"Powder Coating of Non-Metal Substrates"

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ABSTRACT

Powder coating of non-metal substrate, such as plastic, ceramics, glass, and wood, is not only feasible, but being commercially practiced. This paper will describe why powder coating should be considered for these substrates, how powder may be electrostatically applied and what benefit the coated part can offer the manufacturer and the consumer. Both premolding application of the coating material and the postmold coating will be discussed. The special needs for the coating of fiber reinforced plastics will be studied in detail.
INTRODUCTION

As the Powder coating industry continues to grow at a healthy rate, we welcome the challenge and excitement of new materials and new applications in the marketplace. There is little question that the ongoing development in materials technology has meant that many traditional materials such as metal are being replaced by specialty plastics, ceramics, and other engineered materials.

While most of the powder industry is currently focused on the finishing of metal, a variety of other materials are being commercially coated. This paper shall discuss four categories of non-metal substrates: plastics, ceramics, glass, and wood.
Two common misconceptions on the limitations of powder coating have served to impede the progress of powder coatings into non-metal applications. The first is that the substrate needs to be metallic in nature for the charged powder to adhere. The second is that the substrate needs to withstand high oven temperatures for extended periods in order to allow for cure of the coating.

The fact is, powder coatings are being electrostatically applied to non-metal surfaces: sometimes with the assistance of an electrostatic agent, sometimes with a preheat step, and sometimes with no special handling. Also, the development of lower cure temperature resin systems, and the availability of high intensity infra-red (IR) ovens have broadened the scope of powder coatings for wood and heat deformable plastics.

PLASTICS
Much has been accomplished with powder coatings in this area, specifically with thermosetting fiber reinforced plastics (FRP). We can divide our discussion into premold and postmold coating processes with powder. But first, it is important to clarify the reasons for using powder coating over a plastic material.

There are two basic reasons why FRP substrates need to be coated. First, to improve surface appearance. Second, to create a corrosion resistant surface. A powder coating
finish coat improves the surface appearance of an FRP material by hiding the fiber pattern of the reinforcement, by filling the surface porosity, and by providing a color-matched surface.

As a primer/surfacer, a powder coating prevents substrate outgassing, which otherwise can disturb the topcoat. A powder coating primer over SMC automotive panels can yield excellent distinctness of image with the finish paint.

A powder coating also becomes the corrosion resistant surface for FRP substrate. Although plastics do not rust like steel, there are other mechanisms of corrosion which damage the product. A powder coating eliminates the "wicking" phenomenon by forming a barrier between the reinforcing fibers and the external environment. Without the coating, water and/or other solvents are pulled ("wicked") into the substrate via the reinforcing strands (e.g. fiberglass) to corrode the material. The coating, therefore improves the resistance of the FRP to water, which if unchecked, can cause blistering and/or fiber disbondment.

Finally, the use of a solvent-free powder coating allows the plastics finisher the ability to coat the FRP substrate without contributing to VOC emissions. Since every plant is concerned about total emissions, the elimination of solvents
from the finishing area can allow for more production of the VOC-containing FRP.

Premold applications

Powder can be used with thermosetting substrates as a premold coating in a variety of molding operations including matched metal die compression molding, vacuum bag molding, open mold/hand lay-up operations, and reaction injection molding.

The premold powder coating can be used with a variety of molding compound chemistries including unsaturated polyester, urethane, phenolic, and epoxy. The most common molding compounds are SMC and BMC (sheet and bulk molding compounds), and the most common reinforcements are fiberglass and graphite. Another group of specialty molding materials are prepreg composites, for lightweight, high strength requirements.

In the premold process, the powder coating is applied to the hot mold before the nonreacted fiber reinforced plastic (FRP) is introduced into the cavity. The powder melts virtually instantaneously and reacts within seconds when applied to the heated mold surface (250F - 320F). However, the coating that remains open to the atmosphere is nonreacted. This surface does not begin to react until it is in contact with the plastic substrate. A portion of the coating is able to flow and fill substrate voids, and with some coating/substrate
systems, there is a chemical reaction between the substrate and the coating creating optimal adhesion. Systems with less similar chemistries rely on mechanical adhesion for good adhesion.

