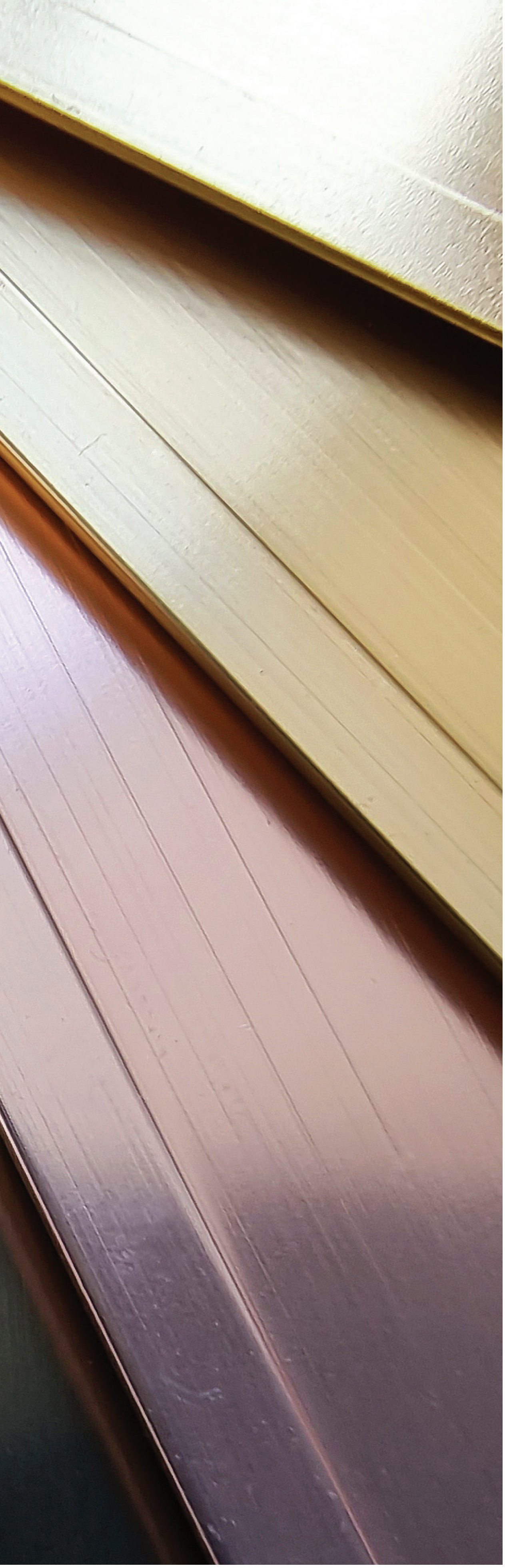
METALLIC AND PEARLESCENT PIGMENTS for Powder Coatings

By Cynthia Gosselin
The ChemQuest Group, Inc.



Color has a way of creating impact and enhancing spaces and objects. There is evidence all around us to suggest that people are drawn to colorful, shiny things. While color perceptions are subjective and deeply personal, there are some color and gloss effects that have universal meaning. Perhaps it is because many cultures have come to associate gloss with wealth, luxury, and beauty.

Luminosity, iridescence, and holographic effects are a few of the ways that the love for metallic and pearlescent finishes has evolved. These additives enhance color by adding shimmer and brilliance, providing contrast and metamerism for the entire color palette.

New technologies are making strong statements in all aspects of coatings and design, allowing colors to appear and disappear in light in a kaleidoscope of color displays and illumination across the entire color spectrum. The luminosity of metallic and pearlescent finishes stands out, immediately grabbing our attention.[1]

Specialized metallic and pearlescent pigments have been developed that allow coated surfaces to exhibit a more glamorous appearance, with luster and brilliance that sets them apart from finishes produced by using conventional pigments.

Appliances, vehicles, cosmetics, printing inks, packaging, soaps, and even food and beverages are a few of the markets that have taken advantage of these additives to project beauty and command attention in a crowded world.

