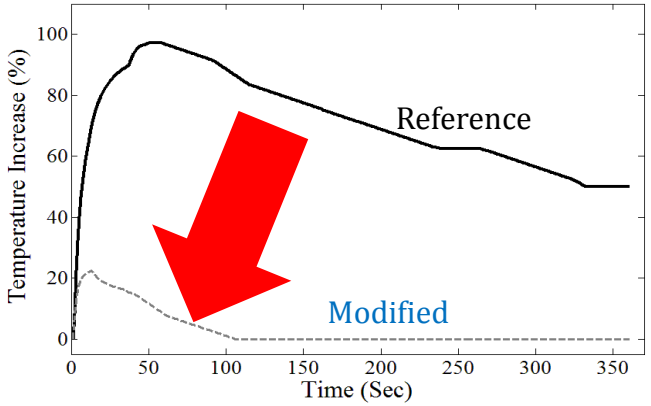
**PI: Yu Qiao (yqiao@ucsd.edu)**

**In intense collision**

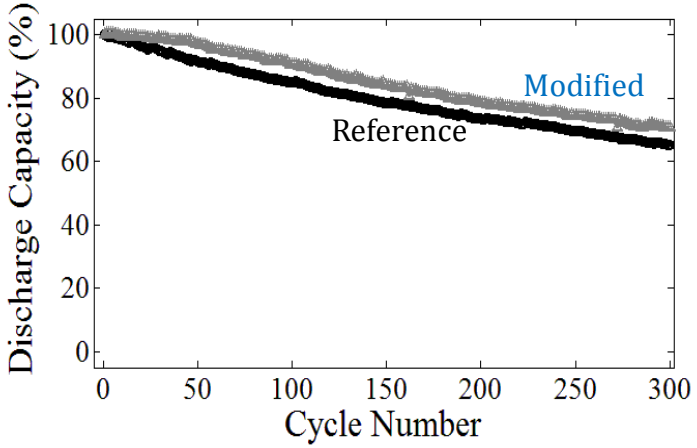
- Robust electrodes shut down electrochemical reactions

## Robust Electrode

**Response in Impact Test**




**Normal cycle life**




*Award# DE-AR0000396*

# Robust, Multifunctional and Low-Cost Battery System for Electric Vehicles: A Non-Electrochemical Approach (DE-AR0000396)

**PI: Yu Qiao (yqiao@ucsd.edu)**

**Functional Current Collector:**

- Mechanically triggered isolation of internal shorting sites
- No increase in cell mass

**Functional Binder:**

- No increase in cell mass
- Low softening temperature; large swelling upon heating
- Working well up to 4.1 V

**Functional Additives (Thermal-Runaway Retardants):**

- Direct addition into the cell (<0.5% cell mass)
- Using separate containers (< 4% cell mass)
- Functional coolant (ample)

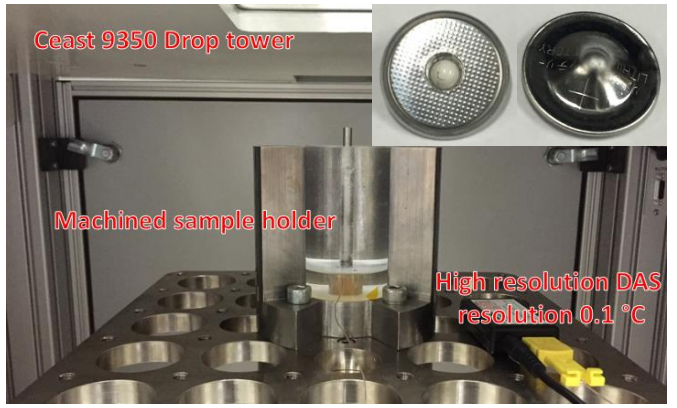
UC San Diego | Columbia University | University of California UC Merced | A.L.E.C. American Lithium Energy Corp