FRP parts coated in the mold include whirlpools, bathtubs, lavatories, kitchen sinks, automotive panels, motorcycle helmets, marine outboard motor shrouds, and aircraft interior panels. Application equipment varies from a highly automated coater-box system, to a robotic arm, to basic hand-spraying with smaller molds. What is most impressive are the complex geometries which can be coated by powder to yield complete part coverage, and still promote excellent release from the mold.

While all active premold applications of powder coating involve thermosetting substrate, this coating has also been successfully utilized in an injection molding process with thermoplastic resins, including PPO and PBT (polyphenylene oxide and polybutadiene terephthalate respectively).

**Postmold applications**

Powder coating can be used on a myriad of FRP materials out of the mold as well. In this case, the cured thermoset part must be treated with an electrostatic agent or be preheated before spray application. The electrostatic agent is usually an aqueous or alcohol dispersion of a metal salt which is
sprayed onto the part and allowed to dry before coating normally with powder application equipment.

It is often best to preheat the plastic part before it is powder coated, thereby allowing volatile components in the substrate to be expelled. In the absence of this preheat step, such escaping volatile materials can cause crater-like defects in the cured coating film. Specific preheat and bake schedules vary from FRP type to type. Usually, parts are preheated and baked in the 375F range. Times and temperatures may vary due to factors such as the specific heat capacity of the substrate, the part size, and the powder coating type.

One successful application is the use of powder on an FRP architectural piece which requires excellent surface appearance, durability, and weather resistance. Further, to fit within the manufacturing conditions, the powder had to be applied and cured in under 5 minutes. The success was found in the correct combination of powder coating and application/bake system.

In the above application, the chemistry of the powder coating was carefully balanced to give a fast cure time as well as a controlled cosmetic surface; leaving a surface that was not only durable, but smooth, color-matched and gloss-correct.
For a rapid cure, a combination convection oven with high intensity IR oven was utilized for both preheat and bake.

FRP parts coated out of the mold include include such varied products as automotive panels, architectural pieces, composite tubing, and graphite golf shafts.

**CERAMICS**

As the powder coating of ceramic materials becomes increasingly proven in Europe, U.S. manufacturers are stopping to take a closer look, and for good reason. First, there is the economy of organic powder coatings relative to the traditional ceramic glaze. As one ceramist put it, "up to now, we only had the choice between an expensive and very expensive glaze."

The overall economy in the use of powder coatings comes from several factors. First, oven temperatures for powder in the 400 F range are considerably lower than kiln temperatures approaching 2000 F. This lowering of the process temperature results in not only considerable energy savings, but finished parts are able to packed or stocked much faster (no need for a lengthy cooldown). The powder coating also permits very high yields and low defect rates. While organic powder coatings do not match the superior scratch resistance of a ceramic glaze, they do offer exceptional adhesion and excellent chip resistance on this porous substrate.
Another major consideration in choosing a powder coating over ceramic glaze is the regulatory advantages. Government regulations from the EPA, FDA, and OSHA have all tightened the use of glaze components such as lead, cadmium, and crystalline silica. Formulation restrictions can affect product performance, handling and disposal costs have increased substantially, and the prospect of further restrictions is still ahead.

With respect to the application of powder, normally parts are preheated at 390F - 440F, sprayed, and baked at 350F - 390F. While it is possible to spray powder onto a ceramic part without preheating, it usually gives an end product with poor flow.

The use of IR ovens are also of interest here. According to a recent article in Finishing magazine: "Using infra-red ovens to precisely preheat ceramic gives pottery manufacturers the ability to develop powder coat finishes for a fraction of the cost of conventional high temperature glazes..."