Today's natural inorganic pigments have come a long way since prehistoric times when natural ochre, charcoal, and clays were used as color pigments. The pigment industry began to develop in earnest in the 18th century, after which new discoveries and technological advancements led to today's focus on better performing, less toxic, and more ecologically friendly effect pigments of all kinds.

In fact, in 2015, the FDA issued a final approval ruling whereby mica-based pearlescent pigments could even be used as color additives in Easter egg decorating kits and distilled spirits that contained 18-23% alcohol.[2] Most cordials, liqueurs, flavored alcoholic malt beverages, wine coolers, and cocktails currently contain some form of FDA-approved pearlescent pigment to add an aesthetic component to adult beverages.

Pigments that produce lustrous, brilliant, glittery surfaces are known as effect pigments. Effect pigments react to light in a unique way because of the high aspect ratio (width to height) of the platelet geometry. This allows for a large variety of colors and special effects including shimmer, metamerism, or metallic reflection.

Several factors combine to influence the finish, luster, and glitter effects on the surface. These include flake orientation, particle size, pigment concentration, layering effects, and coating-film transparency.

There are three main classes of effect pigments commonly used in various applications. The three pigment categories are defined by their interaction with light—specifically absorption, metallic, and pearlescent.

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ABSORPTION PIGMENTS

Absorption pigments are conventional organic and inorganic pigments. They represent "true" colors as they absorb certain wavelengths of incident light that strike the surface and scatter the rest. The scattered component of the reflected visible light produces the observed color, and all other color wavelengths are absorbed.

Titanium dioxide reflects all light and absorbs none, while carbon black absorbs completely and reflects nothing. These are considered one-dimensional pigments that do not have luster or iridescence—just color. Watercolors are examples of paints that use absorption pigments.

METALLIC EFFECT PIGMENTS

Metallic effect pigments are planar flakes of opaque reflective materials. Aluminum, copper, copper-zinc, zinc, silver, and other metals are typically used. These flake pigments (or sometimes, pastes) can be used to provide uniquely attractive aesthetics (high brilliance, strong color, flop, etc.) in a wide variety of coating applications.

Metallic flake platelets are opaque to light and therefore no light is transmitted. All the light is reflected, and if colorants are added, the opaque flakes do not allow light to penetrate. Light is reflected in a specular manner. Light incoming at a 45° angle will reflect back at a 45° angle.

Particle size is also important. Luster will increase as the particle size increases. Practically speaking, the optimal distribution is 10 to 60 microns to produce the brightest luster and adequate coverage.

Aluminum flakes are often favored because of high reflectivity. However, if colorants are added, the aluminum does not allow penetration of light, so the colors are somewhat subdued and sometimes even muddied depending upon the metallic flake/color combination. At different viewing angles, lightness changes rather than color. Even so, metallic finishes have a luster and brilliance not found with conventional absorption pigments.

The surfaces of platelet structures are chemically treated specifically for either solventborne or waterborne paint systems. This treatment stabilizes the metal within the resin system between the platelet structure and assists with orientation within the film. The most intense color is realized at the angle of reflection.

PEARLESCENT PIGMENTS

Pearlescent pigments were developed to mimic the inherent gleam and luster of natural pearls. These pigments are partially transparent interference pigments as they are created from depositing layers of mineral mica onto metal oxides and rutile (a natural mica) titanium dioxide.

The platelets of mica are very smooth, so that light is reflected while maintaining a high degree of transparency. This means that only a portion of light is reflected, with the part not reflected transmitted through the platelet for further reflection.[3] Color effects are dependent upon the viewing angle because the two complementary beams respectively dominate at different viewing angles.[4]

There are two types of pearlescent pigments. The first is a substrate-free pigment that consists of only one optically homogeneous material. The second is that of a layered structure with at least two optically different materials either deposited onto a substrate or as a several layer substrate structure.[5]