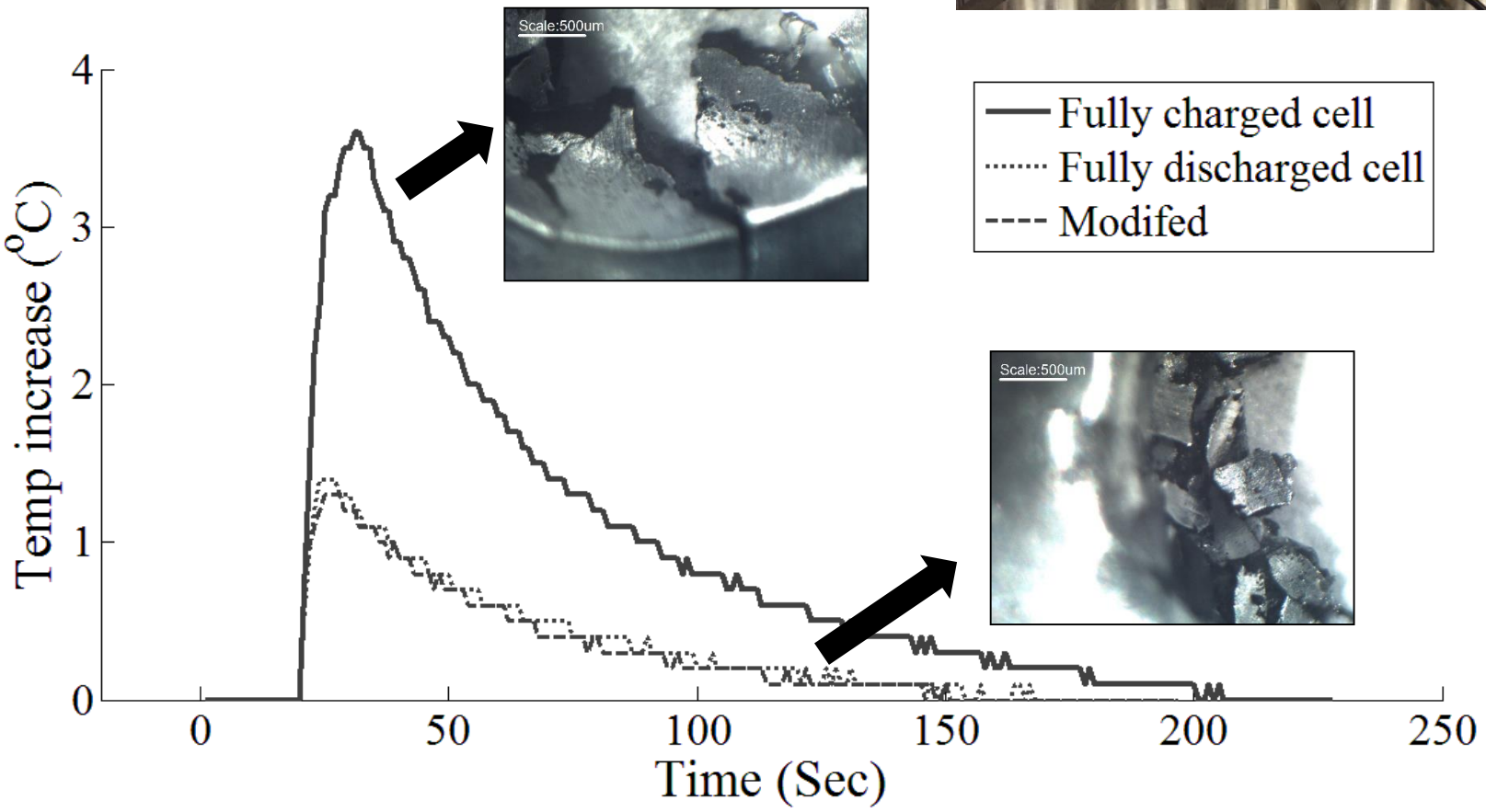
arpa·e CHANGING WHAT'S POSSIBLE

*Award# DE-AR0000396*

# Impact tests on modified cells

Test setup, input impact energy 3.5J



# Robust, Multifunctional and Low-Cost Battery System for Electric Vehicles: A Non-Electrochemical Approach (DE-AR0000396)

**PI: Yu Qiao (yqiao@ucsd.edu)**

**Functional Current Collector:**

- Mechanically triggered isolation of internal shorting sites
- No increase in cell mass

**Functional Binder:**

- No increase in cell mass
- Low softening temperature; large swelling upon heating
- Working well up to 4.1 V

