Latest Development in Coating and drying of battery Electrodes

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Presentation outline

✓ Battery Electrode Manufacturers and Equipment Suppliers
  ❖ Challenges
  ❖ Critical Success Factors

✓ Technology Innovation:
  ❖ Coating
  ❖ Drying
  ❖ Air emissions and energy management

✓ Future Requirements
Next Generation

✓ … a line that could run at 50mpm!
✓ … a line that could coat to >1,000mm in width!
✓ … a line could coat both sides in the same pass!
✓ … and dryers 50% of their existing length!

These are all possible today with recent advances in coating and drying technologies!!!!
Coating Technology: Current Process Standards

- Most battery coatings are currently applied a single side at a time
- Lane or intermittent coating
- Extensive material handling and roll storage
- Treatment of solvent by oxidation or carbon adsorption
Challenges for Battery Manufacturers & Equipment Suppliers

- Cost reductions of up to 50% needed
- Diverse product demands
- Need for productivity increases
- Shift in coating process technology
- Limitations of coating and drying techniques
Accurate, flexible coating system

- One or two-side coating.
- Die coater technology.
  - Alignment and coating thickness uniformity.
- Intermittent or « spot » coating capability.

High performance drying systems

- Non-contact convection air drying systems and web handling systems for a wide range of substrates.
- Deep knowledge of processes for advanced battery electrode technologies.
- Patented nozzle designs for applications that require effective drying of coating for anode, cathode and separator elements.

Solvent recovery, condensation & distillation systems

- Energy efficient vapor-phase solvent recovery systems and distillation systems.
- Control of VOC to comply with environmental regulations.
Market Demands and Specifications

✓ Cost reductions needed to sustain product viability in key markets
✓ Productivity increases
  ❖ Increase Output per coating line
  ❖ Reduce Waste
✓ Both thicker and thinner coatings depending on battery type
✓ Equipment design will need to be flexible to allow for changes in market demands
✓ Coating thickness, density, and registration that “pushes” the limits of sensors and equipment

Shift in coating process technology to meet demands
Coating Technology: Current Process Standards

- Most battery coatings are currently applied a single side at a time
- Lane or intermittent coating
- Extensive material handling and roll storage
Coating Technology: Current Process Standards

Slot Die Coater in Horizontal Backing Roll Arrangement
Electrode Coating Configurations

Continuous Coating

Lane or Stripe Coating

Mass-Free or Skip Coating
Coating Technology: Current Process Standards

Typical layout of Single Side Slot Die Coating Line

Typical layout of Tandem Coating Line
Coating Technology: Next Generation

✓ Simultaneous horizontal dual side coating
✓ Line speeds > 50 m/min
✓ Web widths > 1,000mm
✓ Ultra clean room designs
**Clean Room Standards – Current and Future Needs**

**ISO 14644-1 cleanroom standards**

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<th>Class</th>
<th>maximum particles/m³</th>
<th>FED STD 209E equivalent</th>
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<td>≥0.1 μm</td>
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- **Practical Limit for Large Scale Prod.**
- **Current Installed Base**
- **Market need based on Product and Safety Demands**
Example of Coating/Drying Equipment in an ISO Class 5 Clean Room
Drying Technology: Current Process Standards

✓ Roll supported convection drying
✓ Flotation convection drying
✓ Infrared drying
Typical Roll Support Dryer
Air Flotation Dryer Designs

- Allows simultaneous coating of both sides in one pass
- Reduced Equipment Cost
- Double output
- Better product quality especially with thick coatings
Drying Principles

- Drying involves energy input into coating and evaporation of solvent
- Heat and mass transfer driven process
- Solids, solvent properties, and residual solvent levels drive rates and overall dryer length/residence time in dryer
Precision Nozzle Designs
Key Parameters in Dryer Design

✓ Slot or Jet velocity
✓ Air mass flow per slot or jet (volume x density)
✓ Total volume of slots or jets per unit of web surface area
✓ Distance of travel to web surface
✓ Spacing distance to adjacent slots or jets
✓ Angularity of slot or jet at web surface
✓ Spent air path – impeded or non-impeded
✓ Flow disturbances

More than just blowing around hot air!!!
Drying Technology: Next Generation

- Ultra Clean Design
- Multi-pass configurations
- Combined convection and infrared drying
# Li-Ion Battery Electrode — Technology Roadmap

<table>
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<tr>
<th>Technology</th>
<th>Use</th>
<th>Scale (meter)</th>
<th>Speed (mpm)</th>
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<td>Lab Line</td>
<td>R&amp;D; formulation development</td>
<td>3 to 5</td>
<td>1 to 3</td>
</tr>
<tr>
<td>Pilot Line</td>
<td>R&amp;D; test electrode material; process development</td>
<td>5 to 15</td>
<td>3 to 10</td>
</tr>
</tbody>
</table>

| Modeling        | Scale-up to production stage                     | N/A           | N/A         |

| Full-Scale      | Electrode Production                            | 15 to >50     | 5 to >40    |
Environmental Waste Reduction

- Solvent type (NMP, NEP, acetone, water, etc.)
- Recovery and reuse
  - Purity of recovered solvents
  - Effects of coating additives on solvent reuse
- Oxidation and residual effects of emissions
- Development of water-based and solvent-less coatings and materials
- Overall carbon-footprint
Summary and Conclusions

✓ Cost reductions of up to 50% needed to sustain product viability in key markets

✓ Productivity increases also necessary to sustain product viability in key markets

✓ Shift in coating and drying process technology to meet demands
Thank You!