# Emerging Technical Trends in

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The latestintr<br/>tainadvancementsresiare opening evenandmore opportunitiesandin alternative substrates,ee-transportation, applicationsin highly corrosive environments,and thin-film powder coatings.

he past year marked a rebound in powder coating revenue as well as investment in R&D. In particular, both the North American and Latin American powder markets showed growth of 3.5% and 1.8%, respectively, in 2022.<sup>1</sup> These growth figures coincided with the introduction of several innovations in sustainability, low-temperature cure, corrosion resistance, outdoor durability, thin films, and thermoplastic application technology.

#### Sustainability

Sherwin-Williams recently introduced a powder coating product line based on *post*-consumer recycled plastic. Powdura® ECO powder coatings are formulated with polyester resins based on recycled polyethylene terephthalate plastic (rPET). Earlier versions of Powdura® ECO powder coatings were based on *pre*-consumer waste plastic that is generated in factories. This latest development will have an impact on recycling post-consumer plastic that comes mainly from beverage bottles.

According to the company, one pound of Powdura ECO TGIC/TGIC-free (triglycidyl isocyanurate) coatings contains the rPET equivalent of about sixteen 16-ounce water bottles, depending on the final product formulation Sherwin-Williams estimates that one pound of Powdura ECO hybrid coatings contains approximately the rPET of seven to ten 16-ounce water bottles, depending on the formulation.

# the Powder Coating Industry

#### Low-Temperature Cure

Pengchen (Simon) Yang, a senior researcher in allnex's Corporate Innovation Group located in Wageningen, Netherlands, introduced a potentially game-changing powder technology at the 2023 European Coatings Conference. The breakthrough was described in his presentation, "Ultra Low Temperature Curing Powder Coating via Real Michael Addition."

Yang's work introduces a new chemistry to the low-temperature-cure powder coating universe. This fascinating technology is based on Real Michael Addition (RMA) chemistry that includes an innovative catalysis system that provides cure latency to this highly reactive chemistry. An RMA reaction relies on a combination of a "Michael donor" in the form of a nucleophile with an  $\alpha,\beta$ -unsaturated carbonyl to create a Michael adduct. The allnex team, led by Yang, crafted this chemistry into solid polymers/oligomers that are extrudable and capable of film formation at relatively low temperatures, i.e.,  $\leq 120$  °C. In addition, these polymers/ oligomers are reportedly stable at room temperature storage conditions.

This chemistry is comprised of two crosslinkable species: component A is a material containing C-H acidic moieties, and component B is an unsaturated polymer. The most preferred component A is a malonate functional polyester resin, and methacrylated polymers (polyester-, epoxy-, or urethane-based) are the most preferred B component.

The catalysis system is rather complex and is based on a catalyst precursor (P1) in combination with a catalyst activator (C1). P1 is a weak base (DABCO<sup>™</sup> or tetramethyl guanidine) that reacts with C1, generally an epoxide compound, to produce a strong base catalyst. The epoxide compound can be TGIC, glycidyl methacrylate (GMA) acrylic resin, or Araldite<sup>™</sup> PT-910/912. This catalyst technology is quite reactive; therefore, a retarder, typically a carboxylate, is used to introduce a degree of latency. Latency is critical to enable processing through the conventional extrusion techniques that are common in the powder coating industry.

MINIMUM PARA

Latency is further enhanced by macrophysically separating reactive species in independent compounded mixtures. For example, the C1 catalyst activator may be extruded into binder components independent of the P1 catalyst precursor/ retarder blend. Two powder materials are generated that are then post-blended into a pseudo-2K powder mixture that is then applied to a substrate and cured at low temperatures, typically about 110–130 °C.

This groundbreaking technology is comprehensively detailed in the international patent application WO-2022/236519 A1, which was issued on November 17, 2022. It is the author's

## Emerging Technical Trends in the Powder Coating Industry

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hope that the powder coating world will take notice of Yang's fascinating lowtemperature RMA-curing technology and that this will open a spectrum of opportunities for growth into new markets and applications.

In other developments, AkzoNobel debuted Interpon W, a product group specially formulated for application to heat-sensitive substrates. Not only can these products be used to coat wood and engineered boards, but they can also be used on various plastics, gypsum, and plastic composites. Interpon W includes thermoset as well as UV-curable powder technologies.

