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Color Selection and Pigment

By Cynthia Challener, Contributing Writer

Color selection and pigment development go hand in hand. End users gather data on trends in consumer color preferences to determine new colors for upcoming product lines. Those color selections then must be realized using existing or new pigment technologies developed to address attributes such as hue, opacity, brightness, and appearance.

Color selection and formulation are complex processes. There are, according to Hannah Yeo, manager of color marketing and development for Benjamin Moore, hundreds of unique color spaces, but that is only part of the story.

There are also different shades within each unique color space, which can result in colors being unique for each vendor based on their manufacturing process and raw materials. The overall color selection process, therefore, must involve the product designer, paint formulator, and pigment manufacturer.

"A close partnership is of utmost importance to ensure a regular exchange on market needs and trends on the one hand and coloration possibilities and innovations on the other hand," says Tom Landuydt, head of industry management for automotive coatings with the BASF Colors & Effects® pigment business. "Long-term collaboration enables services around the colorant and mutual understanding about the requirements for ideal pigment selection based on color and performance," he adds. "Moreover, it forms the basis for the development of next-generation pigments for future color selections."

COLOR FORECASTING AND PALETTE DEVELOPMENT

Color selection for future product development depends on many factors. Customer preference is a top consideration, but with larger products such as vehicles, product design can also be important. "Color selection is a dynamic process," says Craig Swift, senior mastering specialist at the Ford Motor Company Product Development Center. "And at Ford, we often use coatings to differentiate our vehicle series from the competition."

Some color spaces, he adds, may allow for emphasis of a particular set of attributes, but everything must adhere to production standards. In addition, the rapid move toward automotive electrification creates additional challenges around pigment detection and interference with advanced sensor systems, and some series on the same vehicle platforms can have different needs. Finally, Swift says that while Ford pays close attention to trends, the company is not so rigid that it can't be a trendsetter.

Technology Development

Coating formulators help their end customers with color selection by providing insights on color trends. PPG, for instance, offers a broad palette of more than 2,000 architectural coating shades but also curates specific palettes that reflect annual trends to make the selection process simpler for its customers, according to Kristi Kauffman, PPG senior technical manager for architectural coatings, research and development, color.

Benjamin Moore's portfolio contains 3,500-plus colors that are appropriate for architectural coatings and meeting the needs of customers, but the company also develops curated palettes for project-specific products chosen based on in-depth research on demand and usage in that specific application, Yeo says.

The specific palettes at PPG are developed once PPG's global color styling team builds industry color trends based on global, cross-cultural lifestyle, fashion, and design insights. "We always develop colors that are not only trending and resonate with consumers, but that can also pass all finishing tolerances set by customer standards," says Vanessa Peterson, PPG's color design manager for consumer electronics.

For automotive applications, pigments are selected that guarantee the necessary durability, stability, and workability, while also enabling sustainability, innovation, and coatings compatibility with new vehicle technologies (i.e., radar and LIDAR) needed for assisted and autonomous driving, according to Federico Menta, PPG global technical director for automotive OEM coatings.

In PPG's automotive refinish and commercial fleet/industrial business, formulas are provided that meet repair needs specific to each market and match the variation of colors seen on vehicles on the road. PPG's team of color formulation experts located at various ports of entry are a crucial component of the company's success because they identify new color variations as soon as vehicles are introduced to the U.S. market, notes Natalie Scott, PPG marketing manager, automotive refinish color, in North America.

PIGMENT AND COLORANT INNOVATION

When it comes to developing new colorant and pigment technologies, some drivers apply to all pigments, while others can be application-specific. Jerry Powers, technical director—Coatings Americas for Chromaflo Technologies, identifies four development buckets: to satisfy the market need for improved technology; to create products that meet regulatory requirements and anticipate future changes; to achieve product sustainability

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in a competitive market that can also be impacted by raw material costs and availability; and to "think outside the box" and enable market disruption (the fun bucket).

Paul Nowak, director of sales and marketing in the Americas at Korean pigment manufacturer CQV, identifies four primary drivers for pigment innovation: the market demand for unique materials; emerging color trends; the need for functionality or other physical properties to meet customer requirements or create a competitive advantage; and upgrades in manufacturing processes and changes in application technologies.

Regardless of how development drivers are categorized, the overall goals, according to Landuydt, are expanding the color and effect space and improving performance and processability. In general, he adds, new pigment chemistries enable formulators to reach the vibrant shades requested by consumers and designers across all applications.

