More than Just Wood: Low-Temperature-Cure Technology Opens Up a World of New Substrates for Powder Coatings

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Presentation Overview

The concept of low-temperature cure powder coatings has loomed since the dawn of powder coating technology. In recent years, novel technology has emerged that can be cured at ever-lower temperatures.

This presentation explores the following:

• Why Low-Temperature Cure?
• Heat-Sensitive Substrates
• Dealing with Conductivity
• Low-Temp Cure vs. Ultra-Low Bake
• Low-Temp Cure – Chemistries
• Ultra-Low Bake – Thermoset Chemistries
• UV-Curable Powder Coatings
• Future Trends
The ChemQuest Advantage: Navigating the intersection of strategy, markets, operations, and technology

Four Pillars of Expertise
Deliver distinctive, thorough, actionable, confidential, and professional work and support our clients in every aspect of sustained, profitable growth, including:

- **Team** is more than 130 minds strong, including ~ 48 Ph.D. chemists.
- **Senior personnel** each have a minimum of 25 years of experience in specialty chemicals and materials.
- **Extensive roster** includes former senior managers from major manufacturers, business owners, and senior technical managers.

Our Mission is Enabling Our Clients to:

- **Build enterprises** that challenge established thinking and drive transformation.
- **Gain competitive advantage** through distinctive, targeted, and substantial improvements that sustain profitable growth.
- **Unlock new and hidden insights**, empowering an organization’s smart risk-taking, catalyzing innovation excellence and value creation.
- **Be successful** — because our success emanates from yours.

Extensive Industry Relationships and Knowledge
Stakeholders across the value chain trust our thought leaders:

- **Team is more than 130 minds strong**, including ~ 48 Ph.D. chemists.
- **Senior personnel** each have a minimum of 25 years of experience in specialty chemicals and materials.
- **Extensive roster** includes former senior managers from major manufacturers, business owners, and senior technical managers.

100% All of our work is proprietary, offering a full portfolio of services under NDA.
Technology Development

Design, formulate, test, accelerate, and scout innovative technology.

- For suppliers, manufacturers, and users
- Advanced lab facilities tailored to CASE R&D and polymer processing
- Services from molecular architecture to sophisticated application research
- Client-owned IP
- Education courses to enhance the capabilities and knowledge of your internal team
Powder Coating Benefits

- No VOCs
- Non-Toxic
  - No heavy metals
- Little or No Waste Stream
- Efficient
  - Collect and reuse overspray
- High Performance
- Excellent Overall Economics
Low-Temp Cure Opportunities

- Heat-Sensitive Substrates
- Pre-Assembled Parts
- Plastic Substrates
- Wood Substrates
Heat-Sensitive Substrates: Pre-Assembled Parts

- **Electrical Equipment**
  - Motors, generators, switchgear

- **Pneumatic/Hydraulic Equipment**
  - Door closers, jacks, shock absorbers, suspension parts

