



# PAKISTAN COATINGS JOURNAL

FEBRUARY - MARCH | 2020

## PAKISTAN COATING SHOW 2020

THE DEMAND FOR  
COATINGS RAW  
MATERIALS

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A FACILE APPROACH  
TO A SILVER  
CONDUCTIVE INK

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SAFETY RACE  
WITH SCISSOR LIFTS

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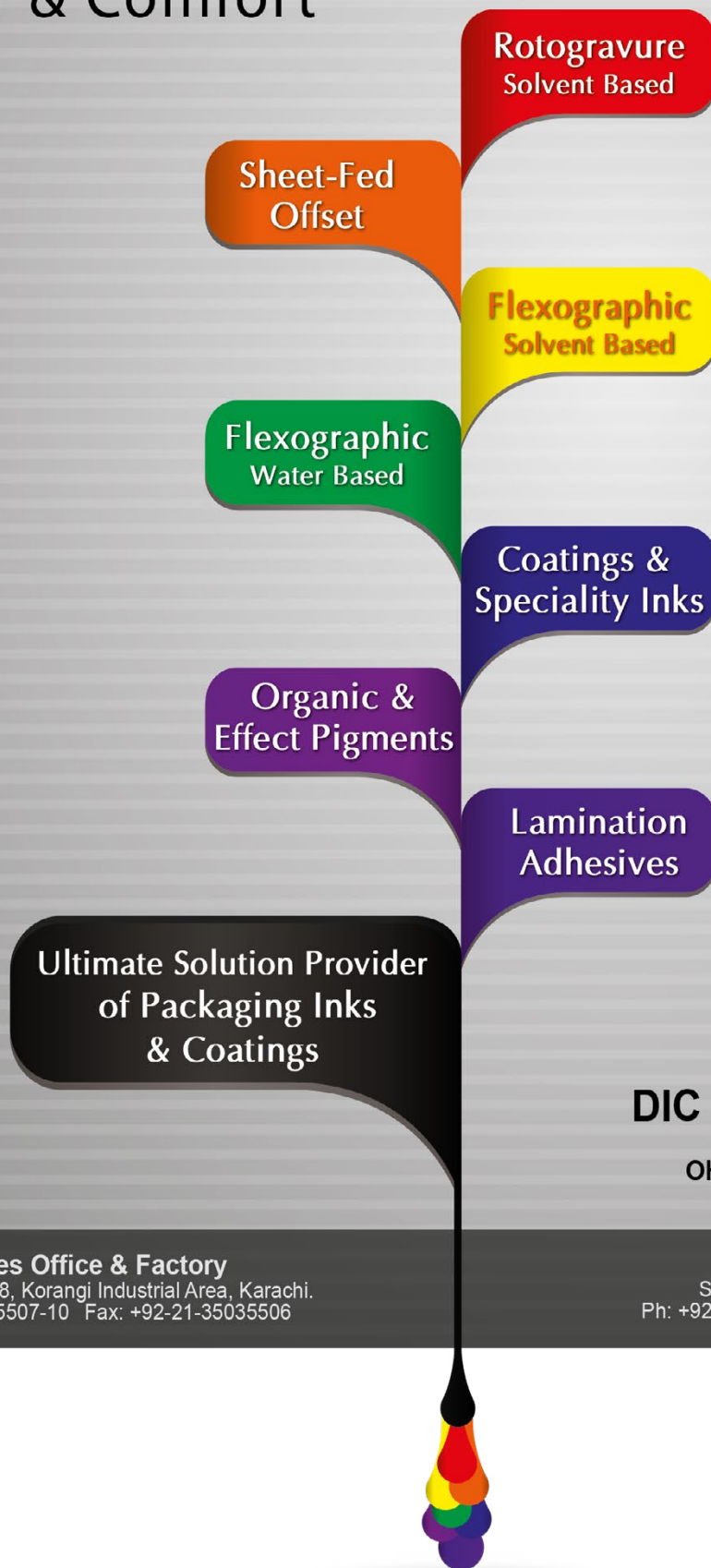




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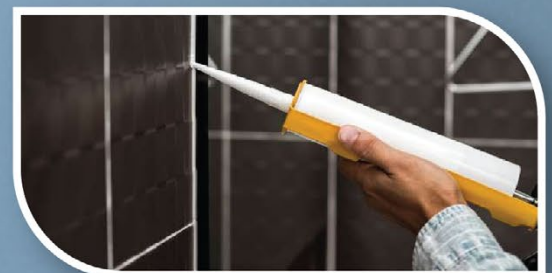
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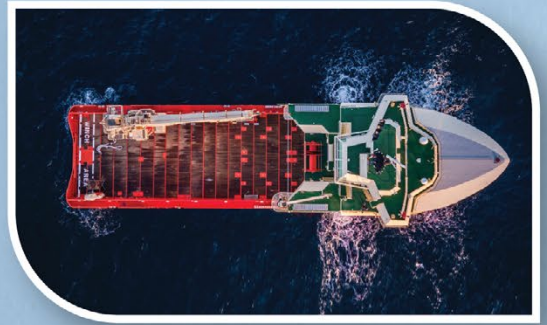
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PAKISTAN

# COATINGS JOURNAL

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## EDITOR'S NOTE



Heartily  
*Welcome*  
**DEAR READERS**

The journal in your hands is not so heavy but its contents of knowledge make you feel heavier in the fields addressed in it. Many areas which are not explored for a quite a while till now but exist are presented herein for the enhancement and improvement of knowledge to make technology pace faster in our country.

The rainbow of colors attracts and similar in this magazine having topics on raw Materials, Construction chemicals and customary coating and the list of contents contained in at the very start of the mag. The topic might be interested to one and the other to other which levels up the readership and hopefully success also becomes following the good efforted contents of the goal journal.

Thus, it is a slope-up beginning of presenting education and knowledge of "coating" to the industries and to whom it may concern so that related development around the world should be known to them as well as it is our best effort to bring colors of knowledge around educational and research institutions relating industry too because of their increasing use in all day life.

*Pleasure Readings!*

**MOAZZAM RASHEED**



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# NEWS

## PPG DIRECTORS ANNOUNCE QUARTERLY DIVIDEND OF 51 CENTS PER SHARE



The board of directors of PPG declared a regular quarterly dividend of 51 cents per share, payable March 12 to shareholders of record Feb. 21.

This marks the company's 486th consecutive dividend payment. Through ongoing dedication and expertise of its workforce, the company has raised its annual dividend payout for 48 consecutive years and paid uninterrupted annual dividends since 1899.

## TALGA COMPLETES 2ND COMMERCIAL SCALE GRAPHENE COATING TRIAL

Talga Resources Ltd announced the commencement of a new large scale commercial trial of its Talcoat graphene additive for maritime coatings.

At the core of the Talcoat product is Talga's new

patent-pending graphene functionalization technology in the form of an on-site dispersible powder that can successfully add graphene's exceptional strength into paint and coatings.

Supported by the same shipowner, Talga has provided its next-generation graphene additive to enhance a primer coating successfully applied over a sizeable area of a second large container ship.

Unlike the first trial (ASX:TLG 4 Oct 2019), the Talcoat product and the 2-part epoxy-based commercial coating system were supplied separately and mixed on-site by the paint applicators before spray application to the vessel during dry-docking.

The application of the coating was successful in meeting all conditions and standards required for ships of this size, confirming the potential of the Talcoat product as a ready-mix component for on-site incorporation by coating companies or paint applicators alike.

To further test the versatility and compatibility of the Talcoat additive, the trial used a commercial coating system from a world-leading coating supplier different from that used in the first trial.



The ocean-going cargo vessel, of similar size to the initial container ship being approximately 225m long and weighing 33,000 tons, has re-entered service at sea where over the next 12-18 months the test area

will be evaluated on the performance boost delivered to the coating system.

"We continue taking graphene out of the lab and into the real world with these large scale coating trials underway on cargo ships," Talga Managing Director Mark Thompson said. "This application joins the other large scale clean technology product verticals we have been developing for several years such as graphene-enhanced concrete, plastics and packaging products."

## SUN CHEMICAL PERFORMANCE PIGMENTS



Sun Chemical has been in the color business for over 100 years. Sun Chemical Performance Pigments is a leading provider of organic and inorganic pigments, pigment preparations and effect pigments. The markets served by these products include automotive, architectural and industrial coatings. Sun Chemical also provides the coatings market industry leading acrylic, polyester, PUD and epoxy resins. Sun Chemical is a leading producer of printing inks, coatings and supplies, pigments, polymers, liquid compounds, solid compounds, and application materials. Together with DIC, Sun Chemical has annual sales of more than \$7.5 billion and over 20,000 employees with regional manufacturing in North America, South America, Europe and Asia to support customers around the world.

### MARKETS SERVED AND TECHNOLOGIES

Sun Chemical offers coatings formulators an extensive range of innovative pigments, resins and additives. The Performance Pigments group offers high performance, classical, effect pigments and preparations.

Sun Chemical's Advanced Materials group, with world class resin engineering, produces the full range of general and specialty polymers including polyester, acrylic, epoxy, polyurethane and fluorochemical.

Together these groups provide customers with solutions tailor made for the automotive, industrial,

architectural, decorative, and powder coatings markets.

### TECHNICAL SERVICES

Sun Chemical's unparalleled global presence, backed with 17 research and development centers, allows for the delivery of local service and support that is customized to the markets it serves. Each manufacturing facility produces solutions tailor-made to the specific needs of customers in each region, bringing them the value and service they need to be competitive.

### MAJOR PRODUCTS

- Perrindo<sup>®</sup> : High performance red and violet perylene pigments for automotive coatings and specialty applications.
- Quindo<sup>®</sup> : High performance quinacridone pigments for automotive, industrial and architectural coatings.
- Sunbrite<sup>®</sup> : Classical pigments for architectural and industrial coatings.
- Fanchon<sup>®</sup> : High performance yellow and orange pigments for industrial and automotive coatings.
- Palomar<sup>®</sup> : High performance blue pigments for automotive and specialty coatings applications.
- Benda-Lutz<sup>®</sup> Metallic Effects: Aluminum pigments for coatings, including cornflake and silver dollar types with a wide range of flake sizes.
- SunMICA<sup>®</sup> : Industrial- and exterior-grade natural mica-based pearlescent effects.
- WATERSOL: A family of conventional and hybrid resin technologies designed to deliver high performance properties in waterborne coatings.
- BURNOCK: A diverse line of crosslinkers and resins, including polyester, acrylic, and phenolic resins, allow formulators to meet the performance requirements of a broad range of applications.

## BASF INCREASES PRODUCTION CAPACITY FOR IRGANOX 1520L ANTIOXIDANT IN PONTECCHIO MARCONI, ITALY



BASF will add 20% to its existing capacity for Irganox<sup>®</sup> 1520L at its Pontecchio Marconi production plant in Italy by debottlenecking operations. BASF plans to increase the production capacity for its antioxidant Irganox 1520L by 20 percent at the site in Pontecchio



Marconi, Italy. Irganox 1520L is a key product in BASF's antioxidant portfolio.

"The production expansion of Irganox 1520L underlines our clear commitment to continuously support the growth of our customers. By debottlenecking operations at our Pontecchio plant in Italy, we are able to respond quickly to an increasing market demand," says Achim Sties, Senior Vice President, Performance Chemicals Europe, BASF. Irganox 1520L is a highly effective thermo-oxidative stabilizer in a wide range of solution polymerized, emulsion polymerized and thermoplastic elastomers, plastics, adhesives, sealants, oils and lubricants. It is unique in its ability to provide both processing and long-term heat-aging stability used alone, at low levels and without co-stabilizers. Where necessary, Irganox 1520L can be used with other additives such as secondary antioxidants, benzofuranone, light stabilizers and other functional stabilizers.

## CLEAN FUTURE ACT FRAMEWORK RELEASED

Last week, leaders from the United States House Committee on Energy and Commerce released legislative framework for the draft Climate Leadership and Environmental Action for our Nation's (CLEAN) Future Act. The climate plan intends to achieve net-zero greenhouse gas pollution in the U.S. no later than 2050. The framework was released on Jan. 8, by Energy and Commerce Committee Chairman Frank Pallone, Jr., D-New Jersey; Environment and Climate Change Subcommittee Chairman Paul Tonko, D-New York; and Energy Subcommittee Chairman Bobby L. Rush, D-Illinois.

"Record wildfires, flooding, heat waves and drought have spelled out a dire reality: the climate crisis is here, and we can no longer afford to address this crisis along the margins," said Pallone.

"Today we are providing the kind of serious federal leadership this moment requires. This plan represents



Last week, leaders from the United States House Committee on Energy and Commerce released legislative framework for

the draft Climate Leadership and Environmental Action for our Nation's (CLEAN) Future Act.

our commitment to achieving net-zero greenhouse gas pollution. For the sake of the American people, the long-term sustainability of our economy, and public health, we must act boldly, and that is exactly what we intend to do."

### About the CLEAN Future Act

Beginning in July 2019, Pallone, Tonko, and Rush announced a plan that aimed to achieve 100% clean economy by 2050. The target was decided upon the scientific consensus that all countries must shift to net-zero greenhouse gas emissions by 2050 to avoid the most devastating consequences of climate change.

Upon receiving warning from the United Nations the following November that global temperatures were on track to increase by as much as 3.9 C above preindustrial levels by the end of the century, the Committee on Energy and Commerce started cracking down on policy solution developments to address the climate crisis.

According to the committee, the CLEAN Future Act is a reflection of extensive feedback gathered from months of expert testimony and stakeholder engagement collected throughout the 116th Congress, the Subcommittee on Environment and Climate Change and the Subcommittee on Energy.

The 15-hearing series included, among others and witness testimonies:

- Time for Action: Addressing the Environmental and Economic Effects of Climate Change (Feb. 6, 2019);
- Clean Energy Infrastructure and the Workforce to Build It (Feb. 27, 2019);
- Building America's Clean Future: Pathways to Decarbonize the Economy (July 24, 2019);
- Building a 100 Percent Clean Economy: Solutions for the U.S. Building Sector (Sept. 20, 2019);
- Building a 100 Percent Clean Economy: Solutions for the U.S. Power Sector (Oct. 30, 2019); and
- Building a 100 Percent Clean Economy: Solutions for Economy-wide Deep Decarbonization (Dec. 5, 2019).

In addition to these efforts, the committee also led in-depth stakeholder engagements involving leaders from the labor community, environmental justice communities, environmental organizations, think tanks, the clean energy and energy efficiency industries, the power sector, the oil and gas sector, the agricultural sector, the industrial sector, and the transportation sector.

"Meeting the climate crisis head-on is our only hope of avoiding grave and costly outcomes for our



communities,” said Tonko.

“Acting swiftly means we can still turn the looming climate threat into opportunity for economic growth and job creation as we build America’s clean energy and climate-resilient future. This legislation will be the top priority for my Subcommittee this year. I look forward to our work together with countless climate stakeholders as we continue to build this bold, consensus driven plan for America to, at long last, truly act on climate.”

Outlined in the legislation’s framework are the following key areas that will involve adopting new policies within the Committee’s jurisdiction:

- **National Climate Target:** Championed by Rep. Donald McEachin, D-Virginia, the National Climate Target directs all federal agencies to use all existing authorities to put the country on a path toward net-zero greenhouse gas emissions by 2050. To ensure federal agencies’ collective efforts remain on track, the draft legislation directs the Environmental Protection Agency to evaluate each agency’s plans, make recommendations and report on progress each year;
- **Power Sector:** Guided by Reps. Ben Ray Lujan, D-New Mexico and Diana DeGette, D-Colorado, on Clean Electricity Standards, the Power Sector proposes a nationwide CES requiring all retail electricity suppliers to obtain 100% clean energy by 2050, mandating that all retail electricity suppliers provide an increasing supply of clean energy to consumers starting in 2022;
- **Buildings and Efficiency:** The Building Sector draft legislation aims to improve the efficiency of new and existing buildings, as well as the equipment and appliances that operate within them. The section plans to assist states and Tribes in adopting updated model building energy codes and support full compliance, while also establishing national energy savings target leading to a requirement of zero-energy-ready buildings by 2030;
- **Transportation:** This portion of the draft legislation directs the EPA to set new, increasingly stringent greenhouse gas emission standards for light-, medium-, and heavy-duty vehicles, including non-road modes of transportation, in addition to requiring year-over-year improvements to those standards—and that the level of the standards be set in accordance with the path to net-zero emissions by 2050.

- **Industry:** To set performance targets that steadily reduce emissions from construction materials and products used in projects that receive federal funding, the Industrial Sector will establish a Buy Clean Program, transforming carbon-intensive industries by ensuring that these projects only use the cleanest construction materials;

- **Environmental Justice:** Requires that states’ individual climate plans and state implementation plans for other hazardous air pollutants proactively consider the needs of frontline and environmental justice communities. This sector also includes various grant programs to allow impacted communities to participate in the permitting and regulation of petrochemical facilities in their neighborhoods;

- **Super Pollutants:** Focusing on heat-trapping pollutants, the Pollutants Sector directs the EPA to regulate methane emissions from the oil and gas sector—the largest source of domestic methane emissions—in addition to black carbon emissions. The sector also creates a grant program within the Department of Energy to help states reduce methane emissions from natural gas infrastructure;

- **Economy-wide Policies:** The largest of the sectors, the Economy-wide Policies will involve State Climate Plans (empowering states to complete the transition to a net-zero economy, based on the existing federalism model in the Clean Air Act), National Climate Bank (championed by Rep. Debbie Dingell, D-Michigan, to mobilize public and private investments to provide financing for low- and zero-emissions energy technologies, climate resiliency, building efficiency and electrification, industrial decarbonization, grid modernization, agriculture projects, and clean transportation), Transitioning to a Prosperous Clean Economy Workforce and Integrating Climate Change into U.S. National Security Planning.



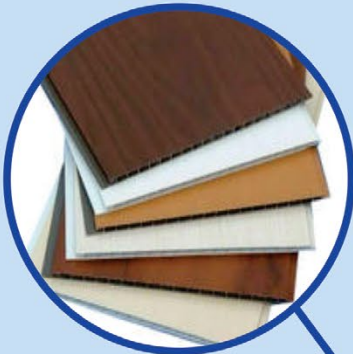




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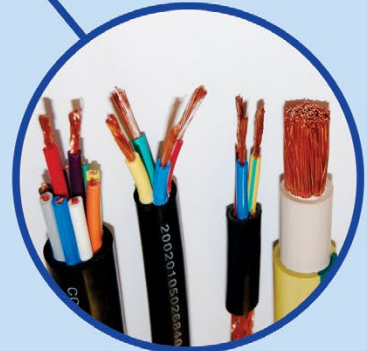
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# THE DEMAND FOR COATINGS RAW MATERIALS TO 2022

By: George R. Pilcher, The ChemQuest Group, Inc.



**R**aw materials, in the form of individual chemical constituents that are incorporated into paints and coatings, represent an exceptionally diverse and vitally important sub-set of the overall specialty chemicals industry. They may either be added to a paint or coatings formulation during the product manufacturing process or,

in the case of multiple-component coatings systems (2K, 3K, etc.) may be used to make coating components intended to be combined in the field to produce reactive, limited potlife products.

Coatings raw materials can be grouped into four broad categories of chemical constituents:

**Resins:** Polymers either dissolved—or carried—in water or organic solvents

**Pigments:** Both chromatic (“primary pigments”) and extender, filler, flattening, etc. (“secondary pigments”)

**Solvents:** Organic—water is not discussed in this article

**Additives:** Rheology modifiers; surfactants; dispersants; biocides; coalescents; catalysts; defoamers; adhesion promoters; and a host of other specialized chemical constituents typically used at very low levels, as a percentage of the formula weight. The global coatings raw material market is estimated to be valued at approximately \$63.5 billion on 34.3 million metric tons of materials.

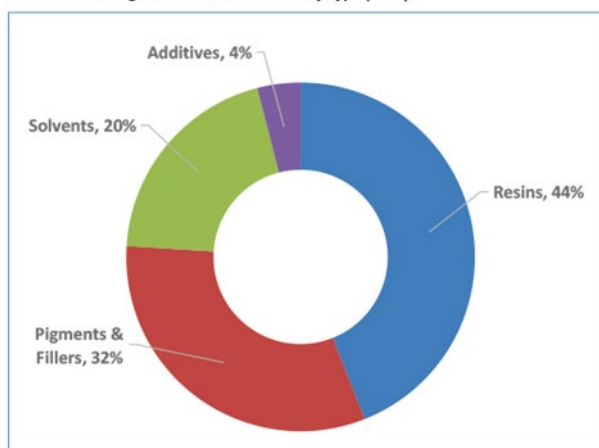


## RAW MATERIALS MARKET ANALYSIS

Raw materials used in the manufacturing of paints and coatings represent a relatively small (~5%) but extremely important component of the \$4.5 trillion global chemicals industry.

All of the world's leading chemical producers are active in the coatings market, and many coatings raw materials are used in other industries as well, including plastics; synthetic lubricants; adhesives; sealants; household, industrial and institutional cleaners (HI&I); personal care products; paper; plastics; water treatment and many others.