Regulatory drivers, including reduced use of biocides, elimination of heavy metal pigments, the need for APEO (alkylphenol ethoxylate)-free and low-VOC colorants and DCB (dichlorobenzidine)- and PCB (polychlorinated byphenyl)-free pigments, and the desire for increased sustainability, which is driving the shift from solventborne to water-based coatings, are also common across applications, says Gabriela Seefeldt, head of industry management architectural and industrial coatings at BASF Colors & Effects. She also points to a general expectation for increased durability and a greater ease of use, such as easy dispersible pigment preparations and innovative technologies like dry dosing at the point of sale.

Companies are also always looking to optimize the "cost" of pigments either on a cost-by-weight or cost-to-performance basis, according to Mark Ryan, marketing manager at The Shepherd Color Company. Functionality beyond color gains is also increasingly important. As examples, he cites adding hyperspectral properties to coatings in the near-infrared (IR), which keep materials cooler and can also create visually invisible markings that are readable by autonomous driving vehicles.

Improvements in manufacturability can entail a multitude of advances in manufacturing equipment and process control. Nowak of CQV notes examples such as computer-metered addition of raw materials for reduced operator errors, use of artificial intelligence to monitor chemical reactions for greater operational efficiencies, in-line sensing to obtain real-time feedback for more consistent manufacturing processes. "All of these approaches lead to higher quality, more cost-efficient products," he says.

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Changes in end-user technologies can also create a need for new pigment chemistries, according to Nowak. The ink industry, for instance, is shifting to energy-cure and digital printing and away from traditional liquid heat set processes. The movement from liquid to powder coatings for some applications is also requiring modification of existing pigment chemistries. Air vs. electrostatic spray application may also require changes in particle size or the creation of more robust pigments that can handle the extrusion process used for powder coating production.

The "holy grail" for a pigment supplier is to develop a colorant that can provide a new, fresh, never-before-seen, widely applicable, visual experience that is globally accepted across multiple markets and product lines, Nowak says. "Such tools, when put into the hands of a creative design person, can spark a global wildfire leading to economic prosperity for the colorant manufacturer and the manufacturers of consumer products," he says.

When it comes to choosing pigments for a specific application, Nowak adds that expected life cycle (warranties), consumer protections in the form of governmental safety or environmental requirements, ability to change colors easily and often, cost, are all determinants in what colorants are used. If a supplier wishes to sell into a specific industry or for a specific application, the pigment/colorant must be suitable and meet the minimum requirements for that application or industry, and that, he says, may require product development.

"To achieve competitive advantage, pigments might be made brighter, more chromatic, more easily dispersed, more durable, non-dusting, or more environmentally acceptable (sustainable, lower carbon footprint during manufacture, or suitable for recycling) or have added functionality, such as anti-corrosive properties, acid etch resistance, better adhesion, or improved resistance to outside detrimental influences like pollution, depending on the specific application," Nowak explains.

For different industry segments, some specific drivers are worth mentioning. For automotive coatings, bright, highly transparent, and durable pigments are essential. Pigments must also be compatible with new resins, and there is growing demand for LIDAR-ready pigments, according to Andreas Harz, head of preparations coatings in the Americas at Clariant. "These evolving technologies, like self-driving cars, require unique road markings to function safely and effectively; consequently, a lot of attention is being paid to what is needed for those developing transportation concerns," he says.

In the architectural space, Harz notes, exterior coatings such as those for decks require improved resistance to mildew and color permanency, which is leading to the development new coatings systems, and colorants must be compatible with these new technologies. Similarly, IR-reflecting pigments aid "cool coatings" for roof and wall coverings but also must meet requirements for color fastness and resistance to efflorescence. Meanwhile, for interior applications, antimicrobial (antibacterial, antiviral) coatings are receiving significant attention, and thus pigments and additives that can help improve microbial resistance have become important, according to Harz.

COLLABORATION ACROSS THE SUPPLY CHAIN

Truly successful color and pigment development involves cooperation between experts at end users, formulators and pigment manufacturers. Ford, for instance, works closely with both paint and colorant suppliers to evaluate new pigments that can enhance a traditional color space in a new and exciting way, according to Swift. Typically, the big coating suppliers to the automotive industry hold shows each year to introduce their different color lines. "Sometimes these formulations can be used as is except to ensure they meet all production specifications, but other times alternative colors are needed to fit a specific theme," Swift says.