Allnex Resins is also supporting the development of low-temperature-cure powder coatings with the introduction of ultra-low-temperature-cure polyester resins. These include UVECOAT (UV cure) and Crylcoat (thermoset) resins specifically designed to cure at temperatures 80–135 °C.

#### **UV-Cured Powder Coatings**

Keyland Polymer in Cleveland, OH, is opening an expanded resin development laboratory in Barcelona in response to increasing interest in Europe for UV-cured powder. Staffed with six resin chemists and technicians, the lab will be capable of conducting small-scale and pilot-scale reactions and developing new resins for UV-cured powder coatings and other UV-curable materials.

The focus is the development and manufacturing of UV-curable powder coating resins for heat-sensitive substrates, wood, MDF, plastics, composites, and carbon fiber. The next phase of the expansion is the addition of a UV powder formulation and application test and evaluation laboratory. The aim of this phase is to enable Keyland to accelerate the pace of not just resin development but also of UV powder process and performance validation.

Rising energy costs, the uncertainty of energy supply, and the availability of water make UV-cured powder coatings a highly desirable alternative to thermoset powder coatings and waterborne liquid paints and coatings. In addition, managing thermal deformation and surface conditions that compromise adhesion are critical when coating any heat-sensitive material. UV-cured powder has significant time and thermal advantages over many ultralow-bake or low-bake powders, and Keyland says its UVP1300 resin is unsurpassed in processing and performance as well.

### **Corrosion-Resistant Primers**

Considerable focus has been placed on improving the corrosion resistance of powder coatings, which has resulted in performance advancements in primers and topcoats.

AkzoNobel's Interpon team recently commercialized its Redox Plus range of powder primers that give enhanced corrosion protection across a range of metal substrates, including mild steel and aluminum. The primers are designed to protect products for ISO 12944-2 C5 environment conditions for 7–15 years, while providing more than 25 years of durability at a C3 corrosivity level. Interpon's Redox Plus range is also free from volatile organic compounds (VOCs).

The Redox Plus range of powder primers debuted with 3Brothers, an international lighting design and manufacturer in Cairo, Egypt. Egypt experiences many extremes of temperature, along with high salinity in the air and frequent sandstorms. The Redox Plus range of powder primers were coupled with a UV-resistant powder topcoat to provide the most effective protection in the challenging environment of North Africa, where the manufacturer's products are primarily sold.

Also in the EMEA region, Axalta has launched Alesta® ZeroZinc UniPrime, the newest addition to its Alesta ZeroZinc primer range. Like the other products in the Alesta ZeroZinc range, the ZeroZinc UniPrime has been formulated in accordance with High-Density Crosslinking (HDC) technology to protect against corrosion and help extend the working life of painted structures. The company says that Uniprime meets stringent anti-corrosion requirements and is easy to apply.

PPG recently introduced its Envirocron Primeron primer powder portfolio, which is designed to provide high corrosion resistance for metal substrates, including steel, hot-dip-galvanized steel, metalized steel, and aluminum. PPG says the portfolio has been tested according to the ISO 12944-2 corrosivity categories and is approved by the Qualisteelcoat International quality label for coated steel. The series covers a range of requirements depending on end use, operating environment, and application to challenging substrates.

Unlike many other flameretardant coatings, Plascoat® PPA571 FR does not contain a halogen constituent, such as chlorine or bromine, which minimizes the evolution of toxic fumes.



#### **Thermoplastic Powder Coatings**

Axalta Coating Systems recently launched a high-performance thermoplastic powder, Abcite® 2060, designed for flamespray applications. This product is based on ethylene copolymer chemistry and is touted for its ability to provide exceptional corrosion resistance in a single-layer coat. The powder is applied to grit-blasted metal in the field by using a flame-spray technique. This technology is designed to provide a coating that protects surfaces in extremely adverse environments as it passes the demanding CX specification of the ISO 12944 6/-9 standard for steel and galvanized substrates. Axalta says it does all this without the need for a primer coat.