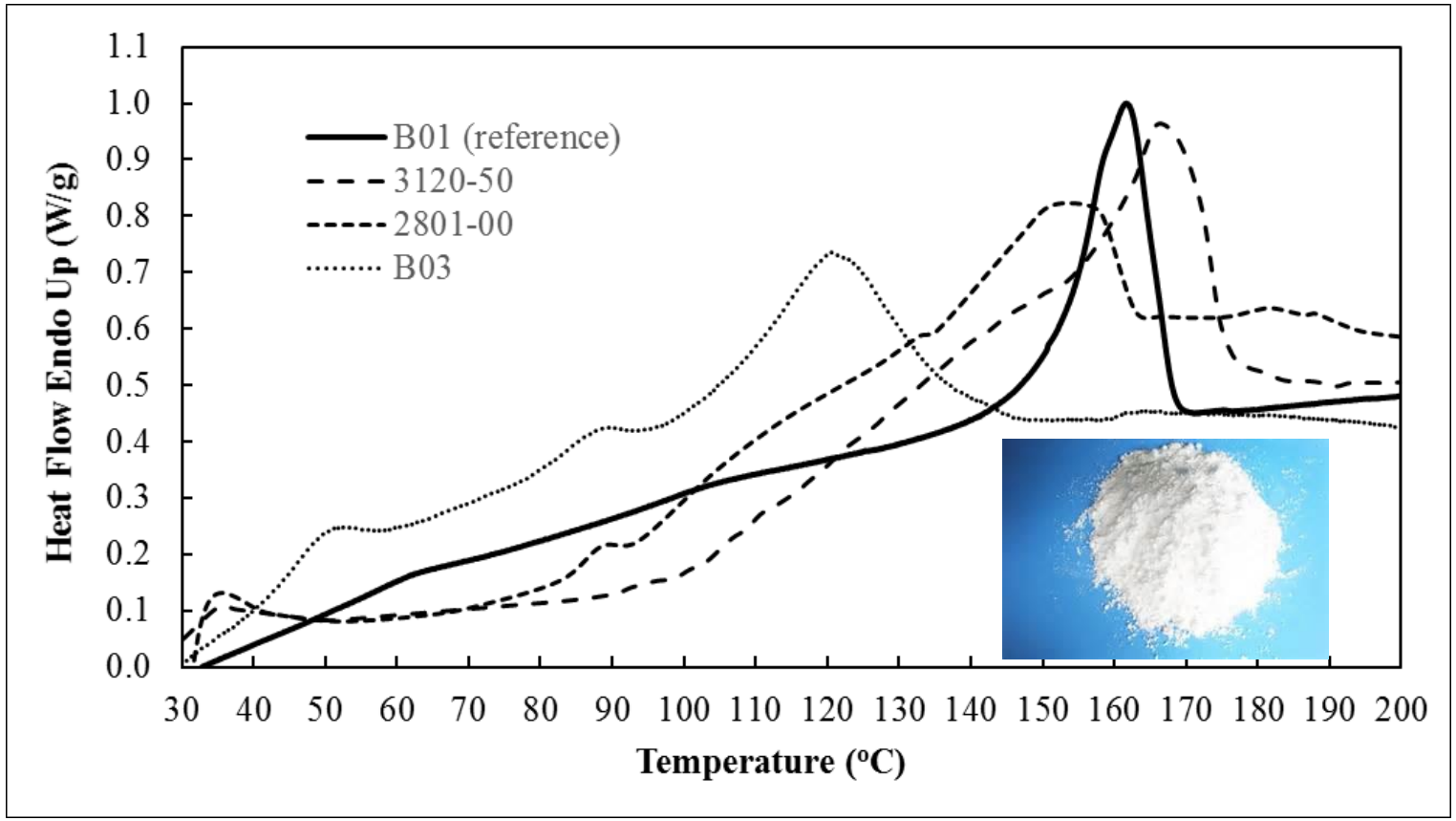
**Functional Additives (Thermal-Runaway Retardants):**

- Direct addition into the cell (<0.5% cell mass)
- Using separate containers (< 4% cell mass)
- Functional coolant (ample)

UC San Diego | Columbia University | University of California UC Merced | A.L.E.C. American Lithium Energy Corp

arpa·e CHANGING WHAT'S POSSIBLE

*Award# DE-AR0000396*


Heat Flow Endo Up (W/g)
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
B01 (reference)
3120-50
2801-00
B03
30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200
Temperature (°C)

