THE NEXT REVOLUTION IN **POWDER COATING** TECHNOLOGY:

CONQUERING PLASTIC SUBSTRATES

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CAPTURING THE METAL FINISHING MARKET

The notion of powder coating was first conceived in the 1950s by the German scientist Erwin Gemmer.[1] Significant commercial acceptance did not materialize until the early 1960s when pipeline makers began using thermosetting epoxy powders to replace multiple coats of liquid technology.[2] These functional powders were applied at thick films to heavy gauge steel pipes and valves used to convey oil and natural gas.

It was not until the late 1970s that the powder coating industry's commercial growth accelerated.[3] Through the combination of new resin technology (mainly polyester) and refinements in electrostatic application techniques, the nascent powder coating industry entered markets requiring not only functional performance but aesthetics as well. Groundbreaking innovation captured large portions of the appliance (white goods) and fabricated metals markets. This growth progressed through the 1980s as powder coatings replaced liquid finishing lines throughout Western Europe and North America.

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The 1990s ushered in significant advances in application and formulating technology that provided materials and processes able to exceed demanding automotive specifications. High quality powder coatings were introduced as primer–surfacers at numerous General Motors and Chrysler assembly plants. Perhaps one of the most significant achievements in powder coating technology occurred in 1997 when BMW introduced acrylic-based powder coatings as their clear topcoat finishing process in their Dingolfing, Germany plant (*Figure* 1).[4]

Figure 1—Powder clearcoat automatically applied to a BMW 7-Series body. *(Photo courtesy of BMW.)*

By the turn of the century, powder coating technology had conquered the fabricated metal finishing industry. If a manufactured part was metal and could fit in an oven, there was a high probability that it was powder coated. Unfortunately, the new century also brought an economic recession and with it stagnation in growth in the European and North American powder markets. There were too many powder producers pursuing the same established business. Consolidation and market contraction ensued, leaving advances in powder coating technology to stall in the background.[5]

A SEA CHANGE IN SUBSTRATE TECHNOLOGY

Historically, manufactured goods have been engineered from steel, aluminum, and various metal alloys. Mounting environmental and manufacturing efficiency pressures have motivated industrial engineers to seek alternatives to traditional metal fabrication techniques. The transportation industry in particular has been replacing metal components at an ever increasing pace, mainly stimulated by the quest for lighter products to achieve increased fuel economy. Not only do plastic materials provide lighter weight components, but they almost invariably offer improvements in fabrication processes as well.

This sea change in substrate technology brings the powder coating industry to a crossroads. Well-worn powder coating technology serving these industries is largely unsuitable for plastic substrates. Plastic surfaces are inherently non-conductive, thereby complicating the use of conventional electrostatic application techniques. In addition, many of these plastic materials melt or deform at temperatures significantly below powder coating cure requirements (*Table* 1).

Table 1—Heat Deflection Temperature of Common Thermoplastic Resins[6]

Substrate	Composition	Heat Deflection Temperature (0.46 MPa Load)
ABS	Acrylonitrile butadiene styrene	98°C
Acetal copolymer	Polyoxymethylene (ethylene)	160°C
Acrylic	Acrylic	95°C
Nylon 6	Polyamide	160°C
PC	Polycarbonate	140°C
PC/ABS	Polycarbonate/ABS blend	80–100°C
HDPE	High density polyethylene	85°C
PET	Polyethylene terephthalate	70°C
PMMA	Polymethylmethacrylate	105°C
PP	Polypropylene	100°C
PS	Polystyrene	95°C
PVC	Polyvinyl chloride	90°C
Noryl GTX	Polyamide/polyphenylene ether	231°C
PEEK	Polyetheretherketone	160°C

Table 2—Low Cure Powder Coating Chemistries

Chemistry	Low Cure Potential
Epoxy	25 min at 110°C
Epoxy–polyester hybrid	25 min at 125°C
Polyester–TGIC	25 min at 130°C
Polyester–urethane	30 min at 160°C
GMA acrylic	25 min at 135°C

LOW TEMPERATURE CURE POWDER COATINGS

In recent years, significant progress has been made in cure mechanisms and catalysis techniques, enabling some powder coating chemistries to adequately cure at relatively low temperatures. *Table* 2 depicts practical low temperature curing potential for common powder coating systems.[7]

Advancements in low temperature cure technology have opened the door to the possibility of curing powder coatings well below the heat deflection temperature of many plastics. Many of these low cure powder coatings can be used to coat common plastics including nylon 6, acetal copolymer, and polycarbonate. Engineered plastics such as PEEK and Noryl GTX can be powder coated and cured with either low temperature or conventional powder coating technology.

