NEI Corporation

Serving the Advanced Materials Needs of Customers Worldwide

In Partnership With:

PneumatiCoat TECHNOLOGIES

Commercializing "nano"

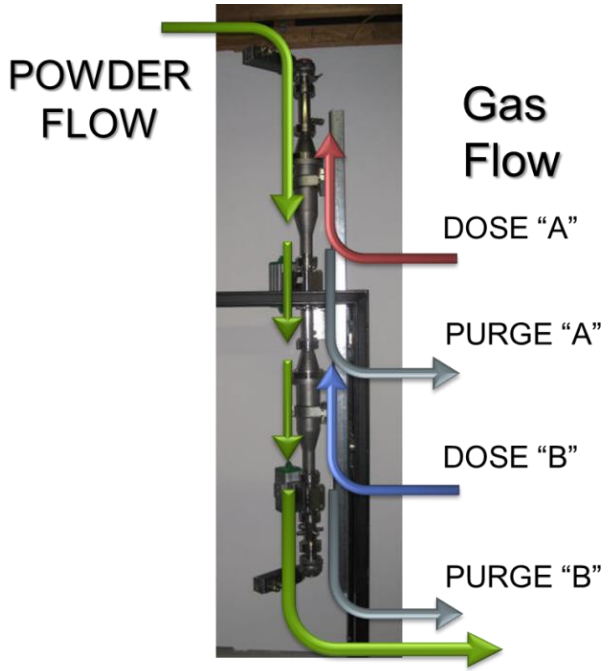
Low Cost and High Throughput ALD-Coated Battery Materials

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

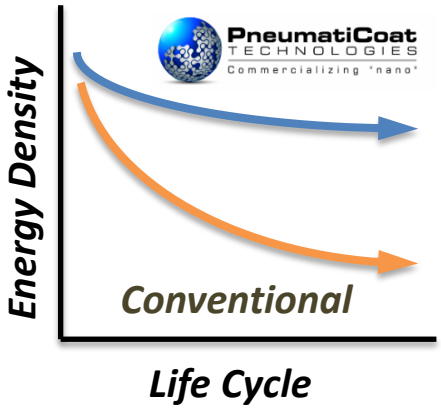
Position in Battery Materials Value Chain

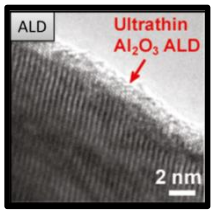
PCT's Services and Systems Objectives

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

PCT's IMPACT: Bringing Value to Customers and OEMs

Smaller, lighter, safer and cheaper batteries





Up to 70% less material for comparable energy

Base Electrode Powders → **ALD Coatings on Particles** → **Produce Battery Systems**

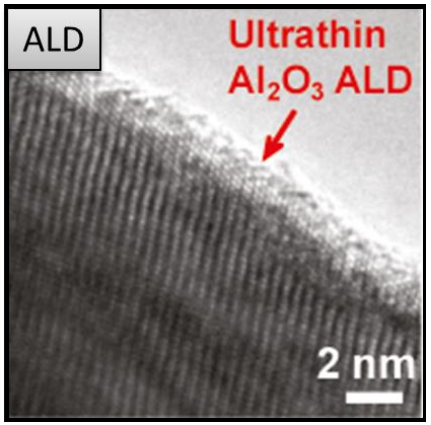
PICOSHIELD™ protection for Li-ion Batteries

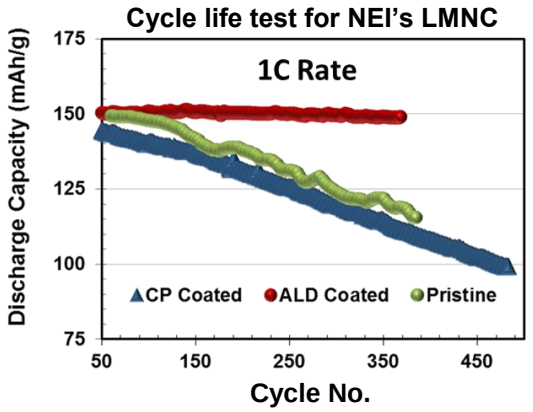
ALD delivers low-cost value propositions in many market applications