# Robust, Multifunctional and Low-Cost Battery System for Electric Vehicles: A Non-Electrochemical Approach (DE-AR0000396)

**PI: Yu Qiao (yqiao@ucsd.edu)**

**Functional Current Collector:**

- Mechanically triggered isolation of internal shorting sites
- No increase in cell mass

**Functional Binder:**

- No increase in cell mass
- Low softening temperature; large swelling upon heating
- Working well up to 4.1 V

**Functional Additives (Thermal-Runaway Retardants):**

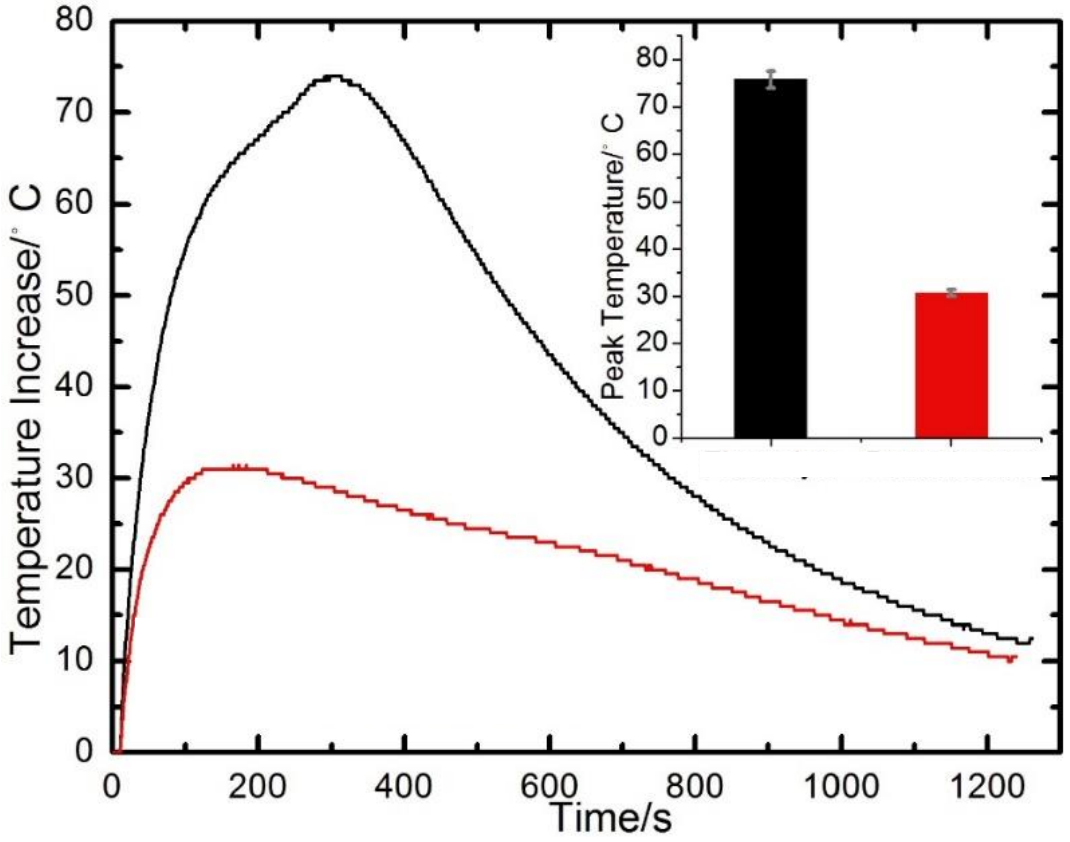
- Direct addition into the cell (<0.5% cell mass)
- Using separate containers (< 4% cell mass)
- Functional coolant (ample)