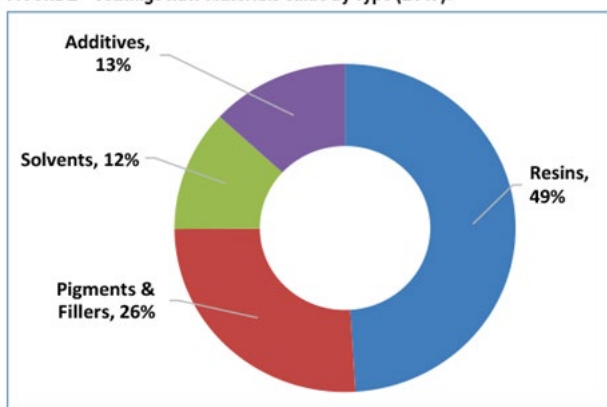
FIGURE 1—Coatings Raw Materials Volume by Type (2017).



Source: The ChemQuest Group, Inc. estimates.

The basic chemical components that are used to produce coatings chemical constituents can also be used to produce a wide array of other chemical compounds. This can be a problem at times, since this diversity of uses can create competitive situations for raw materials and their pre-cursors that are typically used in coatings, particularly during periods of tight supply.

FIGURE 2—Coatings Raw Materials Value by Type (2017).



Source: The ChemQuest Group, Inc. estimates.

Resins ("binders"), pigments, and fillers represent over 75% of the global coatings raw materials market. Figure 1 shows the estimated distribution of coatings raw materials volume by type.

As might be readily anticipated, the distribution of the types of raw materials, based upon value, is somewhat different than distribution based on volume. Figure 2 shows the estimated distribution of coatings' raw materials value by type.

## RESINS

Total global sales of resins for use in coatings systems are estimated to be \$31 billion on roughly 15.2 million metric tons.

Globally, acrylic resins are the most commonly used binder in paint and coatings systems. This is particularly true for decorative paints, and includes all acrylics, both pure and modified, such as styrene-acrylics and vinyl-acrylics. It is estimated that acrylic systems, both solventborne and waterborne, comprise approximately 27% of total coatings binder demand. It should be no surprise then, that acrylic resins tend to be the most susceptible to periodic disruptions in supply, accompanied by price fluctuations. In 2017, for example, shortages of methyl methacrylate (MMA), due to a variety of causes, including a shortage of acetone and two major U.S. suppliers of MMA being down (for different reasons) at the same time, led to nearly monthly increases, with MMA climbing roughly \$0.50/lb, from "mid-\$0.80s/lb" in February 2017 to "mid-\$1.30s/lb" in January 2018. Prices on both the spot market and the black market during 2017 were reported to be "sky high." While supplies are somewhat more stable going into 2018, price increases were announced for both January and February, and there are still likely to be additional increases.

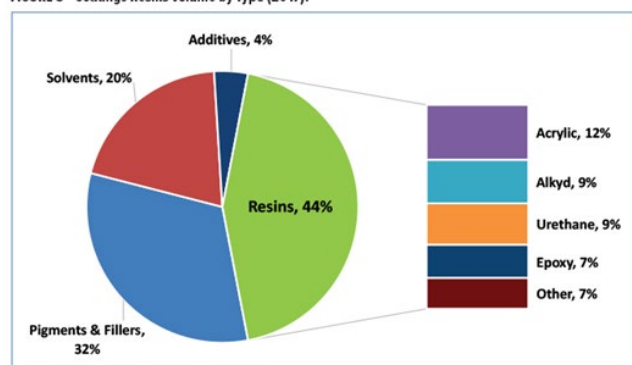
On a global basis, alkyds are used to some degree in virtually every end-use coatings segment, and represent the second most common type of resin system used in coatings formulations. Alkyds comprise roughly 20% of resin demand in the global coatings market ( $\leq 10\%$  in the United States). Although alkyd resins have been steadily declining in use, particularly in North America and EU, as VOC limits continue to drop, and the market has been moving to other resin types for water-based and higher-solids formulations, newer water-based alkyd systems are being introduced into the market, at least in part due to the increasing interest in resins made with higher renewable resource content.

Polyurethane coatings, either 1K, 2K (or occasionally 3K) are widely used in the automotive OEM, other transportation, automotive refinish, wood, industrial finishes, decorative coatings and even severe-service marine and high-performance industrial segments. Urethane resins currently comprise roughly 21% of the global demand for resins in coatings. Usage of polyurethane resins has been growing over the past

several years due to their performance properties and their ability to be used in lower VOC formulations. An important, and growing, sub-segment of polyurethanes in the United States is 2K polyureas. To comply with increasingly stringent VOC requirements, polyurethane waterborne dispersions (PUDs) have been developed and used to formulate single-component coatings with improved abrasion resistance compared to waterborne acrylics. They can also be combined with other waterborne resins to meet cost targets and performance needs.

Approximately 16% of total demand for binders used in coatings is supplied by epoxy resins. Various resins in the epoxy family are widely used in electrodeposition (ED) coatings and in industrial coatings, particularly in the transportation, industrial maintenance and marine markets. Epoxy resins are also widely used in powder coatings. In recent years, high solids and ultra-high solids formulas using liquid epoxy resin dominate and continue to grow. Liquid epoxy resin is also used for 100% solids epoxy formulas applied as concrete surfacers, tank linings, and for other select applications, often augmented with phenoxy and novolac resins to enhance certain performance features. While the performance of waterborne epoxy resin technology has improved, even accounting for higher consumption due to its improved performance, it has only attained a small technology share, albeit with major usage in metal can coatings. These are, however, coming under increasingly close scrutiny in the United States, where BPA toxicity concerns continue.

FIGURE 3—Coatings Resins Volume by Type (2017).



Source: The ChemQuest Group, Inc. estimates.

Additional binders that are used as coatings raw materials include amino, polyester (with low-bake versions as the growth area), cellulosic, silicone/polysiloxane, silicate and vinyl resins. Fluoropolymers are another interesting type, with waterborne versions now being offered for high-end architectural exteriors and other applications. Also included in this sub-segment are hydrocarbon resins and natural resins such as rosins and shellacs. While technically not resins, linseed oil, tung oil and similar products are also included since they act as film formers. This sub-segment comprises approximately 16% of total resin

demand in the global coatings markets. Another small but growing resin chemistry is that of radiation cure, with the current greatest volume used in wood and plastic coatings—where sometimes even dual WB/UV cure technology is used. See Figure 3 for a breakdown of the major resin types.

## PIGMENTS

The value and volume of pigments, both primary and secondary, for use in coatings formulations were estimated to be \$16.5 billion on 11.0 million metric tons of product. On a volume basis, fillers and extenders are the largest sub-set of the pigments category and represent roughly 56% of all demand for pigments in the coatings market. Compounds that comprise this sub-segment include clay, calcium carbonate, talc, silica and other inorganic materials.

The second largest sub-set of the pigments category is titanium dioxide (TiO<sub>2</sub>), which is the single highest-volume pigment used in coatings. Its largest use is in decorative coatings, but it is widely used in a variety of industrial OEM coatings and industrial maintenance/protective coatings, as well. Titanium dioxide represents approximately 31% of all pigments used as coatings raw materials, and this is likely to be somewhat problematic in 2018, with Q1 lead-times of 60–90 days, and scattered instances of allocation as well. The global economic climate currently favors all market segments that use TiO<sub>2</sub>, most notably the building and construction segment. This will, therefore, be a year of continued price increases, which could easily take TiO<sub>2</sub> as high as \$3100/mt, albeit still significantly short of its 2011–2012 historic high price of ~\$4500/mt. Increases in Chinese chloride-process TiO<sub>2</sub> production are essentially being offset by continued closure of sulfate-process plants, and Huntsman's plant in Finland is not scheduled to be back to full production until the end of 2018. If the acquisition of Cristal by Tronox is finalized (the U.S. Government filed a complaint aimed at stopping the deal on December 5, 2017), it is unlikely to unleash any additional pigment into the market during 2018, although might be reasonably be expected to add an additional 100Kmt to global output in subsequent years.

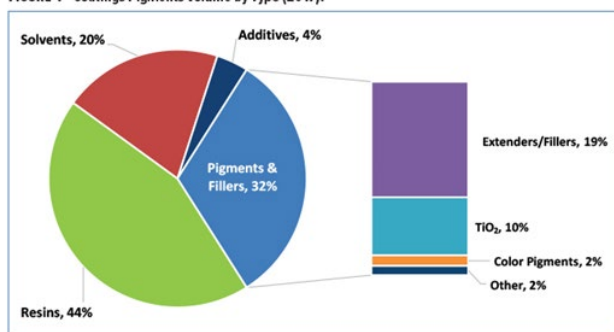
For certain end-use applications such as decorative, automotive OEM and automotive refinish, color is a primary driver of product selection. Hence, color pigments play a vitally important role in the coatings industry. Despite the importance of these materials, color pigments represent only a small component of pigment demand. Included in this segment are both inorganic and organic pigments. Inorganic color pigments such as iron oxide are the most frequently used and represent over 80% of the volume of color pigments. Organic



color pigments are among the highest-priced raw materials and, thus, despite their relatively low volume, represent a significant portion of the market value. Organic color pigments are likely to increase 3–4% in 2018, as a result of competition for the basic chemicals from which they are built, and that largely come out of the AP region—production of which can be affected at almost any time as the Chinese government becomes increasingly proactive about shutting down chemical processes in an effort to improve air quality. Complex inorganic color pigments (often referred to as CICPs or ceramic pigments) are growing in importance because they meet the higher performance demands of chemical inertness and heat stability, along with lightfastness and excellent weathering properties. Moreover, with only a few exceptions (such as perylene black), CICPs comprise the majority of IR-reflective pigments that now enable formulation of various colors with energy efficiency properties. Color pigments represent >6% of the volume of all pigments used in coatings.

In addition to the pigments listed above, there is a wide array of other specialty pigments, such as anticorrosive pigments, metallic pigments, pearlescent pigments, carbon black and zinc oxide. While some of these pigments play an important role in coatings volume, none individually represents a significant volume. These other pigments represent roughly >6% of the total pigment demand. See Figure 4 for a breakdown of the major pigment groups.

FIGURE 4—Coatings Pigments Volume by Type (2017).



Source: The ChemQuest Group, Inc. estimates.

## SOLVENTS

Solvents are the key contributors to the volatile organic content of paints and coatings emitted into the atmosphere and, as a result, are regulated by various local, regional, state and country regulatory agencies around the world.

Global revenues for solvents used in coatings formulations in 2017 were approximately \$8 billion on 6.5 million metric tons.

Oxygenated solvents comprise over 60% of demand within coatings formulations, and include chemical

components such as alcohols, ketones, esters, glycols and glycol ethers. Hydrocarbon solvents are either aliphatic or aromatic and comprise less than 40% of total usage within coatings formulations. As a result of the continuing shift in paint and coating formulations from solvent-based to water-based technologies, ultra-high solids and 100% solids, overall usage of solvents is declining as a percentage of the total coatings raw materials usage. While solvent usage as a percentage of total raw materials continues to decline, however, many end-use segments that use solvent-based coatings continue to grow. As a result, total solvent usage has been relatively flat over the past decade or so, and this trend is expected to extend into the foreseeable future. Similarly, within the solvents family, shifts are ongoing as formulators seek to find less toxic and more compliant, environmentally friendly solvents. Unfortunately, VOC regulations—and the concept of “what is exempt and what is not”—differ around the globe.

For example, 2,2,4-trimethyl-1,3-pentanediol monoisobutyrate (“Texanol™”), historically the most effective coalescing agent for latex paints, is listed as non-exempt by the U.S. Environmental Protection Agency, but in the EU it is listed as exempt. This can make formulating “global coatings formulations” anywhere from tricky to impossible, depending upon the coating, application, and performance requirements.

## ADDITIVES

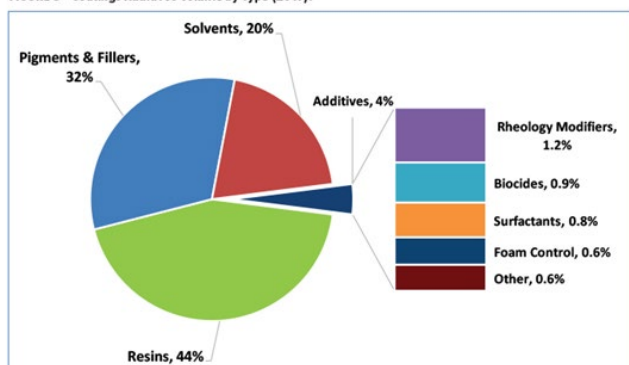
Additives comprise a broad category that covers a wide array of chemicals used as raw materials for coatings. Recent innovations include multi-functional additives to simplify the number of formula ingredients and also include those that help to achieve low- to zero-VOC formulations. Total revenue for additives used in coatings is estimated to be \$8.4 billion on approximately 1.25 million metric tons.

Rheology modifiers are the largest sub-segment, representing over 30% of demand, and are used to control viscosity and to affect flow and leveling. Plasticizers are incorporated into formulations to improve the flexibility of the film, and may also be used at times for their coalescent properties.

Biocides are added to formulations to prevent the growth of bacteria and other microorganisms while the coating is being stored, and also as a dry film preservative. Biocides, including special chemical components that are used to minimize marine fouling, comprise approximately 22% of total additives used in coatings. Surfactants represent approximately 19% of additive demand on a volume basis, with foam control additives at 15%.

The list of other additives is quite long. While none represents a significant component of coatings raw materials individually, “Other Additives” collectively comprise a significant portion of all additives and include adhesion promoters, antifoaming agents, anti-skinning agents, corrosion inhibitors, driers, flattening aids, flood control agents, sag control agents, slip aids and UV absorbers, to name a few. See Figure 5 for a breakdown of the major functional classes of additives.

FIGURE 5—Coatings Additives Volume by Type (2017).

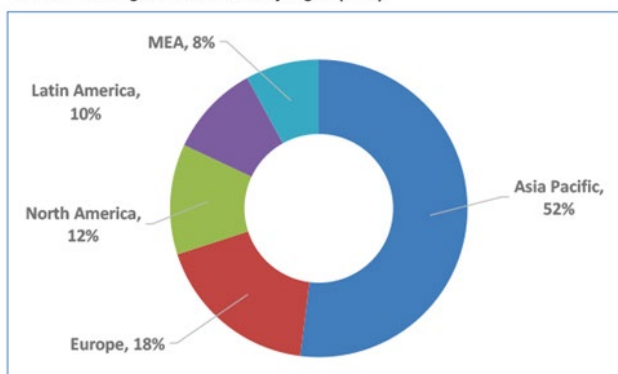


Source: The ChemQuest Group, Inc. estimates.

## REGIONAL DISTRIBUTION

Globally, regional distribution of coatings raw materials generally follows overall production of coatings. Figure 6 depicts total global demand for coatings by region.

FIGURE 6—Coatings Volume Demand by Region (2017).



Source: The ChemQuest Group, Inc. estimates.

## COMPETITIVE LANDSCAPE

The competitive landscape is quite complicated. In general, there are three types of competitors that operate in this market:

The first type of competitor is large, multinational chemical companies serving many industries that compete across coatings raw material categories. Examples include:

- o BASF
- o Celanese
- o Allnex
- o DowDuPont

- o Eastman Chemical
- o Evonik
- o Huntsman
- o Lanxess
- o Momentive
- o W.R. Grace, et al.

Large, multinational chemical companies play a significant role in the coatings raw material market and command a considerable share of the raw material demand.

The scale, degree of integration and broad product portfolios of these competitors are perceived as key advantages.

Merger and acquisition activity among the large, multinational chemical companies has had a significant impact on the coatings raw materials market, and acquisitions are forecast to continue. Private equity firms continue to show an interest in acquiring raw materials suppliers.

The second type consists of multinational product specialists that focus on a limited product offering. These companies tend to specialize in a specific product or chemistry niche(s), and are frequently innovation drivers in the market. Competitors of this type vary widely in size, based upon geographic scope, product breadth and market focus. Examples include:

- o Cathay (pigments)
- o Heubach (pigments)
- o Nubiola (pigments)
- o Alberdingk Boley (W/B resins)
- o Reichhold (resins)
- o Worlee-Chemie (resins)
- o ALTANA (BYK—additives)
- o Troy Corporation (additives)
- o Michelman (additives)

As is the case with multinational chemical companies, mergers and acquisitions are anticipated to continue, impacting the specialist competitors as they are acquired by either larger chemical companies to complement their portfolio, or by other specialists to gain scope and share.

The final type of competitor is the local/regional suppliers. These generally focus on a limited product offering. Examples among the numerous local/regional suppliers:

- o Optimal Chemicals
- o Organik Kimya
- o Silberline Synthopol
- o Specialty Resins
- o OPC Polymers



- o Orion Engineered Carbons
- o Many, many others

While none of the local and regional suppliers have significant share on their own, collectively they are an important source of coatings raw materials. Competitors in this group offer an assortment of value propositions tailored to their customer mix.

In some cases, due to lower overheads, local/regional suppliers are able to provide lower cost alternatives to the major suppliers. In other cases,

they are able to provide unique products or services that allow them to effectively compete. Significant consolidation is anticipated among this group.

growth of perhaps 3–4%. North America is forecast to post somewhat more robust growth of 4–5%, but the exact mix of raw materials consumed within each region will depend on specific end-use market growth.

### Economic Influences

Significant numbers of raw materials used in coatings formulations are either derived directly from oil for their chemical composition, or indirectly as a result of energy derived from oil for their mining and/or processing. The price of oil can be highly volatile and many factors can impact this forecast, driving the price/barrel either up or down.

As a result, oil prices have a significant impact on the price of coatings raw materials. ChemQuest estimates that there is a “pass-through factor” of roughly 50%—i.e., if the price of oil doubles, raw material prices will increase by 50%.



## MARKET TRENDS AND DRIVERS

### End-Use Markets

Demand for coatings raw materials is directly linked to coatings demand. Over the coming five years, demand for coatings is anticipated to grow at a rate of 4–5% annually.

This would result in a 2022 demand for raw materials of approximately 42 million metric tons. Asia Pacific is forecast to experience the greatest volume growth (5–6%) to 2022.

Europe is likewise forecast to experience moderate

A realistic worst-case scenario might see prices of crude oil 50% higher than the forecast, which would increase raw materials for paints and coatings roughly 25%. Over the coming five years, the price of oil is forecast to remain relatively stable, within the range of \$60–\$70/barrel according to the U.S.

Energy Information Administration (EIA). The implication for raw material suppliers and coatings formulators is that the price of the base materials that comprise coatings will likely rise at a rate similar to the rate of inflation to 2022.



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CUSTOMARY  
COATINGS

# *Trends in Interior Wood Coatings*

tracking the shift from solvent  
to waterborne and uv

By: Cynthia Challener, CoatingsTech Contributing Writer

**T**he interior wood coatings market comprises many different sub-segments: trim, windows, doors, cabinetry, furniture, and flooring in residential, commercial, industrial, and institutional settings. Coatings must be formulated to meet the performance expectations for the end-use application, as well as the applicator, who might be a do-it-yourselfer (DIY), professional contractor, or original equipment manufacturer (OEM). As a result, there are many different types of products offered for the coating of interior wood substrates. One commonality across all of the applications, however, is the ongoing shift to formulations with lower volatile organic compound (VOC) and formaldehyde content and lower odor. While some newer coatings are high solids solvent-based systems, the emphasis appears to be placed on waterborne solutions. Regardless of the approach, all new interior wood coatings must also be cost-competitive and

meet performance expectations in terms of ease of application, appearance, and durability.

CoatingsTech canvassed various representatives of coating, resin, and additive manufacturers regarding their perceptions of the current wood coatings market. Some of these insights are shared by Carla Torquato, marketing manager in North America for wood coatings, Anthony Woods, research and development director for wood coatings, and Thomas Palm, regional solutions lab manager in Europe for wood coatings, all with AkzoNobel; Christian Connelly, director of brand management for Benjamin Moore; Sylvia Insogna, North America marketing director at Dow Coating Materials; Martin Vlak, a business director at DSM Coating Resins; Julie Fuell, sales director and Scott Cooley, technology director, both with Reichhold's North American coatings business; Shauna McAuliffe, Americas marketing manager for coatings with Air Products; and Matt

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### **CT: WHAT IS THE CURRENT STATE OF THE MARKET FOR INTERIOR WOOD COATINGS, AND WHAT ARE THE KEY TRENDS/DRIVERS OF DEMAND?**

Insogna, Dow Coating Materials: The interior wood coatings market is very dependent on the housing market and the overall economy. Refinishing and cabinetry activities in North America decreased during and after the recession in 2008 and 2009, and demand is now slowly returning. This market in North America also happens to be more segmented than in other areas of the world, like Europe. This segmentation offers unique challenges when coatings are specifically formulated for factory-finished wood versus interior wood coatings for DIY consumers, versus traditional architectural coatings commonly used by consumers on wood substrates.