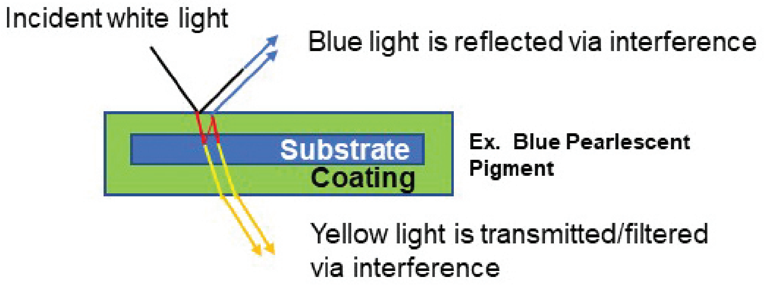
Pearlescent (interference) pigments are governed by Snell's Law, which states that when incident light travels through one medium into another, the refracted light may change the angle of travel. The refracted angle relative to the incident angle in air is called the Index of Refraction.

At each interface between materials with different refractive indices, the light beam is partially reflected and partially transmitted. Reflection and refraction mechanisms occurring at each interface cause shifts in the light wave returning from the pigment, leading to interference mechanisms. Since pearlescent pigments have at least three layers of materials, all with different refractive indices, specular reflection of the light beam from the different interfaces produces the desired effect (*Figure 1*).[6]

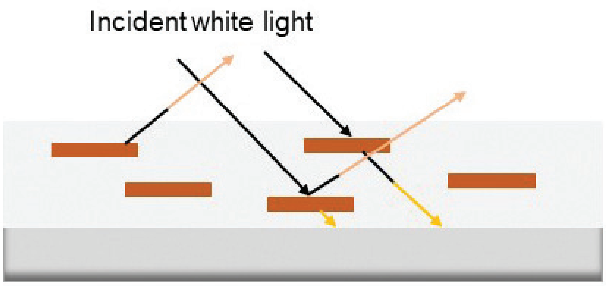
A variety of special effects can be achieved vis-à-vis the reflected angles by varying the size, orientation, and composition of the platelets, the coating film thickness and transparency, choice of substrate, and pigment concentration. All these factors determine the luster and appearance of the surface.

Whether the goal is a metallic or pearlescent look, particle-size distribution must be controlled and adjusted

FIGURE 1—Diagram depicting the optical behavior of pearlescent pigments made of a substrate and high-refractive coating.[3]



Platelets of coated mica reflect a portion of the light due to a high degree of transparency. The remainder is transmitted to the next layer for further reflection.



Multiple reflections from many layers of coated mica that creates a shimmery luster called pearlescence.

for the desired effect. Luster increases with particle size and opacity increases with decreasing particle size. *Table 1* lists typical particle size distributions and their visual effects. *Figure 2* depicts the competing characteristics of coverage/opacity and sparkle effect as a function of particle size.

Orientation of the effect-pigment flakes is very important in obtaining the desired optical properties. Non-leafing pigments tend to distribute evenly throughout the powder coating film. This pigment orientation provides for significantly better surface physical properties such as chemical, rub, mar, and abrasion resistance (*Figure 3a*).

Because of their high surface tension, leafing-effect flakes migrate to the surface of the powder coating. The high volume of pigment at the surface provides the enrichment necessary to produce some of the most brilliant metallics and highest gloss in a powder coating. The finer the flake, the more mobility toward surface—resulting in an even more defined chrome-look effect, as shown in *Figure 3b*.

Leafing flakes migrating so close to the surface sacrifice mechanical and chemical resistance. It is often necessary to add a clearcoat to protect and enhance surface properties without dulling optical effects.[7]

GLAMORIZING POWDER COATINGS WITH PEARLESCENT PIGMENTS

Solvent- and water-based coatings have been taking advantage of metallic and pearlescent pigments for quite a while because of the ease of adding these pigments to conventional resins.

Powder coatings, on the other hand, long considered the utilitarian workhorse of the coatings world, have not yet lived up to their potential of producing a lustrous aesthetic. These coatings have excellent functional properties but generally lack the pizzaz expected of today's designs. Many industries from appliance to automotive to interior design are paying more attention to obtaining the deep, lustrous, rich surface appearances demanded of their products.

