UV Wood Finishing

A fine finish is the crowning touch that brings out the beauty of wood

By Greg Trojan

Wood finishing processes incorporating radiation curing differ substantially from conventional finishing processes. UV technology can bring fantastic results, however, the transition can at times be costly and time consuming particularly when the process is poorly understood.

The Nature of Wood

Wood in its many forms, lumber, plywood, particle board and engineered woods (MDF) are the primary substrates used for manufacturing household and office furniture, kitchen cabinets, paneling, moldings and many other items, which makes wood the most useful natural substrate on this planet.

For all practical purposes, we may classify woods used in wood finishing into three broad categories.

Lumber from broad leaf trees –hardwoods

lumber from coniferous (cone bearing) trees -softwood

and engineered woods.

Lumber from broad leaf trees, such as oak , mahogany and walnut-contain large vessels and therefore are very porous. When the lumber of this trees is cut and planed at the mill, either as solid cuts or veneer, the tubular cells are ruptured, leaving minute troughs running lengthwise requiring filling.

Soft woods, such as pine, cedar and redwood are devoid of vessels, and therefore, are grouped as non-porous.

Other woods such as basswood, while being extremely soft to the touch, is classified as a hardwood.

One aspect affecting the nature of wood, is the age of the tree's. Old growth lumber, 200 – 300 year old species, are substantially different in density than the same trees harvested at about 50 to 70 years.

Understanding the nature of wood is fundamental to understanding the interaction of wood properties with wood finishing processes.

The Business

Environmental regulations, waste disposal regulations and health & safety issues combined with soaring labor costs are just some of the many issues facing North American wood finishers. To meet those challenges it becomes essential to use coatings that are less labor intensive, are applied and cured fast to facilitate high speed production, and are environmentally friendly. UV curing technology provides the answers to many of those issues.

The UV Curing Process

Also called "photopolymerization " the Ultraviolet (UV) curing process is a photochemical reaction. When exposed to UV energy, photoinitiator chemicals in the coating start a rapid free radical generation, crosslinking the liquid coating into a solid. This chemical reaction occurs between two basic components of the coating – monomers, which are low molecular weight polymers, and oligomers, which are higher molecular weight polymers.

The main properties of a crosslinked coating come from the various types of oligomers, which also constitute the backbone of the formulation There are essentially for major types of oligomers available to the wood finishing industry. They include; urethene, epoxy, polyester acrylates, and unsaturated polyesters. Each offers distinct advantages which can be tailored for a particular application.

While the oligomer polymer is the backbone of the formulation, there are many other components that complete a stain, filler, primer or topcoat coating formulation. Single and multifunctional monomers are the "connection" to the oligomers that form the molecular network during the exposure to UV energy. As the number of reactive groups increases, the higher the crosslink density becomes. Monomers are relatively low in viscosity and therefore also serve as a diluent in reducing the overall viscosity of the coating. Other components of UV coatings include additives, pigments and fillers, similar to conventional wood coatings, which are added to achieve desired flow, leveling, color and curing characteristics.

The benefits of using UV curing technology can be quite impressive: much less waste, lower energy consumption, higher productivity and reduced or eliminated pollutant emissions are just a few.

Benefits of UV Coatings in wood finishing applications

- **Little or no VOC**.

UV stains, fillers primers and coatings can be formulated at 100% solids.

- **High productivity**

UV cured components can be packaged immediately after curing.

- **Low floor space requirement**

In a typical vacuum coat or spray line application, cure equipment are only 10 to 20 feet long.

- **Low energy requirement**

Typical energy requirements for UV lines are only about 15 % of a thermal curing system

- **Coating can be reclaimed**

With the lack of solvents, the volatility is very low, those reclaiming can be achieved without any change to viscosity.