Car manufacturers face different challenges. "It is a very complex process to get all the different paint chemistries that go on all the different substates and geometries to look the same as you walk around a vehicle," Swift says. Sheet metal is painted at the plant with one coating technology; an ABS spoiler is made by one supplier and painted with a totally different chemistry; and the TPO facia comes from another supplier and is coated with yet another chemistry. "In addition, the paints used on all of the different parts of one vehicle may come from five or six different paint suppliers. The key is developing effective color masters and working closely with suppliers to help them adjust processing parameters so all of the components, regardless of substrate and paint chemistry, end up with an applied color that matches the master," Swift explains.

Formulators, meanwhile, work with both customers and pigment suppliers to develop optimal coatings with the right color performance. Benjamin Moore, for instance, is in constant contact with architects, designers, and contractors to understand their needs and ensure they are equipped with appropriate product and color, Yeo says. For new product launches, department members from Product, Color Marketing & Development, Color Technology, and R&D work together to provide the best solution. They gather as much information as possible from pigment suppliers to ensure that the company's proprietary chemistries marry well with pigments in the target color spaces to deliver dispersions with robust chroma that deliver the broadest palettes, Yeo explains.

The team also meets regularly with pigment suppliers to discuss technological advances in pigment chemistries, novel new color spaces, logistics, regulations, and more. "Creating pigment dispersions is a delicate balance of chemistry and physics. The chemistries required to do this are specific not only to colors, but often to the vendor as well," Yeo says. "Our laboratory works closely with vendors, procurement, and manufacturing to ensure we have the highest quality pigments for use in efficient manufacturing processes and that we deliver an outstanding customer experience."

One of PPG's core principles is to partner with customers to create mutual value. As a best practice, Kauffman notes, the company aims to anticipate the needs of customers and work alongside them to leverage PPG's long-standing, insights-driven approach to innovation and color trends. In the auto industry, for instance, new color programs are built in partnership with each automakers' design team to ensure that the uniqueness of each brand and their designs are taken into consideration.

The key is developing effective color masters and working closely with suppliers to help them adjust processing parameters so all of the components, regardless of substrate and paint chemistry, end up with an applied color that matches the master.

PPG customers across businesses visit the company for face-to-face color workshops, but in light of the COVID-19 pandemic, it is more common to discuss options via remote workshops, according to Peterson. Digitalization in general is becoming increasingly important as part of the color-creation process. Menta says that PPG is creating future-forward digital tools to increase collaboration and intimacy with its customers, allowing increased efficiency and shortening the time to market.

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Working with pigment suppliers is equally important for formulators. "Our customers are always looking for the latest trends and that which will separate them from the competition," Peterson says. "Color trends push boundaries within the industry and lead to experimentation in new ways of preserving color, especially within electronic materials and industrial coatings. It's vital that we continue to work closely with suppliers to inspire them and educate them on the needs of the clients in the hope that these desired effects will be manufactured."

The key element to a successful outcome of this process is to have a thorough technical discussion at the beginning of the project to determine the requirements of the colorant and the impact on the coating performance.

For the automotive market, PPG predicts needs in the early stages of the design process and works closely with pigment suppliers to develop new products/pigments in order to provide differentiated color developments for its customers, according to Menta. "We strive to reduce our complexity in order to be able to drive sustainable innovation and environmental stewardship," Menta says. "Those goals are in part achieved by delivering new pigments and effects each year based on the work done with our suppliers."

Pigment suppliers, meanwhile, have the deep knowledge and understanding of their technologies and are best positioned to recommend optimal pigment solutions for a given application, particularly when they have expertise with a broad palette of both organic and inorganic pigments, according to Frank P. Lavieri, executive vice president of sales and marketing at DCL.

Based on Chromaflo's experience, having a range of options that suit different market segments is crucial for guiding colorant selection because what colors/colorants a coatings company requires can depend on the application. Input from formulators is absolutely crucial as well, Powers adds.

"While there are industry-accepted standards and methods, sometimes coatings companies have expectations that can be higher than typical benchmarks or may add other requirements specific to their technical objectives," he explains. "Considering the application that the colorants will be used in and the potential exposure requirements before the color project begins is also necessary for identifying the pigment choices that provide longer-term value. The key element to a successful outcome of this process is to have a thorough technical discussion at the beginning of the project to determine the requirements of the colorant and the impact on the coating performance."

At BASF Colors & Effects, pigment experts are also engaged throughout the coating production process to ensure that customer requirements are well-translated into the correct product selection and highest level of service, according to Seefeldt. Those services can include recommendation of a pigment that adds the required benefit to a formulation, guidance to ensure optimal processing, and laboratory, heat management, and mixing-system calculation support for optimization of the complete coating system.