The basic powder coatings market has grown considerably during the past 20

TABLE 1—The effect of particle-size distribution on pearlescent appearance.[4]

FRACTION	SIZE DISTRIBUTION (µm)	APPEARANCE
Ultra-fine	<15	Satin Finish
Fine	5 to 25	Soft Luster
Standard	10 to 60	Bright Luster
Sparkle	10 to 100	Medium Glisten
Glitter	20 to 200	Intense Sparkle
Super Glitter	70 to 700	Glitter Effect

FIGURE 2—The effect of particle size on coverage and appearance.[3]

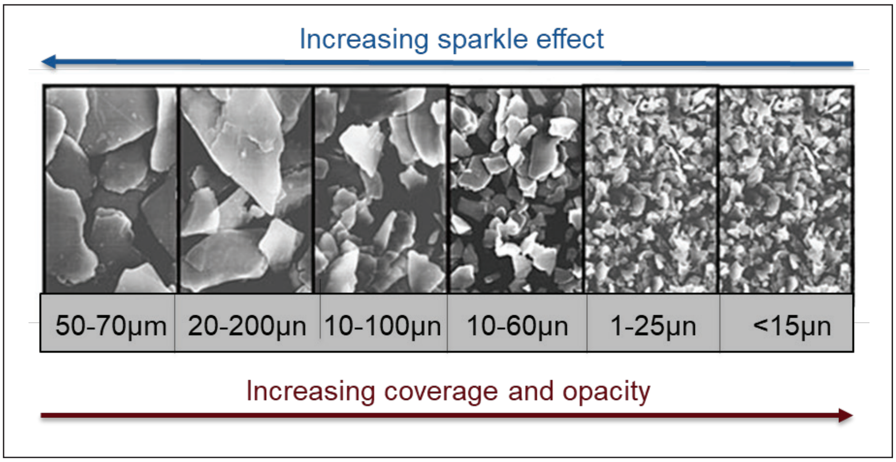
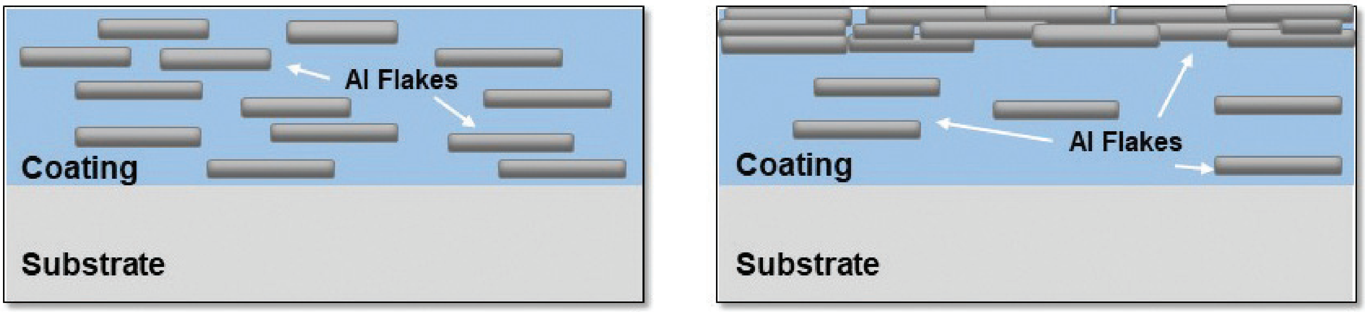


FIGURE 3—Schematics of non-leafing (a) and leafing (b) pigment orientations in powder coatings.[7]



years. Currently there are many special effects appearances achievable with powder coatings, including gold metallic, luster pearl effects, and sparkles. The metallic powder coatings market is expected to grow from $2.3 billion in 2020 to $3.3 billion by 2025 with a compound annual growth rate (CAGR) of 7.5% during that time.[8]

Demand for metallic and pearlescent pigments from the architectural and automotive markets and the large aftermarket for wheels and long-haul truck accessories are among applications fueling the metallic coating powders market.