UC San Diego | Columbia University | University of California UC Merced | A.L.E.C. American Lithium Energy Corp

arpa·e CHANGING WHAT'S POSSIBLE

*Award# DE-AR0000396*

# Capsuled TRR



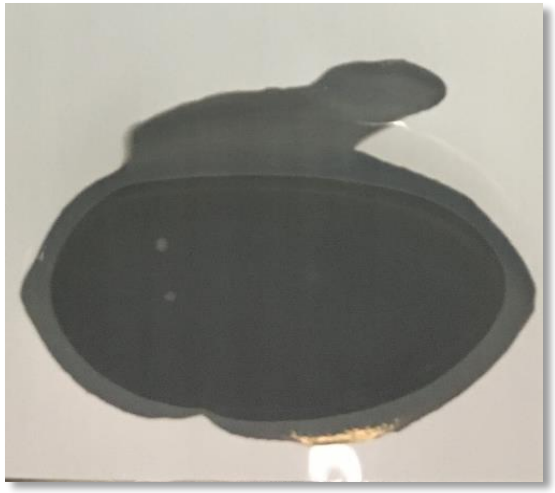

Nail penetration test temperature profiles and peak temperatures

**Create a blocking layer on solid surfaces**

**Temperature increase and heat generation reduced**

# Capsuled TRR

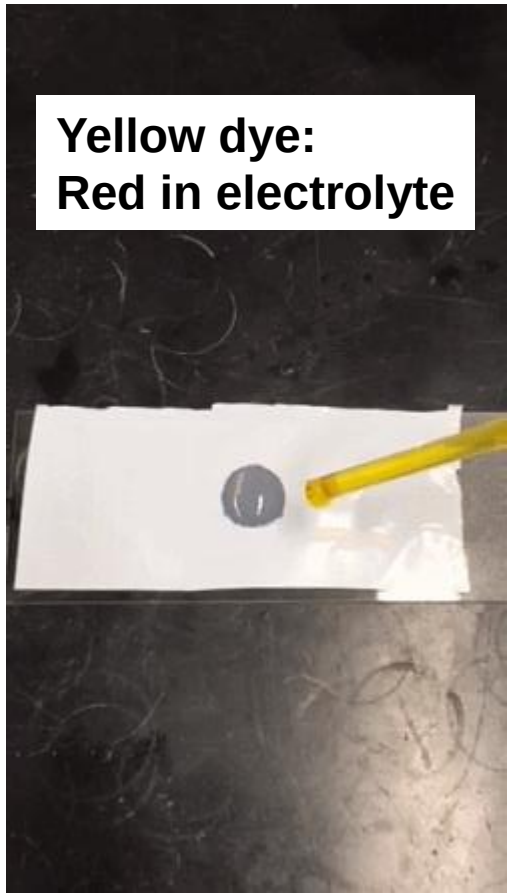
Electrolyte
on separator



TRR
on separator

TRR: Much more wettable to solid surface

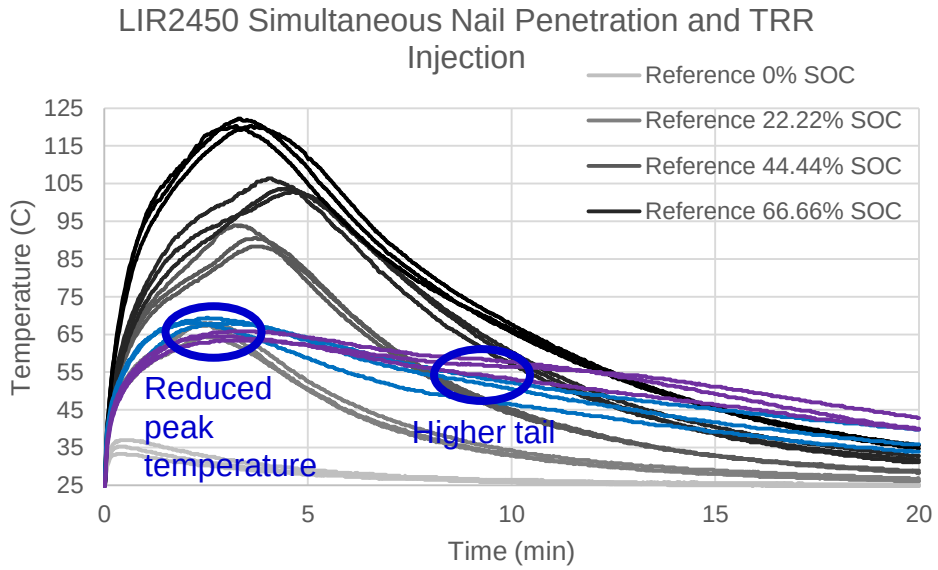
This mechanism is ideal for *deep penetration* in large-sized pouch cells