- **Lower applied cost**

UV coatings costs are 2.8 cents per square foot, 7.8 cents for solvent lacquer and 11.6 cents for water based coatings (based on 40% transfer efficiency for solvent and waterborne)

- **Enhanced product quality**

UV coatings provide a high crosslink density, which yields a higher scratch resistance, improved stain, water and abrasion resistance.
A abrasion test performed using a Tabor Abrasion resistance tester and utilizing a CS 17 wheel with a 1000g load the UV curable coating passed 3,400 cycles while the solvent coating performed to 850 cycles.

- **One component system**

UV coatings are supplied ready to use with a typical shelf life of six month or longer.

Process Considerations

Finishing processes incorporating radiation curing differ substantially from conventional finishing processes. Implementing UV technology is making some fantastic impacts in the wood finishing industry. However, the transition can at times be costly and time consuming particularly when the process is poorly understood.

- **Raw Materials**

With radiation curable coatings, inks and adhesives you are dealing with raw materials rather than pre-polymerized formulations

- **UV Curing**

UV curable formulations are converted to solid polymers within a spectral range of UV in seconds versus 30 to 40 minutes for conventional coatings

- **Characteristics**

The optical and physical

characteristics of the curing system and their interaction with the optical properties of the coating formulation are an integral part of the coating performance. Neglecting any aspects of their interaction will result in the limitation of the cure window

- **Limitation**

The limitation of line of sight curing must be taken into consideration when developing both the product and the process for 3D wood products.

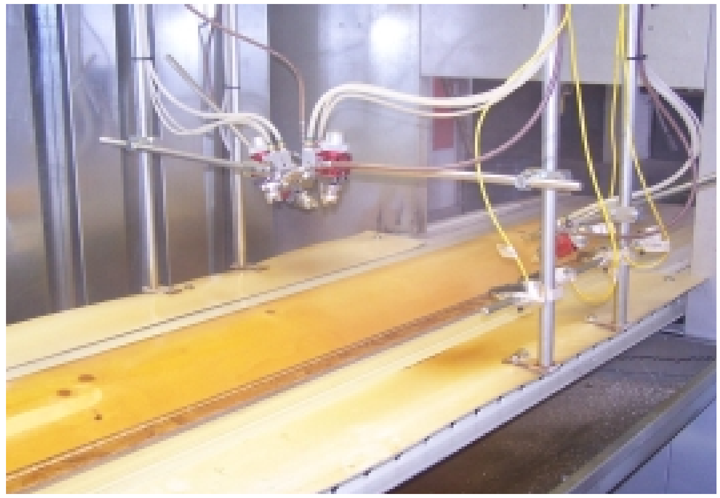
Types of UV-Curable Coatings

Essentially there are three types of UV curable coatings available—100% solid UV, water reduced UV and solvent reduced UV.

100% solid UV

100% solid UV coatings are liquid coatings that do not contain any evaporative solvents or water. Their composition or formulation is totally based on active chemistry that converts to a solid finish upon exposure to ultraviolet energy. Since there is no requirement to evaporate any solvent or water, the product can immediately be exposed to UV energy for curing. UV curing is instantaneous and the parts are immediately ready for the next process step.
A very significant advantage of 100% solid coatings is the fact that the overspray or overflow coating from roll and flow coat applications can be recaptured and re-use immediately.

The disadvantages of 100% solid coatings are absolutely minimal. The two most common concerns raised in wood finishing with 100% solid coatings are:



Pine River Inc. located in Charlevoix MI. manufactures log siding systems for the log home industry. Pine River applies two coats of 100% solid UV stain, providing a environmentally sound base coat, formulated by Allied PhotoChemicals Inc. of Kimball MI., to protect against fungus and algae growth, insects and damaging effects of the sun's rays.
Picture courtesy of Allied PhotoChemical Inc. Kimball MI.

1. With 100% solid coatings build film thickness to fast and conventional wood appearance id not obtainable.

2. With 100% solid coatings a low gloss appearance is hard to obtain.

Both issues are pure perception and can easily be avoided through application techniques.