Overall, whether applying the coating themselves



or looking for a factory-finished product, consumers generally lean toward a high gloss finish, which solventborne coatings easily and consistently provide. However, in terms of other performance properties, there is great variation based on application. Commonly desired properties for wood trim and cabinetry include bleed-through resistance to ensure that knots and imperfections in the wood substrate are masked, while durability is critical for doors and staircases exposed to significant wear and tear. In addition, industrial and institutional interior wood applications require more durability and resistance versus residential and commercial applications.

From a regulatory perspective, this particular market tends to be very conservative, and regulations remain less strict than those seen in the broader architectural market, particularly for factory-applied coatings. However, the demand for more sustainable products is becoming stronger. As has been observed in the broader architectural coatings market, this trend is slowly starting a corresponding shift toward the use of waterborne coatings in this segment as the technologies available improve and begin to match the performance of solventborne coatings.

Connelly, Benjamin Moore: Market estimates for interior vertical wood finishes are approximately \$200–\$250 million for North America, including paints, primers, stains, clears, and sealers that are applied to trim, doors, and cabinets. Paints and stains are estimated to each make up about one-third of demand, with the remaining third being all others. The key trend drivers are all dependent on consumer demand and evolving regulatory issues, which both play a factor in residential,



commercial, institutional, and industrial applications.

Torquato, AkzoNobel: In North America, there has been increasing interest in sustainable products for interior applications, due in part to the negative publicity regarding formaldehyde in adhesives. Awareness of formaldehyde has increased significantly among our customers and consumers, and this is starting to impact coatings for interior wood. Of course, there are significant differences between regions in North America. In California, the formaldehyde limitations are much more stringent, but we see this approach expanding to nearby states, and ultimately expect there to be a stricter standard for the entire North American region. We are also seeing a global, demographic trend towards individualization, which is reflected in a growing desire for custom colors. Consumers want custom and unique interior furnishings. Instead of being forced into buying off the shelf, they want to create something that is unique to them—which is achieved with custom and semi-custom products, often for multiple finishes.

process used by its suppliers, and the ease with which furniture can be recycled.

#### **CT: WHAT ARE THE MOST COMMON TYPES OF PAINTS/COATINGS USED TODAY FOR INTERIOR WOOD APPLICATIONS, AND WHY ARE THEY PREFERRED?**

Vlak, DSM Coating Resins: There are many different types of coating technologies used for interior wood coatings, depending on the sub-segment, performance requirements, and cost, with the latter factor increasing in importance over the last years. The most common systems include nitrocellulose, solvent-based polyurethanes, acid-cured systems, unsaturated polyesters, ultraviolet (UV)-cured systems, and waterborne acrylics, urethane, and hybrids.

Fuell, Reichhold: The performance of interior wood coatings is enhanced by the various polymers available from resin manufacturers to meet specific application requirements, which explains why numerous different types of paints or coatings are used. Typical chemistries include alkyd for high gloss trim enamel and furniture coatings, urethane for wood floor coatings, and UV resins for factory-applied finishes.

Linares, Evonik: The most popular do-it-yourself wood coatings are typically based on waterborne acrylics or polyurethanes, as well as solventborne oil-modified urethane systems, which are preferred for their relatively good durability, fast dry times, and ease of use. For contractor-applied coatings, two-component acrylics and urethanes have become very popular;



these systems offer some of the best durability when it comes to floor coatings.

Insogna, Dow Coating Materials: The type of coatings selected for an interior wood application also depends on the desired texture and grain of the substrate is to be highlighted or hidden. Solventborne, high gloss coatings are still most common for factory-finished interior wood products, and are also still widely used in DIY applications when showcasing the beauty of the wood is the goal. However, most architectural coatings today can offer an alternative, waterborne solution that can achieve excellent performance properties without being formulated strictly for wood applications. For instance, waterborne binder technologies for semitransparent and solid color wood stains that are designed to weather the elements in exterior applications perform just as well when applied to interior wood substrates. In addition, many clear sealer, elastomeric and semi-flexible, masonry, paint-and-primer, and high gloss binders can impart the desired performance properties consumers are seeking for interior wood coatings. As one example, we see a large demand for interior wood coatings that can withstand bleed-through of the wood itself, which many traditional, waterborne architectural coatings can offer.



**CT: HAVE THERE BEEN ANY NOTICEABLE CHANGES IN RECENT YEARS REGARDING THE TYPES OF PAINTS/COATINGS USED FOR INTERIOR WOOD APPLICATIONS, AND IF SO, WHAT HAS SHIFTED AND WHY?**

Connelly, Benjamin Moore: As mentioned, there has been a shift towards water-based coatings in recent years due to their lower VOC content and reduced odor, which allows for their use in residential environments.

McAuliffe, Air Products: We also have observed a shift to waterborne, UV, and hybrid waterborne/UV systems, particularly for factory-applied interior wood coating applications, as replacements for solvent-based formulations.

Linares, Evonik: An additional trend as VOC regulations have tightened has been the shift to higher solids solventborne wood coatings.

Insogna, Dow Coating Materials: While there have been regulations passed recently to reduce formaldehyde in the manufacture of wood products, no regulation of formaldehyde in coatings has yet been adopted. However, although the formaldehyde is now condensed and scrubbed from the air during wood manufacture,

this VOC is not completely eliminated from the end product. Solventborne coatings rely on oxidative curing, and when applied to formaldehyde-emitting substrates like engineered wood or varnish-coated trim, they end up yellowing over time. Thus, there is strong interest in coatings with yellowing resistance. This interest adds to the pressure on suppliers and formulators to develop effective solutions using new waterborne technologies. As waterborne coating performance characteristics improve and increasingly mirror the desirable qualities that solventborne coatings offer, we expect this trend to continue.

**CT: WHAT HAS BEEN THE IMPACT OF GREEN CERTIFICATIONS ON THE INTERIOR WOOD COATING MARKET?**

Torquato, AkzoNobel: The green movement and indoor air quality has been influencing the interior wood coatings market for quite some time, including the reduction and elimination of formaldehyde. But the rates at which companies are adopting this change vary from region to region. Europe, the Middle East, and Africa (EMEA) have fully adapted to this shift, and China is now moving in that direction due to air quality concerns and rising health costs. Within Europe, various countries also have strict indoor air quality legislation, with the French A+ standard becoming a required performance level for many customers. Furthermore, the Nordic Swan and Ecolabel certifications all have strict limitations on VOCs, free formaldehyde, and other hazardous ingredients.

In the office furniture and hospitality segments, the reliance on green certifications has been in place for several years. Many municipal projects in Europe are scored, and sustainability is one of the drivers. Therefore, a more sustainable product offer can help win contracts and is a key factor for larger building projects. Connelly, Benjamin Moore: In the United States, the impact of green certifications on the interior wood coating market is similar to that on all architectural paints and coatings. There are two main standard and certification organizations: the U.S. Green Building Council (USGBC) and Green Seal. USGBC, through its Leadership in Energy and Environmental Design (LEED) program, certifies wood products that are formaldehyde-free and low-emitting. The latest requirements under LEED v4 cover all wood finishing and preparation products, such as wood treatments, adhesives, and stains. To acquire Green Seal certification, stains and clear wood products must have low VOC content and not contain specific restricted hazardous ingredients, such as carcinogens, mutagens, and reproductive toxins. Green Seal also has packaging requirements that must be followed. McAuliffe, Air Products: Overall, green certifications appear to be preferred, but are not equally important





in all segments yet. Presently they seem to be more critical in office furniture for government buildings/offices/hotels than for applications like kitchen cabinets. However, we expect that in the next 5–10 years, green certified products will become more critical, and the need for formaldehyde-free and lower-VOC emissions will continue to be requirements for most products and segments.

Fuell, Reichhold: Some coatings producers are on the forefront and already formulating entire product lines with low or zero VOCs, while other producers are working to have something ready for the marketplace when regulations require a move in this direction. From our perspective, the majority of North American companies who participate in the interior wood coating market know about GS-11 Green Seal and LEED, but at this point in time haven't really pursued them. Reichhold has developed a portfolio of biobased products, many of which are certified through the U.S. Department of Agriculture's voluntary BioPreferred® labeling program, that provide a green alternative combined with the performance properties of traditional solvent-based systems. Insogna, Dow Coating Materials: The rise of green trends has resulted in several technology developments that help improve the environmental, health, and safety profile of coatings across the entire industry, including interior wood. While regulations on interior wood coatings have remained in favor of solventborne offerings, the opportunities, trends, and regulations further down the value chain and across the broader industry are driving innovation to solve the complex challenges in this market space. As the standard for high performance, sustainable architectural and industrial coatings continues to rise, the interior

wood market will be forced to catch up. There are green certifications offering increased incentives for architects, contractors, and carpenters to take a holistic look at their products and processes and thus ensure coatings are part of the equation. Although coatings regulations may not require waterborne alternatives for interior wood, the increasing pressure from customers interested in sustainable practices and products will only continue to grow.

### **CT: WHAT DO YOU SEE AS THE GREATEST CHALLENGES IN FORMULATING INTERIOR WOOD COATINGS TODAY?**

Vlak, DSM Coating Resins: The industry uses a wide window of different technologies and application methods. This diversity, in combination with the number of substrates, sub-segments, and constant changes in fashion trends, makes it difficult to meet the expected high level of performance for interior wood coatings. Growing regulations and the movement away from certain hazardous raw materials is also a challenge for the coating industry, particularly given the fact that the industry is very price-sensitive and cost increases are not acceptable. Palm, AkzoNobel: One of the big challenges is coping with the increasing and constantly changing environmental legislation demands around the world. This situation has a significant impact on our global customers that have to manufacture products to meet different standards in nearly every country. Examples include IOS-Mat regulations, CLP, REACH, and VOCs in Europe and the United States. China is also now demanding reform of all parts of the coating life cycle. As if this regulatory complexity isn't sufficiently challenging, coatings suppliers are expected to keep the cost of the formulation down and provide the same level of performance.

Currently, the Chinese government is driving the change from solventborne coatings to waterborne coatings due to problems with smog in many of the country's cities. While such regulations are important, the speed of implementation of new technologies required by the government is not only a challenge for us as a coating supplier, but also for the end users with respect to adopting them.

Linares, Evonik: The greatest challenges are to continue to develop more durable coatings that maintain ease of use and still meet VOC requirements.

Cooley, Reichhold: Low-VOC, waterborne coatings, which are the preferred approach to meeting lower VOC requirements, suffer from application issues, such as flow and leveling, foaming, wood grain raise, and adhesion to previously painted substrates. Poor block resistance is also an increasing problem as homeowners move toward darker and richer colors in their decorating

palettes due to the level and type of colorants used. Therefore, as end users move to waterborne systems, it is critical that the selected resin system is coupled with carefully chosen additives for optimum performance and appearance.

McAuliffe, Air Products: Low-VOC waterborne coatings provide the unique challenge of requiring coalescence and film formation in order to provide durable, adhering, and aesthetically pleasing coatings. It is a challenge to develop coatings that perform acceptably and are forgiving under a variety of application conditions. Elimination of brush marks also remains a significant issue for waterborne coating formulators.

Woods, AkzoNobel: Industrial customers are pushing to use lower energy curing methodologies and also components in which no free monomer or formaldehyde emissions occur. Therefore, the big drive has been to create acid-catalyzed crosslinkers or other curing mechanisms that do not emit formaldehyde and preferably are not based on isocyanate technology (due to growing concerns about the potential for low-molecular-weight oligomers within the isocyanate hardener to cause asthma and sensitization). For the most advanced UV technologies, focus has thus shifted to very reactive, hyper-branded oligomers that can be cured using lower energy LED UV technology, which offers much lower energy costs, reduced workplace emissions of ozone, and a significantly prolonged bulb life. There has also been a focus on reducing the levels of free photoinitiator.

For interior furniture, there has been extensive focus on developing suitable waterborne latexes that still give the exceptional clarity and wood warmth of a conventional solventborne system. There is still significant need for further development of interior waterborne resin technologies to allow the combination of a long pot life with the stain and chemical resistance demanded by the kitchen cabinet and public furniture segments. Currently the only technologies are based on waterborne two-component polyurethane products, which have exceptionally short pot lives and are prone to popping and blistering at high film builds.

#### **CT: WHAT ADVANCES IN RESIN/ADDITIVE/ PIGMENT TECHNOLOGIES HAVE BEEN ACHIEVED TO TRY AND ADDRESS THESE CHALLENGES?**

Connelly, Benjamin Moore: There are many newly formulated water-based acrylic products that equal older oil-based paints, but have lower odor and lower VOCs combined with the quick-dry advantages of waterborne paints. There are also many acrylic primers that have been formulated to equal solvent-based



specialty primers in applications requiring specific characteristics, such as tannin blocking, the hiding of pine knots, protection from fire and smoke damage, etc.

Cooley, Reichhold: Resin manufacturers are aware of the challenges when using low-VOC waterborne coatings and commonly work with additive suppliers to find the best combination of materials to combat the issues. In many cases, the most effective path is to develop a waterborne system that performs like a solventborne system.

Linares, Evonik: Waterborne resins have continued to improve in durability. Alternatively, some solventborne resin manufacturers have effectively substituted VOC-exempt substances like octamethylcyclotetrasiloxane (D4) in place of mineral spirits. The development of specialized matting agents based on fumed silica technology and utilizing unique treatments have also helped formulators to achieve low gloss, clear wood coatings while maintaining a useable viscosity.

Vlak, DSM Coating Resins: In addition to waterborne and UV technologies, recently researchers have begun investigating the use of powder coatings in order to meet VOC regulations.

#### **CT: WHAT ARE THE REMAINING LIMITATIONS OF CURRENT TECHNOLOGIES? IS THERE ANYTHING IN DEVELOPMENT TO TACKLE THESE ISSUES THAT YOU CAN DISCUSS?**

Vlak, DSM Coating Resins: All interior wood coating technologies have their pros and cons. There is no single system or technology that is able to meet all



requirements set by the different sub-segments. However, R&D programs that are focused on sustainable solutions, including UV-cured and waterborne systems, tend to emphasize improvement of surface hardness, film transparency, durability, and chemical resistance in low-VOC formulations with a low total cost of ownership and that are easy to formulate and apply.

**Woods, AkzoNobel:** In general, waterborne resins for interior wood coatings all suffer from lower clarity than solventborne alternatives, meaning that narrower application windows are required and performance can suffer. It is expected that the field of one- and two-component waterborne and waterborne UV formulations, particularly in deep colors, will see significant advances over the next few years. LED curing also requires advances in both the bulb technology itself and the resin and photoinitiator chemistries. Current technology makes it difficult to formulate full LED topcoats due to the complications of oxygen inhibition and the fact that conventional photoinitiators are not effective with the narrower wavelengths of UV LED bulbs. In many cases, changes in technology need to go hand in hand with new application equipment development, which requires a move towards a three-way partnership between the customer, coating supplier, and machine producer in order to truly tune a system to a customer's specific needs.

**Linares, Evonik:** One remaining limitation in the wood coatings market is getting a waterborne system to behave exactly like a solventborne system. Waterborne

systems cause problems like "grain raise" as the water is absorbed into the wood, leading to the need for extra sanding between coats and the application of additional coating layers of coating. In addition, on wood floors, waterborne systems tend to cause what is called panellization, a phenomenon that occurs when the coating between some floor boards breaks, but other groups of boards remain stuck together, resulting in large, unsightly, very noticeable gaps in the floor.

### **CT: WHAT ARE YOUR EXPECTATIONS FOR INTERIOR WOOD COATINGS IN THE FUTURE— BOTH SHORT TERM AND LONG TERM?**

**Linares, Evonik:** Waterborne and UV wood coatings will continue to grow in popularity due to the prevalence of lower-VOC regulations. In addition, other chemistries, such as polyaspartic systems and alternative, efficient, durable, high solids (low-VOC) solutions will continue to enter the wood coatings market.

**Cooley, Reichhold:** The market will continue to push for the best balance of environmental friendliness, performance, and cost, and we believe that alkyd latex technology has a key role to play in this space.

**McAuliffe, Air Products:** Continued improvements in technologies will lead to more durable, easy to use/apply, lower-VOC, and more sustainable coatings that will become more cost-competitive over time. Long term, we can also expect more water-based fine finishes in the market.



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# CONSTRUCTION CHEMICALS

By: Willie Kay

PAST

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**M**aterials that enhance construction which I list below in table I. I have expanded this list to include what I define as building products. Enhance means to speed up construction. To add value through long life, protecting from the environment or operating conditions. It can also mean to restore durability when the construction process was inadequate. Material technology for these products include cement, modified cements resins, both aqueous dispersions as well as epoxy, polyurethane and so on. The chemical base is large and in Asia to some degree unregulated.

Table I

Construction Chemicals	Building Products
Admixtures / Additives	Spray Plasters
Grouts	Self Levelling Floors
Coating, Flooring	Floors
Sealants, Sealing	Tile Adhesives
Repair, Injection	Bonding Agents
Protective Materials	Latex Paints

If I look back when I started in this industry in 1966 admixtures were virtually unknown, the only admixture I used was air entrainment for frost resistance as an experiment on a concrete farm access road. Pre-packed repairs were unknown and epoxy and polyester resins were in their infancy. Joint sealants developed in World War II for sealing aircraft cockpits these were originally based on polysulphide though polyurethanes were available.

As construction technology methods of construction advance demands were made on our industry. Early technologies were in concrete repair; high early strength concretes and finishes for precast. At the same time industry – food, engines and pharmaceutical were driving the resin flooring market.



Working for Taylor Woodrow in their materials research lab started my knowledge of how small amounts of chemical materials were changing our industry.

The nuclear power industry need “hard” resin floors that could be decontaminated, joint sealants to allow cladding to move yet be watertight all fuelled this technology. In the late 60s and early 70s many large contractors had construction chemical divisions. Cementation led by Peter Hewlett, Wimpey Labs with L. Tabor and Laings with S.B.D to name a few. Concrete repair was something I became involved in with our team developing injection materials, protective coating, which then led to industrial flooring. Roger Browne who was head of Research for Taylor Woodrow Research and Laurence McCurrah head of materials were true pioneers and inspired many developments that are now taken for granted.

## DEVELOPMENT POLYESTER CONCRETE

Admixture Technology was also advancing with the introduction of superplasticiser. One of the first commercial materials developed in 1968 by SKW was Melment 10. Although its launch at the UK CaCA in the early 70s was a slight disaster it proved on site its capability. At Kishorne where we were building concrete platform for the North Sea Melment was used on the Precast units used in construction.



Built by Howard Doris for Chevron UK from 1975-1977. The structure stands on a base slab of 140 metres diameter and has a displacement of 600,000 tonnes. The platform I understand is still operational. At the same time admixtures and protective coatings were used at the Ardyne Point site with excellent results. Other construction chemical developments running simultaneously were retarding admixtures for slip form, high performance coating for curing and waterproofing and resin anchors and seals. The most significant development was the move into polymer modified cements mortars. Prior to this project most repairs were made in epoxy mortars or pre-packed cement grouting but due to the size of slip form and rate of climb new technologies were required.

The first generation materials were very basic in terms of properties and needed skilful application and curing. Over the next 10 years numerous developments were made to include rapid set, high strength, ultra high build and many more variations. Moving repair mortar into the 80s and 90s concrete admixture technology advanced rapidly – slump retention and high fluidity concretes became the norm and speeded up construction.

In Singapore huge basement rafts were cast in large non stop concrete pours. At the same time precast technology advanced and with the Naphthalene Technology a twenty four hour cycle time was easily achieved.

Admixture Technology has continued to advance and self compacting concrete was an outcome of this starting in Japan in 1990.



In the 21st century construction chemicals opened new ways of how we build. In precast insitu concrete, repair, injection and protective coatings all changed due to the advancement of new chemistry and technology.

Injection for sealing leaks and cracks has a range of materials that are safer in terms of toxicity and have absolutely variable properties. The picture shows polyurethane resins in various forms.



Foam



Rigid



Elastic

With variable setting time from 5 seconds to 30 minutes problems that in the past could not be solved are now fixable. However certain people skills and equipment are equally important to achieved success.

Resin Injection in repair has expanded its role to a paint today where earthquake and bomb repair it is part of the repair. However it is critical that correct application of these materials is followed. Injection of cracks to fill and rebond is dependant on three key issues; the viscosity of the given resin, the

injection pressure and the time taken to pump resin into the cracks. In many instances people do not understand this relationship and many cracks are not injected correctly. In earthquake repair this can have disastrous results should secondary tremors occur.

The picture below show epoxy injection to repair bomb damaged cracks concret Precast concrete mould turn around was revolutionised by PCE Technology and



now with tunnel segments 3 casts per day are in use – example Abu Dhabi



The uses of blended cements to reduce heat and increase durability have been developing for many years. This has allowed the used of high strength highly fluid concrete for large basements concrete pours of over 10,000 m3 are not unusual and yet compliant with

temperature controls both peak and differential.

Protecting concrete from chemical attack whether by chloride, carbonisation or acid has led to many developments. The list is endless but I will briefly mention two areas.