**TRR displaces eletrolyte**

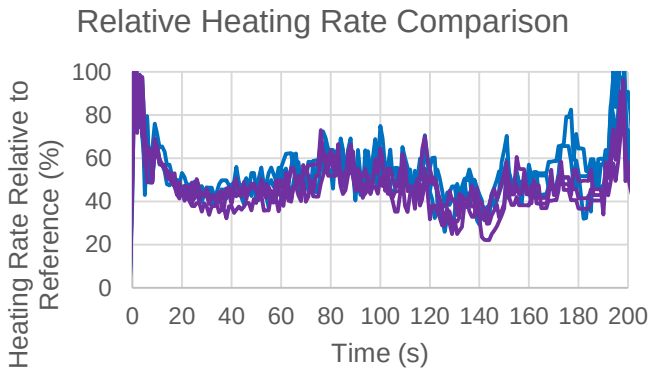
# Functional Coolant

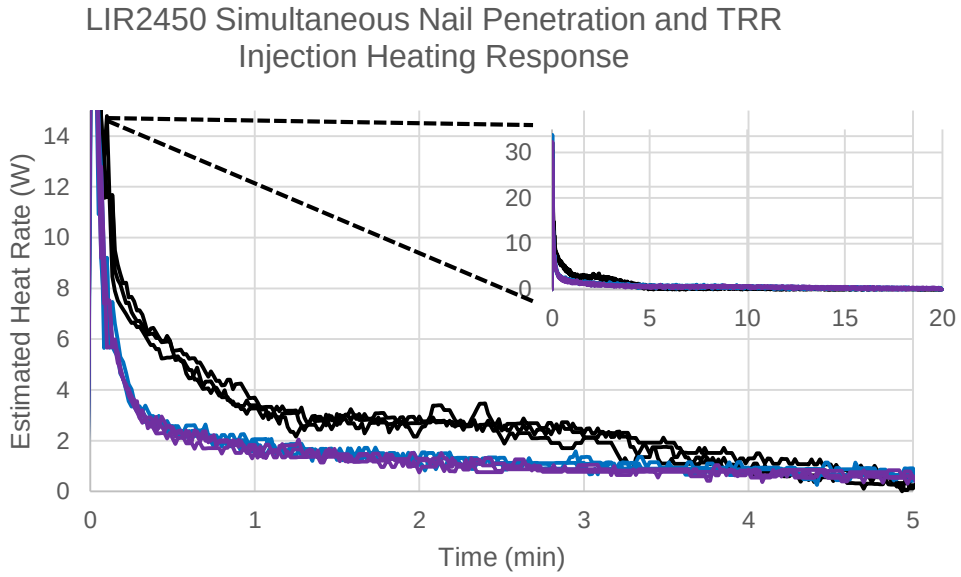
- Peak temperature response is a reflection of short circuit heat generation rate and heat generation capacity
- TRR poisoned cells reduce peak temperature increase by 60%



