Technological Advances in Wood Finishing

Véronic Landry
Ph.D., Chemist, Research Scientist

June 2010
Overview of the presentation

• **Introduction**
  – Main drivers for new developments in wood finishing

• **UV-cured coatings**
  – New developments in UV-cured coatings
  – New equipments (portable, new ovens, new UV lights, etc.)

• **Water-based coatings**
  – New developments in water-based coatings
  – New equipments (drying ovens, application, etc.)

• **Solvent-based coatings**

• **Bio-based coatings**

• **Some ideas of hybrid systems**

• **Nanotechnology in finishing products**
Main Drivers for Developments in Wood Finishing

1. Increase productivity and decrease man labor
   - Be more cost competitive

2. Increase the performance of the products in order to compete with other markets (metal, plastic, etc.)

3. Comply to new regulations on volatile organic compounds (VOC) and hazardous air pollutants (HAP)

4. Get green certifications (Green Guard, LEED, Green Seal, etc.) in order to keep or to find new markets
UV-cured coatings
What are UV-cured coatings?

- UV curing is a process to cross-link (cure) coatings by a chemical process initiated and sustained by UV energy.
- UV coatings are prepared minimally from oligomers, thinner and photoinitiator.

![Comparison of conventional and UV coatings](diagram.png)

- **Conventional Coatings**
  - Solvent or Water
  - Resin
  - Additives
  - Catalyst

- **UV Coatings**
  - Solvent or Water
  - Monomer, Solvent or Water
  - Oligomers
  - Additives
  - Photoinitiators

Viscosity adjustment

---

June 2010

FPInnovations
General information about UV high solids (100%) coatings

**100% solids** doesn’t mean that it’s a solid coating. It is a liquid coating, but 100% of the liquid participate to the curing reaction (no loss).

- **Conventional Coatings**
  - Coating
  - Substrate
  - Drying
  - Substrate

- **UV high solids or 100% Coatings**
  - Coating
  - Substrate
  - Curing
  - Substrate

The thinner is a reactive one (acrylate monomers). The monomers will react with the oligomers (resin) to form the final coating film.
Benefits of UV high solids (100 %) coatings

• Curing is extremely fast!
• Mechanical, chemical and thermal properties are great
• No racking (directly to packaging or assembling)
• Not flammable (lower insurance premium)
• Small footprint (UV ovens take 1/10 of thermal ovens)
• Nearly zero VOC (less paperwork)
• No grain raising
• Energy consumption is low (25-35 % less than with thermal drying)
UV high solids for Flat Stock

- UV high solids coatings are well adapted to flat lines
- Typical examples: pre-finished floors, sheet stock, MDF and Plywood panels, etc.

**Application by roller coater**

**UV Curing on a flat line**

Source: CEFLA finishing
Other Example: Total Door, MI

- Highly customized doors, every shape and size;
- Large flat products and complicated size products;
- Why changing for UV coatings:
  - faster production speed;
  - reduced work in process;
  - reduced manufacturing footprint;
  - reduced energy costs;
  - reduced quality costs;
  - cleaner – no VOCs or HAPs;
  - cleaner and safer work environment

Source: Radtech UV & EB Expo, Baltimore
Other Example: Total Door, MI

*Notes:*
Delivery time was decrease from 6-8 weeks to 4 weeks (goal: 2)

Source: Radtech UV & EB Expo, Baltimore
## Economics of UV high solids coatings

### For 1 mil dry film

<table>
<thead>
<tr>
<th>Coatings</th>
<th>$/gal</th>
<th>Solides, %</th>
<th>Nominal cost cents/sqft</th>
<th>Transfer efficiency</th>
<th>True cost cents/sqft</th>
</tr>
</thead>
<tbody>
<tr>
<td>UV 100 %</td>
<td>52</td>
<td>100</td>
<td>3.2</td>
<td>95</td>
<td>3.4</td>
</tr>
<tr>
<td>Solvent-based</td>
<td>18</td>
<td>22</td>
<td>5.1</td>
<td>45</td>
<td>11.3</td>
</tr>
<tr>
<td>Water-based</td>
<td>22</td>
<td>40</td>
<td>3.4</td>
<td>45</td>
<td>7.6</td>
</tr>
</tbody>
</table>

UV 100% coatings are easy to recycle, energy savings (25-35 % compare to thermal drying), least part handling (less labor), etc.

