



Wood Coatings:

New Technology Restores Life to Waterborne Alkyds for Architectural Applications

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Like most sectors of the paint and coatings industry, the wood coatings segment has been challenged over the past several years by several evolving market conditions and regulatory requirements. Today resin producers face rising raw material and energy costs and, in some cases, raw material related shortages of supply. The introduction of new substrates in the architectural market over the past 10 years has also been a key issue for resin manufacturers. They have responded by developing new technologies that enable formulators to achieve the desired level of performance and functionality demanded by their customers, while meeting increasingly restrictive limits on volatile organic compounds (VOCs) and hazardous air pollutants (HAPs).

The wood coatings segment includes a very broad spectrum of substrates, resin types, and end use applications. Paints and coatings for wood include factory, contractor, and consumer applied finishes that can serve a purely decorative function and/or provide significant resistance and protective properties. They are applied to both interior and exterior surfaces on decks, homes, floors, and furniture.

All types of resins are used for wood coatings. For typical OEM wood finishing situations, wood coatings include nitrocellulose lacquers, conversion varnishes, pre-cat lacquers, ultraviolet (UV) coats, sealers, and stains. In the architectural segment, water- and solventborne "house" paints are used as well as lacquers, urethane varnishes, exterior clear wood finishes and, of course, interior and exterior wood stains. Additionally, millwork or factory-applied architectural coatings include water and solventborne primers, sealers, topcoats, and stains.

UV coatings remain dominant for factory-finished wood flooring because of their ideal combination of coating performance and process efficiency. Both UV waterborne technology and 100% solids UV coatings are being used more for kitchen cabinets as well. Architectural coatings are currently dominated by waterborne acrylic systems. Industrial furniture coatings are largely based on conventional technologies like acid catalyzed conversion varnishes and nitrocellulose lacquers. Waterborne core-shell alkyd emul-

sions are a new and emerging technology for OEM stains and are expected to grow in this market segment.

Overall, the wood coatings market is growing at a modest pace. In the U.S., the market for coatings for pre-finished wood and composition flatboard (hardboard for clapboard exterior siding, door skin, interior panels, etc., and hardwood plywood, softwood plywood, and flooring) is growing at 3% per year, and in 2004 totaled approximately \$200 million based on a volume of 13 million gallons, according to market research firm Kusumgar, Nerlfi & Growney. The greatest use of coatings in this segment is for hardboard clapboard at 4–4.5 million gallons, but this market is declining as vinyl siding continues to make inroads.

The volume of coatings applied to wood furniture and fixtures in the U.S. in 2004 is estimated by Kusumgar, Nerlfi & Growney to be 35–37 million gallons with a value of \$460 million. This segment of the wood coatings market is not experiencing any growth. Solvent-based coatings account for \$375 million, with nitrocellulose topcoats being the largest resin type. Waterborne (largely acrylics) total \$50 million, while radiation cured coatings [mostly UV but also some electron beam (EB)] make up the remaining \$35 million.

For architectural coatings, Kusumgar, Nerlfi & Growney does not segment the market based on substrate. For interior applications, it is therefore difficult to identify an overall volume and value for wood coatings. Wood floorings, however, are clearly demarcated. In the U.S. in 2004, interior water-based coatings for wood floors totaled 10 million gallons and were valued at \$280 million at the manufacturers level. These coatings are experiencing a 10% growth rate which is driven partly by new housing construction and commercial space, a consumer trend towards hardwood floors, and several attractive properties of waterborne coatings including low odor, fast dry times, zero VOCs, easy cleanup, and nonyellowing finishes. Sales of interior solvent-based coatings for wood floors totalled about 2.5 million gallons in the U.S. in 2004 with a value of \$50 million. Demand for newer solvent-based oil-modified urethanes for wood floors is increasing and thus solventborne coatings will account for a larger percentage of the total market for wood floor coatings over time, according to Kusumgar, Nerlfi & Growney. Approximately 3.5–4 million gallons of interior solvent-based stains were

also sold in the U.S. in 2004 for a value of \$55–57 million.

For exterior architectural applications, it is safe to assume that the bulk of the volume and dollars of coating sales is applied to wood-based substrates. In 2004, the U.S. market for water-based exterior paints totaled 190 million gallons and was valued at \$2 billion. This segment is growing at 2% per year according to Kusumgar, Nerlfi & Growney, and includes paints, tin bases, stains and sealers, primer and undercoats, coatings for trim and trellis, decks and flooring, masonry, and other minor coating types. Sales of U.S. solvent-based paints totaled 60 million gallons in 2004 and were valued at \$735–\$740 million. This segment is declining 1% per year as many formulators switch to waterborne coatings to meet VOC requirements and because both performance and ease of cleanup with waterborne coatings are attractive to consumers. This category includes enamels (gloss, semigloss), stains, paint and tint bases, primer and undercoats, varnishes, trim and trellis, and others.