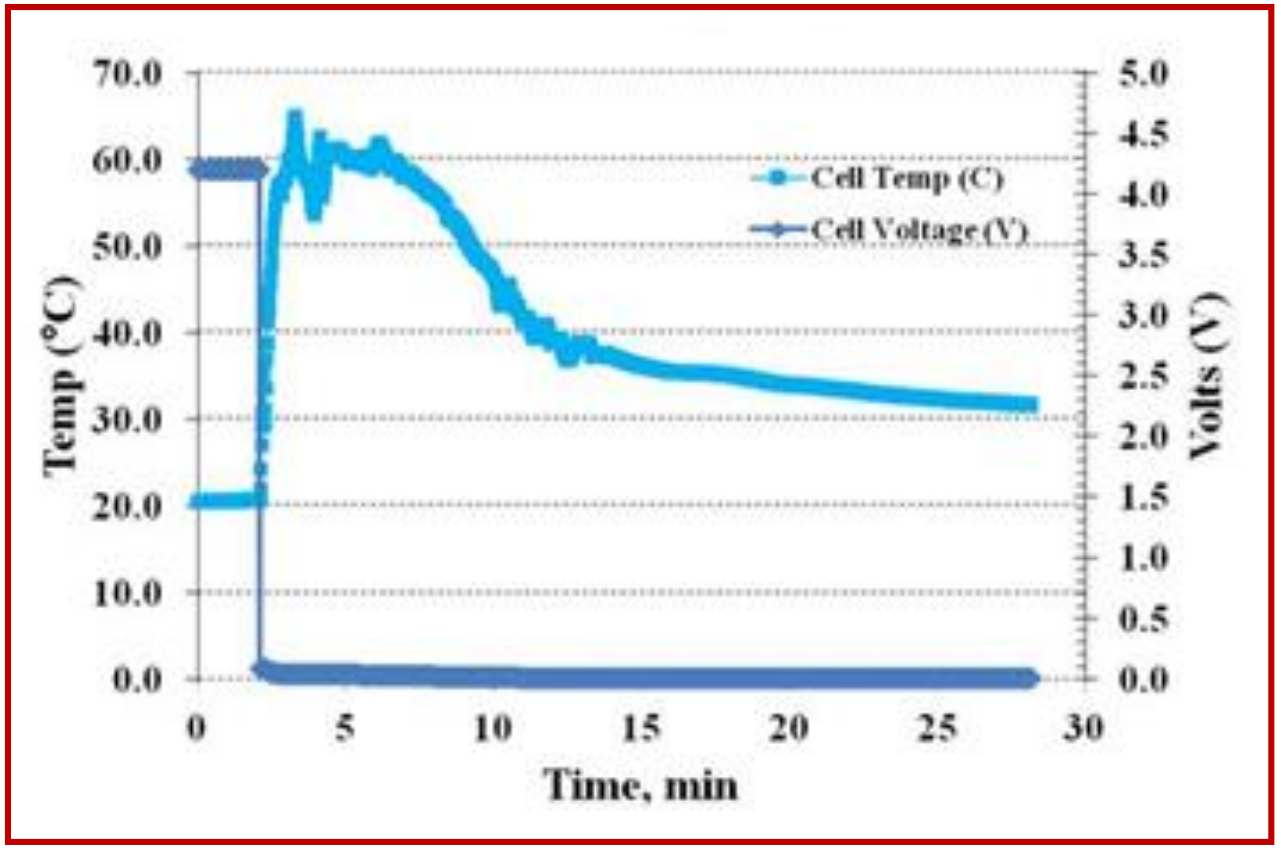
# Functional Coolant

- Rate of heat generation is significantly suppressed which results in reduction in observed peak temperature increase
  - Reduces rate of heat generation by up to 70% relative to reference
  - Effect is apparent within seconds of initiation



# Direct Addition of TRR



# Robust, Multifunctional and Low-Cost Battery System for Electric Vehicles: A Non-Electrochemical Approach (DE-AR0000396)

**PI: Yu Qiao (yqiao@ucsd.edu)**

## Extended Applications

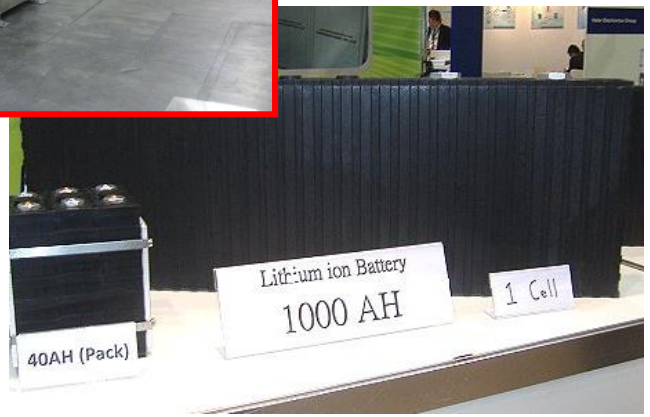
**Objectives of our EV battery system**

| Metric | State of the Art* | Proposed |
|---|---|---|
| Robustness | Poor | Thermal-runaway proof |
| Drive Range | ~100 miles | 250-300 miles |
| Total Cost (for 80 kWh) | $36,000-$60,000 | $9,040-$9,600 |
| Specific Cost | $450-$750/kWh | $113-$120/kWh |
| Energy Density | ~ 150 Wh/L | > 230 Wh/L |
| Effective Specific Energy | ~ 90 Wh/kg | 154-223 Wh/kg |
| Cycle Life | < 1,000 cycles | > 1,000 cycles |

Electric veh

e energy storage

Military applications




Large Li-ion batteries

*Award# DE-AR0000396*