Water Reduced UV Coatings

Water reduced UV curable coatings are predominantly used in high volume door and panel finishing operations. These surfaces have commonly a low build appearance, presumed to be only achievable with coatings that were not 100% active. Today this perception still exists, although 100% solid coatings are used in other applications with the same results obtained.

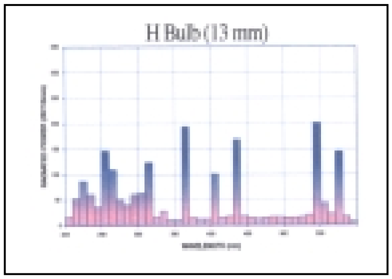
The major disadvantage with water reduced UV coatings is the retention of water particles within the coating during the curing process. Defects caused by the water retention are white spots in the finish, especially in areas were the film build is slightly higher. These white spots are created when suspended UV sensitive materials undergo cure before it had a chance to fully dry and form a uniform film.

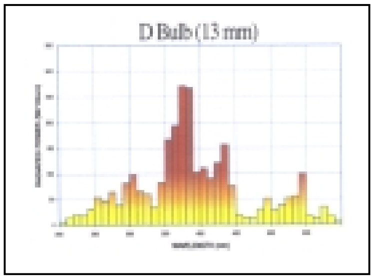
Capturing and reuse of overspray coatings is not as easy as with 100% solids. The reclaimed material must be monitored for viscosity and adjusted accordingly.

Solvent Reduced UV Coatings

Except for the actual curing process, the application of solvent reduced UV coatings is identical to conventional solvent coatings and is easily understood by traditional wood finishers.

Solvent reduced UV curable coatings enable dramatic opportunities, however their negative impact on the environment is the same as that of conventional solvent coatings. My advise to finishers considering solvent reducing UV curable coatings is – explore the options existing with 100% solids. It is quite likely that you will achieve the same results without having to deal with solvents that can be costly and hard to dispose off.





Shown are the bulb spectrums of two microwave powered UV lamps. Graphs courtesy of Fusion UV Systems Gaithersburg Md.

Selecting the right Curing Equipment

There are four basic UV curing technologies available: Arch or electrode UV lamps, Microwave powered UV lamps, Xenon pulse and light emitting diode (LED) light sources. Mercury arc and microwave powered UV light sources are the two most commonly found light sources in wood finishing industry.

UV Spray application system with UV curing chamber seen at end. Picture courtesy of Burkle Process Technology Loerrach Germany

How to Choose

The type of UV curing equipment and specific bulb type appropriate for a given wood coating application is dependant on the chemistry, pigments, coating application technique and overall process design considerations.

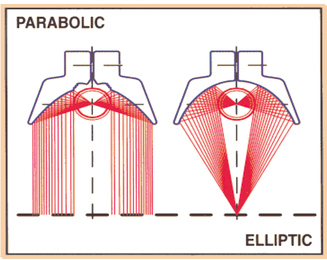
Most pigmented coatings or thick clear coats cure best within a long wavelength of the ultraviolet spectrum as generated by a "D" bulb. Most thin, clear coatings are best cured with a short wavelength as generated by an "H" Bulb. The bulb spectrum of a "D" as well as a "H" bulb is shown above. Additional bulb spectrum output variations are available. Those bulbs are also referred to as doped bulbs, meaning they include metal halides such as iron oxide and gallium halide additives.

Another important factor in selecting the right lamp system is based on the lamp configuration required for the particular part shapes, their size and the handling of the product to be cured.

For example flat wood panels, hardwood flooring, and cabinet doors are typically placed on a flat conveyor. A bulb length of up to 72 inches is available in mercury arc systems. Microwave powered lamps are only available in 10 inch length, requiring multiple lamps to be installed side by side. For vacuum coated shaped moldings or profiles multiple single microwave lamps provide great flexibility.