- **Metal/Plastic Assemblies**

- **Gasketed Parts**
  - Plumbing, taps, pumps, valves
### Plastic Substrates

<table>
<thead>
<tr>
<th>Substrate</th>
<th>Composition</th>
<th>HDT (0.46 MPa Load)</th>
<th>Powder Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABS</td>
<td>Acrylonitrile Butadiene Styrene</td>
<td>98°C</td>
<td>UV</td>
</tr>
<tr>
<td>Acetal Copoly</td>
<td>Polyoxymethylene (ethylene)</td>
<td>160°C</td>
<td>TS</td>
</tr>
<tr>
<td>Acrylic</td>
<td>Acrylic</td>
<td>95°C</td>
<td>UV</td>
</tr>
<tr>
<td>Nylon 6</td>
<td>Polyamide</td>
<td>160°C</td>
<td>TS</td>
</tr>
<tr>
<td>PC</td>
<td>Polycarbonate</td>
<td>140°C</td>
<td>TS/UV</td>
</tr>
<tr>
<td>PC/ABS</td>
<td>Polycarbonate/ABS Blend</td>
<td>80-100°C</td>
<td>UV</td>
</tr>
<tr>
<td>HDPE</td>
<td>High Density Polyethylene</td>
<td>85°C</td>
<td>UV</td>
</tr>
<tr>
<td>PET</td>
<td>Polyethylene Terephthalate</td>
<td>70°C</td>
<td>N/A</td>
</tr>
<tr>
<td>PMMA</td>
<td>Polymethylmethacrylate</td>
<td>105°C</td>
<td>UV</td>
</tr>
<tr>
<td>PP</td>
<td>Polypropylene</td>
<td>100°C</td>
<td>UV</td>
</tr>
<tr>
<td>PS</td>
<td>Polystyrene</td>
<td>95°C</td>
<td>UV</td>
</tr>
<tr>
<td>PVC</td>
<td>Polyvinyl Chloride</td>
<td>90°C</td>
<td>UV</td>
</tr>
<tr>
<td>Noryl GTX</td>
<td>Polyamide/polyphenylene ether</td>
<td>231°C</td>
<td>TS</td>
</tr>
<tr>
<td>PEEK</td>
<td>Polyetheretherketone</td>
<td>160°C</td>
<td>TS</td>
</tr>
</tbody>
</table>
## Wood-Based Products

<table>
<thead>
<tr>
<th>Substrate</th>
<th>Composition</th>
<th>Maximum Temperature</th>
<th>Powder Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>MDF</td>
<td>Medium-Density Engineered Board</td>
<td>135°C</td>
<td>TS/UV</td>
</tr>
<tr>
<td>HDF</td>
<td>High-Density Engineered Board</td>
<td>150°C</td>
<td>TS/UV</td>
</tr>
<tr>
<td>Wood Composites</td>
<td>Wood Pulp plus PVC &amp; HDPE, LDPE</td>
<td>150°C</td>
<td>TS/UV</td>
</tr>
<tr>
<td>Closed-Grain Woods</td>
<td>Maple, Beech, Birch, Cherry, Poplar, Rubber Tree</td>
<td>140°C</td>
<td>TS/UV</td>
</tr>
<tr>
<td>Open-Grain Woods</td>
<td>Oak, Hickory, Ash</td>
<td>100°C</td>
<td>UV</td>
</tr>
</tbody>
</table>
Applying Powder to a “Non”-Conductive Surface

- **Thermal Spray (or plasma)**
  - Thickness control

- **Preheat**
  - Thermal losses

- **Conductive Primer**
  - Solvent or waterborne?

- **Conductivity into Plastic**
  - Expensive to incorporate

- **In-mold Process**
  - Tool is conductive

- **Conductive Solution**
  - Easy, quick
Low-Bake Thermoset Chemistries

**Epoxy**
- Homopolymerized
- Latent catalyst
- 10 min @ 125°C

**Polyester/Epoxy Hybrid**
- High reactivity
- Lower $T_g$
- 10 min @ 130°C; 1 min @ 180°C

**TGIC Polyester**
- Exterior durable
- Good storage stability
- 10 min @ 140°C

**HAA Polyester**
- Limited low-cure capability
- 10 min @ 160°C

**Polyester/Urethane**
- Triazole-blocked isocyanate
- 15 min @ 160°C

**GMA Acrylic**
- High GMA (low EEW)
- Polyanhydride cure
- 15 min @ 140°C

**Unsaturated Polyester**
- Free radical (peroxide) cure
- Divinyl ether crosslinker
- 3 min @ 130°C
Ultra-Low-Bake Thermoset Chemistries: Bio-Based Polyester-Amide

Battelle Technology

- COOH functional
- Cure with TGIC or PT-910
- 85% bio-based COOH polyester-amide resin
- 135-180°C cure window
- Excellent smoothness
- Excellent impact resistance
- Excellent UV durability
Ultra-Low-Temp Cure Caveats