Abcite® 2060 is designed to be highly resistant to alkali and acid attack and intense UV and weathering exposure. Films based on this copolymer have a service temperature from –60 to 75 °C and are said to provide excellent impact and abrasion resistance. The company says the product enables good edge coverage and recommends a film thickness of between 400 and 3000 microns. In addition, this product is BPA-, VOC-, and halogen-free.

With this latest innovation in material technology, the high-volume use of powder coatings outside the controlled environment of a factory setting can be realized. In addition, the well-known advantages of powder coatings—no VOCs, high utilization efficiency, low toxicity, and high durability—will provide a highly sustainable solution for assets requiring high durability in the field.

Axalta also recently announced the launch of a new thermoplastic powder coating designed to protect buildings and save lives in the event of fires. According to the company, Plascoat® PPA571 FR can be deployed in a range of environments to provide fire resistance and act as a barrier to additional damage caused by the spread of flames. Unlike many other flame-retardant coatings, Plascoat® PPA571 FR does not contain a halogen constituent, such as chlorine or bromine, which minimizes the evolution of toxic fumes.

Plascoat® PPA571 FR complies with several industry certifications, including British Standard 476, EN 45545-2 European Railway Standard for Fire Safety, British Standard 6853, International Maritime Organization FTP Code, and the UL 94 Standard for Safety of Flammability of Plastic Materials for Parts in Devices and Appliances.

#### **Architectural Topcoats**

In late 2022, Axalta Coating Systems launched its latest ICONICA collection of Alesta® SD powder coatings aimed at the architectural and construction markets in the United States. The collection, composed of coatings based on a super-durable polyester resin system that are designed to The Redox Plus range of powder primers were coupled with a UVresistant powder topcoat to provide the most effective protection in the challenging environment of North Africa, where the manufacturer's products are primarily sold.



### Emerging Technical Trends in the Powder Coating Industry

impart durability in exterior environments to higher grade pigments and stabilizers, with the intention of extending the lifecycle of architectural projects. ICONICA is compliant with international standards, such as Qualicoat Class 2 and AAMA 2604, and comes with a warranty of up to 25 years. The collection has a palette of 40 key finishes and 14 new colors.

These products were developed with a key focus on the environment. The Alesta SD range of powder coatings is solvent- and VOC-emissions-free and produces significantly less hazardous waste compared with solventborne coatings solutions. Projects on which these powder coatings are used could thus obtain LEED credits. The product range is also supported by an EPD certification.

#### Handling Ultrafine Powder Particles

Although powder coating has been a choice coating process for metal substrates in the industry for over 50 years, one nagging "holy grail" in powder coating technology is the ability to consistently apply thin films. Fundamental to powder coatings' remarkable performance profile is the relatively thick film build inherent to this technology. Whereas many liquid paints can be easily applied at film thicknesses of 10–15 microns, powder coatings struggle to form continuous films below a thickness of 30 microns. This is partly due to the electrostatic application process that rapidly delivers particles to a substrate and creates a relatively thick coating.

The particle size distribution of powder has a significant influence on film formation. Conventional powder coatings are comprised of particles ranging from approximately 1.0 micron to about 90–100 microns. Median particle size typically ranges between 30 and 35 microns. Consequently, the formation of a thin film (i.e., < 10 microns) is impossible, as large particles cannot coalesce to form films that are significantly thinner than the diameter of a particle.

Technologists have investigated using ultrafine (< 25 microns) powder particles to generate thin films; however, powders in this particle size range are difficult to handle. Ultrafine particles, by their nature, exhibit poor dry-flow properties due to inter-particle interactions—mainly clumping and bridging from van der



The Resicoat EV powder coating line improves the performance of the battery by providing insulation from electrical currents and protection against corrosion. The enhanced thermal management of these products helps protect the battery systems, motors, and electrical storage units. Waals forces. The dry handling properties of ultrafine powders can be significantly improved with the addition of fluidization agents. However, these fluidization additives compromise film appearance and performance because they have high oil absorption that significantly increases melt viscosity. Excessively high melt viscosity creates undesirable surface texture, low-gloss films, and film defects.

