EMERGING TECHNOLOGY

One-coat fluorocarbon powder coatings cut VOCs—and costs

Burkhard Maier ***TIGER Drylac USA***

In the US, the standard in high-performance coatings for the architectural market is almost exclusively liquid coatings, among them thermoplastics based on polyvinylidene difluoride (PVDF) resins that require primers. These multicoat systems were the first coatings to meet the 10-year Florida weathering standard of the American Architectural Manufacturers Association (AAMA)[1]. More recently, powder coatings based on PVDF have been in use, but not to the extent that powder coatings are used for architectural applications in other parts of the world, specifically Europe. This article discusses why powder coatings aren't used widely in US architectural applications and then discusses recent advancements in powder technology that has produced thermosetting fluorocarbon powder coatings. The article discusses how these durable, solvent-free systems can cut application costs and points out some limitations to keep in mind when specifying coatings for architectural applications.

A wide range of chemistries are used today to formulate liquid coatings, each with their own strengths, weaknesses, and price structures. These range from alkyds, urethanes, and amino resins to silicone polyesters and fluoropolymer-based materials at the higher end of the performance spectrum.

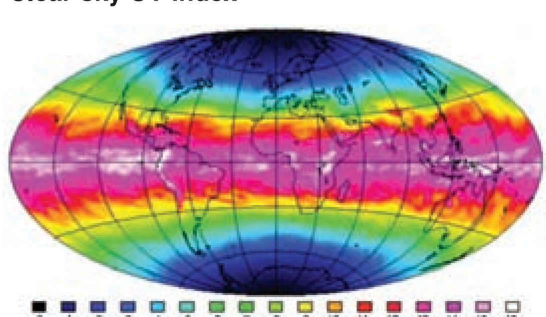
Oddly enough, the landscape of powder coating chemistries for architectural applications (and exterior applications in general for that matter) is rather simple. The vast majority of coatings are polyester-based with different crosslinking agents used, depending on markets and regions. Other chemistries are available, such as acrylics, but they've been used in only a few niche applications where their performance characteristics justify the added cost.

The architectural markets have evolved in different regions along different lines, with different standards of performance being adopted to suit the needs of the respective markets. Figure 1 dramatically highlights why different standards have evolved for applications in Europe compared with those in other parts of the world.

As you can see, most of Europe is in a geographical latitude where the intensity of ultraviolet (UV) radiation reaching the ground is significantly lower than that of the southern parts of the US, as well as many densely populated areas in Southeast Asia and the Middle East. During the summer, the region with high-intensity shifts somewhat northward, but it doesn't shift enough to change the UV intensity in most areas of Europe to a yellow or red level.

FIGURE 1

Clear-sky UV index



Note: Noon, March 23, 2001, KNMI (Royal Netherlands Meteorological Institute)/ESA (European Space Agency)

Key weather factors that cause coatings to degrade

Three factors significantly influence the degradation rate of a coating:

- UV radiation intensity
- Temperature
- Humidity

Figure 1 could very well be a temperature chart, except in humidity levels where some parts of the United States, North Africa, and the Middle East tend to be very dry while other parts tend to be very humid, much like that of some Southeast Asian regions.

In the European area, GSB-International (Guetegemeinschaft fuer die Stueckbeschichtung von Bauteilen)[2] and Qualicoat[3] requirements have become the accepted standards for architectural applications. While these standards are similar to US standards, they also have differences. On the issue of coating weatherability, the requirements are as follows:

• GSB-International

—1 year of Florida exposure (50 percent residual gloss)

—300 hours of QUV-B[4] accelerated-weathering exposure (50 percent residual gloss)

• Qualicoat Class 1

—1 year of Florida exposure (50 percent residual gloss)

—1,000 hours of accelerated weathering exposure (50 percent residual gloss.)

• Qualicoat Class 2

—3 years of Florida exposure (50 percent residual gloss)

—1,000 hours of accelerated weathering exposure (90 percent residual gloss)

Currently, powder coatings technology can meet these requirements fairly comfortably with existing technology as follows:

• GSB-International

—Standard polyester technology

• Qualicoat Class 1

—Standard polyester technology

• Qualicoat Class 2

—Super-durable polyester technology

In the US, the performance requirements for the most part are governed by AAMA specifications. These are tailored to reflect the geographical realities of a country with significant areas further south than most of Europe and with harsher conditions in terms of UV exposure and humidity than most of Europe. AAMA specifications for coatings can be grouped into three sections, with their test requirements as follows:

• AAMA 2603

—1 year of Florida exposure

—1,000 hours of Weather-Ometer[5] exposure

• AAMA 2604

—5 years of Florida exposure (30 percent residual gloss)

• AAMA 2605

—10 years of Florida exposure (50 percent residual gloss)

These requirements represent a greater challenge to powder coatings used in the US than to those used in Europe. Thus far, powder coatings used in the US have met AAMA 2603 (standard polyester) and 2604 (super-durable polyester). The 10-year AAMA 2605 standard has been unattainable with conventional polyester-based powder resins. The high-end market for organic finishes has belonged almost exclusively to liquid coatings, with fluoropolymers meeting 10-year Florida requirements. Siliconized polyesters have also performed well and are used in coil coatings. (For the purposes of this discussion, they won't be considered further.)