APPLICATION CHALLENGES WITH PLASTIC SUBSTRATES

Powder coatings are typically applied by electrostatic spray techniques. This can be accomplished by corona or tribo-charging mechanisms. Corona charging (*Figure* 2) involves transporting an air/powder mixture through an electric field created by an ionizing electrode typically located at the exit of the spray gun. The powder particles pick up free electrons, resulting in

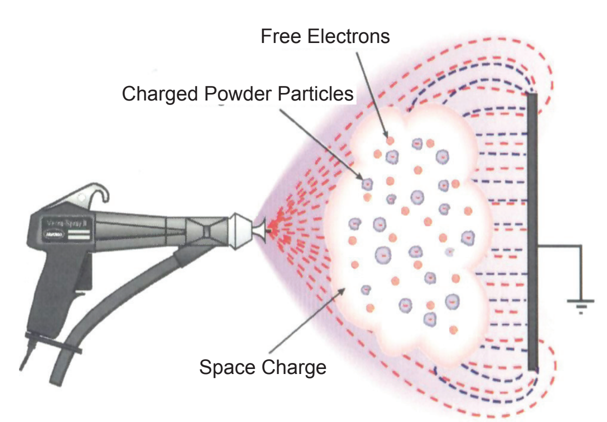

Figure 2—The corona charge technique for powder coating. *(Photo courtesy of Nordson Corp.)*

Figure 3—A typical tribo-charge powder spray gun. *(Photo courtesy of Sames Division of Excel Industries.)*

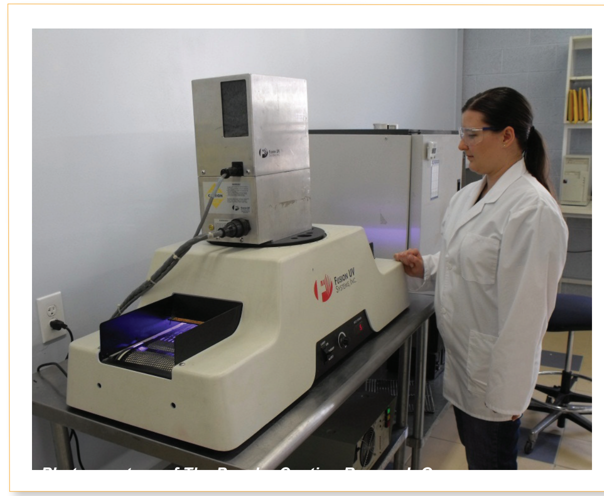

Figure 4—A laboratory technician testing a UV cure powder coating. *(Photo courtesy of The Powder Coating Research Group.)*

a net negative charge on the particle surface. These negatively charged particles are attracted to an electrically conductive substrate. The substrate must be earthed. With metal substrates this process is rather straightforward. The charged particles when applied to a conductive surface are readily attracted and adhere well in a dry form.

Tribo-charging (*Figure* 3) is a unique means to develop a charge on a powder particle. This technique relies upon the frictional charging of a particle as it comes into contact with a material with a highly divergent dielectric. The contact essentially affects a transfer of charge, thereby resulting in a typically net positive charge on the surface of the powder. Tribo-charged powder coatings are attracted to earthed conductive substrates in a similar fashion to corona charged powders.

Plastic substrates are inherently non-conductive and therefore require some means to impart conductivity to the surface of the plastic (*Table* 3).