Clariant shares its color trends knowledge and formulation ideas with coating technicians in the architectural and automotive industries through webinars and in-person meetings and works closely with manufacturers to develop new pigments and dispersions that support their product development objectives, according to Harz.

Shepherd Color also brings experimental products to the attention of the company's key industry partners to gauge interest in new technologies. "Since our products are often used in high-durability coatings, getting new pigments into long-term testing as early as possible allows them to be used at the earliest possible time," Ryan notes.

CQV makes a point of staying in regular contact with the entire chain of teams responsible for developing a color, including those responsible for fleshing out "trend colors," purchasing, personnel responsible for testing and dispersion, and formulators responsible for commercialization, according to Nowak. In addition to offering guidance on global and regional color trends, the company offers prototype examples of those trends using our colorants, providing data on manufacturing specifications, physical properties, and regulatory compliance.

During the pandemic, Shepherd Color has been exploring ways to communicate color by using interactive 3D displays of color space, providing formulators with another context for understanding the potential of new shades and products. Landuydt says through advances in virtual color technology, appearance and color travel can be effectively shown as well, allowing both sides to understand the properties of a colorant even in remote locations.

CUSTOMIZATION WHEN NECESSARY

While both formulators and pigment suppliers have robust portfolios that meet most end-user needs, there are occasions when projects have unique color and appearance requirements and thus the need for unique pigment/colorant solutions. Nowak notes that the need for customized solutions has been growing in recent years.

"Over time, companies have developed their own unique resin chemistries and formulations that have taken many divergent paths. The result is that no one pigment may be universal for all of these variants, and therefore a tailored approach is needed to make pigments and colorants suitable for a specific resin and formulation chemistry," he explains. Examples may include added surface treatments, changes in pigment chemistry, or entire pigment reconstruction.

Established relationships between formulators and pigment suppliers become even more important for these projects. "Close relationships with pigment suppliers enables us as a formulator to order samples quickly and then rapidly develop the desired colors," Peterson explains.

A robust R&D program is also essential for successful, tailored development

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of pigments for specific customer applications, according to Lavieri. Of course, the development work and resources required for such customized project must make business sense, Powers stresses. "These conversations take place quite regularly. Sometimes the customer may not be aware that a certain colorant technology already available within our existing product lines will meet their needs," he says.

In some cases, specialized projects can lead to new product lines. For Clariant, that was the case when a customer struggling with flocculation resistance and color development in a resin system with a specific color index required an improved solventborne industrial dispersion system.

The newly developed technology solution led to the introduction of Clariant's newest product range—Hostatint™ SI dispersions for solvent-based industrial coatings. "Our easily dispersible pigments were designed for a very specific application and that technology has provided major cost savings in the manufacturing of coatings by reducing the need for expensive media mills," says Romesh Kumar, Clariant's senior technical sales manager for coatings in North America.

SPOTLIGHT ON NEW TECHNOLOGIES

Depending on the pigment industry in question (organic vs. inorganic vs. flake effect pigments), there have been numerous developments in pigment technology. In the organic space, the development of pigments that can be supplied as easily dispersed, non-dusting powders, eliminating the need for additional secondary processing, is one notable achievement, according to Nowak. Another is colorant dispersions based on hyper-dispersed organic pigments created using sonic dispersion equipment, which are less prone to agglomeration, resulting in stronger, cleaner, more durable pigments that approach the appearance of a dye.

BASF Colors & Effects, for instance, introduced eXpand!® stir-in slurries for waterborne automotive coatings, including eXpand!® Red EH 3530 in 2020, the first universal grade enabling intense shades in various coating systems. Pacific Yellow and Pacific Orange are other examples of universal pigments from BASF Colors & Effects with a good balance of properties, according to Seefeldt.

Clariant has also focused on the development of all-in-one solutions, and recently introduced Hostaperm® Scarlet GO, Hostaperm® Yellow H3G, and Novoperm® Orange HL70 universal pigments. The Hostafine® and Hostatint™ A 100-ST ranges of super-transparent dispersions for waterborne and solvent-based coatings, respectively, offer alternatives to traditional dyes and provide improved performance in terms of migration resistance, color permanency and color stability in coatings for wood, automotive, and consumer goods, Kumar says.

