3M Advancements in Electrolyte Additives
The Battery Show, November 12-14, 2012

Powering the Future
Agenda

- Advances in 3M LIB Electrolyte Development
  - How additives can impact battery performance and help lower costs
  - Next generation 3M additive development direction and data
- Innovative approaches to identifying useful, new electrolyte additives
  - How 3M is finding the needle in the hay stack
3M™ Battery Materials


3M™ NMC Cathode
Compositions of layered Ni, Mn, and Co metal oxides for a balance of power, energy, thermal stability and lower cost.

3M™ Silicon-Based Anode*
Twice the energy density vs. conventional graphite leading to a significant increase in cell energy.

3M™ Next Generation Electrolytes*
Longer battery calendar life and improved performance at high voltage and high temperatures.

3M™ Battery Electrolyte HQ-115
Improves battery capacity retention and cycle life. Reduces swelling and gas generation in thin form factor pouch cells.

3M™ Redox Shuttle BE-3.9V
Chemical cell balancing that simplifies battery pack electronics and helps reduce cost.

3M™ High Energy Cathode*
Breakthrough of 40% higher cell capacity when matched with 3M Si Anode leading to 25% to 40% increase in available cell energy.

*In development

3M has capability in key lithium ion battery materials and has the unique ability to integrate new materials for customer-specific solutions.
3M™ Battery Materials

3M Battery Materials Technology Roadmap – Automotive LIB

3M materials technology provides a path towards more than a 40% increase in energy.
3M™ Battery Electrolyte HQ-115

**Uses**
- Electrolyte Additive (2-5 wt% in electrolyte)
  - Widely used for the last 10 years
- Principal Electrolyte Salt
  - Lithium Polymer Battery for EV or Telecom back-up applications
  - Certain rechargeable coin cells and primary Li batteries

**Benefits**
- Improved capacity retention at high temperatures
- Reduced gas generation at high temps
  - Reduced swelling/prismatic
  - Reduced venting/round cell
- Impedance control for improved cell life and safety
- Can impact cell design and total cost of the battery pack

Li + N\text{SO}_2\text{CF}_3

SO_2\text{CF}_3
3M Battery Electrolyte HQ-115 additive for impedance control

Float Charge Test: 18650 Graphite/LiCoO₂ cells
Single layer PE separator (23 micron), Constant 4.2V hold at 60°C
Base Electrolyte: 1M LiPF₆/EC:DMC:EMC (1:1:1)
No additive vs. 4% HQ-115 additive

- Shorting observed after ~ 20 days with no electrolyte additive present.
- No shorting observed with 4% HQ-115 electrolyte additive after > 35 days
- Can influence separator and cell design to provide lower total cell cost.
Next Generation Electrolyte Additive Development

Goals:
- Identify next generation electrolyte additives
- Primary objective is Improved High Temperature and High Voltage performance

Strategy:
- Develop additives that are capable of forming a kinetically stabilizing film or layer on the electrode surface (anode or cathode) at low concentrations in electrolyte.
- Leverage 3M fluorochemical core competency
  - > 25 fluorinated materials screened from 3M fluorochemical library
Developmental additives significantly reduce cell voltage drop after storage.
Reversible Capacity Loss on Storage

Developmental additives reduce reversible capacity loss after storage
Developmental additives reduce irreversible capacity loss after storage
Long-term Cycling after Storage

- 4.2-3.0V, C/2 rate, and 45°C Cycle

Power shut down

Developmental additives increased capacity retention after cycling
Developmental additives reduced cell impedance rise during long term cycling.
Summary

- Developmental additives have demonstrated significant benefits at low concentrations in electrolyte formulations
  - Reduced voltage drop
  - Reduced capacity loss
  - Reduced cell impedance rise after storage at elevated temperature.

- Synergy has been observed between new additives and VC
  - Combination of VC additives is most effective
  - Cycle life improvement correlates with reduced cell impedance.

- Developmental additives improve cycle life and reduce impedance at high temperature
Acceleration of additive evaluation using high throughput screening methods

Project Goal: Identify electrolytes that will improve cycling of 3M Si alloy Anode and HE NMC Cathode Materials

- 192 cells made in a single day
- 64 different electrolyte formulations
- Project completion in 2.5 months
3M™ Battery Materials

Acceleration of additive evaluations using high precision coulometry

• Traditional battery cyclers do not measure coulombic efficiency (CE) with great accuracy.
• 100’s of cycles are necessary to identify effects of electrolyte additives on battery performance

High precision coulometry distinguishes changes in coulombic efficiency in only 20 cycles, which greatly accelerates cell evaluation

Excerpt Presented with Permission of Prof. Jeff Dahn
3M Battery Materials Laboratory Capability

Materials, Electrochemical and Abuse Characterization
- Powder x-ray diffraction
- BET surface area analysis
- Horiba Particle size analysis
- State of Art 3M Central Analytical
- 250 m² Dry room facility for cell assembly and electrolyte
- Cell Cycling Equipment >1,200 test channels
- Abuse testing (DSC, ARC, Hot Block, Thermal Ramp, Nail)

Pilot Scale Production and Evaluation
- Anode – Metal alloys and metals - >30 kg per batch
- Cathode - Novel cathode materials - >30 kg per batch
- Perfluorinated products and intermediates - 10Kg /wk
- Hirano Coater (High Precision Automated Electrode Coating
- 50 Ton calendar mills for electrode finishing
- 18650 cell winding, fill, and close - >100 cells per week.
- Stacked Pouch Cell Capability
3M Battery Materials – R&D integration

3M Division Labs

Product Commercialization
- Materials Synthesis and Scale-up
- Global Customer Support
- Supporting Fundamental and Applied Materials Research

3M Corporate Labs

Next-Term R&D 2-5 yrs Out
- Fundamental Materials Research
  - materials discovery
  - synthesis techniques
- Disruptive Technology Selection

3M Country Labs

Customer Commercialization
- Applications Development
- Specific Customer Materials Development and Scale-up

University / Dalhousie

Long-Term R&D 5-10 yrs Out
- Fundamental Materials Research
  - materials discovery
  - synthesis techniques
- Fundamentals of cell performance
- Researcher Development
Thank You!

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