Extrusion Conditions are Critical
- Short dwell time
- Cooler barrel temps

Storage Stability
- May require reefer transportation
- Controlled storage temp and application system
- Shelf-life limitations

Application
Impact fusion

Smoothness?
The UV Curing Process

Thermal Powder Coating

UV Powder Coating

Substrate Pretreatment
Electrostatic Powder Deposition
Melt & Flow 1-2 minutes
UV Cure (seconds) Minimal cooling
Finished Product

Melt, Flow & Cure 5 to >20 mins + cooling
Free-Radical UV Cure

- Photoinitiator responds to UV energy, forming free radicals
- Chain-growth polymerization is initiated
- Can be inhibited by oxygen

**Abstraction**

\[
\text{Benzophenone} + \text{RH} \xrightarrow{h\nu} \text{PhOH} + \text{R'}
\]

**Cleavage**

\[
\text{Benzil dimethyl acetal} \xrightarrow{h\nu} \text{PhOMe} + \text{PhCHO}
\]

\[
\begin{align*}
\text{H}_2\text{C} &= \text{CHR} \\
\text{Z}^* &\rightarrow \left[ \begin{array}{c}
\text{H} \\
\text{Z} \text{CC} \text{Z}^* \\
\text{H} \\
\text{H}
\end{array} \right] \\
\text{H}_2\text{C} &= \text{CHR} \\
\text{Z}^* &\rightarrow \left[ \begin{array}{c}
\text{H} \\
\text{Z} \text{CC} \text{Z}^* \\
\text{H} \\
\text{H}
\end{array} \right] \\
\text{ repeat n times } &\rightarrow \left[ \begin{array}{c}
\text{H} \\
\text{R} \\
\text{H} \\
\text{H}
\end{array} \right]^{n+1}
\end{align*}
\]

\(Z^*\) is an initiating species

\(*\) may be a radical, a cation or an anion
Free Radical-Cured Binders

Acrylated/Methacrylated
- Polyester
- Epoxy
- Urethane
- Homopolymerized

Unsaturated Polyester
- Maleate – vinyl ether copolymerization
- Divinyl ether crosslinker 73:27

Low $T_g$, Low Melt Viscosity
- Processing conditions
- Storage stability
Benefits of UV Cure

- Separates melt from cure
- Smaller footprint
- Shorter time
- Low processing temperature
- Lower energy costs
- Heat-sensitive substrates and assembled parts
Drawbacks of UV Cure

- Line-of-sight curing
- Limited selection of raw materials and chemistry
- Capital expenditure
- Pigment loading and film thickness limitations
- Transportation and storage stability
- Material cost
Powder Chemistries: UV Cure vs. Ultra-Low-Bake Thermoset

**UV Cure**
- Shorter time
- Small footprint
- Lowest energy use

**Ultra-Low-Bake Thermoset**
- Standard equipment
- All colors/thicknesses
- Low energy use
- More chemistries available

**UV Cure**
- Line of sight
- Cap ex
- Film thickness
- Physical storage stability

**Ultra-Low-Bake Thermoset**
- Manufacturing challenges
- Smoothness
- Limited temperature
- Chemical storage stability
Future Trends

More than just MDF
Composites, molded plastics

Real Michael Addition (malonate) Chemistry (allnex)
WO-2022236519 – Powder Coating Composition Blend
Low-Temp Cure Summary

Low-temperature-cure (LTC) powders can significantly reduce energy costs.

Ultra-low-bake (ULB) powders open up a world of alternative substrates to the powder coating market.

Application to non-conductive substrates schemes are well-known and scalable.

UV-cure powder coating technology is alive and well.

Novel technology is being introduced by raw material suppliers.

Powder coating producers are investing in the development and commercialization of LTC and ULB powder technologies.
Thank You
Questions? Comments?
Feel free to reach out:

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https://chemquest.com