Several key issues are driving changes in the wood coatings market. Most resin producers point first to environmental compliance, and the increasing restrictions on VOC limits in particular. Regulations in California and the Northeast (Ozone Transport Commission) will likely spread through the rest of the country, and both resin manufacturers and formulators have been developing new technologies that will allow for production of coatings that meet both regulatory requirements and performance expectations. In addition, certain products in certain areas of the country will be discontinued. "For example," says Ernest S. Gulla, vice president and technical director of the Mace Company, "California now requires finishers to cut their VOCs from 550 g/L to 275 g/L, which has not only pushed solvent-based products out of the market but also impacts present waterborne systems that are supplied at 350 g/L." Replacement of some VOCs with exempt solvents such as t-butyl acetate is also occurring as a means to meet the upcoming VOC limit in California, which is set at 275 g/L for nitrocellulose formulations.

As the shift to waterborne and radiation-cured technologies continues, resin producers are focusing on the development of polymers that meet VOC requirements and offer a reasonable level of performance. "We expect that within the next 10 years there will be another round of



VOC limit reductions, and at that point the final VOC levels will be set," says Jeff Danneman, senior research associate with Reichhold. "Resin manufacturers will continue to generate better and better polymers that afford improved performance across the board. Performance of new polymers will become the focus and means of developing competitive advantage once the final VOC limits are established. Final limits will remove the redundancy of re-inventing the wheel as VOC limits change."

In the OEM furniture market, the listing of formaldehyde as a carcinogen by the International Agency for Research on Cancer (IARC) has led to concern about formaldehyde limits in conversion varnishes for OEM furniture coatings. In Europe, there is a demand for n-methylpyrrolidine (NMP)-free coatings. Alkyl phenol ethoxylates are banned in some European countries. "We need to be concerned about the global trends as we could be next in line to feel the impact from an offshore manufacturer, or our customers could be switching to a coating that is manufactured by a European-based company," notes Mr. Gulla.

Several other general trends are noteworthy as well. The Do-It-Yourself (DIY) segment of the market is growing at the expense of the contractor segment. Sales of paints and coatings have shifted from local specialty paint and hardware stores to "Big Box" retailers such as Home Depot and Lowe's. "The growth in the DIY market, the accelerated shift toward water-based coatings, and increased VOC regulations are related," says Michael Day, industry manager—architectural coatings with NeoResins Inc. "Consumers and contractors alike prefer the low odor, ease of application, and simple soap and water cleanup provided by water-based coatings. With advances in polymer technology, water-based coatings can now provide equal or better performance than traditional solvent-based coatings, without the health issues associated with solvent-containing products," he explains.

The movement of a significant portion of the furniture manufacturing business to places like Southern China, Malaysia, and Vietnam is another critical issue, according to Robert Skarvan, sales & marketing services manager for Nuplex Resins. "The larger wood furniture coatings manufacturers in this sector have worked diligently to set up manufacturing sites in Asia so as to not lose global market share and to take advantage of growth in the Asian coatings market."

Finally, the introduction of new substrates into the architectural segment poses challenges for wood coatings manufacturers. Composite substrates such as plastic-wood and cement fiberboard (Hardiplank®) for deck, porch, household siding, and trim have recently been introduced. These substrates represent new challenges for adhesion and efflorescence resistance. The

switch to alkaline copper quaternary (ACQ) from chromated copper arsenate (CCA) treated wood is also an issue. The two treated woods weather differently, with ACQ changing first to brown and then gray. Coatings formulators must adjust to meet the different behavior of this new substrate. "While individual products have constantly been upgraded for performance, the basic chemistry for architectural paints (alkyd and emulsion technology) hasn't changed in the last 40–50 years. But in the last 10 years we have seen all of these new substrates, which is creating a need to further refine these technologies in coatings applications" says Mr. Danneman.

UV technology is one area receiving more attention as the demand for lower VOC products grows. "Product development in UV waterborne technology is being accelerated, and there have been improvements made in using 100% solids UV technology for certain wood applications," notes Wim

Vanderghinste, market manager Radcure—Industrial Coatings, Americas with Surface Specialties, Inc. "Novel waterborne systems that are crosslinked, self-crosslinked, or low-VOC continue to grow in acceptance, and are closing the gap for balancing economics with performance," he adds.

