NOHMs Technologies, Inc.

Improving Battery Safety & Performance with Advanced Electrolyte

Paul Homburger
Vice President, Business Development
February 2020
NOHMs Technologies

**NOHMS Develops Advanced Electrolyte Additives and Formulations, Significantly Enhancing Lithium Ion Battery Safety**

**Battery Electrolyte is a High-Growth Specialty Chemical Market**

**NOHMs’ Technology Facilitates and Enhances EV Market Growth**

- $3B Market Today
- 20-30% CAGR Through 2030
- NOHMs Proposes a Capital-Efficient Specialty Chemical Business Model

- Addresses Safety Concerns
- Enabler of Safe Advanced Battery Cell Chemistries: Higher Energy Density Materials
- Reduces System Complexity and Safety-Related Costs
What Is “Safety”?

- Completely Non-Flammable Battery
  - Unrealistic; Everything burns, at some temperature
  - Chemistry/Physics gets involved
- China:
  - 5 minutes to egress car after thermal-runaway warning from BMS (time expected to be raised in 2020)
- Tesla:
  - Structural Protection Added:
    - Hollow aluminum deflector bar (1)
    - Expensive titanium plate, est. $35 / car (2)
    - Solid aluminum extrusion (3)
    - Estimated Weight: 4.5 lbs (2 kg)
    - Estimated Full Cost for Retrofit: $200-250 / car
- Boeing 787 Dreamliner (LCO):
  - Structural Protection, Insulation and External Venting Added
    - Additional 185 lbs (84 kg) / Plane (3x the original weight)
      FAA Estimate: $465K / Plane
    - Design Point: Starve a fire of oxygen
  - Fuel Penalty: 17% of Weight / 1000 km
    Potentially $58K / Year
  - 2017: UAL 915, IAD->CDG Incident

Source: NY Times, April 11, 2014

Source: Boeing
Battery Safety Starts With Safe Electrolyte Material

• Heavy Weight Penalty Incurred to Protect Battery and Occupants

• Complex Systems Incorporated To Prevent Battery Fires

• Electrolyte Today Is Highly Flammable

NOHMs’ Electrolyte Platform Is Key To Safety
Battery Pack Safety Costs Increase with System Level

- **Vehicle Structure**
  - Titanium Metal Plate
  - High-Strength Enclosures

- **Power Train**
  - Expensive Management Systems
  - High-Cost Cooling Systems

- **Battery Pack**
  - Flame-Retardant Materials
  - Additional Pack Components (E.g., Gas Venting)

- **Cell**
  - Advanced NOHMs Electrolyte
  - Integrated Separators

![Diagram of battery pack components]

- Battery Module
- Cell Management Controller
- Insulation
- Battery Junction Box
- Cooling System
- Lower Housing Shell

**Confidential: Do not duplicate or share**
Electrolyte Innovation Stagnated… for Three Decades

1991
Sony Commercialized the Lithium Ion Battery
➢ The electrolyte contained carbonate solvents and LiPF6 salt.

Since 1991
95% of Electrolyte Composition Is The Same
➢ In today’s batteries, performance additives do not improve safety.

2020
For future batteries, new electrolyte is needed to improve performance and safety.

Today’s Electrolyte is 95% similar to Sony’s 1991 battery formulation.
NOHMs’ Solution: Simpler, Multi-Functional Molecules

NOHMs’ unique approach introduces multiple functions via core molecules.

- Reduce Internal Resistance
- High Voltage Stability
- Reduce Viscosity

NOHMs’ products address multiple functions with one additive.

- Fire Safety
- Prevent Thermal Runaway
- SEI Protection
- Temperature Stability

- $P$ (Phosphorous) = Flame Retardant

Multiple Functional Groups

NOHMs Core Chemistries
NOHMs Has One Key Benefit:

Improved Lithium Ion Battery Safety

NOHMs’ Safety Co-Solvents Prevent or Delay the Onset of Thermal Runaway at the Cell Level

Ethylene carbonate (electrolyte) reacts with oxygen from the cathode decomposition.
Safety Validation Testing

- ARC
- Autoclave
- Hot Box
- Propagation

- Trigger cell
- Silicone foam spacer
- Propagation cell

TC 1
TC 2
Delivering Safety Without Compromising Performance

**Reference Electrolyte**
- Trigger cell enters thermal runaway upon penetration
- Adjacent cell enters thermal runaway in 4 min