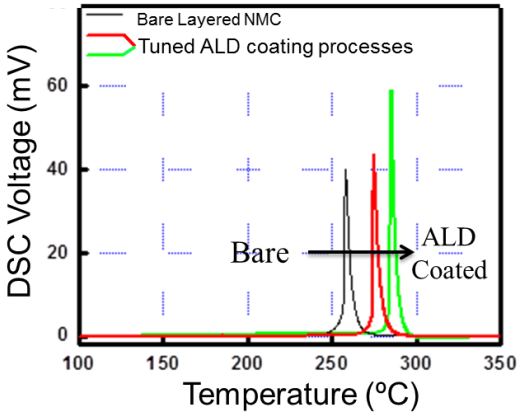
- Increased capacity retention
- Higher temperature stability
- Greater over-voltage protection
- Enables smaller particles
- Reduced gassing
- Reduced material dissolution
- Reduced Cost of Ownership

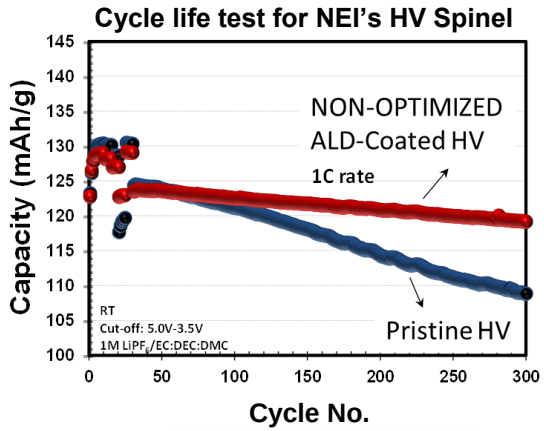
Focused Scale-up Roadmap:

Semi-continuous Particle ALD processing system for high-throughput, lean manufacturing



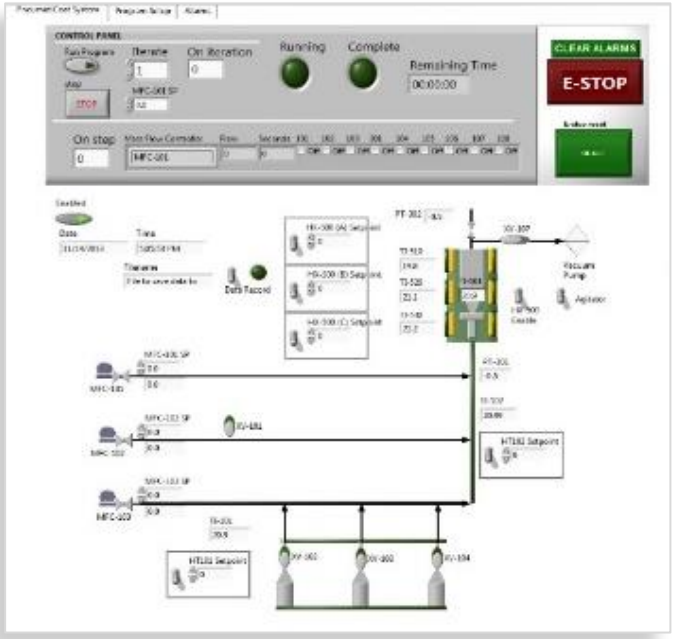






PCT's Turn-key Systems for Li-ion Battery Materials

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



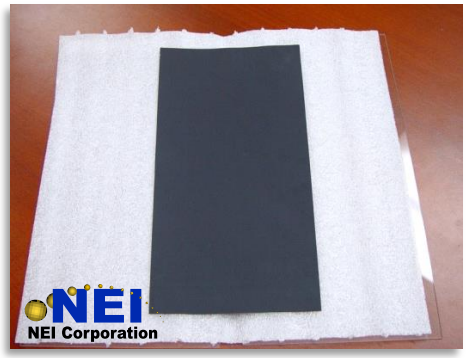
What NEI Does for its Customers

- **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

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^{o}C to + 100^{o}C)
  - Cell failure analysis

How You can Benefit from the NEI – PCT Collaboration

NEI Corporation

PneumatiCoat TECHNOLOGIES
Commercializing "nano"

- ✓ 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