In Singapore we coat the extrados of our tunnel segments to increase durability. Initially following Hong Kong we used a bituminous system which was replaced by a cold tar system. With increased knowledge we became aware of the toxic effects of tars and solvents and now the segments are coated with solvent free water based epoxy. The idea of this coating is to penetrate and stop ingress of any deleterious materials.

The waste water industry has been under pressure to enclose sewerage plants to limit the smell in urban areas. However when waste is enclosed we then encourage biogenic acid gas which accelerates corrosion.

Biogenic corrosion is very dangerous to concrete as the degradation of the H<sub>2</sub>S into acid also has an expansive action thus accelerating the deterioration and quickly leading to failure. The pictures below show the horrific effect of this acid attack.



Conventional epoxy and similar materials cannot resist this acid attack at a pH of 1 or less. This led to a new development of breathable high build coating based on polymer silicate technology. The acid resistance is excellent and it also is resistant to high temperature. Due to its breathability application to below ground concrete is practical.

There are other solutions but sheet repair systems have their practical application difficulties.

## WHAT IS THE FUTURE?

We will continue to be subject to more and more pressure to stop harming our environment. In concrete we are on the verge of launching a “New” concrete free of Portland cement. Using by products from the steel and power generation industry which is olden days were just dumped as fill we can produce sustainable concrete.

In Chemical Technology REACH a European legislation has force companies to disclose what is in their products.



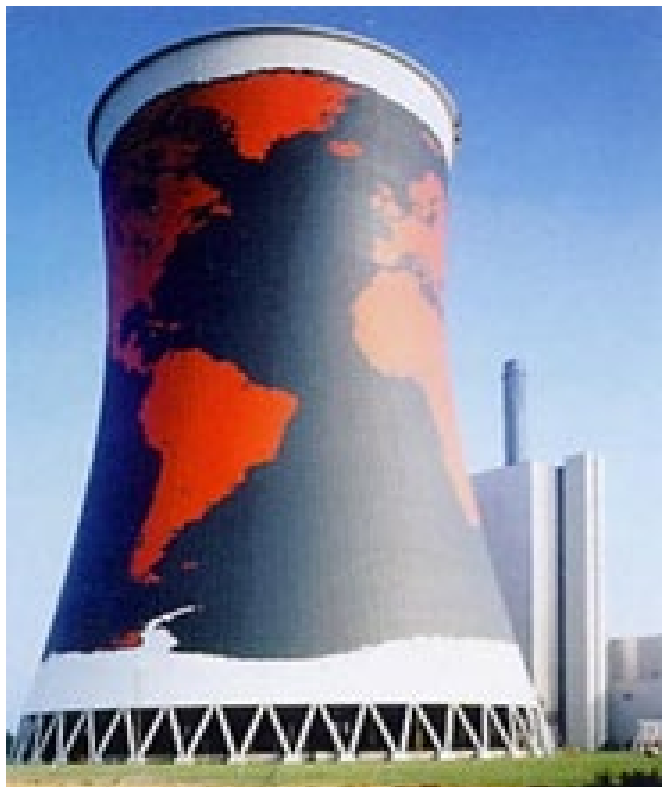
This has led to many products being withdrawn due to toxicity. Many people are unaware that certain chemicals can release obnoxious or harmful compounds into the environment this is especially true of some resin floors. Recyclability will I am sure be part of design so material selection will be checked for suitability. We have already built in Singapore office with 100% recycled aggregate and codes will have to change to allow progress.

In Singapore the government is funding research on recycling of aggregates and will have a world leading position.



In the concrete industry we are sure will see more and more precast production. The advantages of architectural precast is in the thin shapes and curved sections which allow designers to produce aesthetically pleasing structures.

In the future will admixture technology continuing we will see ultra high strength self compacting concrete being the norm self curing and fibre advancements will lead to minimal repair and thinner sections. In Malaysia



a bridge has been built using G200 extruded concrete. In Germany "acid resistant" concrete is being used to build cooling towers for power stations. Historically these were coated but now the durability is from within the concrete.



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# Hot Melt Adhesives for Low Surface Energy Substrates

By: Edward M. Petrie

Low energy polymeric surfaces, such as polyolefins, fluorocarbons, acetals, and polystyrene, are notoriously difficult to bond with adhesives. Wetting becomes a challenge when using conventional adhesives to bond these low surface energy (LSE) substrates.

Traditionally, LSE plastics have been primed or pretreated with flame, corona, or plasma to raise the surface energy so that they can be bonded with conventional adhesives. While finding solutions for better bonding in these substrates, the joint interface becomes the overriding concern.

Thus, in order to find bonding solutions for LSE substrates; first ensure that you have a clear understanding of LSE, difficulties associated with them and hence their respective adhesive bonding requirements.

To ease your problems! We have come up with a solution - Hot melt adhesives for bonding LSE substrates. Certain hot melt adhesives are capable of offering moderate

bond strengths to these substrates without expensive and time consuming substrate pre-treatment. For this reason, they are primarily used in:

- Packaging
- Automotive
- Component assembly
- Medical and electronic assembly, and
- Textiles

Check out the strengths and weaknesses of using hot melt adhesives for bonding LSE substrates from the table below:

Advantages	Disadvantages
<ul style="list-style-type: none"><li>• Forms bonds rapidly (high assembly speeds and short fixturing time)</li><li>• Clean, easy handling</li><li>• Little waste</li><li>• Easy disassembly and repair of joints</li><li>• No problems with solvent or solvent vapors</li><li>• Good storage life and simpler storage requirements</li><li>• Precise bond line control can be achieved through temperature and pressure</li><li>• Equipment available for automated assembly</li><li>• Easily maintained equipment</li><li>• Minimal floor space required</li></ul>	<ul style="list-style-type: none"><li>• Bonds lose strength at elevated temperatures</li><li>• Some bonds may exhibit creep under stress and moderate temperatures</li><li>• Adhesive may be sensitive to moisture and chemicals</li><li>• Some substrates may be sensitive to heat of application</li><li>• Hot melt used in bulk form (heated tanks) may be subject to oxidation and require a nitrogen blanket</li></ul>

## HOT MELT BASE POLYMERS FOR FORMULATING ADHESIVES FOR LSE SUBSTRATES

The base polymer provides the main framework for the hot melt adhesive's overall physical properties.

The table below summarizes the types of hot melt adhesive polymers that have generally been used in the manufacture of plastic products.

Hot Melt Base Polymer	Formulation Characteristics	Variations
Ethylene vinyl acetate (EVA)	<ul style="list-style-type: none"> <li>Most frequently used base polymer</li> <li>Very versatile adhesives</li> <li>Type and amount of wax and resin can control set time and tack</li> <li>Filler can be added in some cases</li> </ul>	Various melt indices and vinyl acetate concentrations
Styrene block copolymer (SBC)	<ul style="list-style-type: none"> <li>Low temperature flexibility</li> <li>High heat resistance</li> <li>Used for PSAs and non-PSAs</li> <li>Fast set</li> </ul>	Styrene-butadiene-styrene, styrene-isoprene-styrene, styrene-ethylene-butylene-styrene, blends of these, and blends with other polymers
Polyolefin (PO)	<ul style="list-style-type: none"> <li>Good, general purpose adhesives</li> <li>Moderate temperature resistance</li> <li>Well suited for porous substrates but relatively rigid</li> <li>Good thermal stability (color, gel)</li> <li>Good resistance to acid, grease, oil</li> </ul>	Polyethylene and polypropylene with various molecular weights and branching, blends with other polymers
Amorphous polyolefin (APAO)	<ul style="list-style-type: none"> <li>Low cost with good acid and fuel resistance</li> <li>Moderate heat resistance</li> <li>Soft, tacky, and flexible</li> <li>Long open times and good adhesion</li> </ul>	Amorphous / crystalline concentration, blends with other polymers
Metallocene polyolefin (MPO)	<ul style="list-style-type: none"> <li>Wider temperature range than EVA</li> <li>Light color, clear, and odorless</li> <li>Good thermal stability</li> <li>Fast set and low density</li> </ul>	Metallocene catalyzed polyethylene and metallocene catalyzed polypropylene

## ETHYLENE VINYL ACETATE

The first copolymer to be used as a base for hot melt adhesives was ethylene vinyl acetate (EVA).

- EVA resins are highly flexible products, compatible with many other polymers and additives, and easy to process.
- They have high cohesive strength and excellent adhesion to a wide range of substrates.
- EVA copolymers can be used in soft, permanently tacky pressure sensitive adhesives or in tough, rigid hot melt compositions used for semi-structural applications.

The table below identifies the major advantages and limitations associated with EVA based hot melt adhesives.

Advantages	Disadvantages
<ul style="list-style-type: none"> <li>Broad formulating latitude necessary for many different applications</li> <li>Adhesion to a wide variety of substrates</li> <li>Quick setting</li> <li>Retention of properties at low temperatures</li> <li>Pressure sensitive systems can be formulated</li> <li>Considered to be safe and non-toxic</li> <li>Relatively low cost</li> <li>Many formulations have FDA approval</li> </ul>	<ul style="list-style-type: none"> <li>Cold flow (creep); temperature resistance only to about 40°C</li> <li>Attacked by some greases, oils, and solvents</li> <li>High viscosity needed for maximum performance</li> <li>The pressure sensitive nature of EVA is generally inferior to other polymers</li> <li>EVA have a tendency to gel or char when subjected to typical application temperatures such as 150°-175°C</li> <li>Cannot easily be formulated as a multi-purpose adhesive</li> </ul>

## EVA RESINS IN HOT MELT ADHESIVE FORMULATIONS

Generally, for hot melt adhesives EVA resins with vinyl acetate concentration of 18-40% are utilized. The vinyl acetate content can be a significant parameter in varying the properties of the adhesive.

The higher vinyl acetate copolymers provide better adhesion to polar substrates such as: vinyl, aluminum, and steel, while the lower vinyl acetate copolymers are often used for bonding low energy surfaces

The materials with high vinyl acetate concentration exhibit reduced crystallinity and increased polarity. At about 50% vinyl acetate content, all crystallinity is lost. Recrystallization rate or setting speed is greatly influenced by the choice of specific EVA resin.

Melt index (MI) or melt viscosity is another important criterion in choosing the correct EVA resins for adhesive formulations.

- Low melt index EVA grades provide high viscosity, strength, and hot tack.
- In contrast, high MI grades enable higher polymer content and low application viscosities. Mid-range MI grades provide formulation flexibility.

Review the table given below for understanding: a starting formulation for a general purpose, EVA hot melt adhesive formulation for bonding difficult substrates (e.g., polyethylene and polypropylene).

Components	Parts by Weight
Ethylene vinyl acetate copolymer resin (28% vinyl acetate, melt index of 25)	50
Microcrystalline wax (190°F to 195°F melting point)	30
Tackifier (Zonarez B-125, Talas)	20
Properties	Value
Brookfield viscosity, cps	
<ul style="list-style-type: none"> <li>@ 350°F</li> <li>@ 390°F</li> </ul>	<ul style="list-style-type: none"> <li>11870</li> <li>6760</li> </ul>
Sealing temperature, °F	177
Adhesion, oz / inch:	
<ul style="list-style-type: none"> <li>Kraft to Kraft</li> <li>Kraft to polyethylene</li> <li>Kraft to aluminum foil</li> </ul>	<ul style="list-style-type: none"> <li>33</li> <li>33</li> <li>39</li> </ul>

The adhesive is stable at high temperatures. It will adhere to most packaging foils and films, including polypropylene. It has increased tackiness and heat sealable properties.



## EVA COPOLYMER RESINS FOR PACKAGING APPLICATIONS

Packaging applications are a primary market for hot-melt adhesives that are based predominantly on EVA copolymer resins. A tackified EVA is necessary for bonding plastic substrates that have a relatively low surface energy.

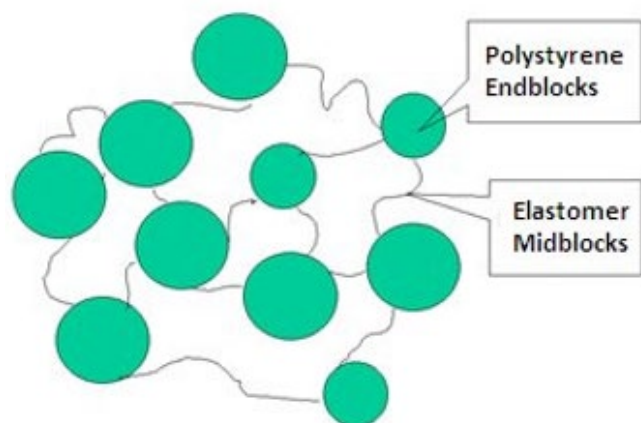
A starting formulation for a low cost, general purpose EVA hot melt formulation for bonding plastic substrates is given in the table below, have a look!

Components	Parts by Weight
EVA polymer (Elvax® 250, Dupont)	35.0
EVA polymer (Elvax® 260, Dupont)	10.0
Tackifier – Polyterpene resin, 115°C m.p.	30.0
Filler – Calcium carbonate (15 µm)	24.8
Antioxidant - Butylhydroxytoluene	0.2
Properties	Value
Viscosity at 149°C, cps	~1500 - 2500
Melting temperature by DSC, °C	~150

Adhesive application temperature is critically important in bonding LSE substrates. This is because it directly affects how long the hot melt remains “open” during the manufacturing process. If the hot melt pot is not hot enough, open time will be too short, and the substrates will fail to adhere properly. If it’s too hot the adhesive may have a detrimental effect on temperature sensitive substrates, and the adhesive’s viscosity will be too thin creating excessive seepage.

## STYRENE BUTADIENE COPOLYMERS

Adhesives that are based on styrene butadiene block copolymers (SBCs) are both useful and unusual. These polymers consist of a polystyrene end-block with mid-

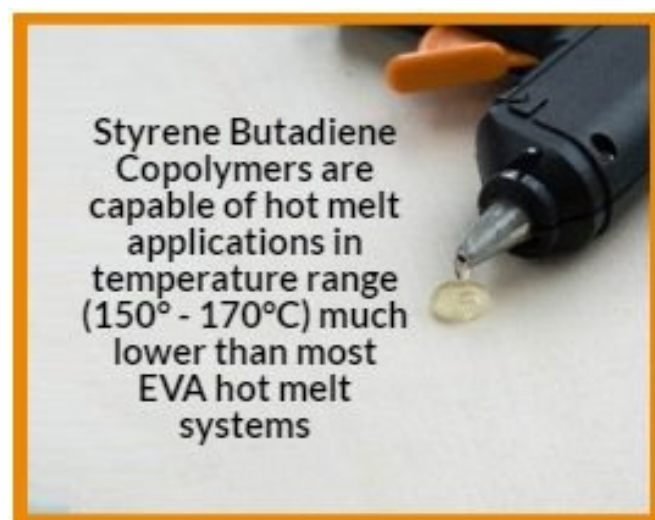


Representation of an SBC Structure in Bulk

blocks consisting primarily of isoprene and butadiene. The mid-blocks are non-polar and result in relatively low surface energies for good bond strength to LSE substrates.

## SBC FOR ADHESIVE FORMULATION

As a hot melt adhesive, the low melt viscosity and fast strength development are significant benefits to end-users. Certain SBC polymers are capable of hot melt application temperature in the 150° - 170°C range. This is much lower than most EVA hot melt systems.



Four types of SBC resins are commonly available for adhesive formulation:

- Styrene-Butadiene-Styrene (SBS)
- Styrene-Isoprene-Styrene (SIS)
- Styrene-Ethylene-Butadiene-Styrene (SEBS), the hydrogenated form of SBS
- Styrene-Ethylene-Propylene-Styrene (SEPS), the hydrogenated form of SIS

Key properties and applications of SBC resins:

- Of these, SBS offers the lowest cost and high levels of cohesive strength.
- In general, the saturated block copolymers (SEBS and SEPS) are used where long term UV, thermo-oxidative, or chemical stability is critical, or where compatibility with other low polarity ingredients is required.
- SIS copolymers are generally used in pressure sensitive adhesives, where high tack is necessary and cohesive strength is LSEs important.

One of the most interesting and valuable properties of SBCs is that they offer a physical form of crosslinking, which greatly broadens their applicability. The thermoplastic polystyrene end-segments on the molecule form “pseudo-crosslinking” sites. This results in a superior resistance to creep while maintaining a very high cohesive strength and degree of elongation. Due

to the pseudo-crosslinking mechanism associated with SBCs and the glass transition temperatures associated with each phase, SBCs provide very good properties at both high and low temperatures.

SBC adhesive manufacturers can tailor properties to match a wide range of applications. Also, SBCs have many other attributes that are very beneficial, besides being:

- Strong
- Highly extendable
- Cost effective
- Processable, and
- Easy to formulate

The table below lists some advantages and disadvantages of SBC based hot melt adhesives:

Advantages	Disadvantages
<ul style="list-style-type: none"> <li>• Aggressive adhesion to most substrates including plastics</li> <li>• Precise molecules with a wide range of structure (results in great formulation latitude)</li> <li>• Clean and non-toxic – many formulations are FDA approved</li> <li>• Low melt viscosity</li> <li>• Formulations can be clear</li> <li>• Cohesive strength adjustable with di-block content</li> <li>• Resistant to water, and most acids and bases</li> </ul>	<ul style="list-style-type: none"> <li>• Poor storage stability when left in the adhesive applicator for an extended period of time</li> <li>• Creep resistance, although better than EVA, was still lacking</li> <li>• When end-block reinforcing resins are used to improve the heat resistance, the adhesion to LSE substrates suffers</li> </ul>

Also review the pressure sensitive hot melt adhesive formulation based on styrene-isoprene-styrene. It has excellent adhesion to oriented film substrates and good melt stability. The adhesive has relatively good bond strength (peel and shear) even after aging. The color and color retention after aging is better than other comparative adhesives.

Components	Parts by Weight
Styrene-isoprene-styrene copolymer (15% styrene, 19% diblock)	35
Tackifier (Wingtack® Plus, Cray Valley)	44
Tackifier (Norsolene S155, Cray Valley)	9
Calcium carbonate	5
Titanium dioxide	1
Naphthenic oil (Nyflex 222, Nynas)	5
Antioxidant	1

Styrene block copolymer type pressure sensitive adhesives can be applied either by hot melt application or solvent solution. The formulation given above is for a hot melt system. However, with the appropriate solvents (MEK, toluene) a solution coating can be provided.

## POLYOLEFINS

Polyolefin base polymers are often used to bond LSE substrates by the principle of surface energy. More precisely, the basic surface energies of the adhesive systems and the bonded substrate are similar.

These hot melt adhesives are based primarily on:

- Low density polyethylene (LDPE)
- Attactic poly- $\alpha$  olefin (APAO), and
- Metallocene catalyzed polyolefin

Due to their low crystallinity, adhesives made from these polyolefin systems generally show good compatibility and long-term thermal aging performance with plasticizing and tackifying agents commonly used in hot melt formulations; however,

- These polyolefin species tend to develop properties only slowly after application that can make them unsuitable for certain porous substrates due to excessive penetration.
- The long open time (especially with APAO polymers) results in enhanced wetting and high bond strength to LSE substrates.

Amorphous polyolefins formed by the copolymerization of alpha-olefins have also been found to be useful for the production of hot melt adhesives. APAO materials incorporate 1-3 monomers to achieve the desired properties.

The property differences exhibited by the two monomers are summarized in table below:

Monomer	Characteristics
Propylene	<ul style="list-style-type: none"> <li>• Produces the greatest softening point</li> <li>• Cost is lowest</li> </ul>
1-Butene	<ul style="list-style-type: none"> <li>• Long open time</li> <li>• High crystallinity</li> <li>• High strength</li> </ul>

APAO hot melt adhesives generally require no formulation to exhibit good adhesive properties. Although, they have lower adhesion properties than EVA based adhesives; they are known to have better thermal stabilities.

## SEBS & APO BLEND FOR IMPROVED HOT MELT ADHESIVE

A blend of amorphous polyolefin and styrene ethylene butadiene styrene (SEBS) copolymer was found to provide thermally stable and a more processable hot melt adhesive. This could be used as alternatives for EVA and SBC adhesives<sup>1</sup>.

SEBS copolymers as noted above have saturated rubber mid-blocks. And when formulated with saturated resins, plasticizers, and stabilizers; SEBS copolymers obtain a good balance of adhesive properties as well as resistance to degradation by oxidation or UV light. When SEBS is added to an amorphous polyolefin, the toughness of the hot-melt adhesive is enhanced, and



the viscosity is also increased.

