Simultaneous Multilayer Coating for Batteries

Enabling higher performance at reduced cost through processing innovation
Simultaneous Multilayer Coating (MLC) can improve performance and reduce cost:

- Enables design freedom to solve problems and improve performance via additional layers
  - Hybrid cathode systems to balance benefits and constraints of independent systems
  - Porosity gradient to enable thicker, energy rich electrodes without compromising charge rates
  - Bottom layer NMC 811 / top layer NMC 532 to enable higher energy density with reduced electrolyte fouling
  - Alternating silicon and carbon layers to manage expansion while increasing silicon content / energy density
  - Coated SEI layer to protect electrodes and increase cycle life
- Enables additional layers without additional passes (cost) through the coating machine
- Imagine coating a primer, a multilayer electrode, and a ceramic separator on both sides of the web in a single pass. A multitude of design ideas can be envisioned.
Partnership Strategy

What
• Partner expertise in battery materials
• Carestream expertise in multilayer coating
• Combine to bring significant value to both companies through performance improvements at reduced manufacturing costs

How
• Enter into a JDA to create a technology package that includes IP, trade secrets, and know-how
• Tech development done jointly to combine critical expertise, reduce costs and drive speed
• Partner to utilize the technology to enable production of multilayer products on Partner’s assets
• Options for pilot or full scale production, and technology transfer from Carestream

IP
• Shared IP related to stack design, chemistry and formulation required to enable multilayer coating will result from the JDA

Alternatives - Carestream is open to other approaches and business models
Why Partner with Carestream?

Manufacturing/Technology Partner with over 100 years in Coating Leadership
- Combining Eastman Kodak’s Health Business and 3M-Imation Health Imaging Businesses
- Significant advanced materials coating expertise, experience, and assets
- Proven coating leader offering lab to production scale for high value, demanding products

High Speed Precision Coating on Flexible Substrates
- Single and multi-layer roll to roll complex systems
- Aqueous and solvent-based systems

From Development to Commercial Scale
- Technology development collaboration
- Slurry/coating engineering for manufacturing
- Process design & implementation
- Exceptional Lean Six Sigma manufacturing

Partnership, Investment, and Capability
- $1.5B company able to invest
- Ability to re-purpose assets for energy storage
- Many business models: capital investment, profit sharing, licensing, JDA, JV, acquisition, etc.
Multilayer Coating Case Studies

**DRYVIEW Medical Laser Imaging Film**

**Process Requirements**
- Coat both sides of the substrate
- 6 layers, single pass through the machine

**Process Design Improvements**
- Increasing number of layers and moving from slot to slide increased line speed by 4x, increased yield, and improved performance

**Results**
- World leader in laser imaging film
- Over 1 billion m² coated since 1996

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**Moisture and O₂ Pharmaceutical Barrier Film**

**Process Requirements**
- Primer (adhesion promoter) + barrier layers
- 3 layers, single pass through the machine

**Results**
- Reduced manufacturing cost at higher yields

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**Optical Display Film**

**Process Requirements**
- Dual layer (aqueous) at coating head #1
- Dual layer (solvent) at coating head #2
- 4 layers, single pass through the machine

**Results**
- Reduced manufacturing cost at higher yields and improved performance

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Carestream has used MLC to deliver significant value to many industries ➔ Why Not Batteries?
What Technical Value Does Carestream Offer?

Multilayer Formulation and Coating Process Trade Secrets and Know-How

• Decades of engineering expertise to solve the most challenging problems

• Solution characterization and formulation:
  o Layers stability – interfacial tension, density, viscosity, diffusion and solubility
  o Formulation guidance for multilayer coating, including proprietary predictive coating modeling
  o Solvent and aqueous systems including solvent based slide coating unique to Carestream
  o Elevated viscosity range for slide coating up to 1,700cP and possibly beyond

Lab, Pilot, and Production Scale Assets with Operational Excellence

• Dynamic coating development and prototyping:
  o Layers stack and equipment design
  o Lab scale verification of layer stability, coating speed, and multilayer drying
  o Generation of small scale samples for functional testing
  o Analytical assessment of layer stability, defect analysis, and correction

• Pilot scale roll to roll process development:
  o Verification of scale up solution delivery, coating, multilayer drying, conveyance, and roll formation
  o On-line optical inspection of coated electrode
  o Evaluation and improvement of process stability and capability for production scale up
  o Produce low volume production to support prototype builds and customer sampling

• QC and analytical labs to support full product life cycle
• Technical and operational infrastructure to support full scale production of MLC product
Carestream Capability and Experience