The first liquid coatings to meet the 10-year Florida requirement have been in use since 1965 and have set the standard in high-performance liquid systems. They are based on polyvinylidene difluoride (PVDF) and possess outstanding durability (more than 10 years). However, they do have drawbacks. For one, they're mostly solvent-based with significant portions of volatile organic compounds (VOC). For another, they aren't air-drying, which means high temperatures are necessary for proper film formation. Their adhesion is also rather poor. As a result, they need a primer. They also have a rather soft surface that is easily marred. In addition, these coatings are expensive based on the cost of the material, requiring a multistep process for a successful finish. This can go as far as a four-step process with some metallic effects.

Chemically crosslinked fluoropolymer powder coatings enter US architectural market

Naturally, the coatings industry has tried to extend the existing liquid coating technology into powder coating technology, with some success in making a solid-grade material from the basic polymer. As might be expected, the properties of the powder system are similar to the liquid system, and while the powder system has the durability that people have come to expect from this class of materials, it also has many of the same drawbacks. For example, PVDF-based powders are thermoplastic in nature, which means they can be molten at sufficiently high temperatures. They also require very high temperatures for film formation (typically around 450°F, or 220°C). Moreover, they have rather poor adhesion and require the use of a primer. Because of their thermoplastic nature, PVDF-based powder coatings have a somewhat soft surface. Furthermore, gloss levels are limited (~30 gloss units at 60 degrees). As a result, only dull, low-gloss surfaces are possible. And of course the requirement for a multistep process adds significant cost to the finished part.

Today, powder coatings based on fluoroethylene vinyl ether (FEVE)[6] with functional groups attached to the backbone of the molecule are available to address these shortcomings. This makes these architectural-grade powder coatings thermosetting polymers, which results in significant differences compared with PVDF-based powder coatings. For one, these coatings are harder than the PVDF-based coatings. Their processing temperatures are also lower than those required for PVDF. In addition, the adhesion of the material is better than that of PVDF, and it can be applied without the use of primers. These chemically crosslinked fluoropolymers also allow the formulation of high-gloss surfaces; therefore, gloss levels between 15 and 80 (at 60 degrees) can now be formulated, which extends the choices available for architectural applications. Just as important, if not more so, the cost to produce a finished part with these powder coatings is lower than that of existing PVDF materials because only a single-step application is required.

Of course, the weathering characteristics of these powder coatings are as good as those expected from fluorinated polymers. The requirements as spelled out in AAMA 2605-02 are as follows:

- Pencil hardness—minimum F: pass
- Dry Adhesion—100 percent: pass
- Wet Adhesion—100 percent: pass
- Boiling water adhesion—100 percent: pass
- Impact resistance, 3 millimeters—no delamination: pass
- Abrasion resistance, falling sand—more than 40 liters per mil: pass
- Hydrochloric acid, 10 percent, 15 minutes—no change: pass
- Mortar resistance, 24 hours—no change: pass
- Concentrated nitric acid vapor, 30 minutes—less than 5 delta E: pass
- Detergent resistance, 72 hours—no change: pass
- Window cleaner resistance, 24 hours—no change: pass

The chemically crosslinked fluoropolymer powder coatings can be formulated to meet these requirements. All the prior requirements can be met by specially formulated polyester coatings, but the UV resistance of fluorinated polymers is significantly better than those coatings. As anyone who is familiar with the performance of polyester powder coatings will appreciate, this represents a significant jump in performance. Whereas polyesters are required to meet 300 hours UVB resistance with a remaining gloss of 50 percent or better (of the initial value), the chemically crosslinked fluoropolymer powder coatings have an almost unchanged remaining gloss even after 4,000 hours (see Figure 2).

Florida testing has also been ongoing for a number of years (see Figure 3). While some people may debate the correlation between the numbers of QUV hours and real-world performance of coatings with respect to UV resistance, accelerated testing such as QUV does give a clear indication of relative performance. The fact that the chemically crosslinked fluoropolymer powder coatings perform 10 times better than polyesters in QUV testing is a strong indicator that real-world performance will also be significantly enhanced.

In other parts of the world, this technology has already been available and reference objects do exist, both in liquid and powder FEVE-based technology. (Figure 4 shows architectural application of FEVE-based powder coatings.)