The process application will also establish the selection of

Shown is a 60 inch 3 bulb system with shutters following immediately after the spray application booth. Picture courtesy of IST Metz - USA reflector to be used. In flat or linear application elliptic (focused) reflectors provide the highest energy, however on 3D moldings and for example fully assembled chairs a parabolic (defocused) reflector would provide a more balanced irradiance.



Factors Affecting Cure

A number of physical and optical characteristics of the curing system (outside the formulation itself) affects the curing and consequent performance of the curing material, be it stain, primer, filler or top coat.

Physical Properties

The four key factors of UV lamps are:

UV irradiance: the radiant power arriving at a surface, per unit area; photon flux; or total photon quantity arriving at the surface. Expressed in Watt/cm^2 or milliWatt/cm^2. Irradiance varies with lamp output power, efficiency, and focus of its reflector system.

UV Irradiance Density: also referred to as dose. The radiant energy arriving at a surface, per unit area; or total photon quantity arriving at the surface. Dose is inversely proportional to speed under any given light source. Dose is the integral of irradiance which a surface is exposed as it travels past a lamp or number of lamps. Measured in Joules/ cm^2 or milliJoules/ cm^2.

Spectral Distribution: Relative radiant energy as a function of wavelength. The wavelength distribution of radiant energy emitted by a UV light source. Measures of dose without identifying the wavelength are irrelevant.

Infrared Radiance: The amount of infrared energy emitted by the quartz envelope of the UV source.

The optical and physical characteristics of the curing system and their interaction with the optical properties of the coating formulation are an integral part of the coating performance. Neglecting any aspects of their interaction will result in the limitation of the cure window

Optical Characteristics

Spectral Absorption: the relative energy as a function of wavelength absorbed in the material at increased depth. More energy absorbed by the coating at its surface means less energy available at deeper levels.

Reflectance and Scattering: relative radiant energy which is "redirected" by or within the coating, rather than absorbed.

Optical Density: combined factor of "opacity" and film thickness; includes light attenuating effects of absorbance and scattering.

Diffusivity: a thermodynamic characteristic combining specific heat, conductivity, and density; the ability of a material to diffuse heat input.

Temperature: has a significant effect on the rate of curing reaction; although exothermic reaction contributes to heat, radiant infrared energy is the dominating source of heat. Excessive temperature rise is one of the most common limiting factors affecting the cure window.

The UV curing Process Window is the practical result of a process design. It is influenced by a large number of factors such as those reviewed. **The Nature of the wood**; **The Coating Formulation; and the Lamp System.** Careful analysis of these factors contributing to properties of interest can provide opportunities to widen the operating limits of the process.

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The fast curing time of the UV curing system enables Pine River Inc. to achieve a high throughput, providing process efficiencies resulting in lower overall costs to the consumer. Picture courtesy of Allied PhotoChemical Inc. Kimball MI.

Finishing Factors

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Virtually any wood species can be finished to a high quality, but the selection and use of the proper UV-curable coating requires certain considerations.

Some of those considerations are:

- Number of coating layers in the structure
- Thickness of each layer
- Properties of each layer
- Performance of each layer

Number of coating layers in the structure

The number of coating layers is based on the specific application and aesthetic requirements of the end product and is mostly driven by market expectations.

It can range from as few as four layers (stain, sealer, first top coat and second top coat) to as many as eleven.

Smooth finishes require multiple filler/sealer coats and may require sanding between layers to give the desired look, whereas finished with open grain characteristics typically have fewer layers.

The extremes in textured products pose special challenges in achieving consistency in coating uniformity.

Thickness of each layer

The thickness of each layer as well as the overall film thickness can vary substantially from application to application, but typically overall total film thickness lies between 2-10 mil.

Properties of each layer

The properties of each layer are determined by the environmental conditions in which the product is to be used.

For example: wood flooring would require a high abrasion resistance, which primarily is achieved in the properties of the filler but also as in the combination of all layers.