A plastic substrate can be preheated and the powder coating applied to an elevated temperature surface. Part density and process control variation can cause inconsistent surface temperature and, consequently, erratic film builds. A conductive primer can be applied to the plastic and cured. Conductive primers are essentially liquid paints containing a conductive filler such as carbon black or metallic particles. Application of a conductive primer can be a successful approach to creating a conductive surface on a plastic substrate. Drawbacks include high material cost and the expense of managing the application and curing processes.

Table 3—Conductivity Options for Plastic Substrates

Technique	Issues
Preheating	Inconsistent temperature profile
Conductive primer	Excellent consistency, process intensive, and costly
Conductive prep	Excellent consistency, simple process
Conductive plastic	Excellent consistency, expensive, limited availability

Conductive preps are comprised of an anti-static agent dissolved in a suitable carrier. The carrier can be water, an alcohol, or a mixture of both. The anti-static agent can be a quaternary ammonium compound, long chain aliphatic amine, or phosphoric acid ester. These are available commercially. Conductive preps are easier to apply and more economical to use than conductive primers.

A number of polymer manufacturers have developed plastics that are inherently conductive. Most notable are various grades of Noryl GTX manufactured by SABIC Innovative Plastics.[8] These products command relatively high prices but behave as fully conductive substrates that readily attract electrostatically charged powder coatings. More recently, formulating schemes have emerged that use nanoparticles such as carbon nanotubes, carbon nanofibers, and graphene particles to impart conductivity to molded thermoplastic parts.[9]

UV-Curable Powder Coatings

Successful powder coating of plastics possessing heat deflection temperatures (HDTs) below 120°C can be accomplished by using UV-curing powder technology (*Figure* 4). This technology consists of a powder coating capable of curing using radiation typically from a high intensity UV irradiator. These powder coatings are specially formulated to melt and flow in a few minutes at low temperatures ranging from 100 to 120°C.[10] Cure is then accomplished by exposing the molten coating to very specific wavelength UV energy for a few seconds. The entire curing process (application, melt, and cure) can be completed in as little as five minutes.

UV-curable powder coatings expand powder's reach into substrates previously considered for finishing by only liquid paints. Combining conductive surface preparation techniques with UV-curable powder coatings allows powder to be seriously considered as a finish for polypropylene, polymethylmethacrylate (PMMA), and PC/ABS blends.

COMMERCIAL REALITY

Significant progress recently made in the laboratory has led to the commercialization of a few powder coating processes for plastics.

In North America, INNOVOC Solutions (Montrose, CO) has developed a proprietary process that makes plastic behave as if it were conductive metal.[11] The process involves applying a non-hazardous solution to the plastic prior to powder coating. Applications include powder coating fiberglass fenestration profiles, epoxy resin fiberglass spring coating, coating of various nylon materials, various interior low density fiberboard materials, and other engineering grade plastics and composites.

Figure 5—A powder coated Genesis Bow. *(Photo courtesy of Mathews, Inc.)*

A similar process has been pioneered by Wright Coatings (Kalamazoo, MI). Their Classic Kote® process[12] enables the efficient coating of heat-tolerant plastic parts with low temperature cure powder coatings. This technology serves the office furniture, appliance, and automotive industries.

Alliance Surface Finishing (ASF) of Vaughan, ON is another company that has commercialized a powder coating process to coat plastics.[13] They have been successfully coating plastic parts for the automotive and office furniture businesses for the last few years (*Figure* 5). ASF is currently working on expanding their technology to serve the architectural market.

A GLIMPSE INTO THE FUTURE

As powder coating plastic becomes more mainstream, commercial applications will rapidly expand throughout North America and Europe. Active projects are underway in the transportation industry (mainly automotive and farming equipment) and for architectural finishes. In the automotive field, low temperature and UV-curable powder coatings are being evaluated for both interior and exterior car parts. In the architectural industry, powder coatings are being analyzed as a durable finish for pultruded composite profiles.

The powder coating industry and its evolving technology have captured countless high quality applications over the past three to four decades. Exciting new substrate technology is providing entirely new opportunities for innovative powder technology. After a brief lull in technical advancements, the next revolution in powder coating technology is about to commence. CT

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