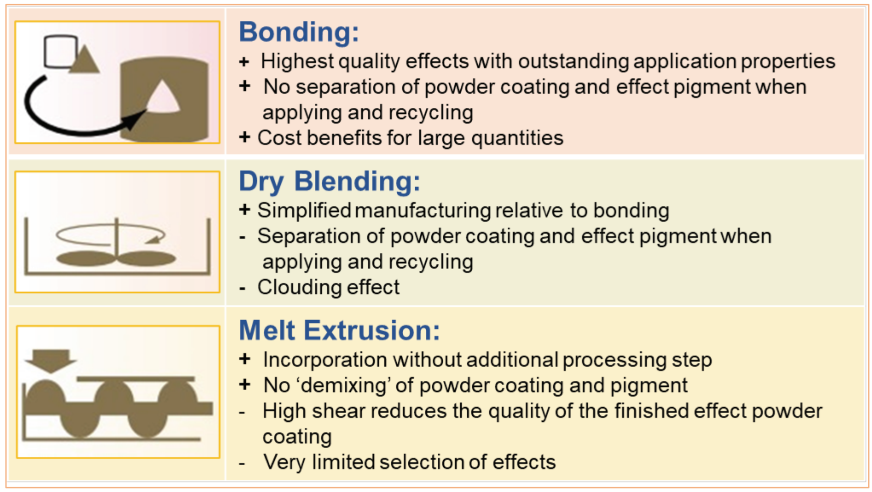
The architectural segment will remain a significant driver for these enhanced powder coatings. Excellent durability is now coupled with the aesthetics desired in interior and exterior architectural applications. Successful applications include façade panels, railings, window and doorframes, and other metal constructions in both residential and commercial buildings. Another positive is that these metallic and pearlescent paint systems have evolved to the point that both professional painters and DIY customers can obtain the desired aesthetics on steel and aluminum.

Recently, a study was conducted to determine the effect on durability of five different alumina-based pearlescent pigments on commercially available powder coatings. These alumina-based pigments had enhanced optical properties and superior pearlescent behavior when compared to mica-based pigments.[6]

To ensure homogeneity of each pigment/powder mixture, the resin was heated to just above the glass transition temperature (T_g) to soften the resin. Then pigment was added and gently mixed until it homogeneously adhered to the resin. This allowed for uniform spray deposition prior to cure, eliminating any variables that could have been associated with pigment agglomeration or loss.

The conclusions from this study showed that the pearlescent pigments did not cause any deterioration to the aesthetics or protective durability properties after 1,000-hour exposure to acetic salt spray. No blistering or other delamination was noted. EIS measurements verified that all the samples retained their expected corrosion potential irrespective of pigment.

FIGURE 4—Comparison of the three methods of manufacturing metallic and pearlescent powder coatings.[7]



Exposure to UVA radiation also exhibited good results. Color changes and variation in gloss and surface roughness were negligible. UVB exposure did register a decrease in gloss, increase in surface roughness, and significant color change after 300 hours, but that was attributable to the matrix resin as opposed to influence from the pearlescent pigments. This study suggests that pearlescent powder coatings have great potential for a wide variety of applications that require a durability component for longevity.

In order to take advantage of metallic and pearlescent effect powder coating, it is important to understand the ramifications of the three main powder manufacturing techniques. Typically, these types of powder coatings can be produced by either extrusion, blending, or bonding. *Figure 4* provides a comparison of the three main methods of manufacturing powder coatings using metallic and pearlescent pigment.

Extrusion techniques generate limited appearance capabilities. With this method, metallic and pearlescent effect pigments are extruded with the base powder resin. Metallic flakes are completely surrounded by resin and fully incorporated into the coating. The coating is extremely consistent and will reclaim well. However, only a limited number of effect pigments can successfully survive extrusion without losing the desired aesthetic.

The extrusion process blends metallic flakes and pulverizes mica flakes, causing them to lose their pearlescent effect. Sparkle is generally diminished, especially with light colors, because the pigment completely covers the metallic. This process works best with deep shades that have some transparency. While the cost is low, the shear inherent in the extruder reduces the metallic appearance. Extrusion is not considered the best processing method for taking advantage of producing specialized optical properties.

Blending metallic powder coatings follows a relatively simple process. The metallic flakes are literally blended into the powder coating resin in the absence of temperature. It is a much simpler and quicker process than that which produces bonded metallics. This process is more advantageous for smaller batches, and it is less expensive than other processes.