In kitchen cabinets chemical resistance in combination with mar resistance would be essential.

In outdoor products just as logs, protection against fungus and algae growth, insects and damaging effects of the sun's rays are the critical properties.

The properties of each layer formulation is determined by the base oligomer used in the formulation of the layers product, which in turn must be selected with the overall performance requirement of the end product in mind.

Performance of each layer

The performance of each layer will be determined by the requirements of the end product relative to texture, gloss, feel and durability.

Factors associated with wood finishing

In closing let's discuss factors associated with wood finishing.

Seal Coat

Regardless of the number and combination of layers to be applied, its is essential to apply the correct amount of sealer when using 100% solid UV coatings. It is critical to be very careful not to apply substantial film build to the wood surface when sealing. The properly sealed wood should look visibly dry and starved for coating. Experience will show that an effective seal coat will dramatically improve the top coats uniformity.

Excessive seal coat application will result in irregular areas of thicker film build and aggressive sanding will be required to produce a uniform surface for top coat application.

It is also common to see what is described as "oatmeal" or broad "orange peel" in the surface texture of the top coat if the flow characteristics of the seal coats are poorly designed.

Equally important is the need to cure the seal coat immediately after application to avoid “strike-in” which in turn can result in a poor cure.

Intercoat Adhesion

There are a number of UV curable coating compositions which exhibit excellent intercoat adhesion without intercoat abrasion, sanding or denibbing. However, overcoats must be applied within a short time frame (within 4 to 24 hours) after the previous coat. Thereafter, sanding would be required to achieve quality intercoat adhesion.

Sanding

UV curable top coating compositions are formulated for hardness and are difficult to sand. This is the reason why many wood finishers use separate sanding sealers than self sealing top coats. Regardless, the sanding media used is very important.

If the sanding media is to coarse, sanding lines may remain, and it may be difficult to prevent potential seal coat removal. The resulting top coat uniformity will be poor.

If the sanding media is to fine the surface may not wet out, as well as jeopardous intercoat adhesion. It also can cause the pore structure of the wood to be filled with sanding dust preventing adequate binding between the seal coat to the wood structure.

Cure Conditions

With 100% UV curable coatings the irradiance level to which the coating is exposed to will influence the gloss level achieved. A low-irradiance cure will result in a lower gloss value while a high- irradiance cure will result in a high high gloss value. This is mainly due to the ability of the flatting agent to rise to the surface.

Pitch, Sap and Oils

Oak, maple and other common hardwoods are relatively straight forward. Sap woods and oily wood species, can present challenges. Excessive heat and high intensity of the UV curing lamps and the exothermic reaction of the UV chemistry can and often does draw pitch, sap and oils to the wood surface. Wood is typically harvested, kiln dried and heat processed to fix pitch and sap, but should adhesion fail, investigating pitch, sap and oil contend may be worthwhile.

Moisture

The moisture range of various wood species as well as in engineered woods is critical in processing 100% UV curable coatings and to the finished quality of the end product.

Hardwood’s should not exceed a 5- 8 % moisture range, while pine species and other sap woods should have a moisture range of 12 – 18%. Medium Density Fiberboard (MDF) a engineered wood product should not exceed a 5% moisture content for best finishing results.

Just to mention; Plywood falls within either category of Hardwood, or Softwood depending on the top veneer layer.

Conclusion

Conventional solvent and waterborne based wood coatings are still the majority of coatings used within the wood finishing industry.

However, as previously stated; Wood finishing processes incorporating radiation curing differ substantially from conventional finishing processes. UV technology can bring fantastic results, however, the transition can at times be costly and time consuming particularly when the process is poorly understood.

For the experienced wood finisher, the above concepts are not new. For the Finisher new to UV technology, perhaps some of the difficulties in making a effective transition will be minimized.

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Practical Relatioship between UV Lamps and the UV Curing Process “Window” by R.W. Stowe Fusion UV Curing System

Glossary of Terms RadTech International

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