Interesting work attempting to tackle this problem was recently reported in the June 2023 Progress in Organic Coatings journal. Professor Jesse Zhu and his colleagues at Tianjin University and the University of Western Ontario published their findings in an article titled "Enhanced Flowability and Film Properties of Ultrafine Powder Coatings Modulated by Modified Flow Additive." The article aptly describes the problem with handling ultrafine particles and the conventional technology that is used to enhance the flowability of powder coating particles, i.e., commercially available nano-silica and nano-alumina that are typically incorporated at levels of 0.2% to 0.5%. Higher levels create what these investigators call the "bridge effect." In addition, the aforementioned film-quality issues are produced by higher levels of these nanomaterials.

Zhu and his colleagues have investigated the use of resin-coated nano-silica flow additives with promising results. They used either a "hybrid" or a polyester resin, commonly used in powder coating formulation platforms, to encapsulate a traditional nano-silica flow additive. Then, they incorporated these coated nanoparticles into ultrafine polyester and "hybrid" powder coatings. The ultrafine powder coatings modified with these encapsulated nanoparticles exhibited enhanced fluidization and handling properties without impairing film appearance and performance.

#### **Electric Vehicles**

The explosive growth in electric vehicles (EVs) has proven to be a gold mine for powder coating producers. Powders have been developed to meet the demanding requirements of the electric powertrain, which include adequate thermal dissipation, high dielectric strength, and excellent corrosion resistance. The team that developed Envirocron<sup>®</sup> LUM, led by Paul Bradley, drew inspiration from the reflective properties of a deer's eyes. Incorporating embedded glass beads into the formulation enables a single-layer coating of this product to refract and retroreflect light, significantly improving the ability of a vehicle driver to see cyclists on bikes with this coating.

AkzoNobel has launched a new range of Resicoat EV powder coatings to protect the battery system and electrical components of a new generation of EVs. The company recognized that the success of EVs is dependent on the performance of the battery and associated systems, which are highly impacted by the environment. The Resicoat EV powder coating line improves the performance of the battery by providing insulation from electrical currents and protection against corrosion. The enhanced thermal management of these products helps protect the battery systems, motors, and electrical storage units. The powder coatings, according to the company, significantly extend battery life and help them maintain performance longer.

AkzoNobel says each of the five product ranges developed within the Resicoat EV range has been specifically designed to enhance the safety and performance of the EV power systems.

Arkema has also developed powder coatings for the EV market. The company recently introduced two polyamide 11 powder coating grades for use in EV battery systems and other related applications. Rilsan® T Orange 7706 is a fluid bed dipping grade designed to achieve high thickness (500 microns) in one dip. Rilsan® ESY Orange 7705 is an electrostatic coating grade for components that require thinner insulation. Both products can be applied in one coat and do not require a primer.

During testing, each grade achieved CTI ratings that were greater than 600 volts and a UL 94 fire-resistance class of V-0. In addition, these materials offer easier processing due to their high level of flexibility and ability to be easily masked. Rilsan® polyamide 11 is a versatile polymer that is 100% biobased (derived from castor oil).



#### **Retroreflective Finishes**

On the bright side, PPG's Envirocron® LUM, a retroreflective powder coating product that provides reflectivity in low-light environments, debuted in 2022 on Lyft's fleet of high-visibility e-bikes, a cyclist-safety program that Time magazine recognized as one of "The 100 Best Inventions of 2021." The team that developed Envirocron<sup>®</sup> LUM, led by Paul Bradley, drew inspiration from the reflective properties of a deer's eyes. Incorporating embedded glass beads into the formulation enables a single-layer coating of this product to refract and retroreflect light, significantly improving the ability of a vehicle driver to see cyclists on bikes with this coating.

#### **Parting Notes**

Innovation in powder coating technology is alive and well thanks to the creativity and hard work of powder formulators and polymer scientists. A renewed effort to innovate and provide ecologically friendly and sustainable powder technology is meeting the emerging needs of the dynamic industrial coatings industry Innovation in powder coating technology is alive and well thanks to the creativity and hard work of powder formulators and polymer scientists.

as they arise. In particular, the latest advancements are opening even more opportunities in alternative substrates, e-transportation, applications in highly corrosive environments, and thin-film powder coatings. 🛠

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#### Reference

1. Powder Coating Institute. Global Powder Coatings Quarterly Newsletter, 1st Quarter 2023.