Source: Radtech UV & EB Expo, 2010
Some limitations of UV High-solids coatings

• Difficult to obtain an open-grain look

• Adhesion is low on oily wood, thermo-modified wood, etc. (skrinkage is about 2-6 %)

• Will not adhere well to oil containing stains (traditional wiping stains, oil becomes mobile and try to go out)

• Viscosity is high (spray applications are difficult, even if possible, they sometimes lead to orange peel)

• Difficult to control film thickness

Possible solution: UV Water-based Coatings

Ex.: oily wood, Bocote
Benefits of UV water-based coatings

• Open-grain look (ex. Oak cabinets)
• Easier to control the film thickness (solid content is around 40 %)
• Allow very thin films
• Allow a lacquer-look finish
• Excellent « block resistance » vs traditional water-based coatings
• Excellent adhesion
• Superior water, chemical resistance than traditional water-based (cross-linking)
• Low sheen is easier (than UV high solids coatings)
UV water-based coatings

Example of a UV water-based finishing line

Surface Preparation

Sanding → Automatic spraying → Application of UV water-based products

Water evaporation

Infrared, thermal or microwave oven → UV Curing

CUSTOMER

Packaging → Cooling

Very Short, ~ 1 minute

Source: Bayer Material Science
# Economics of UV water-based coatings

<table>
<thead>
<tr>
<th>Coating Technology</th>
<th>Cost per gallon ($)</th>
<th>Wet / Dry film thickness (mil)</th>
<th>Cost per sqft</th>
<th>Actual cost per sqft</th>
</tr>
</thead>
<tbody>
<tr>
<td>UV Water-borne (40%, ? Transfer efficiency)</td>
<td>35</td>
<td>2.5/1.00</td>
<td>5.45</td>
<td>6.41</td>
</tr>
<tr>
<td>Solvent-borne (22%, 45% transfer efficiency)</td>
<td>12</td>
<td>4.55/1.00</td>
<td>3.4</td>
<td>7.55</td>
</tr>
<tr>
<td>Water-borne (40%, 45% transfer efficiency)</td>
<td>15</td>
<td>2.5/1.00</td>
<td>2.34</td>
<td>5.2</td>
</tr>
</tbody>
</table>
Example: Kitchen Cabinets, Prieur (FR)

• They use UV water-based coatings for maple and beech

• They use a Giardina reciprocator with Airmix spray guns (two circulations: one for the water-based products and the other one for the solvent-based products)
Drawbacks of UV water-based coatings

• Drying time (compare to UV 100% solids)
  – One more step: water evaporation

• Capital investment is more important
  – Need to have an infrared, thermal or microwave oven as well as a UV oven

• Like all UV coatings, curing of 3D components is challenging: How to cure shadow areas?
For curing of edges and profiles

Ex.: Wood moldings or kitchen cabinet panels

- The wood moldings lie flat on a horizontal conveyor as they move past several UV lamps positioned at a variety of angles to adequately expose all top surfaces of the different shaped parts. One lamp cures the horizontal surfaces, one each placed vertically to cure the vertical "sides" of the moldings, and two more are placed at 45 degrees from horizontal to cure additional contours.

Source: CEFLA Finishing Group
For moldings

Ex.: UV Vacuum Coater For Wood moldings

UV Vacuum Line
This new BRX System incorporates Sanding/Denibbing, UV Vacuum Coating, and 4-sided UV Curing,

Source: Superfici America
More complicated shapes: 3D ovens

UV III Systems, VT

*Three dimensional kit cures parts up to 20” wide X 40” High in 2-6 minutes*

Source: Dubois Equipment Company, UV III Systems
UV-robotic curing

UV lamp must be sufficiently robust to withstand the acceleration and de-acceleration swings of the robot arm;

UV lamp must be able to operate efficiently and reliably in a variety of different positions;

A single robotic UV lamp cell is less expensive than multiple fixed lamps;

**Lower Operating Cost** - Save on energy, UV lamp spare parts;

**Perfect for UV Curing Lines With Mixed Product** - Cure every part as they come down the line;

Another solution: Dual-cure UV coatings

• Dual-cure UV coatings are coatings that polymerized under UV light **AND** temperature (UV/PUD).

• The additional crosslinking-reaction guarantees sufficient surface properties even on areas with low UV-dose.