The end products suitable for a decorative powder coat finish on ceramic substrate include flower pots, electric insulators, wall tiles, lamp bases, and a variety of other decorative ware. Organic powder coatings can offer all the
colors and effects of the traditional inorganic glaze, without the use of heavy metals and other hazardous materials.

GLASS
There are two reasons for powder coating glass. The first is for decoration, and the second, is to form a protective surface. End products for a decorative coating include wine bottles, vases, and perfume bottles. Many of the coatings are "clears" tinted with colorants to retain the transparent feature of the glass, but solid colors are also available.

As a protective coating, the plastic finish contains breaking glass making it "shatterproof". This feature is useful for bottles, flashbulbs, incandescent lamps, photo-lamps, electron tubes, television tubes, and fluorescent strip lamps. Commercial success here has been limited to more flexible thermoset powders and thermoplastics, especially at higher film builds.

The application of powder to glass is the same as that of ceramics. The adhesion of the powder coating to the smooth glass surface can be difficult, however. The chemistry must be chosen carefully; a modified epoxy is the best. With good adhesion, the coating will withstand the humidity test for an extended period. Some standard powder coatings, which may
show reasonable adhesion when first applied to glass, will peel off the surface if exposed to the humidity cabinet.

It is important to point out that when powder coatings are applied to preheated substrates, the electrostatic nature of the spray application plays an important role. The electric charge given to the individual powder grains allow for a well-atomized powder cloud, and a more uniform film deposition on the part.

WOOD

Previous attempts to powder coat wood had two fundamental problems. The conventional baking techniques led to some deterioration or distortion of the substrate. Also, if not properly prepared for electrostatic spray, the wood part did not readily accept the charged powder.

The first obstacle has been overcome with the proper use of IR ovens to cure the powder coating. IR ovens operate on the principle of radiant heat and minimize conduction of heat into the mass of the part. Too much part heat up can lead to sap or resin exuding from the wood, blistering from trapped volatiles, or warping with thinner parts. The benefit of the IR oven is in the speed with which it heats up the outer surface of the part without overheating (damaging) the substrate. IR ovens may also save time and space by reducing the cure time by as much as a factor of ten.
The conductivity of substrate can be elevated to a level of acceptability by controlling the level of moisture in the part prior to powder application. That is higher levels of water in the wood part allow for improved grounding of the substrate and allow for electostatic attraction. Also, as in the postmold coating of plastics, an external electrostatic agent can be applied to improve powder attraction.

There are documented applications of powder applied by gravity spray onto flat panels, lessening the requirement for electostatic attraction. The coating can then be cured by IR with little disturbance of the powder by air flow.

Theoretically, wood substrates can include a variety of cellulose fibre materials including chip board, hard board, card board and even paper. Current practical wood products for powder coating include furniture, shelving, and door panels.

CONCLUSIONS

Why isn't the application of powder on these substrates more prevalent? First, with the healthy industry growth as it is, on traditional steel, aluminum, and brass, there may not be the "need" to promote and develop alternative substrates. Its more common and perhaps easier to do more of what was
done last year, e.g. conversion of metal coaters from solvent based systems to powder coating.

Second, perhaps we are all a little bit biased in our own minds when it comes to powder. That is, we are all very accustomed to thinking it terms of metal applications. And rightly so, because metals have brought us this far. But in order for powder coating to realize its full potential, we must all be innovators; we must expand our boundries on the limitations of our products and processes. When we think powder, let's think plastics, ceramics, glass, and wood, as well as metal.
Author's Biography

Everard Corcoran joined Ferro Corporation in 1983. He is currently a Chemist in the Technology Development group in the Powder Coatings Division, Cleveland, Ohio. Previously, he worked in the company's FRP Coatings Division. Prior to joining Ferro, he was employed by American Colors, Inc., Charlotte, North Carolina. Mr. Corcoran is a graduate of Kenyon College, Gambier, Ohio, where he majored in Chemistry.