SEBS addition to APO in a hot melt adhesive improves T-peel strength, check out from the table below:

Components	Parts by Weight	
	Formulation A	Formulation B
SEBS Elastomer (Kraton™ G-1652, Kraton)	20	10
Tackifier (Eastotac™ H-130E resin, Eastman)	60	60
Mineral oil	20	20
Antioxidant (Irganox® 1010, Ciba (BASF) -Geigy)	0.15	0.15
Amorphous polyolefin (Eastoflex™ P1023 APP, Eastman)	0	10
Properties	Value	
T- peel adhesion, pli	0.05	0.11
Creep resistance, 12 specimens, 8 hrs at 38°C	All 12 passed	All 12 passed

## SEBS Addition to APO in a Hot Melt Adhesive Improves T-peel Strength2

Further development of olefinic polymers has been based on metallocene catalyst technology. This technology results in long chain branching and improved elastomeric and processability characteristics.

Metallocene catalysts offer unique advantages versus conventional catalysts for the production of polyolefin resins. They allow producing consistent, controllable molecular structures that can be designed to:

- Improve toughness and impact resistance
- Provide low off-taste and odor
- Allow tailoring of processing characteristics to fit the conversion process
- Eliminate non-targeted molecular weight species in resins

- Offer a greater control of molecular weight distribution (MWD)

Adhesives formulated using this technology provide:

- Broad temperature sprayability (good balance of low- and high-temperature sprayability), and
- Excellent adhesion with thermal and viscosity stability

The narrow molecular weight ranges provide hot melt adhesives with fast setting times, low-odor, low-color, and clean running characteristics.

Review the table below for formulating water-white metallocene catalyzed polyolefin hot melt adhesive. It will provide:

- Good adhesion to hard to bond plastic substrates such

as PP, PS, PET, PC, PMMA, etc. as well as

- Excellent adhesion to wood, aluminum, and various other metals

The adhesive has good resistance to many chemicals and oils.

Components	Parts by Weight
Metallocene polypropylene (Licocene® PP-1302, Clariant)	25
Hydrocarbon tackifier (Regalite™ 9100, Eastman Chemical)	35
Amorphous polyalpha-olefin (Vestoplast® 828, Evonik)	40

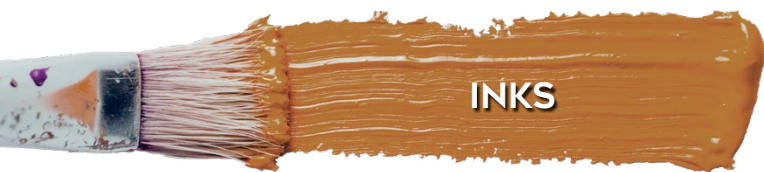
## POLYOLEFIN ELASTOMER BASED HOT MELT ADHESIVES

Polyolefin elastomer based hot melt adhesives have good thermal stability (minimal color changes and reduced gel formation on standing in the melter). Melt viscosities can have a wide range due to molecular design and additives.

The formulations in table below describe hot melt adhesives for general purpose bonding of packaging, non-woven hygienic products, and graphic arts. These formulations offer a wider service temperature range than EVA based hot melt adhesives.

Components	Parts by Weight	
	Conventional Application Temperature	Low Application Temperature
Polyolefin elastomer resin (Affinity™ GA 1900, Dow Chemical)	---	29.5
Polyolefin elastomer resins (Affinity™ GA 1950, Dow Chemical)	34.5	---
Hydrocarbon plasticizer (Eastotac™ H-130R, Eastman Chemical)	35.0	35.0
Wax (Parafint® H2, Sasol Wax Americas, Inc.)	30.0	35.0
Antioxidant (Irganox® 1010, BASF)	0.5	0.5
Property	Value	
Application temperature, °C	177	121
Peel adhesion failure temperature (PAFT), °C	70	72
Shear adhesion failure temperature (SAFT), °C	98	87
Onset of fiber (virgin corrugated) tear, °C	-46	-29
Gardner color after 200 hrs at application temperature	13	9

These formulations offer a wider service temperature range than EVA based hot melt adhesives.



## A FACILE APPROACH TO A SILVER CONDUCTIVE INK WITH HIGH PERFORMANCE FOR MACROELECTRONICS

By: Yu Tao, Yuxiao Tao, Biaobing Wang, Liuyang Wang and Yanlong Tai

### ABSTRACT

An unusual kind of transparent and high-efficiency organic silver conductive ink (OSC ink) was synthesized with silver acetate as silver carrier, ethanolamine as additive, and different kinds of aldehyde-based materials as reduction agents and was characterized by using a thermogravimetric analyzer, X-ray diffraction, a scanning electron microscope, and a four-point probe. The results show that different reduction agents all have an important influence on the conductive properties of the ink through a series of complex chemical reactions, and especially when formic acid or dimethylformamide was used as the reduction agent and sintered at 120°C for 30 s, the resistivity can be lowered to 6 to 9  $\mu\Omega\cdot\text{cm}$ . Furthermore, formula mechanism, conductive properties, temperature, and dynamic fatigue properties were investigated systematically, and the feasibility of the OSC ink was also verified through the preparation of an antenna pattern.

### BACKGROUND

Most research efforts in macroelectronics have opened the door for the manufacture of lightweight, flexible, cost-effective electronic devices that are beyond the conventional silicon-based devices, including flexible displays [1], flexible and conformal antenna arrays [2], electronic solar cell arrays [3], radio-frequency

identification tags [4], flexible batteries [5], electronic circuits fabricated in clothing [6], and biomedical devices [7]. Usually, most of them require electrical contacts. Up to now, various materials such as conjugated poly-mers, graphene, carbon nanotubes, and metals have been used for the preparation of electrodes and conductive patterns using solution processing methods [8-11]. Specifically, metal nanoparticle inks have attracted more and more attention due to their high conductivity and thermal stability after having been sintered [12-14].

However, metallic nanoparticle inks often require high annealing temperatures ( $>150^\circ\text{C}$ ) to decompose stabilizing agents and other polymeric additives that inhibit electrical conductivity, with the high annealing temperature limiting the choice of substrate. Besides, they still cannot completely avoid the condensation and agglomeration of nanoparticles, especially after long term storage. The agglomerated particles may damage the equipment and influence the printing quality. During preparation, a high-speed centrifuge or vacuum dryer must be used to take nanometal particles out, so these inks cannot be produced on a large scale. All of these will cause a higher production cost [15-18].

There is no surprise to the fact that organic silver conductive ink (OSC ink) has received increasing attention as a potentially much lower cost alternative [19-21].



This kind of ink mainly consists of a silver carrier, weak reduction agent, solvent, and additives, and a continuous conductive silver track can be fabricated during the sintering process. This strategy can compensate for the lack of conductive metal nanoink and thus becomes the development direction of conductive ink for macroelectronics [22-25].

In our previous research, the relationship between different kinds of amines and ink properties was investigated systematically. The addition of different amines not only increased the solid content of the conductive ink but also decreased the sintering temperature by complexation [26-28].

Here, based on the previous results, the formula of the conductive ink will be further optimized using silver acetate as silver carrier, ethanolamine as additive, and different kinds of organic aldehyde as reduction agents, such as ethylene glycol, acetaldehyde, formic acid, dimethylformamide, and glucose. Furthermore, the formula mechanism, conductive properties, temperature, dynamic fatigue properties, and feasibility verification of the OSC ink through the preparation of an antenna pattern were also investigated systematically [29-31].

## METHODS MATERIALS

Silver acetate was obtained from Shanghai Lingfeng Chemical Reagent Co., Ltd. (Shanghai, China). Polydimethylsiloxane (PDMS) including base and curing agents was obtained from Dow Corning Co. (Midland, MI, USA; SYLGARD 184 silicone elastomer). Polyester film ( $0.1 \pm 0.02$  mm) came from Shanghai Weifen Industry Co., Ltd (Shanghai, China). Ethylene glycol, acetaldehyde, formic acid, dimethylformamide, glucose, ethyl alcohol, and other solvents were of analytical grade and used without further purification. Deionized water was used in all experimental processes.

## SYNTHESIS OF OSC INK

For the preparation of conductive ink (1 g), silver acetate (0.32 g; which means if all silver ions are reduced to elemental silver, the content of elemental silver is 20 wt.%) and ethanolamine (0.2 g) were added to ethanol (0.13 g) and different reduction agents (0.35 g; ethylene glycol, acetaldehyde, formic acid, dimethylformamide, or glucose, etc.) under vigorous stirring until a transparent solution was obtained.

## PREPARATION OF ANTENNA PATTERN

For the preparation of the PDMS pattern as template, polyethylene terephthalate (PET) was adhered to a sheet glass using both side tapes, and 3-g PDMS (base/curing

agent is 15/1) was dropped on the center of the PET film. Then, after spin coating (800 rpm), baking at 80°C for 3 h, and laser etching, the desired PDMS pattern as template can be fabricated with the conductive track (a thickness of 200  $\mu\text{m}$  and a width of 200  $\mu\text{m}$ ).

For the preparation of the antenna pattern, the synthesized OSC ink was dropped into the trench of the PDMS template track using a syringe, and the ink will flow to all of the track spontaneously until full; then, it will be sintered at 120°C for 30 s. Finally, the PDMS template can be peeled off easily by forceps, and the desired antenna pattern was achieved [32].

## INSTRUMENTATION

OSC ink was characterized by using a Ubbelohde viscometer (CN60M, Zxyd Technology Co., Ltd., Beijing, China); a surface tension instrument (A101, Kino Industry Co., Ltd, New York, USA); X-ray diffraction (XRD; max 2550 PC, Rigaku-D, Rigaku Corporation, Tokyo, Japan) using Cu K $\alpha$  radiation; scanning electron microscopy (SEM; S-360, Cambridge Instruments Ltd., Cambridge, England) operated at 10 kV; thermogravimetric analysis (TGA; QS-500, TA Instruments Inc., New Castle, DE, USA) with a heating rate of 5°C·min<sup>-1</sup> in a nitrogen atmosphere; a four-point probe equipped with a semiconductor characterization system (BD90, Shanghai Power Tool Institute, Shanghai, China); a memory recorder (8870-20, HIOKI, Nagano, Japan) with a heating device from room temperature to 120°C, a steady current mechanism (10 mA), and an amplifier ( $\times 100$ ); and a dynamic fatigue tester (built in the lab) with steady current mechanism (10 mA). The antenna pattern was investigated using a Usan explorer with 3D profilometer system (D46047, Nanofocus, Oberhausen, Germany).

## RESULTS AND DISCUSSION FORMULA MECHANISM

Compared with nanosilver conductive ink, the synthesized silver organic ink is transparent and clear without any visible particles. During the preparation process, this kind of conductive ink was mainly composed of a silver carrier, weak reduction agent, solvent, and additives. At the room temperature, it was very stable and can be kept for at least 1 month. Once it was heated, the complex chemical reaction occurred between the various components. Generally speaking, the sintering process can be divided into four stages: firstly, from simple silver ion to silver ion complex, then to silver oxide, and finally to elemental silver. Meanwhile, the color also changes from colorless to faint yellowish brown, to black, and to metallic luster. The details can be seen from Figure 1 directly.

In this formula, silver acetate was chosen as silver carrier, which can control the reaction rate effectively by adjusting the concentration of the silver ion in the mixing solvent because of its worse solubility. Ethanolamine was used to increase the silver content of the conductive ink to guarantee the conductivity and

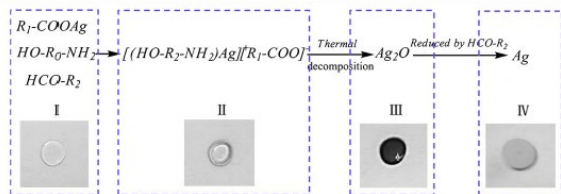


Figure 1 Scheme of chemical reaction mechanism of OSC ink.  $R_0$ ,  $R_1$ , and  $R_2$  are carbon chains.

further to decrease the sintering temperature. Different aldehyde-based materials were chosen as weaker reduction agents, which have been discussed in detail as shown in Figure 2. Generally speaking, such materials can be divided into two types: one for itself with the aldehyde group, such as acetaldehyde, formic acid, dimethylformamide, and glucose; another for itself without the aldehyde group, but after heating, the aldehyde group can appear, such as ethylene glycol which can change to acetaldehyde at a high temperature and glycolic acid which can be decomposed into formaldehyde, carbon monoxide, and water at 100°C. The results show that reduction agent plays an important role on the properties of the conductive ink. Usually, a stronger reduction agent will bring in the instability of the ink, leading to the precipitation of silver particles and lower conductivity. Conversely, a weak reduction agent will result in a higher sintering temperature. It can be inferred that a suitable reduction agent is very important to get lower resistivity. From Figure 2, at the sintering temperature of 120°C for 1 h, the resistivity of the silver thin film with different formulas should be very stable.

It can be seen that formic acid and dimethylformamide show lower resistivity of about 6 to 8  $\mu\Omega\cdot\text{cm}$  and 7 to 9  $\mu\Omega\cdot\text{cm}$ , respectively. In view of the formula stability, in the following research, dimethylformamide was chosen as the reduction agent.

## OSC INK PROPERTIES

For further investigation of the OSC ink, dimethylformamide was used as reduction agent in the formula. The viscosity and surface tension were adjusted to 13.8 mPa·s and 36.9 mN/m (20°C), which can totally fulfill the requirement of ink-jet printing, as shown in the inset of Figure 3a.

The thermal properties of the prepared OSC ink were investigated by TGA with a heating rate of 5°C/min, as depicted in Figure 3a. It can be seen that there exists an evident mass-decreasing area, from 80°C to 160°C, which is related to the evaporation of organic materials;

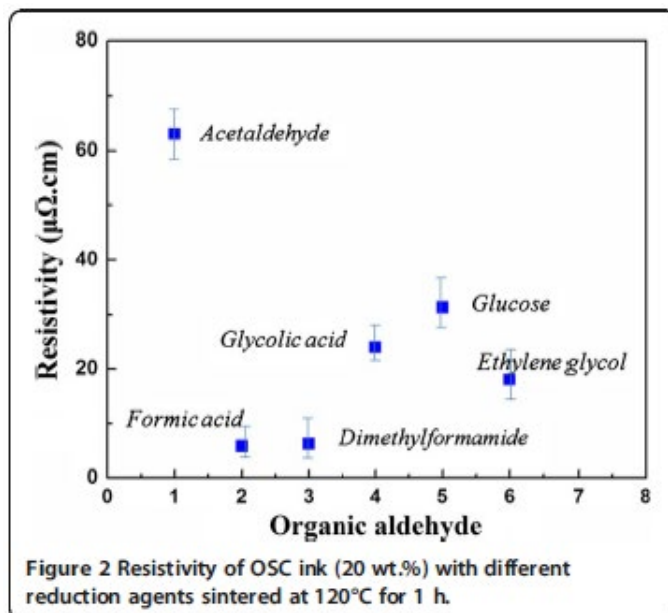


Figure 2 Resistivity of OSC ink (20 wt.%) with different reduction agents sintered at 120°C for 1 h.

finally, 20.3 wt.% of the mass remains, which indicates that the ink contains 20.3 wt.% silver and agrees well with the calculated value (20 wt.%). If several drops of ammonia were added, the solid content can be further increased to 28 wt.% at most because of its stronger coordination ability than ethanolamine. However, more ammonia will cause the instability of the conductive ink due to its volatilization.

The conductive properties of the prepared OSC ink were investigated using different sintering temperatures (90°C, 120°C, 150°C) for different durations of time (from 0 to 60 min), which also can be explained by percolation theory, as shown in Figure 3b. During the sintering process, initially, there are only silver acetate and silver oxide, without any elemental silver, so there is no conductivity. Then, almost all of the silver oxide was reduced to elemental silver at the same time, indicating that a continuous conductive track has been fabricated and showing metallic luster and high conductivity. Especially, based on the present formula of the ink, when the sintering temperature is 120°C for 30 s, the resistivity can drop to 7 to 9  $\mu\Omega\cdot\text{cm}$ .

Figure 3c shows an XRD pattern of the silver ink after sintering, and all diffraction peaks could be indexed to the face-centered cubic phase of silver. The lattice constant calculated from this XRD pattern was 4.098, which was very close to the reported data ( $a = 4.0862$ , JCPDS file no. 04-0783). The inset is the surface morphology of the conductive ink after sintering, and more information also can be seen from Figure 3d.

## Temperature and dynamic fatigue properties

To verify the applicability of this approach in macroelectronics, the correlations between resistivity and temperature, and dynamic fatigue of the conductive silver line were investigated systematically, which were shown in Figure 4.



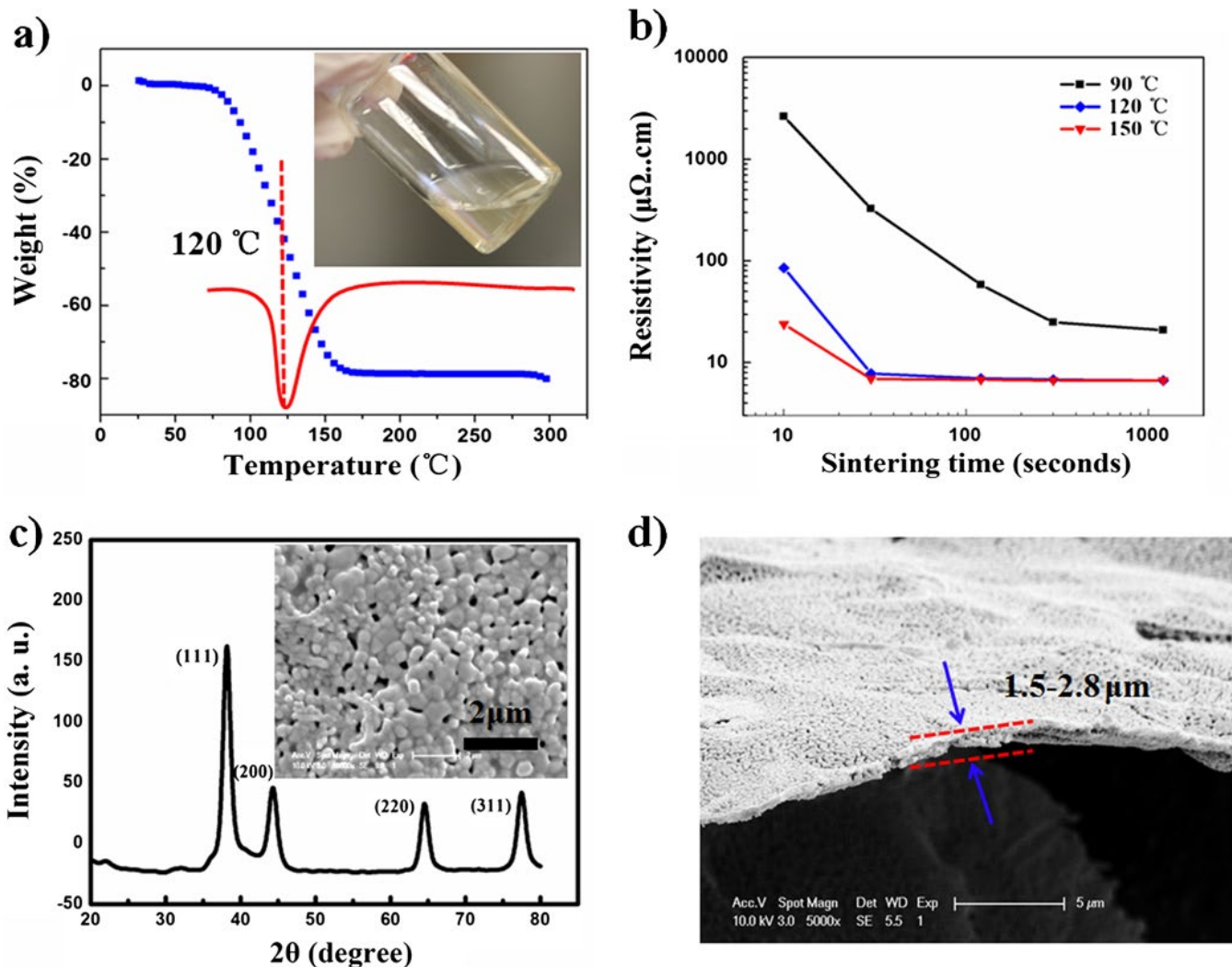


Figure 3 Ink properties. (a) TGA and DTG curves (inset, OSC ink). (b) Variation of resistivity sintered at different temperatures for different times. (c) XRD pattern of sintered OSC ink with a solid content of 20 wt.% (the inset shows the top-view SEM image of the conductive film). (d) Lateral view of the SEM image of the silver film sintered at 120°C for 30 s (dimethylformamide was used as reduction agent in the formula).

This phenomenon is mainly caused by the complex micro-structure of the silver thin film which will bring more barriers during the electron-transfer process. Moreover, it also can be seen that though the heating curve and cooling curve have the same TCR, the cooling curve is always below the heating curve. This is mainly because the natural cooling process (about 28 min) needs more time than the heating process (15 min).