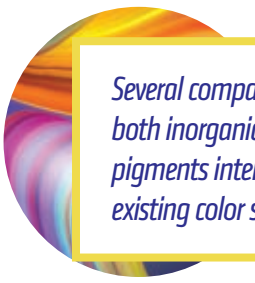
Increasing durability and pigment loading while reducing VOCs has been a focus for Chromaflo. The company has introduced new low-VOC pigments and colorant technologies for the architectural market that help coatings formulators with opacity and durability in both interior and exterior applications, according to Powers.

One example is the Colortrend Pearls 2020® line of 11 solid colorants for waterborne architectural and industrial traditional solventborne systems. The new Chroma-Chem FLV series of biobased colorants are, Powers adds, a comprehensive improvement from older, standardized industrial colorants for use in industrial epoxy, polyaspartic, and polyurethane flooring applications. For industrial waterborne applications, the Chroma-Chem 897 line also enables industrial coating formulators to move away from solventborne systems, according to Powers.

DCL provides value beyond color with its new range of very opaque and strong organic pigments that enable low-cost formulas with excellent light and weather fastness properties, especially for liquid industrial coatings, says Lavieri.

Several companies have developed both inorganic and organic pigments intended to expand existing color spaces. Shepherd Color has improved on existing cobalt blues, which offer bright red shades, but with lower opacity and higher oil absorption than other inorganic pigments. By radically reducing the physical surface area without changing the chemistry, the company developed Blue 10C595, which offers lower oil absorption and much higher loading levels for greater coating opacity while still giving higher gloss and better flow, leveling, and distinctness of image, according to Ryan.

Close relationships with pigment suppliers enable formulators to order samples quickly and the rapidly develop the desired colors.



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Shepherd Color's patented NTP Yellow pigment chemistry, meanwhile, enables bright chromatic yellows with high opacity and excellent weathering. "When you pair the NTP Yellow with our RTZ Orange pigment, you can cover a wide range of the yellow color space with all inorganic, highly durable pigmentation," Ryan says.

Bismuth Vanadate RMXS from DCL, according to Lavieri, is the strongest, most opaque bismuth vanadate pigment and allows for highly durable, lighter weight yellow vehicle coatings that lead to savings on fuel costs. BASF Colors & Effects recently launched highly chromatic inorganic pigments Sicopal® Turquoise and Red also provide for super-durable coatings without having to limit the color palette, according to Seefeldt.

BASF Colors & Effects has also expanded the red to blue color space with Lumina® Royal Exterior Blue Russet S6903D, which Landuydt notes also provides superior sparkle to automotive OEM and refinish, aerospace, general industrial, and powder coatings.

The development of functional black pigments enables formulators to surpass new performance requirements without giving in on the color.

To address the unique needs of pigments for coatings on autonomous vehicles, BASF Colors & Effects has developed functional black pigments such as Spectrasense™ Black L 0086 and Sicopal® Black L 0095. In addition to providing detection of autonomous vehicle applications, these pigments also allow formulators to produce colors that meet heat management targets for architectural and industrial applications, according to Seefeldt. "Ultimately, the development of functional black pigments enables formulators to surpass new performance requirements without giving in on the color," she says.

There have also been numerous advances in effect pigment technology. One that Nowak highlights includes the development of aluminum-flake pigments that are supplied as non-hazardous, easily dispersed, dry powders that are universally compatible (water/solvent/powder), circulation-degradation resistant, and available in thin silver dollar geometries, allowing the creation of brighter, cleaner, effects with smaller particle-size distributions. He also points to the development of colored aluminum pigments that allow the creation of highly chromatic colors with good opacity in the red, orange, gold, and copper color spaces as being notable.

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True universal colorants that can reduce the overall number of products needed to tint coatings and pigments for bright, opaque yellow, red, and orange shades are desired.

Others worth mentioning, according to Nowak, include extremely thin, aluminum-based pigments that approach a liquid-metal effect; "real" white pearlescent pigments based on synthetic mica that are neutral in hue (not too warm "yellow" nor too cool "blue") with good luster; and higher chroma, smaller particle-size-distribution effect pigments (< 25 um d(90)) in the red, blue, and violet color spaces.

Finally, two developments in colorant systems should be noted. In 2018, PPG developed FormulaPro™ High Strength Colorant, a new state-of-the-art colorant system used to develop colors for PPG's architectural coatings. During the development of this system, PPG benchmarked commercially available colorant systems and worked closely with pigment providers to select features that would provide industry-leading performance with respect to durability, colorfastness, hiding power and range of colors, according to Kauffman.