In the OEM furniture market, UV spray systems are growing rapidly as they offer reduced VOCs and HAPs in combination with excellent cure rates, which translate to faster line speeds and improved throughput, particularly for kitchen cabinets. The excellent abrasion resistance, fast cure rates and line speeds, and very low-to no-VOC properties of UV systems are making them attractive in the pre-finished flooring area as well," according to Mr. Skarvan.

Resin manufacturers are also investing a significant amount of time in new emulsions, urethane dispersions, and hybrid systems for wood coatings. According to Sue Anderson, a director with The ChemQuest Group, Inc., a management consulting firm located in Cincinnati, OH, the U.S. market for waterborne alkyd-containing coatings is still a very minor segment of the



wood coatings market, with a total under 10 million dry pounds. Alkyd-containing coatings for deck stains account for the largest amount of waterborne alkyds at four million dry pounds. Anderson pegs growth for these products at 6% per year. Waterborne alkyds in OEM wood applications are estimated by ChemQuest to total 2.4 million dry pounds, but these products are being challenged by UV coatings. Interior applications for waterborne alkyd-containing coatings including trim enamels are estimated to account for two million

dry pounds. Ms. Anderson expects that this application will grow the strongest at 8-9% per year.

"Overall, alkyds have provided better performance on wood surfaces because their penetration is much better," says Mr. Danneman.

"Alkyds soak into the wood

whereas emulsions, due to their particle size, cannot do so. Alkyd emulsions and dispersions con-

tain very fine particles and have been shown to achieve the same level of penetration as solvent-based products," he continues. However, the long-term stability of alkyd dispersions and emulsions is an issue, with traditional water reducible alkyds lasting about one year.

"As VOCs are reduced in alkyd formulations, there are several other areas of concern as well, including, lapping, exterior durability, brushability, and ease of manufacture, and even penetration into the wood substrate, to name a few," says Wes Huff, senior development chemist with Süd Chemie Inc. "With lower molecular weight resins and longer crosslinking, polymerization, and cure rates, these formulations have slow dry times, increased viscosity, reduced flexibility, yellowing, reduced penetration, and increased difficulty in formulating and manufacturing," he adds. Acrylics also tend to have poor lapping and penetration properties, and these attributes are worsened with reduced VOC formulation.

Hybrid technology that includes both alkyd and acrylic resins has recently been developed to address many of the problems associated with waterborne

alkyd coatings. The "core-shell" morphology consists of an alkyd polymer in the core and an acrylic polymer as the shell. The acrylic shell is water soluble and hydrolytically stable, protecting the alkyd core from hydrolysis. As the dispersion is applied, the water evaporates and the fine particles in the dispersion penetrate into the wood. The polymer chains uncoil and tangle, and oxidation provides crosslinking to form the film.

Expected applications for waterborne alkyds using "core-shell" technology will include replacing solvent-based alkyds in transparent and semitransparent stains on cedar and other natural woods, deck stains, and interior and exterior trim paints. First generation core-shell products have been commercially available for some time and have been marketed for semitransparent deck stains and are now being formulated into gloss and semigloss white enamels for trim, according to Mr. Danneman. Limitations of the current core-shell technology include wet edge or open time, dry time, and yellowing, which is partially the result of the use of amines for neutralization of the polymer reaction. Mr. Danneman expects these issues to be fully addressed in the coming years. "The core-shell technology has a very good opportunity for growth from its existing small base because it provides the desired performance properties while meeting VOC restrictions," notes Ms. Anderson.

Reichhold has already introduced an improvement on the basic core-shell technology with the inclusion of secondary hydroxyl groups in the ester linkages of the alkyd core polymers. These secondary hydroxyl groups are much more resistant to hydrolysis and provide improved stability at the water/"oil" interphase area of the dispersion. Tertiary alcohols would lead to optimum hydrolytic stability, but secondary alcohols are commercially available and are more reactive with the polybasic acids used in alkyd polymers.

Kelsol 8100 is a semitransparent stain vehicle based on the core-shell technology from Reichhold and was first introduced at the ICE show in 2004. Reichhold also launched the new technology using secondary hydroxyl functionality for industrial maintenance and/or architectural applications at the show and is currently sampling research quantities of the material to customers for testing. "In the architectural, and to a lesser extent the industrial maintenance market, 'left over' coatings are re-used for touch up and an extended lapse between the production and consumption of coating products often occurs," notes Mr. Danneman. Thus, long-term stability is required. The polymer composition of the novel alkyd dispersion was designed to match the solvent-based medium oil alkyd performance that is widely accepted in the industrial maintenance market, but the technology is capable of mimicking short, medium, and long oil alkyd products



through polymer modification and/or by varying the core-to-shell ratio. The new product has quick set-to-touch and the requisite viscosity and hydrolytic stability for maintenance and architectural finishes.