From Figure 4a,b, a set of equipment including a heating device from room temperature to 120°C, steady current mechanism (10 mA), amplifier ( $\times 100$ ), memory recorder (HIOKI, 8870-20), etc. were assembled together, aiming at monitoring the changes of the resistivity of the conductive silver line during the heating and cooling processes. It can be obtained that between 20°C and 100°C, the largest variable quantity of the resistivity is just about 0.28  $\Omega$ . After linear fitting, the slopes of the heating curve and the cooling curve, which can be called temperature coefficient of resistance (TCR), approximately have the same slope ( $k_h = k_c = 0.0007 \text{ a}\Omega/\text{C}^{-1}$ ), indicating the good thermal stability of the conductive silver line. The TCR is a little different compared with the TCR of bulk silver ( $0.0038 \text{ a}\Omega/\text{C}^{-1}$ ).

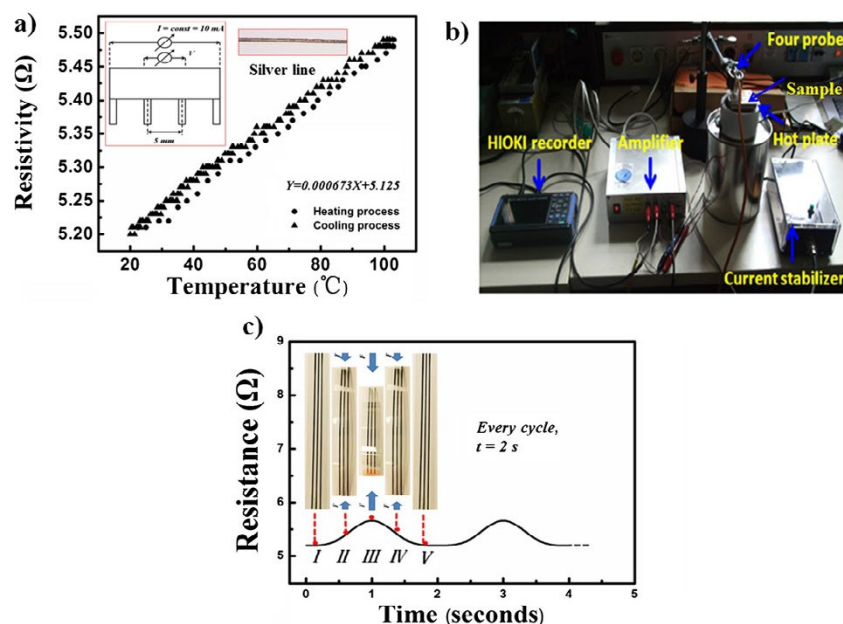


Figure 4 Correlations between resistivity and temperature, and dynamic fatigue of the conductive silver line. (a) Relationship and (b) measurement equipment of resistance versus the change of the temperature. (c) Dynamic fatigue properties of PET-based conductive patterns sintered at 120°C for 30 s.

From Figure 4c, a bending tester was used to study the dynamic fatigue of the PET-based conductive silver line. During the test, the conductive line makes a peri-odic bending movement from I to V, and every period needs 2 s. The details also can be seen from the set in Figure 3b. It is very interesting to find that the resistivity of the conductive silver lines also increases with the increase of the bending angle. From I to III, the resistivity increases from 5.2 to 5.76  $\Omega$ . It can be explained that when bending, the silver thin film was stretched and became thin, especially on the top point of the conductive line, so the stack density and conductivity decreased. From III to V, the resistivity was back to 5.2  $\Omega$ , and after a periodic movement like this for 1,000 times, the resistivity did not significantly increase due to the good ductility of the metal silver. Generally speaking, compared with other printing technologies, this method also shows good adhesion between the silver thin film and PET, showing good results.

## PREPARATION OF AN ANTENNA PATTERN

To test the practical applications of the prepared OSC ink here, an antenna pattern (11 mm  $\times$  12 mm) was designed and fabricated using fit-to-flow or drop method, which also can be seen from Figure 5 directly. The thin film PDMS pattern with a thickness of 200  $\mu\text{m}$ , a width of 200  $\mu\text{m}$ , and a total length of 15.8 cm on the PET substrate was prepared using a laser and used as template. The synthesized OSC ink with blue dye (seen more clearly) was dropped to the center of the template using a syringe (20  $\mu\text{L}$  per drop). Due to the good wetting and film-forming ability of the ink, it will flow along the template track until it fills the whole track, especially after plasma treatment with oxygen. After sintering at 120°C for 30 s, the continuous conductive track can be fabricated, and the total resistor  $R_{ab}$  decreased to 4.6  $\Omega$  measured by a multimeter (middle image of Figure 5) with a width of 200  $\mu\text{m}$  and thickness of 22  $\mu\text{m}$  according to the surface profile.

## CONCLUSIONS

In summary, an unusual kind of high-efficiency, transparent organic silver conductive ink (OSC ink) was synthesized with silver acetate as silver carrier, ethanolamine as additive, and different kinds of aldehyde-based materials as reduction agents successfully. The results show that different reduction agents have an important influence on the ink properties

through a series of complex chemical reactions, and when formic acid or dimethylformamide was used as the reduction agent and sintered at 120°C for 30 s, the resistivity can be lowered down to 6 to 9  $\mu\Omega\cdot\text{cm}$ . It also can be obtained that the fabricated conductive pattern shows good temperature and dynamic fatigue properties. Besides, the feasibility of the synthesized OSC ink was verified through the preparation of an antenna pattern using drop or fit-to-flow method successfully.

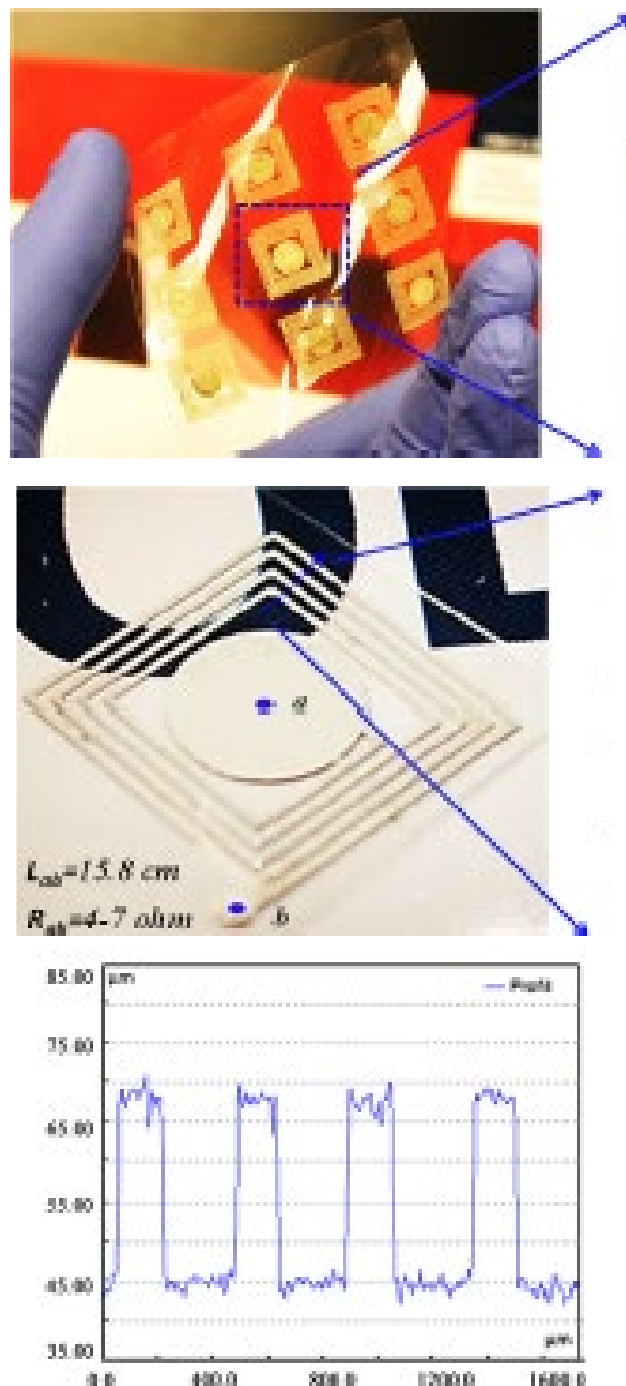


Figure 5 Antenna pattern after sintering at 120°C for 30 s and surface profile curves of conductive pattern. The prepared antenna pattern was fabricated using drop or fit-to-flow method.



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# LATEX PAINT PRODUCTION EQUIPMENT'S

By: Bilal Butt, Fatima Ilyas

## INTRODUCTION:

This description is designed for the general audiences who are interested in the effective use of the different types of paints and the general paint manufacturing procedures. American coating association defines that paint is a group of emulsions mainly composed of pigments in a liquid medium. Paint is one of the essential components in people's lives. With the use of the paint, people can communicate each other and even set the rule in the society. This article will mainly present a manufacturing process of latex-paint and its productive equipment's.

## HISTORY AND BACKGROUND KNOWLEDGE OF PAINT MANUFACTURING

A paint has been used since ancient time, 30,000 years ago. Ancestor used paints to record their lives, to communicate each other, and to decorate their pictorial symbols. As times goes by, the paint and coatings industry has been remarkably developed for the mass production during the Industrial Revolution era. Especially, in the mid-1880s, paint factories and its business began to grow. The paints were used in different sectors; housing, aviation, vehicles, cans, furniture, and so on. Since the paint is an artificial and



chemically complex product, some of the elements in the paint are harmful to people. Specifically, lead pigments were limited and finally removed in the house painting for people's health.

## PAINT COMPONENTS:

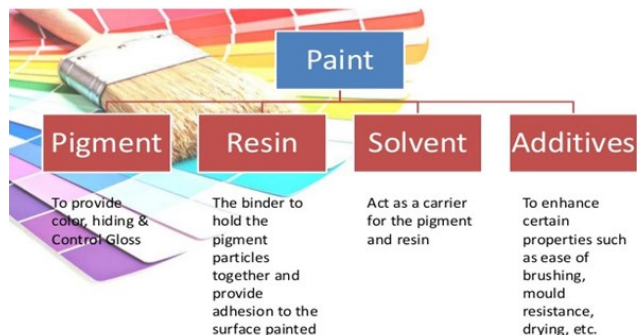


Figure 1 Components of Paint

## OVERVIEW OF PAINT MANUFACTURING EQUIPMENT'S AND PROCESS:

### 1. Preparing raw materials

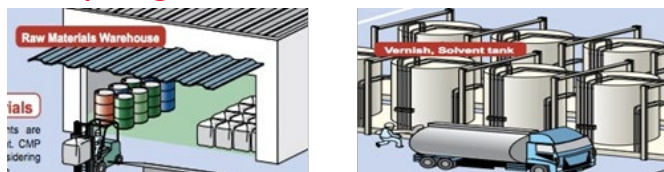


Figure 2 Raw Material Settler

Resin, pigment, and additives are purchased or stored before manufacturing the paint. Normally, power pigments are stored in the warehouse, and the resins and other solvents are stored in tanks.

### 2. Mixer

All the raw materials are sent to mixing tanks and premixed in a mill base machine.

Figure 3 Mill Base Machine

### 3. Sand Mill

Sand mills are mainly used by the coatings, inks and paints industries to reduce the size and dispersion of pigments in liquids. Pigment particles disperse up to 2 microns in a single pass. The grinding chamber is equipped with a grinding medium, where the feed is pumped from the lower chamber.

Figure 4 Sand Mill

### 4. Blending Tank:

All grinding and color dispersion are adjusted in the mixing tank. The paint mixing process is fast, very efficient and uses less energy to mix and re-mix the



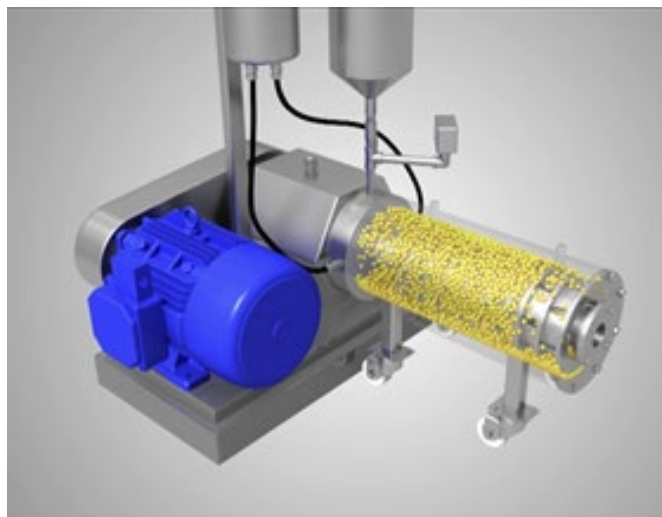
separated solids evenly and deposit the solids in the paint. The process is ideal for all tanks, tubs and drums of all sizes.

Figure 5 Blending Tank

### 5. Filtering

By filtering the paint, it determines the thickness of the paint and also the viscosity of it.

Figure 6 Industrial Filter



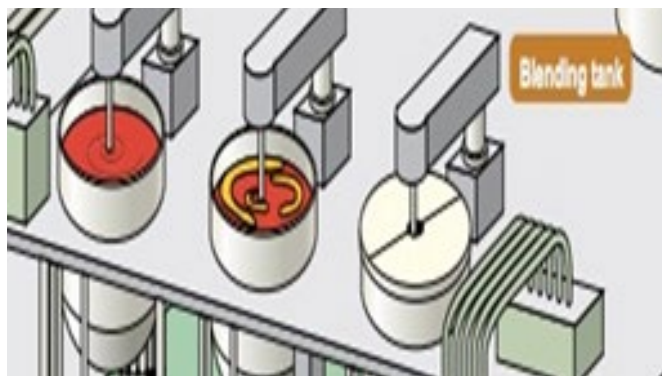
### 6. Quality Check Equipment's

#### i. Rheometer

#### ii. Pycnometer

#### i). Rheometer

A rheometer is a paraphernalia used to measure the way in which a liquid, suspension or slurry flows in result



to applied forces. It is used for those fluids that cannot be defined by a single value of viscosity and therefore require more parameters to be set and measured than

is the case for a viscometer. Viscosity in the paints



industry is essentially a measure of its thickness, which is important, because viscosity determines whether a paint needs to be applied using a brush, roller, sprayer or more high-tech application.

## ii). Pycnometer

Specific gravity is a measure of a paint's density and is generally expressed in terms of weight per gallon. Density is determined by the ratio of solid raw materials that make up the paint solution and can be affected by improper thinning, environmental conditions and improper mixing ratios. For high-precision painting, specific gravity is measured using pycnometers, which are pressure density cups that test the resistance of a paint solution to cracking or detachment from a metal panel. The metal panel is bent around a cylindrical mandrel, and the amount of cracking or detachment is carefully measured by the calibrator component of the pycnometer.



Figure 7 Pycnometer (Density Estimator)

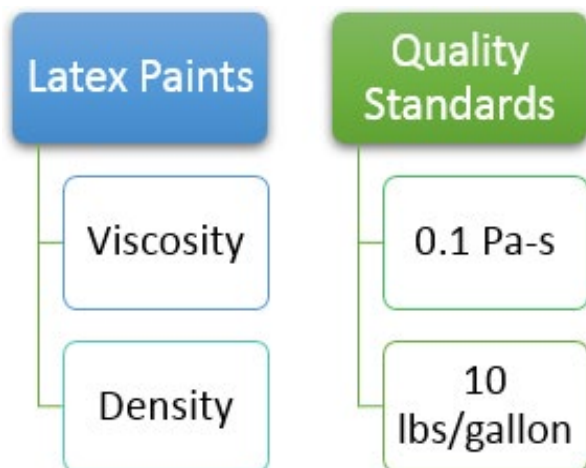


Table 1 Quality Standards for Latex Paints

## 7.Package

Once the quality control has been carried out against the standard paint, it begins to fill the paint in the containers. All filling processes are carried out with the conveyor belt and palletized for mobility.



Figure 8 Palletized Machine

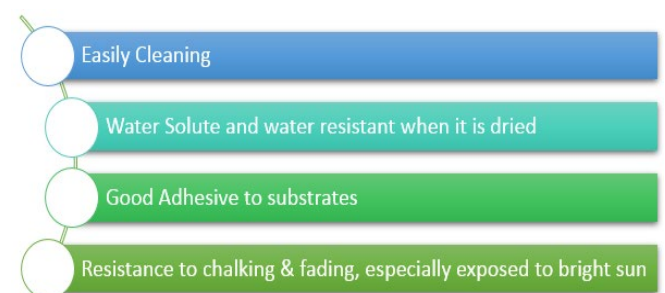
## 7. Shipping and storing

It could either store in the warehouse before the shipment or directly load on the truck by the forklift for the transport the paints.



Figure 9 Shipping Container

## Properties of Latex Paints:







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## A DIGITAL FORMULATION ASSISTANT FOR THE LAB

Bearing names such as Siri and Alexa, virtual assistants are now a part of the family in one out of five American homes. Boasting endless patience, they accept any voice command they are given and, if everything works right, will then play the desired music, provide a weather forecast or update the user's calendar. Voice-controlled digital assistants promise to provide us help in our daily lives. They are rapidly spreading. Whereas they were found in only one percent of U.S. households in 2016, this figure rose to 20 percent just two years later. They are also used in no less than 13 percent of German households.

If everything goes according to Dr. Gaetano Blanda's wishes, this will only be the beginning. Blanda wants to turn voice-controlled digital assistants from simple helpers for daily life into chemistry



experts, and use them in a place where a comprehensive amount of specialized knowledge is needed and a technical language is spoken: the laboratory.

As the Head of the Coating Additives Business Line at Evonik, Dr. Blanda knows about the great demands that the new lab assistants have to fulfill with regard to scientific expertise and language skills. His team specializes in formulations for the coatings industry and the associated additives. In order to exactly meet the customers' wishes with respect to color, gloss and durability, the experts have to create complex mixtures that they supplement with the right additives. Thousands of combinations are possible - far more, in fact, than the human brain can handle. The experts spend correspondingly much time searching through notes and data



sheets on their desks. So a digital assistant will now help users research and adjust ingredients directly in the laboratory. The assistant's name is COATINO™. The idea for COATINO was born during a strategy meeting at Coating Additives. "We talked about new ways in which

"Although this was rather ad hoc, we wanted to tangibly test our idea with customers and quickly get feedback." The video was shared with a number of customers, and the team also conducted structured interviews. The idea engendered a great amount of interest.



business could develop," says Dr. Oliver Kröhl, Head of the Strategic Business Area Development at Coating Additives and the project's manager. "Innovations are no longer just limited to finished products or processes. Instead, you need to demonstrate your ability to come up with solutions in the form of new services and business models." The researchers focused on everyday challenges for the formulation of coatings and paints, and soon decided that they could use a voice-controlled digital formulation assistant. The team was thrilled by the idea. But is this what the experts in the lab actually need?

### FROM CAN TO PROTOTYPE

To find this out, the scientists decided to simply start working. They coated an empty can of paint in the company's colors. They then put it into the laboratory, where they filmed a discussion between a colleague and the can. In the video, the user asked the can about a suitable waterborne anti-foaming agent for a wood coating. The can gave its reply, provided the lab employee with a selection of products, and ordered a sample. "Back then, the questions were answered by a colleague who stood behind a wall," says Kröhl.

This approval encouraged the developers to move into uncharted territory. "We're experts for paints and coatings, but not for voice-controlled assistants," says Kröhl. "That's why we knew that the project might not work. However, we and our customers thought it had such great potential that we were willing to take the risk." Their aim was to develop a prototype assistant in time for the European Coatings Show, the world's most important trade fair for the paint and coatings industry.

This was no easy task, because conventional voice-recognition systems were unable to handle the specialist vocabulary. "The usual assistants simply can't understand our language," says Kröhl. They quickly reach their limits when you ask them about dispersion, rheology or silicone resins, for example, and they can, at best, only supply general information.

"They have to be able to do a lot more in order to formulate a coating," says Kröhl. "If they don't know the components' properties and how they interact, they won't be any help in the laboratory."

## UNIQUE CHALLENGES

Paints, lacquers and other coatings basically consist of four components: solvents, binders, pigments and additives. The various components influence each other's effects, depending on the mixture. The number of possible combinations is immense. Even if only 10 curing agents, 10 binders, 10 pigments and 10 additives are considered during the development of a coating formula, these numbers translate into 10,000 possible combinations. And this doesn't even take into account variations in the ratios of the components used. "Customers have very precise ideas about the capabilities that a product should have once it's finished," says Blanda. In order to develop a functional, voice-controlled assistant for the coatings industry, the researchers at first began to structure all of the available information and feed it into a huge database. In the next step, they made it possible to call up this information using a voice-control function.

For example, if you ask the assistant, "Which additive is suited for printing ink?" the system obviously has to be able to understand each word. Among other things, COATINO had to learn that "additive" designates a certain category of coating components. In the next step, the assistant has to access its data, search through it, create suitable links and assign the data to a possibly relevant result. To do so, it first breaks down the sequence of sounds into their smallest components and conducts a data search on the basis of characteristic properties. A special challenge for the assistant is that COATINO has to be able to understand not only German nouns in the nominative case but also in other cases. The researchers also want to make sure that the speaker's dialect or accent won't hamper the result. The ultimate aim is to enable COATINO to understand customers' pronunciations worldwide. Added to these challenges are the speakers' different talking speeds and pitches, as well as the specific context of a discussion. "The training process is very nerve-wracking," says Kröhl. "And after the trial run with our colleague in Shanghai was finally successful, it went wrong with our colleagues in Essen." For almost two years now, COATINO has been jointly developed and trained by the business line and an external development company from Berlin. The assistant passed its first important development test when the prototype was demonstrated at the ECS.