High-Speed, Continuous, Precision Coating of Up to 8 Layers in One Single Pass
Manufacturing Excellence

World-Class Coating Facilities
- Solution Making
- Multilayer Coating
- Converting
- Analytical and Quality Testing

World-Class Suppliers and Supply Chain
- Cooperative Improvement Programs
- ISO 14001, 13485, and 9001 Certified
- CTIA Battery Certification

World-Class Employees
- High Performance, Involved Workforce
- Resources Include:
  - Chemists, Material Scientists, Coating Scientists (BS through PhD)
  - Chemical, Mechanical, Electrical, Material, Process, Coating, Converting, Packaging, and Systems Engineering
  - Purchasing and Supply Chain Management

World-Class Results
- Comprehensive Manufacturing Strategy: Health, Safety, Environment, Quality, Productivity, Delivery, Cost, and Inventory
Manufacturing Locations

Oregon, US
(Pilot, Production, Mixing, Converting)

Colorado, US
(Coating Assessment Lab, Production, Mixing, Converting, PET manufacturing)

New York, US
(Pilot, Mixing)

Xiamen, CH
(Slitting, Sheeting, Packaging)

Over 100 Years of Precision Coating Leadership
From Process Development to Production

1. Coating Assessment Lab
   - Modeling
   - Process Development
   - Prototyping

2. Pilot Coating
   - R2R Process Development
   - Sample Roll Production
   - Low Volume Production

3. Production Coating
   - Mass Production

Transfer
- Mixing process
- Design for Manufacturing recommendations
  - Solution delivery design
  - Coating method and set up
  - Predicted process speed
Coating Assessment Lab (CAL)

CAL capability

- Solution Characterization and Formulation
- Solution Mixing and Delivery
- Multilayer Stability Evaluation
- Support Characterization
- Coating
- Drying and Curing
- Coated Sample Testing
- Microscopy
- Process Modeling
Pilot & Production Coaters

Pilot capabilities
- Widths from 4” to 12”, speeds from 4 fpm to 200 fpm
- High efficiency multi-zone drying up to 375F

Production capabilities
- Widths from 24” to 58”, speeds from 50 fpm to 450 fpm
- Two coating stations – one or both sides
- 1 to 8 layers in single pass
- 3 to 6 zones drying up to 300F and 1,400ft of drying path

Pilot & Production capabilities
- Solvent and aqueous solutions
- Temperature controlled solutions and coating
- CDT, web cleaning, UV curing, lamination
- 100% optical inspection to 25 micron resolution
- Real time process control and feedback and analysis
- Variety of coating technologies (slot die, slide, curtain, gravure, etc.)
- Highly uniform < 2% to 5% thickness variability
- Class 100 clean room capable coating and web path
- Slitting capabilities
Solution Making & Delivery

Solution Making

- Stainless Steel Mix Tanks
  - Capacities of 200 - 1750 gallons plus portable pilot tanks
  - Nitrogen inerted and jacketed with heating and cooling
  - Variable speed agitation with multiple blade types
- Particle dispersion via multiple high shear options
- Bulk solvent storage and DI water generation
- Recipe control and robust standard work
- Distributive control system with data historian

Solution Delivery

- Inline mixing and filtering
- Closed loop mass flow control
- Variety of pumping options
- De-bubbling
- Process verification (T, P, flow rate, level control, etc.)
- Overhead lines with filtration direct from solution making
- Pails, drums, or totes at the coating station for small volume experiments and production
Quality & Analytical Testing Capability

Test Equipment Includes

- Optical Microscopy
- Scanning Electron Microscope (with EDX)
- Atomic Force Microscopy (AFM)
- High Performance Liquid Chromatograph
- X-Ray Fluorescence Spectrometers
- Gas Chromatograph with Mass Spectrometer
- Thermogravimetric Analysis - Fourier Transform Infrared Spectrometer (TGA-FTIR)
- Optical Profilometry
- Inductively Coupled Plasma Spectrometer
- Dynamic Scanning Calorimetry
- Dynamic Mechanical Analysis
- Ultra-Violet / Visible Spectrometers
- Microtrac Particle Size Analyzer
- Microtome
- Titrations

Test Properties Include

- Thickness / Uniformity / Coat Weight
- Viscosity / Density / % Solids / Surface Tension
- Cosmetics (streaks, point defects, etc.)
- Peel force / Adhesion
- Retained solvents
- Porosity / Density
- Particle size
- Roughness
- Contact Angle
- Moisture analysis
- Conductivity / Resistivity
Carestream
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