• Example of Applications:
  – Wood chairs
  – Sun shine cure coatings (even the shadow areas will cure)

Source: Bayer Material Science
Portable equipment for UV-cured coatings

For in plant touch up, flooring, kitchen cabinets, guitars, furniture, etc.

Source: Radtech UV & EB Expo, 2010
Equipment for UV-cured coatings

Low heat generation equipment;
Decrease microchecks and resin bleeding

Source: UV X-Cold UV Curing Technology, Delle Vedove
Equipments for UV-cured coatings

Low heat generation equipment - UV-LED systems

UV-LED System from Phoseon

* For wood, furniture, PVC flooring, metals
* No heat, long bulb life, mercury-free, ozone-free
* Still some issues related to the formulations, power, etc.

Clearstone

Source:
Water-based Coatings
Water-based Coatings

**MAIN BENEFITS**

- VOC levels are low, typically around 1 pound per gallon. (compared to 5+ pounds for a cat. varnish)
  - VOC comes from co-solvents used for a good coalescence, adjusting the drying time, good film properties
- Better work environment

**MAIN DRAWBACKS**

- Drying time (longer and variable according to the temperature)
- The grain raising
- The appearance
How to limit the Grain Raising?

- **Type of substrates**
  - The more important the wood density, the less important is the grain raising

- **Surface Preparation**
  - A better sanding (less fragments of fibers at the surface) leads to a lower grain raising
  - Planing leads to a less important grain raising than sanding

- **Wood humidity**
  - Optimal humidity for interior products is around 8%. A more important humidity lead an higher grain raising and darker colors.

- **Drying time**
  - The more important is the drying time, the more important will be the grain raising.
Grain Raising - Effect of substrate density

Source: Phil Evans, UBC
Grain Raising - Sanding vs Planing?

Grain raising of sanded and planed surfaces (Sa, μm)

p = 0.009

Source: Phil Evans, UBC
Grain Raising - Quality of the sanding

**Good sanding (no debris at the surface): Low Grain Raising**

**Poor sanding (high concentration if debris): High Grain Raising**
Water-based Ovens

Aquadry from Cefla Finishing

3 to 5 minutes flash or dry times

2 zones:
• high velocity heated air
• short wave infrared

From Vendry

Infra-red drying unit using pre-conditioned air for pre-drying of water-borne finishes
# Drying the Water-based Coatings

<table>
<thead>
<tr>
<th></th>
<th>Benefits</th>
<th>Drawbacks</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hot air</strong></td>
<td>• Well Known, well adapted for 3D parts</td>
<td>• Big volume of air circulation</td>
</tr>
<tr>
<td></td>
<td>• Low temperature drying</td>
<td>• High risk of dust on the coatings, may be necessary to filter the air</td>
</tr>
<tr>
<td></td>
<td>• Low energy consumption</td>
<td>• More voluminous</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Humidity is important at low temperature, dehumidication could be recommended</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Infrared</strong></td>
<td>• Direct transfer of the energy without air movement</td>
<td>• Difficult to treat 3D parts with homogeneity, needs to add hot air.</td>
</tr>
<tr>
<td></td>
<td>• Rapid drying (less than 45s, 15 s with catalytic oven)</td>
<td>• Short IR: different settings depending of the colors</td>
</tr>
<tr>
<td></td>
<td>• Rapidly dust free</td>
<td>• Drying temperature more important than with convection oven</td>
</tr>
<tr>
<td></td>
<td>• Easy to use</td>
<td></td>
</tr>
<tr>
<td><strong>Microwave</strong></td>
<td>• Well adapted to high speed water evaporation</td>
<td>• High energy consumption</td>
</tr>
<tr>
<td></td>
<td>• High efficiency</td>
<td>• Limited power available</td>
</tr>
<tr>
<td></td>
<td>• Low temperature drying</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Good drying quality</td>
<td></td>
</tr>
</tbody>
</table>
Hybrid systems

• Hybrid Systems are systems with at least two different coating technologies.

• Example:
  – Solvent-based stains with water-based sealer and lacquers
    • Same colors, decrease in VOC
  – UV high solids sealer with UV water-based top coat
    • No grain raising, lacquer-look finish
  – Solvent-based sealer (without formaldehyde) and water-based acrylic topcoat.
Bio-based coatings

• Bio-based coatings are coatings prepared from renewable raw materials.
  – Renewable raw materials: Can be regenerated by natural processes at rates comparable to or faster than rates of consumption by humans.