**NOHMs Electrolyte**
- No Propagation To Adjacent Cells

**Propagation Test: 622-Gr 40Ah cells**

**Long-Term Cycle Life**
- NOHMs electrolyte achieves comparable electrochemical performance.

*Confidential: Do not duplicate or share*
Cost/Performance Benefits

NOHMs Offers System Cost Reductions:
Improved Performance With Reduced Costs

• Higher Energy Density
  — Transition from NMC622 to NMC811: ~16% Improvement
  — Silicon Anodes: 25% or More

• Larger-Capacity Cells
  — Greater Energy in Large-Capacity Cells Makes the System Inherently Less-Safe.
  — But It Also Reduces Cost of the Overall Pack: System Safety Components, Wiring, BMS, Etc.
Cost Reduction via Advanced Electrolyte

NOHMs’ electrolyte components (12% by weight)
- High voltage stability
- Broader temperature range
- Non-flammable

Benefits to Partners/Customers:
- Overall Improvement In Performance
- Reduction in Battery System Cost by 36% (Estimated)

6% * 24% Cost Increase = 1.44% Increase in Total Battery Cost
Potential Cost Savings – Advanced Electrolyte

<table>
<thead>
<tr>
<th>Normalized Cost</th>
<th>Cost Profile Using Advanced Electrolytes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Today’s Commercial Battery Packs</strong></td>
<td>10% Si Anode</td>
</tr>
<tr>
<td>System Cost</td>
<td>30%</td>
</tr>
<tr>
<td>Cell Cost</td>
<td>70%</td>
</tr>
<tr>
<td><strong>Total Cost</strong></td>
<td>100%</td>
</tr>
</tbody>
</table>

- **10% Silicon Improves Energy Density:**
- **20% More Nickel, 16% Increase in Energy Density:**
- **Larger Cells That Are Safe:**
- **Safer System Due to Safer Cells:**

**Physical Step**

**Cost Reduction Impact**

- **20% Cell**
- **16% Cell**
- **20% System 5% Cell**
- **10% System**

_Easily Offsets the Approximate 1.44% Increase in Electrolyte Cost_
NOHMs Safe Electrolyte Platform

- **LFP-Gr (170 Wh/kg)**: Safe electrolyte for very large format cells. ESS applications
- **Hi Ni (250 Wh/kg)**: Enabling 811 cathode chemistries. EV focus; Power tools
- **Silicon Anode (300 Wh/kg)**: Improving safety of High energy cell chemistries. EV focus
- **Li Metal (500 Wh/kg)**: Safe liquid electrolytes for Li metal anodes
Business Model: Collaboration With NOHMs

Cell Manufacturing Partner

- Provide Superior Product to Customer
  - Safety
  - High Performance SEI
- Partner’s Cells In-Line With Customer Requests
  - Customers Understand NOHMs Positioning
- Shortens Partner’s Time-to-Market
  - Extensive Testing Already Performed
- Customized and Optimized Electrolyte For Partner’s Products
  - Marketing Advantage

End Customer

- Achieve Their Main Goals
  - Safe / Non-Explosive Cells
  - Performance Targets
- Extensive Testing During E/L Development
  - Customer Acceptance of Technology Occurs Prior to “A Samples”

NOHMs

- Close Integration Into Supply Chain
- Expanded Development and Testing
  - Focus On Exact Requirements
  - Performance and Safety Targets Established Early On
Summary

**Benefit**
NOHMs Proposes Advanced Electrolyte Additives And Formulations
Significantly **Enhancing Lithium Ion Battery Safety**

**Growth**
Battery Electrolyte Is A High-Growth, Specialty Chemical Market
• $3 Billion Today
• 20 – 30% CAGR Through 2030
• Addressable by NOHMs Via a Capital-Efficient Chemical Business Model

**Low Risk**
Experienced Start-Up Managing and Innovation Team
• *Product De-Risked With $20M and 100+ Person-Years Since 2010*
• *Customer De-Risked With Funded Joint Development Efforts Since 2015*

**Future**
Technology Accelerating EV Market Growth
• *Safety Concerns*
• *Cost Reduction of Battery Systems*
Electrification of Vehicles Is Key Component of GreenTech’s Positive Impacts