When asked about suitable additives, COATINO not only presents a list of products but also prioritizes them. "COATINO can tell me which additive would be best suited for my formulation and my requirements. It can thus give me well-founded recommendations," says Blanda. Once a user has found the desired product, he or she can issue a voice command to tell COATINO to order a sample, directly call up the pertinent technical data sheet by e-mail or have a conversation with an

expert arranged. "For us, customer-oriented digital solutions enable people to talk with one another more efficiently about innovative solutions," says Kröhl.

## NEW FORMULATIONS FROM THE DATABASE

The COATINO prototype was ready just in time for the start of the European Coatings Show. "We immediately presented it to a select group of our customers," says Blanda. Instead of a can, the users imparted their wishes to a tablet via a microphone. "The feedback was even better than we'd hoped. We were able to gain some of the customers as first users who will test the assistant." They will pass on their experiences to Blanda and his team. "We wanted to get the customers involved at an early stage," says Blanda. "Such a project can only work if customers also think it benefits them." In 2020 the researchers plan to make COATINO available for the entire coatings industry.

However, there is no end in sight for the system's further development. "When you use digital assistants, you continually come up with ideas for new features," says Kröhl. For example, COATINO could conceivably not only supply existing formulations, but also suggest its own new mixtures. The scientists could directly test these mixtures in the lab and enhance them for their own use. "Our COATINO might one day really become an artificially intelligent entity," says Blanda. "But we still have a long, long way to go until then."







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# NOVEL 1K AND 2K MOISTURE CURING VINYL ALKOXYSILOXANE TECHNOLOGY

## as Alternative to 2K Polyurethane Topcoats

By: Nathalie Havaux, Catherine Romanowska, Denis Heymans, Bo Ngiabprasert, and Marcelo Herszenhaut

Moisture-curing topcoats based on acrylic- and epoxy-alkoxysiloxane resins have been increasingly used as isocyanate-free alternatives in marine and protective applications. Similar to 2K polyurethanes, these systems display a broad range of performance characteristics, depending on their structure and composition. However, these alternatives have seen limited market penetration, due to an unfavourable cost/performance ratio.

This article presents a new family of polymers, which combine vinyl (neo)ester and vinyl alkoxy silane monomers. Variation of process parameters, monomer composition and alkoxy silane levels yielded

a series of polymers with solids content between 70 and 100%, and exhibiting a wide range of attractive properties.

Performance evaluation of 1- and 2K moisture-cure coatings based on this cost-efficient and highly versatile technology demonstrates that it brings high solids content, fast hardness development and very long shelf life, in addition to being isocyanate-free. These factors make these vinyl silane copolymers an attractive alternative to 2K polyurethanes and acrylic-alkoxysiloxanes for several topcoat applications, especially protective coatings.

### MOISTURE CURING ALKOXYSILOXANES

Silicone-containing coatings play an ever-increasing role since their introduction in the mid-90's. Today they are specified for a wide range of steel constructions, including highly demanding applications such as offshore platforms, storage tanks and pipes. They are particularly appreciated for their very high durability and have often replaced polyurethanes. The durability of polysiloxanes,  $[-Si-(O-Si)_n-O-]$  can easily be understood considering that the Si—O bond is in an oxidized state and cannot be further oxidized, unlike carbon — carbon bonds in organic compounds. Furthermore, the bond dissociation energy for the



Si—O bond is about 33% higher than that of C—C bonds. The extreme durability and resistance of glass, which is actually a giant polysiloxane network, exemplifies the outstanding properties of polysiloxanes well. Coatings based solely on polysiloxane resins, however, have limited market penetration. Instead, silicone coatings usually combine an inorganic polysiloxane with and organic resin.<sup>1</sup>

Today, most leading protective coatings suppliers offer silicone-containing coatings based on epoxy-polysiloxane and/or acrylic-polysiloxane chemistries. In both cases, an inorganic polysiloxane resin is reacted with the organic epoxy or acrylic resin to balance and optimize properties like viscosity, durability, cohesive strength and adhesion.<sup>2</sup> To achieve optimal performance, the typical level of a methy-phenyl polysiloxane ranges from 37 to 77 wt%,<sup>2</sup> which brings the cost of these systems to excessively high levels.

In the case of epoxy-polysiloxanes, the curing mechanism of the oxiranes is typically activated by an aminosilane monomer, like aminopropyltrimethoxysilane. The amine and the aliphatic epoxy must therefore be kept in two separate cans and mixed shortly before coating application to avoid premature curing (2K). After mixing and coating application, the curing via epoxy-amine organic crosslinking occurs within hours. This is complemented by an inorganic curing of silane groups, initiated by the ambient moisture (Figure 1). The combination of these two curing mechanisms, organic and inorganic, provides outstanding properties to the coatings.

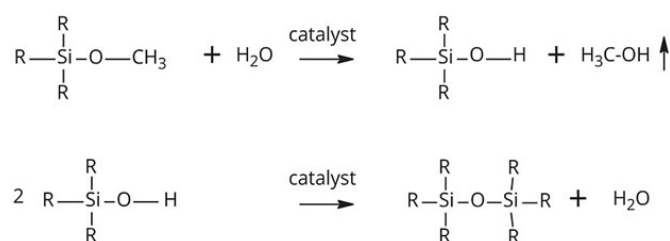


FIGURE 1 » Moisture curing of alkoxy silane-based coatings.

Acrylic-silane systems, on the other hand, cure only via the inorganic hydrolysis-condensation sequence of the silane groups.<sup>3</sup> These systems are manufactured via radical copolymerization of silane-functional acrylates and (meth)acrylate monomers. Most commonly, gamma-methacrylopropyltrimethoxysilane (MPTMS) is reacted with methyl methacrylate, butyl acrylate and styrene or other vinyl monomers to form copolymers with pendant alkoxy silane groups.

Once a silane functional coating is applied, the moisture-curing process occurs in two steps. In the first step, the silane reacts with water to yield a silanol and an alcohol (typically methanol or ethanol). In the second step, two

silanol groups condensate to form a siloxane bridge, with the release of one molecule of water. Half of the water consumed in the first step is thus released in the second step, ensuring further curing deeper into the coating. One or sometimes a mix of different catalysts is required to promote these hydrolysis-condensation reactions.

In theory, alkoxy silane-based acrylics could be easily formulated as single-component (1K) systems. The coatings should not begin to cure until they are applied to a surface and exposed to air and moisture. However, pigments and additives used in paint formulations usually contain some moisture, which can initiate premature curing in the can.<sup>4</sup> Numerous solutions have been proposed to solve this issue, some with success. Certain solutions are based on the use of moisture scavengers<sup>5</sup> while others use mixtures of reactive polysiloxanes and silane-free acrylic resins.<sup>6</sup>

Acrylic-silane polymers also need to be of sufficiently low molecular weight to achieve the required low viscosity for spraying, especially after being formulated into paints. Such low-molecular-weight polymers often require long curing times to develop mechanical properties, especially when applied at room temperature. It has therefore been proposed to mix these acrylic resins with polysiloxane resins to address this issue,<sup>2</sup> however this solution leads to much higher cost.

Despite their high apparent potential, 1K moisture-cure alkoxy silane-acrylics have so far only achieved a fairly limited market penetration. The high cost of MPTMS monomer and the polysiloxane resins is probably partly responsible for this. Park et al. found excellent UV and weathering resistance in moisture-cured alkoxy silane-acrylic based coatings<sup>7</sup> with a high level of MPTMS of up to 30 wt%.

## NEOCARBOXYLIC ACID-BASED MONOMERS FOR COATINGS

In 1954, Koch and Huiskens of the Max Planck Institute in Germany described a three-step chemical reaction between mono-olefins, carbon monoxide and water leading to monocarboxylic acids<sup>8,9</sup> with a high degree of branching. Acids prepared by this process, known as Koch acids, Versatic™ acids or neocarboxylic acids, can potentially be incorporated as such into polymers. However, they lack sufficient reactivity to achieve high conversion in conventional esterification reactions. This is why they are more commonly used in their vinyl or glycidyl (epoxy) ester derivative forms (Figure 2).

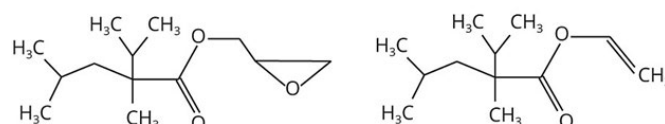


FIGURE 2 » Typical structures of glycidyl neodecanoate and vinyl neodecanoate with five methyl groups.

For more than 50 years, neoacid-based monomers have found most of their applications in the world of coatings, where they are well known for upgrading the performance and quality of vinyl, acrylic, polyester and other resins. The most common monomers used in these applications, based on C10 neoacids, are glycidyl neodecanoate and vinyl neodecanoate, with three to six methyl groups per molecule.

The chemical structure of these vinyl and glycidyl monomers, with a high number of methyl groups, contributes to a number of attractive properties of the derived coatings. Vinyl neodecanoate homopolymer was found to have a critical surface tension as low as 24 dyn/cm,<sup>10</sup> and to provide high contact angles to derived coatings. Moreover, the tertiary structure of the original acid ensures excellent chemical stability, and the absence of aromatic structures explains excellent UV resistance. Vinyl neodecanoate and vinyl neononanoate are well known by resin and paint producers under their tradename VeoVa™ 10 and 9 monomers. The homopolymer Tgs of these monomers are -3 °C and +70°C, respectively.

In the frame of the present work, an important difference between vinyl and (meth)acrylate esters derives from the orientation of their ester groups. In the case of (meth)acrylates, the ester group is electron withdrawing, whereas it is electron donating for the vinyl esters (Figure 3). This has a major influence on the reactivity of the respective double bonds in radical polymerization processes, as will be discussed below.

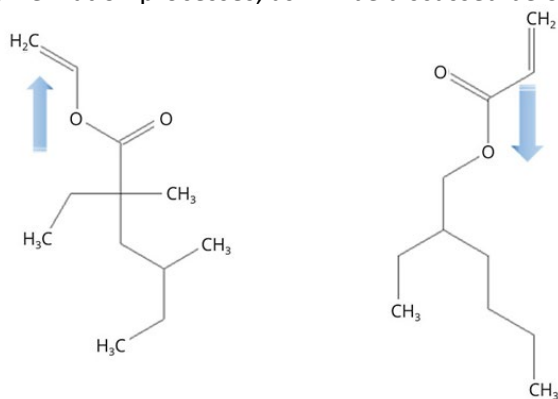


FIGURE 3 » Electron donating and withdrawing effects on vinyl esters and acrylate monomers.

## VINYL SILANES

Vinyl trimethoxysilane (VTMOS) and the related vinyl triethoxysilane (VTES) are bi-functional compounds, featuring both a vinyl group and a hydrolytically sensitive alkoxy groups (Figure 4). Their alkoxy groups are activated and hence these silanes are extremely

reactive towards water. The reason for this effect is an electronic interaction between the silicon atom and the electron donor in the  $\alpha$ -position.<sup>11</sup> VTMOS, in particular, is very well known by coatings formulators as an efficient and affordable water scavenger.

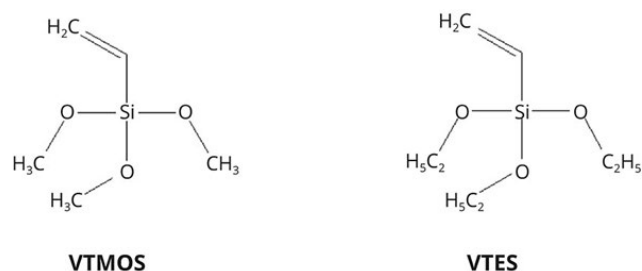


FIGURE 4 » Common vinyl silane monomers.

The vinyl group, on the other hand, has relatively low reactivity. It does therefore need highly activated radicals to be efficiently incorporated into polymer backbones by radical polymerization. Attempts to build VTMOS into (meth)acrylate polymers have therefore faced severe issues of final monomer conversion.<sup>12</sup> VTMOS copolymers with more reactive radical monomers like ethylene are however well known, for example, in the field of electrical insulation for cables. Copolymers of VTMOS with vinyl acetate are for the same reason also well known in the field of emulsion paints.

## COPOLYMERIZATION OF VINYL SILANES AND VINYL ESTER MONOMERS

To start the present work, we asked ourselves whether the vinyl silanes like VTMOS and VTES, and hydrophobic vinyl esters described above, could be combined into affordable and high-performance polymers for 1K, moisture-curing protective coatings. The reactivity ratios between these monomers are not available, but we could estimate them using an  $e$  and  $Q$  scheme as proposed by Alfrey and Price.<sup>13</sup> Table 1 shows that calculated  $r_1$  and  $r_2$  are actually very close to 1. In practice, this means that vinyl silanes should distribute evenly in vinyl ester copolymer backbones. This important finding opens the possibility to use low-cost vinyl silane monomers as a crosslinker for high-performance protective coatings.

Monomer 1	Vinyl Acetate		VeoVa 10		VeoVa 9	
Monomer 2	$r_1$	$r_2$	$r_1$	$r_2$	$r_1$	$r_2$
Vinyl trimethoxy silane	0.53	1.44	0.77	1.27	0.76	1.22
Vinyl triethoxy silane	0.62	1.31	0.88	1.19	0.87	1.10

TABLE 1 » Estimated reactivity ratios between vinyl esters and vinyl silanes.

## EXPERIMENTAL

The resins presented below combine vinyl alkoxy silane monomers with vinyl neodecanoate (VeoVa 10 monomer), vinyl neononanoate (VeoVa 9 monomer)



and vinyl acetate monomers. Their detailed preparation procedure has been described in a recent patent application.<sup>14</sup> Monomers were chosen in order to combine the unique properties of neoacid derivatives, such as hydrophobicity and durability, with the moisture-curing mechanism of silanes. In the first part of this work, resins were optimized for their performance in clear and pigmented topcoats. In a second step, selected vinyl silane resins for clear and pigmented protective topcoats were benchmarked against commercial systems: 2K polyurethanes and 1K acrylic-polysiloxanes.

## RESIN OPTIMIZATION

The variables evaluated and the typical properties of resins are displayed in Tables 2 and 3. In particular, the glass transition temperatures of the polymers were manipulated by varying the ratios between vinyl esters. The molecular weight of the polymers was varied by modifying the process conditions and by using low levels of certain additional monomers. The resulting vinyl silane resins were then formulated into 1K moisture-curable clearcoats.

Composition Variables	Weight (per hundred monomer)	Purpose
Vinyl silane	0-35	Crosslinking
Methacrylic silane	0-15	Higher curing rate
Veova 9	0-100	High Tg (+70 °C) vinyl ester
Veova 10	0-100	Low Tg (-3 °C) vinyl ester
Vinyl acetate	0-60	Cost reduction
Organic peroxide	2-6	Molecular weight control
Butyl acetate	0-30	Viscosity control
<b>Polymerization</b>		
Temperature	80-140 °C	Molecular weight control
Reaction time	2-6 hrs	Easy processing

TABLE 2 » Resin variables evaluated.

Composition	Weight (kg)
Vinyl trimethoxy silane	20
Acryloxypropyl trimethoxy silane	5
Veova 9	50
Veova 10	25
Organic peroxide	4
Butyl acetate	25
<b>Properties</b>	
Solid content	80%
Molecular weight	12,000 g/mol
Viscosity	10,000 mPas
Free monomer level	0.3%

TABLE 3 » Example of resin composition and properties.

The various resins were mixed with catalysts and diluted with butyl acetate to the application viscosity (100 mPas). Films were then applied at 100 µm wet with a barcoater and allowed to dry at 23 °C and 50% relative humidity. Typical solids content of the clearcoats ranged from 65 to 70 wt%. All formulated clearcoats (i.e. with catalyst) had a shelf life of at least several months. In some cases, skin formation was observed on top of the product in cans that had been open several times, indicating reaction

with moisture from the air. In all cases, however, the bulk viscosity of the coatings remained constant. This important observation indicates that vinyl silane resins are suitable for true one-component (1K) coatings. For comparison, a similar clearcoat made from a reference acrylic silane resin had a shelf life of less than 1 hr, while the reference 2K polyurethane had a shelf life of 2 hrs. The glass transition temperature (Tg) of the resins and the level and type of silane monomer were varied with the aim of optimizing cure speed, solvent resistance and coating flexibility. Figure 5 shows solvent resistance (MEK double rubs) of a series of clearcoats as a function of the level of silane after 7 days of drying at room temperature. Additional clearcoats with 25 wt% silane and Tgs ranging from +60 °C to -3 °C were also included in this evaluation. As expected, solvent resistance increases with the level of crosslinking monomers. However, the increase in solvent resistance with the decrease of the Tg may be somewhat surprising. This is possibly due to a limitation of the crosslinking density because of the reduced mobility of polymers with higher Tg.

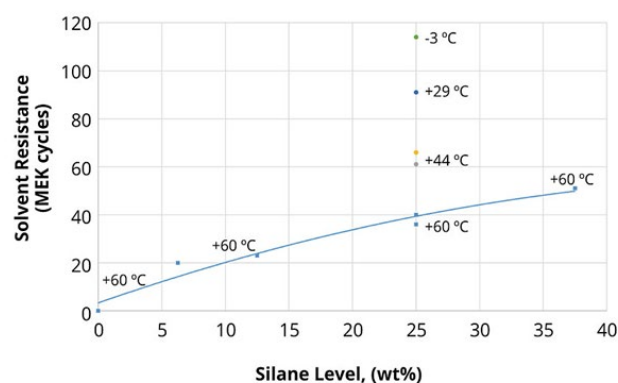


FIGURE 5 » Effect of the level of silane and resin Tg on solvent resistance of clearcoats.

Silane groups attached to polymers with lower Tg, however, may have more opportunity to crosslink and thus to improve solvent resistance. This hypothesis is supported by the fact that the abrasion resistance of the clearcoats was also found to be better for resins with lower Tg. Further testing of both solvent and abrasion resistance of coatings cured at elevated temperatures supported this hypothesis. More details about this resin optimization work have been presented elsewhere.<sup>15</sup>

## BENCHMARKING EXERCISE

After the optimization of the resins described above, a new series of resins were formulated into clear and pigmented topcoats (Table 4). A first resin was made using exclusively hydrophobic, branched vinyl esters (Veova 9 and 10 monomers) and methoxy silane monomers. In the second resin, ethoxy silanes replaced the methoxy silanes for HSE reasons. The third resin contains methoxy silane and 40 wt% vinyl acetate to minimize cost. The performance of the corresponding clearcoats was compared with a commercial 2K

polyurethane. The pigmented topcoats were compared with both a commercial 2K polyurethane and two 1K acrylic-polysiloxane coatings (Table 5).

	Methoxy Hydrophobic	Ethoxy Hydrophobic	Methoxy Cost Optimized
Composition	(wt %)	(wt %)	(wt %)
Silane monomer	20	20	20
Veova 10	28	28	28
Veova 9	52	52	12
Vinyl acetate	-	-	40
<b>Properties</b>			
Calculated T <sub>g</sub> (°C)*	35	35	35
Solids content (wt %)	80.3	80.1	70.2
Mw (weight average)	16,700	21,700	Nd
Viscosity (Pas)	15.5	12.4	2.2

\* T<sub>g</sub> calculated with Fox equation considering only vinyl ester monomers.

TABLE 4 » Properties of the liquid resins used for benchmarking purpose.

Properties	Viscosity as Applied	Solids Content Applied	Water Contact Angle	Dust-Free Time	König Hardness after			MEK Resistance after		Conical Mandrel Flexibility after	Gloss @ 60°
	(mPas)	Wt %	(°)	(min)	4 hrs	24 hrs	3 weeks	24 hrs	3 weeks	(mm)	(%)
Clearcoats											
Methoxy silane hydrophobic	290	64.0	91.5	8	8	30	75	76	>200	Failed (>25 mm)	85
Ethoxy silane hydrophobic	280	63.3	84.3	9	1	8	49	59	>200	< 23 mm	86
Methoxy silane optimized	320	60.9	80.7	10	6	16	50	58	>200	< 5 mm	85
Commercial 2K PU	260	65.4	87.4	39	0	12	121	>200	>200	< 5 mm	94
Pigmented topcoats											
Methoxy silane hydrophobic	800	61.5	90.7	18	7	23	54	>200	>200	< 7 mm	26
Ethoxy silane hydrophobic	750	65.5	81.8	24	3	8	29	47	>200	< 5 mm	40
Methoxy silane optimized	750	63.4	89.3	18	8	12	39	149	>200	< 5 mm	76
Commercial 2K PU A (Hexion formulation)	nd	78.4	82.8	29	1	12	112	>200	>200	< 5 mm	95
Commercial 2K PU B (Commercial paint)	1000	79.3	75.7	16	7	20	94	>200	>200	< 18 mm	69
Acrylic polysiloxane B	1150	82.3	87.5	28	3	20	61	55	160	Failed (>25 mm)	83
Acrylic polysiloxane A	1450	83.2	85.6	129	1	15	80	29	>200	Failed (>25 mm)	79

TABLE 5 » Properties of the vinyl silane and benchmark coatings.