Naturally, corrosion resistance of the coating system is a concern, and laboratory testing has shown solid performance on chromate pretreated and chrome-free aluminum surfaces to more than 4,000 hours. It stands to reason that the hydrophobic nature of the coating has a beneficial effect here in reducing corrosion, as well as

Figure 2

QUV-B accelerated weathering testing of thermosetting fluoropolymer powder coatings

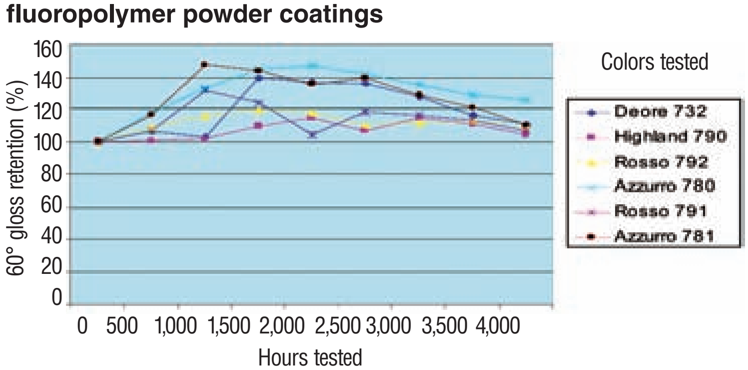


Figure 3

Gloss retention according to American Architectural Manufacturers Association (AAMA) 2605

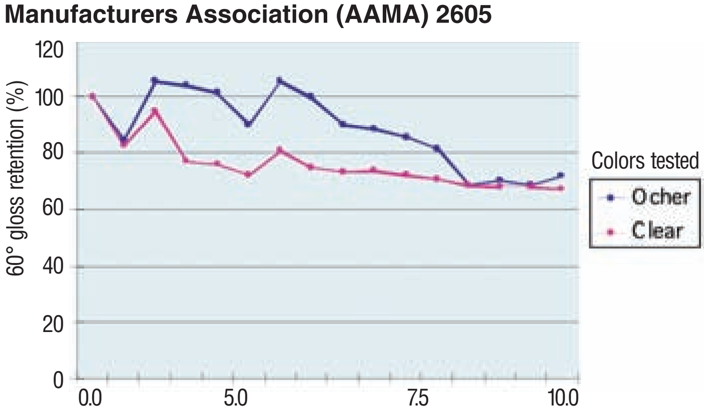


Figure 4

TIGER facility in the Czech Republic coated with chemically crosslinked fluopolymer powders

dirt pickup, which translates into easier cleaning properties over the service life of the object. This aspect is frequently overlooked and can translate into substantial savings.

Awareness of strengths and weaknesses assures success of application

What should you be aware of when considering whether these type of coatings are the right choice for a project? As the trend continues towards higher-performing coating systems and longer service life and warranties from the finishing technologies, specifiers and architects may consider adopting the AAMA 2605-02.

Clearly, economic aspects will limit the use of this technology to only the highest levels of performance requirements. It needs to be understood that this coating isn't meant to compete against polyester technology or other general industrial liquid coating technologies. It is intended to compete against liquid coatings in the same performance class. Evaluations by custom coaters have shown that the economics are favorable for single coat, thermosetting powders based on this technology.

As indicated earlier, the coating system is thermosetting in nature, with E-caprolactam blocked isocyanates as the crosslinking agent. This means that during cure there will be some evolution of smoke and odor. Work is progressing to minimize the impact of these volatiles, thus far without success. The hope remains that future development of crosslinking agents will allow the formulation of emission-free powder systems.

Architects and specifiers need to be aware of limitations in color selection. Because of the extreme durability requirements, organic pigments as a class can't be used. This limits the colors to earth tones and colors of similar chromaticity in other parts of the spectrum, such as red, blue, and green. In addition, the flexibility of the polymer is limited because of its molecular structure. However, field testing has shown that normal fabrication processes such as profile cutting, drilling, and milling can be conducted without problems.

To sum up

With the new chemically crosslinked fluoropolymer technology, powder coatings can now be used in even the highest performance categories, historically only attainable with liquid systems. These powder coatings offer excellent performance at a favorable cost compared with other coating systems with equivalent UV resistance and durability. **PC**

Endnotes

1. See [www.aamanet.org], or contact 847/303-5664.
2. See [www.gsb-international.de], or contact (from the US) 011-49-7171-68055.
3. See [www.qualicoat.net], or contact (from the US) 011-41-43-305-09-70.
4. QUV-B accelerated weather tester by Q-Panel Lab Products
5. Weather-Ometer by Atlas Material Testing Technology
6. TIGER Drylac® Series 75

Further reading

For further reading on the topic discussed in this article, see *Powder Coating* magazine's Web site at [www. pcoating.com]. Click on Article Index and search by subject category. Have a question? Click on Problem solving to submit one. To receive the magazine's weekly Q&A newsletter, scroll to the bottom of the home page and send us your e-mail address.

Burkhard Maier is technical director at TIGER Drylac USA, 1261 E. Belmont St., Ontario, CA 91761; 909/930-9100. See [www. tigerdrylac.com]. Born and raised in Austria, he came to the US in 1988, worked as plant manager at PCI Inc, Ontario, Calif., and later was lab group leader at H.B. Fuller from 1994 to 2000.