• Ex.: Soy, linseed, cellulose, lipids (oil, fat), starch, proteins, lignin, hemicelluloses

• Why?
  – Availability of unique chemical structures not available from petrochemicals, uncertainty about long term cost/availability of oil, marketing, driven by sustainability concept (reduced carbon footprint), etc.
# Example of Bio-based coatings

## CHEMICAL TECHNOLOGY:

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Multi-Purpose</td>
<td>Low-Medium Use</td>
<td>Low-Medium Use</td>
<td>High Traffic</td>
<td>High Traffic</td>
<td>High Traffic</td>
</tr>
<tr>
<td>Bio-based- W.B. Modified Acrylic-Soy Ester</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bio-based- W.B. Modified Urethane-Soy Ester</td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bio-based- W.B. Modified Acrylic-Urethane-Soy Ester</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

## APPEARANCE:

<table>
<thead>
<tr>
<th>Finish</th>
<th>No Sheen</th>
<th>Satin Sheen</th>
<th>Gloss Sheen</th>
<th>Wet Look</th>
<th>Gloss Sheen</th>
<th>Gloss Sheen</th>
</tr>
</thead>
<tbody>
<tr>
<td>Film Forming</td>
<td>No Film</td>
<td>Yes-Thin</td>
<td>Yes-Thin</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

### APPLICATIONS: (Interior or Exterior)

- Wood Decks & Floors
- Wood Cabinets & Furniture
- Decorative Wall Panels (FRP, Fiber Boards, Wood)
- Poured Concrete/Countertops
- Plaster/Drywall/Stucco
- Tilt-Up/Pre-Cast Concrete
- Deco-Poz Microtopping
- Masonry: Block Walls, Retaining Walls
- Brick Pavers
- Porous Natural Stone Tiles
- Tile Grout
- Submersible- Concrete, Plaster, Fiberglass

Source: Ecoprocote
Example of Bio-based coatings

Ecology Coatings Introduces Bio-Based Technology in UV-Curable Coatings

Auburn Hills, MI – February 22, 2010 – Ecology Coatings, Inc. (OTCBB:ECOC), a leader in the discovery and development of nanotechnology-enabled, ultraviolet-curable advanced coatings, today announced it has developed bio-based materials for use in a new family of EcoQuik™ UV-curable coatings. Products incorporating bio-based additives are being used in commercial development applications that exhibit enhanced curing speed, pigment coverage and useful surface effects.

Other companies working on it: PPG, Sherwin Williams, Rust-Oleum, etc.
Source: Ecology Coatings
Solvent-based coatings

- Green Guard certification for solvent-based products (ex. Valspar)
- Low formaldehyde lacquers and sealers
- Low-VOC lacquers and sealers.
- Solvent substitution (use of solvents not listed as VOC, exempt solvents)

Certificate of Compliance

Zenith G1 Topcoat
Valspar
This product has been certified according to the GREENGUARD Indoor Air Quality (IAQ) Certification Program for Low Emitting Products.

Certificate Details:
Certificate No.: 0910211-01
Status: Certified
Restrictions: Certified with a 24 day cure before installation.

Product Type: General Products

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Allowable Limits</th>
</tr>
</thead>
<tbody>
<tr>
<td>TVOC</td>
<td>&lt; 0.5 mg/m³</td>
</tr>
<tr>
<td>Formaldehyde</td>
<td>&lt; 0.03 ppm</td>
</tr>
<tr>
<td>Total Aldehydes</td>
<td>&lt; 0.1 ppm</td>
</tr>
<tr>
<td>Individual VOCs</td>
<td>&lt; 0.1 TLV</td>
</tr>
</tbody>
</table>

Listing of measured carcinogens and reproductive toxins as identified by California Proposition 65, the U.S. National Technology Program (NTP), and the International Agency on Research on Cancer (IARC) must be provided.

Any pollutant regulated as a primary or secondary outdoor air pollutant must meet a concentration that will not generate an air concentration greater than that promulgated by the National Ambient Air Quality Standard (U.S. EPA, code of Federal Regulations, Title 40, Part 60).

See referenced standard for a complete technical explanation.