## CLEARCOAT PERFORMANCE

Table 5 shows that these vinyl silane systems have very short dust-free time and fast early hardness development when compared to the 2K PU system. These are critical properties for professional painters as they enable a higher productivity. The observed performance is probably mostly due to the high molecular weight of the vinyl silane resins combined with a T<sub>g</sub> above room temperature. During the first four hours of drying, crosslinking of the methoxy-based vinyl silanes is also fast enough to ensure rapid hardness development and solvent resistance. The ethoxy silane system, on the other hand, cures slower than expected, yet also develops good performance over time. The cost-optimized system, containing vinyl-acetate, has slightly lower solvent resistance due to the more polar nature of vinyl acetate.

## PIGMENTED TOPCOAT PERFORMANCE

Figure 6 shows the development of Koëning hardness of the vinyl silane resins (solid lines) compared to the commercial 2K PU (dotted lines) and acrylic-polysiloxane (dashed lines) benchmarks. As expected, both methoxy silane-based topcoats show excellent hardness development during the first hours of drying. After 3 weeks, all polysiloxane systems exhibit lower hardness than the polyurethanes. Consequently, the softer vinyl silane systems exhibit better flexibility than

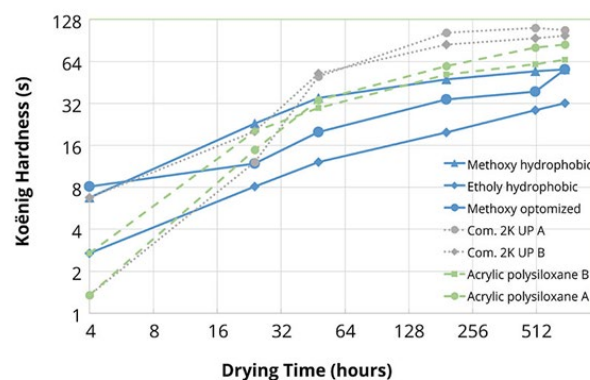


FIGURE 6 » Hardness evolution of pigmented topcoats.

the commercial acrylic-polysiloxanes (Table 5). The 2K PU A system, formulated in Hexion's lab with a relatively soft isocyanate (HDI trimer), combines excellent hardness and flexibility after 3 weeks. However, this is at the expense of the early hardness development (<24 hrs). In contrast, the commercial 2K PU B, derived from the same polyol, lacks flexibility, probably because it is formulated with a hard isocyanate to ensure fast early hardness development. Figure 7, which shows the balance of properties of the various systems on radar charts, illustrates the versatility of this new technology very well. As can be seen, a significantly better balance of properties than the commercial acrylic-polysiloxane paints is obtained.

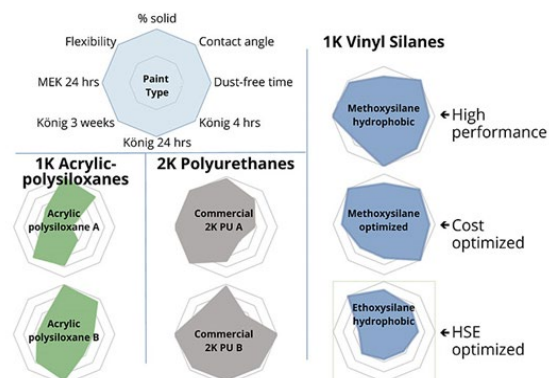


FIGURE 7 » Properties of the vinyl silane pigmented topcoats compared with commercial benchmarks.

## CONCLUSIONS

- Vinyl silane resins can be formulated into high-performance, true 1K protective coatings. Unlike with 2K PU systems, end users using these new systems do not need to mix two components shortly before use. Because true 1K systems have very long pot lives, users do not need to dispose of the unused mixed coating.
- Vinyl silane systems are free of isocyanates.
- High-solids coatings based on vinyl silane binders can be formulated to deliver very fast early hardness development, combined with good flexibility, solvent resistance and final hardness.
- Vinyl silane-based protective coatings exhibit better balance of properties compared to commercial 1K.





# *Winning* the Safety Race with Scissor Lifts

By: Justin Kissinger

Whether young or old, short or tall, every employee has the right to be safe while performing tasks on the jobsite. Proper ladder usage may seem like common sense, yet according to OSHA, falls remain the No. 1 cause of death in the construction industry. The good news? These falls are almost always preventable. But, it all starts with putting ladders in their place, and low-level scissor lifts are the best ally.

## THE PROBLEM WITH LADDERS

Ladders have long been the go-to tools for work-at-height jobs; they are inexpensive, compact and convenient,

but that all comes at a cost, and a high one at that - safety. There will always be a time and place for ladders, and when set up and used correctly they can be a great tool for getting high-reach work done. However, setup and usage is also where the problems with ladders arise, and the result of not following proper guidelines can lead to injuries and costs. OSHA recommends users place extension ladders at a 75-degree angle, set it one-quarter of the working height away from a wall, and ensure the top of a ladder extends 3 feet higher than the elevated surface. Users must also choose ladders that are the

appropriate Duty Rating for the task, which ensures it can hold your weight and the weight of your load. And while working on or climbing up and down a ladder, the "3 Point Rule" should always be enforced. This means users must maintain three points of contact at all times to minimize the risk of slipping and falling. Ladder setup and usage doesn't sound so common sense anymore, and these are just a few guidelines. It's no wonder training on proper ladder set up and usage gets overlooked. In fact, according to a Bureau of Labor Statistics study of 1,400 ladder accidents, 66% who were injured had not been trained on how

to inspect and set up the ladder. It's evident the idea that ladders are convenient and show up to the jobsite ready to go is a myth, which is why they should be considered last for any job. There is, however, equipment that does show up to the jobsite ready - low-level scissor lifts; and users get more than enhanced safety.

## LADDERS DON'T SIZE UP

Low-level scissor lifts allow workers to reach up to 22-foot working heights, which accounts for about 90 percent of high-reach work. While many think a lift's overall size is a setback, low-level units are quite compact and in some cases take up less space than a ladder. For instance, the legs of a 12-foot stepladder spread nearly 80 inches apart, which means the ladder consumes about 19.43 square feet of floor space. A low-level push-around lift with a 10-foot platform, however, takes up just 10.45 square feet of space. Both offer 16-foot working heights, yet the scissor lift has a 46% smaller footprint, enabling it to be used in more confined areas.

But what about when it comes to navigating through doorways, around tight corners or throughout confined areas? A ladder may be fairly simple to move by collapsing it or folding it up, but the taller it gets, the more cumbersome moving it becomes. Not only do ladders get heavier as they get taller, but those taller heights also make it challenging to get around corners and into tight spaces. Low-level lifts, on the other hand, take lifting and awkward maneuvering out of the equation. Operators can simply lower the units down to an overall height as low as 63.6 inches, and if it's a self-propelled lift, use the controls on the platform to navigate to the next area. In addition, a zero-turn radius feature on some lifts, coupled with widths as narrow as 30 inches, means maneuvering around 32-inch doorways and down hallways is hassle-free. A lift also eliminates the risk of a strain associated with lugging around a heavy ladder.

Low-level scissor lifts can never compete with ladders' light weight, but some of the lightest scissor lift models can be used on tile, laminate and raised floors without the risk of damage. Some push-around units weigh just 575 pounds and have wheel loads as low as 115 psi. Some self-propelled units are more impressive yet, with dual front wheels that enable them to achieve wheel loads as light as 75.8 psi.

We've proven low-level scissor lifts can get into nearly all the same areas as ladders. But the impact these small machines can have on worker safety are much larger than their small stature.

## RISE ABOVE THE RISK

High-reach work comes with challenges, and when using a ladder to perform that work, those challenges become compounded and can test the human body. For example, HVAC and plumbing technicians installing pipes and ductwork overhead need ample materials and tools as the job progresses. When they've completed one section, they must step down, move the ladder, grab more materials and climb back up. This is not only inefficient, but the repetitive climbing can cause injuries to knees and hips, and standing on the rungs for long periods can lead to painful plantar fasciitis. This scenario also sets the installer up for a fall. In fact, ladder users should never carry heavy objects or tools up the ladder. In addition, once workers are on the ladder their lateral



reach is limited, restricting how much work they can accomplish in one spot. As a result, many are tempted to - and often do - overreach and risk the ladder toppling over. These reasons are why improper ladder usage continues to make OSHA's Top 10 most cited



violations, year after year. In fact, according to the last study provided by the Center for Disease control, 81% of all fall injuries among construction workers in 2011 involved a ladder. All of those injuries likely could have been prevented with a low-level lift.

Some self-propelled low-level scissor lifts can hold as much as 750 pounds and offer as much as 15 square feet of platform space, including their extensions. That's plenty of capacity for ample materials and supplies. Also, loading the lift with those supplies is substantially easier and less taxing on the body due to lower platform heights. Operators simply load the lift, step up the 20 or so inches to get on the lift, then drive and elevate. And because workers can load the lift with more materials, they make fewer trips up and down, which enhances productivity. In addition, some units feature integrated pipe racks, which give installers a place to rest longer materials, while ensuring the lift stays balanced even with two people on the lift. These types of features help boost efficiency while maintaining safety.

### **DON'T PAY THE PRICE**

Most would agree a low-level lift is substantially safer and more efficient than a ladder, but there is still one problem - accessibility to a low-level scissor lift. If a lift isn't available on the jobsite, an employee isn't likely to ask for it and wait around for it to show up. They will instead move ahead with what they have, which is often a stepladder; and just like that the risk of injuries from a fall on the job skyrockets.

It's not just injuries employers need to worry about, though. Those falls aren't cheap. Just one worker's compensation claim can cost tens of thousands of dollars, which is just a fraction of the U.S. Consumer Product Safety Commission's estimated \$24 billion in annual costs associated with ladder injuries.

Under the Occupational Safety and Health Act, employers are responsible for providing employees with a safe workplace. Making safer equipment, such as low-level scissor lifts, available to employees is just one part of the equation, however. Employers must also train employees on when and where to use that equipment, and to understand that ladders should always be considered last. If a scissor lift can get in the space, it should always be

used in place of a ladder. In fact, some contractors who clearly understand the risks and associated expense of ladders simply do not allow them on the jobsite unless absolutely necessary and with specific protocols enforced.

Aside from minimizing injuries and worker's compensation costs, there is one more benefit to offering low-level lifts not many talk about: employee retention. The workforce is a different landscape than it was 30 years ago, and keeping employees is harder than ever. The younger workforce simply doesn't want to put their bodies through the day-to-day physical demands of construction work, and those who have been in the industry for years take a bit longer to recover from those tasks.

Providing all employees, whether 25 or 55, with equipment that allows them to do their jobs safely and efficiently not only minimizes their risk of injuries, but also demonstrates that employers value their workers and the time they dedicate to their businesses. The benefits of that are twofold — employees get a safe worksite and are generally happier while employers get more productive employees.

### **PUTTING LADDERS IN THEIR PLACE**

Just like a runner wouldn't expect to win a race injury-free wearing sandals, a contractor shouldn't expect optimal safety when using a ladder. Safety isn't a race, but if it were, ladders wouldn't stand a chance against low-level scissor lifts' safe and spacious platforms, easy maneuverability or ergonomics. Ladders will likely always be an option when it comes to work-at-height jobs, but there is a time and place for them, and typically it's last.





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March 12- 14, 2020

Bombay Exhibition Centre, Mumbai

### **TURKCOAT 2020**

Time: Mar 19-21-2020

Location: Istanbul, Turkey

### **EUROPEAN COATINGS SHOW RELOADED**

March 18 - 25, 2020

Virtual

### **EUROCOAT 2020**

Time: Mar 31- Apr 2, 2020

Location: Paris, France

### **AMERICAN COATINGS SHOW 2020**

March 31 - April 2, 2020

Indiana Convention Centre, Indianapolis, Ind

### **PAINTEXPO 2020**

Time: Apr 21-24, 2020

Location: Karlsruhe, Germany

### **UTECH NORTH AMERICA 2020**

May 19 - 21, 2020

Renaissance Schaumburg Convention Centre Hotel

### **ASIA-PACIFIC INDUSTRIAL, POWDER PAINT & COATINGS EXHIBITION AND SUMMIT**

May 28- May 30

Chongqing International Expo Centre

### **EXPO PAINT AND COATINGS**

02 - 04 JUL 2020

PRAGATI MAIDAN, NEW DELHI, INDIA

### **PAKCHEM EXPO 2020**

20-21-22 AUG 2020

International Expo Centre-Lahore Pakistan

### **CHINA INTERNATIONAL CHEMICAL INDUSTRY FAIR**

16 - 18 Sep 2020

Shanghai New International Expo Centre(SNIEC), Shanghai, China

### **SURFACE & COATINGS**

24-27 Jun 2020

BiTEC | Bangkok international Trade & Exhibition Centre, Bangkok, Thailand

### **PAKISTAN COATING SHOW**

14-15-16 April 2020

International Expo Centre Lahore

### **POLYURETHANE PAKISTAN EXPO**

14-15-16 April 2020

International Expo Centre Lahore

### **PAKCHEM EXPO**

20-21-22 August 2020

International Expo Centre Lahore

### **CONSTRUCT PAKISTAN EXPO**

30 SEP - 02 OCT 2020

International Expo Centre Lahore

### **PAKLAB EXPO**

06-07-08 October 2020

International Expo Centre Lahore

### **PAKISTAN PAPER, STATIONERY & EDUCATION EXPO**

September, 2021

International Expo Centre Lahore

### **PITEX EXPO 2020**

10-11-12 December, 2020

International Expo Centre Lahore



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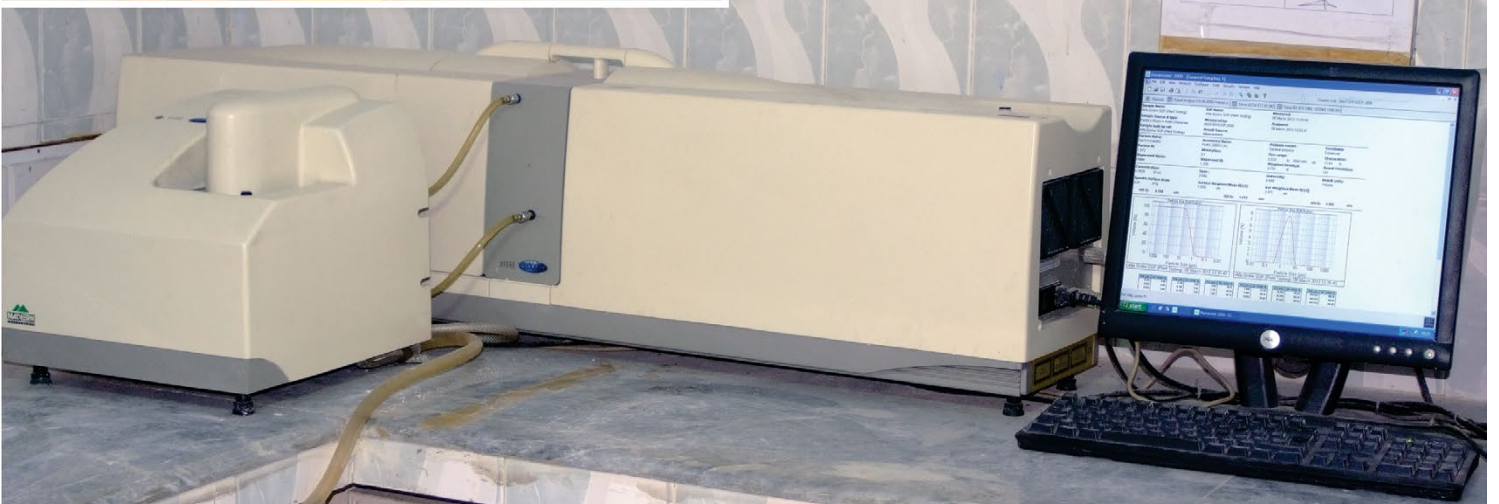
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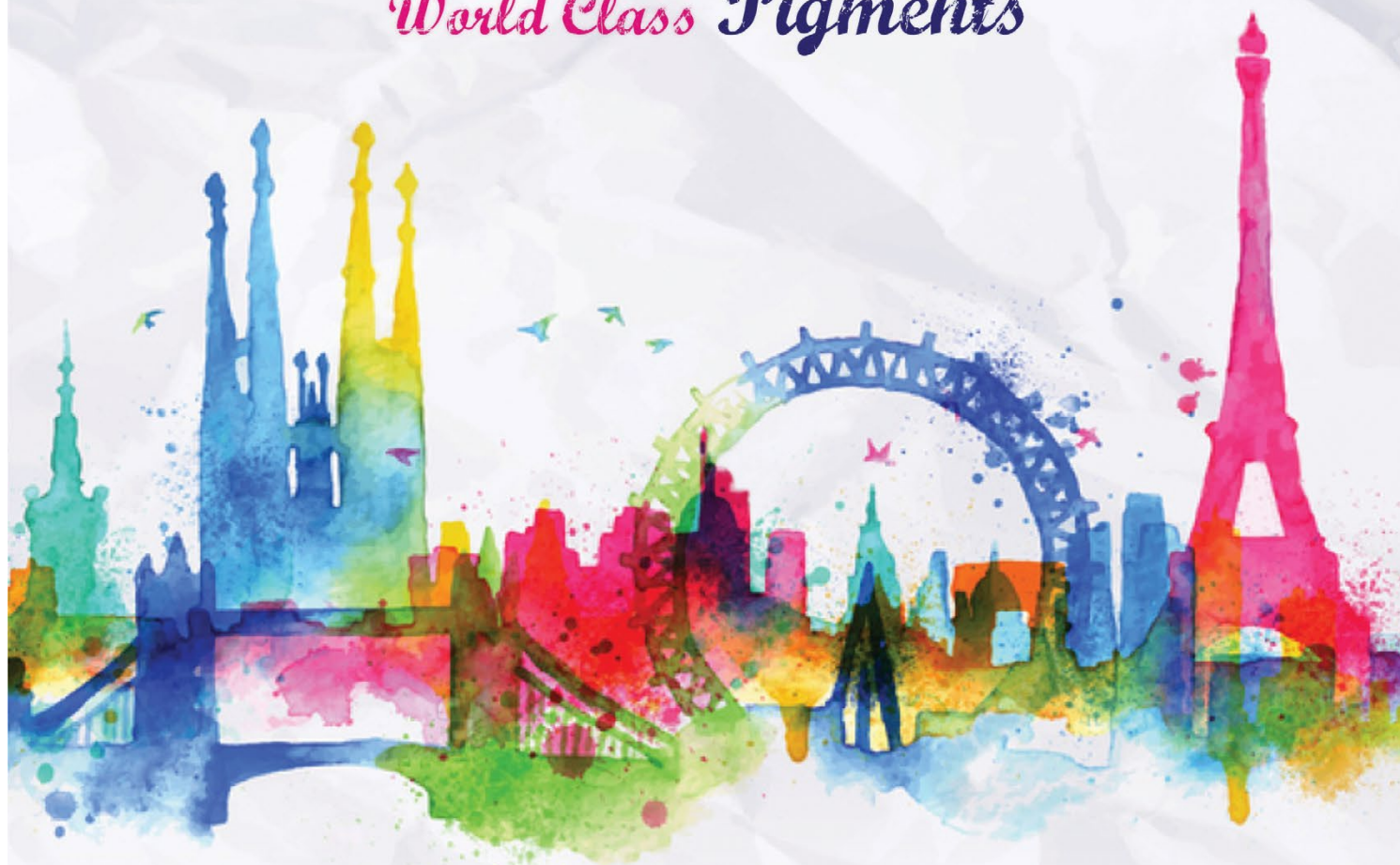




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- **BIOCIDES** ( In-Can & Dry Film Preservatives )
- **HIGH PERFORMANCE ADDITIVES** ( For Paints, Inks, OPV & Coatings )
- **WAX EMULSIONS** ( For Paints, Inks, OPV, Coatings, Textile & Leather Finishes )
- **FUNCTIONAL & MICRONIZED WAXES** ( For Inks, Coatings, Masterbatches & PVC )
- **WHITE PIGMENTS** ( TiO<sub>2</sub>, Lithopone & Zinc Phosphate )
- **IRON OXIDE & CHROME PIGMENTS**
- **PIGMENT PASTES** ( Water Based Exterior & Interior )
- **ALUMINUM PASTES** ( Leafing, Non-Leafing & Hi-Sparkle )
- **TRANSPARENT PIGMENTS** ( Toners )
- **DRIERS & Anti-Skinning Agent**
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