However, because the metallic pigments are not bonded to the powder particles, it is much more difficult to obtain a smooth, consistent metallic look. Sparkles can migrate toward the edges or disperse unevenly. This technique can produce bright metallic shades with high sparkle.

Application experience and attention to detail while applying the coating is extremely important to reduce the possibility of obtaining an uneven, splotchy, or cloudy surface appearance. This may be a processing technique better suited for small parts. A fluidized hopper is recommended to eliminate segregation during application.

Bonding is the most expensive method—and the most consistent. The

FIGURE 5—Palette of brilliant pearlescent powder coatings offered today.[11]

main purpose of bonding technology is to physically adhere the effect pigments (aluminum, pearlescent layers, mica) to the powder coating particles. This allows for a more homogeneous mixture of pigment in the resin, which in turn provides much better spray consistency and end appearance. Using bonded powder is particularly important when coating large or multiple parts that would suffer from a blotchy or nonuniform appearance.

During bonding processes, the base resin is blended using high-intensity mixing which generates heat. This allows the powder particles to soften (not melt) at or just above the T_g. Once this temperature is achieved, the effect pigments are added and mixed for a short time.

The blended resin is then removed from the mixer and cooled quickly to minimize agglomeration. It is important to understand that the T_g referred to here is not necessarily the resin T_g but that of the *binder* that usually contains additives such as waxes, flow agents, and crosslinking agents.

In the case of metallic powder coatings, the better the bond quality, the more consistent the end appearance. Bonded metallic powder coatings have the widest range of optical properties available with the most brilliant and lustrous offerings of the three manufacturing techniques. However, it can be difficult to obtain extremely bright high sparkle in some colors using bonding methods. Handling properties and reclamation are also better with bonded powder coatings.

A relatively new technique allows for the use of encapsulated aluminum pigment, although this method can run the risk of shearing the pigment and exposing the aluminum. State-of-the-art mixing equipment can generally eliminate this risk. Aluminum pigments are protected by an inorganic sol-gel silica encapsulation and an additional organic surface coating using thermosetting resin molecules.

With this pigment preparation, it is possible to create high-gloss metallic powder coatings that withstand comparisons with liquid coatings. Using only one powder layer, these pigments provide three-dimensional metallic effects with unique optical depth. When exposed to direct sunlight, these coatings exhibit extraordinarily high-gloss sparkle that was previously possible only with wet coating processes. Due to pigment encapsulation, a protective clearcoat is often not necessary.

Another advantage of encapsulation technology is that it enables powder coatings to be recyclable without using bonding technology. Because this is a dry blending process, the application properties are comparable to bonded powder coatings—particularly when it comes to recoverability.[9]

ARTISTS AND DIYERS

It is interesting to note that many artists and DIYers are making inroads into mixing their own metallic and pearlescent paints using mica-pigment powders. They are cheaper and less toxic than many other pigments. These mineral-based powders are in flat, flake-like forms that give an iridescent shine.

Mica pigments are so easy to disperse in just about any medium that they can simply be stirred by hand in most cases. Taking advantage of natural pearlescent qualities of mica, they can be modified to make many different colors. In addition, they can be further mixed and modified to create the exact desired appearance for the application.

For these individual customers, cosmetic suppliers usually have more than 100 different colors with prices cheaper than an artist pigment shop. Perhaps not surprisingly, Amazon and eBay are also popular shopping spots for the DIY and artist crowds.[10]

The advancement in effect-pigment technology, improved powder-coating processing methods, and a growing popularity of metallic and pearlescent coatings for a wide variety of applications have provided powder coatings with an opportunity to literally shine. There are a variety of metallic and pearlescent colors and finishes available for powder coatings today that are perfect for the plethora of markets looking to upgrade surface optics (*Figure 5*). ❄

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CYNTHIA A. GOSSELIN, Ph.D., is director at The ChemQuest Group/ChemQuest Technology Institute/ ChemQuest Powder Coating Research; *cgosselin@chemquest.com; www.chemquest.com.*