Low Cost and High Throughput
ALD-Coated Battery Materials

September 2014
PneumatiCoat’s Breakthrough: Faster, Cheaper Particle ALD

The PneumatiCoat Process Advantage

• “Spatial Atomic Layer Deposition (ALD)”
  – Powder and gases flow counter-currently
  – Production rate 200x faster relative to batch
  – Multi-pass, single chamber for scale validation
  – Single-pass, multi-chamber for MFG
  – High throughput = low $/kg, $/kWh
  – Lean manufacturing for higher efficiency
  – Ideal for high volume, low “coating intensity” materials such as Batteries, Catalysts, etc.

PneumatiCoat System Transforms Powder Flow to Rate Limiting Step
Position in Battery Materials Value Chain

PCT’s IMPACT: Bringing Value to Customers and OEMs

Smaller, lighter, safer and cheaper batteries

Improve the system performance and cost via coatings that deliver sustainable $/kWh advantages

Up to 70% less material for comparable energy

PCT’s Services and Systems Objectives

Base Electrode Powders
ALD Coatings on Particles
Produce Battery Systems
PICOSHIELD™ protection for Li-ion Batteries

ALD delivers low-cost value propositions in many market applications

- Increased capacity retention
- Higher temperature stability
- Greater over-voltage protection
- Enables smaller particles
- Reduced gassing
- Reduced material dissolution
- Reduced Cost of Ownership

Focused Scale-up Roadmap:
Semi-continuous Particle ALD processing system for high-throughput, lean manufacturing

Cycle life test for NEI's LMNC

Cycle life test for NEI's HV Spinel
PCT’s Turn-key Systems for Li-ion Battery Materials

PCT’s turn-key systems provide an alternate option for customers that prefer to maintain and drive R&D projects and early-stage product development internally.
What NEI Does for its Customers

- **Produce Materials for Energy Storage Devices**
  - Lithium/Lithium-ion, Thermal Battery, Supercapacitor
    - Cathode | Anode | Solid Electrolyte

- **Develop & Produce Application-Specific Materials**
  - Nanoscale and micron-scale

- **Perform Cell-level Testing**
  - Half-cell, Full-cell, RT and Low temperature testing

- **Characterize Materials**
  - Analytical services
NANOMYTE® Electrode Powders and Tapes

NEI offers both powders and electrode tapes of the following materials:

- Lithium Titanate (LTO)
  - BE-10
  - BE-15

- Lithium Manganese Oxide (LMO)
  - BE-30
  - BE-35

- Lithium Aluminum Nickel Cobalt Oxide (NCA)
  - BE-40
  - BE-45

- Lithium Nickel Manganese Oxide (LMNO)
  - SP-10
  - SP-15

Detailed Specifications are available at: [www.neicorporation.com](http://www.neicorporation.com)
Energy Storage Materials Research:
Cathode | Anode | Electrolyte

- Silicon and silicon composites
  - Composite with conventional anodes

- Lithium Manganese/Titanium Phosphate
  - Doped with transition metal ions, di-/tri-valent cations

- Lithium Titanium Oxide
  - Doped with multi-valent cations

- Lithium Manganese Nickel Cobalt Oxide
  - High capacity

- Iron Disulfide (FeS$_2$)
  - Ultra-pure nanosize FeS$_2$ for Thermal Battery
Cell Fabrication & Testing

- Half-cell Assembly (vs. metals such as Li) & Testing and Full-cell Assembly (vs. graphite, LTO) & Testing
  - Cast electrode films/tapes
  - Cycle life, voltage profile, cyclic voltammetry
  - Electrochemical Impedance Spectroscopy (EIS)
  - Testing at different temperatures (-20°C to +100°C)
  - Cell failure analysis
How You can Benefit from the NEI – PCT Collaboration

✓ Cost effective product development using ALD-coated battery materials
✓ Access to a broad range of cathode, anode and solid electrolyte powders
✓ Partners for new materials and processes