Separately, BASF Colors & Effects introduced the XF200 dispenser, a solid dispensing system for point-of-sale (POS) use. The Xfast® Easy Color software allows dosing of customized formulations of solid colorants directly into base paints. "By tackling three of the major cost factors of liquid systems—service, colorant viscosity changes, and sedimentation—it reduces expenses significantly and improves the everyday handling of POS systems," Seefeldt says.

ALWAYS LOOKING TO EXPAND

Despite the numerous advances in pigment and colorant technologies that have been made over the years, there remain areas for improvement—and challenges to addressing them. "Our R&D team is constantly looking into new pigment varieties that can improve performance properties, make the life of coatings formulators easier and expand the color space, but they must be economical solutions; achieving the

optimal cost-performance balance is the challenge," Landuydt says. In addition, he notes that coating formulators ultimately would like a "one fits all" solution—a pigment that is compatible with all paint systems, provides the highest performance properties, can be stirred in and thus eliminate the need for milling, and achieves the highest variety of colors for a low price.

Kumar agrees, noting, "True universal colorants that can reduce the overall number of products needed to tint coatings and pigments for bright, opaque yellow, red, and orange shades are desired."

The regulatory hurdles that must be overcome to get new pigment chemistries approved present another set of challenges, according to Ryan. "When you factor in the time and cost of these regulatory hurdles and then the restrictions placed on new chemistries, to bring new pigment technologies out to the market becomes a daunting task that requires a broad range of laboratory, regulatory, production and marketing resources," he explains.

Development needs also differ for organic and inorganic pigments. As the demand for more chromatic shades increases in coating applications, so does the need for increasingly durable organic pigments capable of meeting strict exterior industry specifications, according to Seefeldt.

In fact, Kauffman notes, PPG is always looking for pigments that can offer more durability and hiding power, especially for organic pigments.

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There is a particular need for an exterior durable neutral shade yellow-effect pigment that is not too red or too green, an effect pigment that gives a true "chrome" or liquid-metal look.

Conversely, Seefeldt says that inorganic pigments with improved chroma would be well received by the industrial markets. From a coloristic point of view, she points to highly durable exterior coatings in the bluish-red area, especially formulations of magentas and violets, as the biggest challenge.

Ryan agrees that a red that performs like other high-performance inorganic pigments is the "holy grail." The gap created by the necessary exit of heavy metal pigments for industrial coatings applications remains to be filled, Powers adds. "Bright, chromatic, durable (exposure to chemicals and weathering) pigments required for creating deep blues, greens, and especially yellows and reds, are needed in the market today," he says.

For effect pigment manufacturers, Nowak says that there is yet another layer of difficulty created by the laws of physics, which will need to be broken if the current substrate oxide coating technology model continues to be applied.

"Our challenge is to find a new method to somehow engineer color and effect using a totally new model, which requires a breakthrough in some manufacturing process or discovery of a new raw material," he says. "In the meantime, we must identify various permutations to the standard model that have unique properties but also are sustainable, environmentally friendly, low-carbon-footprint variants of our existing technologies."

Nowak notes that there is a particular need for an exterior durable neutral shade yellow-effect pigment that is not too red or too green, an effect pigment that gives a true "chrome" or liquid-metal look, and cost-effective optically variable pigments fine-tuned to have very specific color travel that can be consistently produced. PPG is also receiving requests for tonal color shifts, or metallic effect pigments that have the ability to shift along with deep fluctuations within the same tonal color family, according to Peterson.

Sustainable solutions—pigments derived from biomass and that take less energy to produce—and those designed to support the electrification of vehicles are in demand in the automotive industry, according to Swift. The need for LIDAR reflectivity, and radar transmissivity place severe limits on the colors and thus pigments that can be used in exterior coatings for these vehicles. Coatings containing flake pigment based on aluminum cannot be detected efficiently at all angles, and dark colors are nearly impossible to detect. In fact, pure solid white exhibits the best performance.

"Many aluminum pigments will interfere with radar and LIDAR detection systems, so there is significant effort being focused on exploring how this issue can be resolved so that specific colors can still be achieved. One alternative is to use inert substances such as mica, but it is difficult to create a silver look without aluminum," he says.

In addition, Nowak notes that how hot the surface temperature of a vehicle gets is a concern for autonomous vehicles. "Total Solar Reflectivity needs to be controlled with light reflective pigments and color spaces," he says. Swift says he believes that as more companies such as Ford delve into autonomous vehicle technologies, how much more they need to learn will become more evident. ❊

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