1. Defined to be the total response of measured VOCs falling within the C₁-C₉ range, with responses calibrated to a toluene surrogate.
2. Defined to be the total response of a target list of aldehydes (2-butanal, acetaldehyde; formaldehyde; 1, 1-dimethylolurea; 2-methylacrolein; acrolein; 2-propanal; formaldehyde; hexanal; pentanal; propionaldehyde, with each individually calibrated to a compound specific standard.
3. Any pollutant must meet the standard of 1.00 x the Threshold Limit Value (TLV) Industrial Worker Standard as defined in the American Conference of Governmental Industrial Hygienists, 2010 Threshold Limit Values and Biological Exposure Indices. (ACGIH, 2010-2011).

GREENGUARD Certification affirms that products meet the criteria of the referenced standard and the requirements of the specific certification program. Certification testing is conducted according to a consistent, defined protocol. The testing does not evaluate emissions under use conditions other than those defined in the protocol and does not address potential environmental impact other than chemical and particle emissions.

The GREENGUARD Environmental Institute (GEI) is an industry independent, third-party certification organization that qualifies products for use in interior ambiances. GREENGUARD Certification programs use defined product standards, test methodologies, product sample collection and testing procedures, product application processes, and on-going verification procedures. GREENGUARD standards, methods, and procedures are available at www.GREENGUARD.org.

© 2010 GREENGUARD Environmental Institute

38
What is « Nanotechnology »?

Mountain 1 km
Children 1 m
Ant 1 mm
Bacteria 1 μm
Molecules 1 nm
Why using Nanoparticles?

- For the same %, nanoparticles lead to more transparent coatings.
- We need to add less nanoparticles than microparticles.
Defy Extreme Wood Stain has been formulated using state of the art Nano-Technology to create a level of durability that has not been available in a clear wood stain in the past.

The Nano Particles are similar to Sunscreen. When the Particles are distributed at a rate of over 30 trillion per square inch, they will reflect the sun and provide UV protection that has never been seen in a "Crystal" Clear Wood Finish.

**NewPro-Nano Wood**

NewPro-Nano Wood is an aqueous inorganic-organic coating material for untreated wood based on chemical nanotechnology. Self-organizing anti-adhesive components offer untreated wood surfaces an invisible layer with hydrophobic and oleophobic (water, grease and oil repellent) characteristics.

**I-CanNano**

<table>
<thead>
<tr>
<th>Product Type</th>
<th>Properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>PU/Alkyd Wood Primer</td>
<td>anti-bacterial, UV/Termite resistant,</td>
</tr>
<tr>
<td>PU/Alkyd Wood Sealer</td>
<td>weather resistant, crack sealer</td>
</tr>
<tr>
<td>PU/Alkyd Wood Paint</td>
<td>anti-bacterial/fungus, UV/Termite resistant, water repellent</td>
</tr>
<tr>
<td>Epoxy Wood Sealer</td>
<td>weather resistant, crack sealer</td>
</tr>
<tr>
<td>PU/Alkyd Clear Coat (air drying)</td>
<td>transparent, anti-bacterial, anti-corrosive, termite resistant, water repellent</td>
</tr>
</tbody>
</table>

Source: Defy Stain, Graffiti Magic, I-CanNano
## MIRAGE – Boa Franc

<table>
<thead>
<tr>
<th>New</th>
<th>1 year</th>
<th>2 years</th>
<th>3 years</th>
<th>4 years</th>
<th>5 years</th>
</tr>
</thead>
</table>

![Image of Mirage Hardwood Floors](image-url)

Source: Mirage Hardwood Floors
Nanoshell de BSL

Source: BSL Wood Products
Some useful links

- CEFLA Finishing Group: http://www.ceflafinishinggroup.com/it
- Dubois Equipment: http://www.duboisequipment.com/
- UV Robotics: http://www.uvrobotics.com/
- Fusion UV lights: http://www.fusionuv.com/
- Ecoprocote: http://www.ecoprocote.com/
- Ecology Coatings: http://www.ecologycoatings.com
- Defy Stain: http://www.defystain.com/defy-extreme-stain.html
- NewPro Nano Wood: http://www.g-pro.com/English/450/6.htm
- Phoseon: http://www.phoseon.com/
- Clearstone Technologies: http://www.clearstonetech.com/2.html
- Superfici: http://www.superficiamerica.com/
Thank you for your attention!

To contact me:
Véronic Landry
Tel: (418) 659-2647 (3325)
Fax: (418) 659-2922
veronic.landry@fpinnovations.ca