Surface Specialties, Inc. has launched a new resin carrier technology to the market for architectural coatings, stain, and primer applications. The new carrier technology offers ultra-high solids at very low viscosity with improved performance over traditional waterborne technologies. It can be used for high-gloss and semigloss architectural coatings at formulated VOCs that are well below today's requirements, according to Terry Scoville, market manager—liquid coating resins with Surface Specialties, Inc. "Until now, customers have sacrificed gloss, hardness, scrub, and adhesion. With the new carrier resin technology, all performance is back at the VOC, solids, and appearance level that is desired by the market," he states.

These new core-shell alkyd dispersions from Surface Specialties are based on a patented core-shell process using a carrier resin for the outer shell and emulsification. Because no amine is present for neutralization and only highly refined or high grade fatty acids are used, these resins exhibit very low yellowing characteristics. The water-based resin behaves like a traditional solvent-based alkyd in its application properties. The alkyd core provides dry time properties, fullness, hardness, and penetration, while the core-shell provides the desired stabilization, open time, leveling, and rheology.

Surface Specialties is also launching its latest generation of Ucecoat[®]-UV curable waterborne resins, which are especially suitable for wood coatings. The company has also invested in an industrial line for vacuum coatings to support its customers' product development, and to provide technical support for this emerging technology.

Süd Chemie has developed its zero-VOC waterborne alkyd-like copolymer emulsion, Encore NF55E, using a proprietary method that enables formulation at a neutral pH. With an acid value of less than 2, Encore NF55E exhibits excellent shelf stability and resistance to phase separation and therefore can be formulated at a lower viscosity. It also has no saponification value, inferring excellent saponification resistance. "One of the novel properties of the Encore NF55E is its nontraditional film forming capability, which contributes to its ability to re-emulsify the first coat by the second coat. When formulated at or below 25% resins weight solids, open time is increased and lapping is dramatically improved," notes Mr. Huff. The low molecular weight product is prepared from linseed oil and a special fatty acid, providing good wood penetration and superior exterior durability. Encore NF55E is supplied at 52-55% solids with an emulsion viscosity of 3000 cps, is both pourable and pumpable, and can be

formulated at a much lower volume solids and lower viscosity. It can be blended with acrylics, waxes, and stearates, is compatible with both oil and water soluble biocides, and the finished stain can be applied using traditional methods.

DSM Coating Resins pioneered water-dilutable Uradil alkyd emulsions over 30 years ago and continues to extend and improve its range of products. Recently, the company introduced its Uradil hybrid system to provide higher gloss coatings while retaining the drying speed and yellowing resistance of water-based acrylics. Amine and solvent-free Uradil resins are available from DSM for use in primers and top-coats.

Mace Company has investigated the application of nanotechnology to the development of wood coatings. "In addition to aesthetics, long-lasting performance with less frequent maintenance or recoating is a point of great interest to the wood industry," says Mr. Gulla. In response, Mace has introduced NT 447, a resin made with the use of nano-engineered additive systems that exhibits significant improvement in performance properties. "We expect that NT 447 will have application in the gymnasium, sports, and hardwood floor markets due to its outstanding durability, which is superior to the performance of all waterborne resins currently on the market," Mr. Gulla notes.

NeoResins, Inc. introduced nine new products at the 2004 ICE Show in Chicago, three of which are designed specifically for wood coatings. NeoRez R-9407 is a self-crosslinking, one-component, fatty-acid modified, urethane dispersion for high performance wood flooring. This product delivers optimum properties within 48 hours and meets current VOC regulations. NeoPac R-9036 is an NMP-free, nonyl-phenol surfactant-free, polycarbonate-based, aliphatic, urethane/acrylic co-polymer that offers superior durability and stain resistance for wood flooring, flexible flooring, and other diverse substrates. NeoCryl XK-225 is an adhesion promoted, 100% acrylic emulsion polymer for interior and exterior enamels that delivers superior adhesion, hardness, and exceptional chemical resistance even when formulated at < 50 g/L VOC.

Nuplex Resins, formerly Akzo Nobel Resins, features a substantial line of emulsions for wood finishes based on patented self-crosslinking technology. This Setalux range of products features an excellent balance of hardness development and flexibility while also providing improved chemical resistance. Nuplex Resins has waterborne products for factory and consumer applied clear finishes, millwork applications, and exterior wood stains. The company has manufacturing facilities throughout Asia including its recently commissioned plant in Suzhou, China. 