Characteristics of Powder Coating Materials

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GENERAL DISCUSSION OF POWDER COATINGS

Powder coating is one of the most recent and exciting developments in coating technology. Powder coatings have not only been found to provide excellent appearance and superior film integrity (protection) but, because they contain little or no volatile emissions, are fully regulatory compliant. For this reason, powder coatings are being used in more applications each day. This broad-based growth has spurred great advancements in the raw materials used in powder.

Powder Coating Manufacturing

Typically, powder coatings consist of 4 to 5 components: resin, crosslinker (not used in thermoplastic-type powders), pigments and extenders, flow aids, and a degassing solvent (solid). During processing, all components are first high-speed blended. This reduces all materials to a uniform particle size which improves melt mixing. During melt mixing (extrusion), individual ingredients are thoroughly dispersed and wetted (encapsulated) by the resin to produce a homogeneous composite. The extrudate is then pelletized and forwarded to the grinding operation where it is ground to the final particle size and packaged for shipment. Grinding is critical to powder coatings. Improper particle size distribution can lead to poor performance and appearance. Some powders must be cryogenically ground to ensure proper particle size distribution. All of the above components can be tailored to provide specific properties for a specific application.

Functional Versus Decorative

Even though there is widespread use of functional powder coatings for protective purposes, the vast majority of powders are utilized in decorative applications where color, gloss, and appearance may be the primary attributes. Most decorative coatings are applied as relatively thin coatings (1-4 mils [25-100 μ]) frequently using electrostatic spray process and thermosetting powder coatings. Decorative thermosetting powder coatings are used in too many applications to list here. However, a few examples are: appliances (refrigerators, stoves, washers, etc.), various automobile parts, clear coating of brass and other metal parts, lawn mowers, etc. In general, decorative thermosetting powder coating will be used where appearance and durability are required.

THERMOSETTING POWDER COATINGS

Thermosetting powder coatings are primarily composed of relatively high molecular weight solid resins (compared to liquid) and one of a variety of available crosslinkers. Types of resins commonly used in thermosetting powder coatings include epoxies, polyesters, and acrylics. Crosslinkers (curatives) used include chemical types such as amines, anhydrides, and blocked isocyanates. It should be noted that other types of crosslinker chemistries have been introduced such as melamines, glyco-uril, hydroxy alkyl amide, non-blocked isocyanate resins, and various glycidyl-based compounds.

When a thermosetting powder coating is applied to a substrate and subjected to an elevated temperature (baking), it will melt, flow, and chemically react to form higher molecular weight polymers in a network-like structure. This newly formed chemical species will have significantly different properties than those of the starting materials. For instance, the film will be more heat stable, and exhibit an increased glass transition temperature (T_g). A cured thermosetting powder coating will not remelt upon further heating.

Low molecular weight resins and crosslinkers are necessary to ensure lower melt viscosities. Low melt viscosity leads to higher flow during heating which in turn produces the smoother thin films (2 mils [50 μ] or less) required in most decorative applications. In addition, enhanced flow improves substrate wetting and thereby increases adhesion to the substrate being coated.

The high molecular weight polymer resulting from the chemical reaction during curing results in excellent physical properties (i.e. exceptional resistance to moisture and chemicals, improved flexibility, etc.). Improved film properties are what makes powder coatings the logical choice when thin films, a highly decorative finish, and superb substrate protection are needed.

The majority of powder coatings produced today are of the thermosetting type. Therefore, the end user has a wide variety of powder coating chemistries from which to choose.

Before beginning the discussion of various powder types and the properties of each, it should be noted that powder coatings are also divided into two subgroups: those that maintain their appearance longer when exposed to sunlight (as a source of ultraviolet light [UV] (polyester formulated with durable crosslinkers and acrylics) and those that do not (polyester / epoxy hybrids and pure epoxies). Whether or not a powder coating is suitable for exterior exposure is determined solely by the ability of the film to resist degradation caused by ultraviolet light (UV). This property is commonly referred to as weatherability. In fact all powder coatings can usually retain their original appearance for between one and five years of outdoor exposure. Contrary to this, epoxy and hybrid coatings will generally lose some of their original appearance (chalking) within three to nine months when placed outdoors. Even though these coatings change from their original appearance, their ability to protect the substrate will continue as long as the film remains intact.

Polyester Powder Coatings

Polyester powder coatings being used commercially are divided into several types: polyester urethane coatings, polyester TGIC coatings, and other newer types of polyester-based coatings.

Polyester Urethane Powder Coatings

Urethane-cured polyester powder coatings combine very smooth, exceptional thin film capability, with excellent mar and chip resistance, and good weathering properties. Adhesion to properly prepared (pretreated) substrates will provide very durable coatings with long-term resistance to humidity and corrosion. They are typically resistant to many dilute aqueous acids, salts, aromatic and aliphatic hydrocarbons, grease, and oils. Polyester urethanes exhibit a wide range of chemical and physical properties depending on the resin and crosslinker chosen. Typical IPDI-based crosslinkers used in polyester urethanes are blocked with ε-caprolactam, but occasionally other agents, primarily oximes, are also employed. It is necessary for the crosslinker to unblock before the powder can cure. For this reason, cure temperatures must be above the unblocking temperature. With standard ε-caprolactam containing powder coatings, unblocking occurs at approximately 360°F. Normally polyester urethanes are applied in 1 – 3 mils (25 – 75 μ) thicknesses because higher film builds may exhibit a decrease in mechanical properties and outgassing effects due to ε-caprolactam evolution.

Typical applications utilizing polyester urethane coatings are fluorescent light fixtures, lawn and garden equipment, electrical enclosures, playground equipment, range panels, air conditioners, automotive trim, plumbing fixtures and patio furniture.

Polyester TGIC Powder Coatings

Polyester TGIC coatings utilize the epoxy functional crosslinker TGIC (triglycidylisocyanurate). Use of this low molecular weight, multifunctional crosslinker enables polyester TGIC formulations to contain 90% or greater resin within the binder system. Weathering of polyester TGIC powders is comparable to polyester urethane coatings.

Polyester TGIC coatings typically offer faster, or lower temperature, curing than do polyester urethanes. Unlike urethane coatings, polyester / TGIC coatings maintain excellent mechanical properties at film builds above 3 mils (75 μ) with no outgassing (TGIC is non-blocked). Additionally, polyester TGIC coatings will provide good edge coverage when sharp edges are present, due to the inherent higher melt visosities of TGIC-based coatings, which may also increase surface roughness (orange peel). Overbake color stability of TGIC-based coatings is excellent. Although adhesion and corrosion resistance properties are similar to polyester urethane coatings, chemical and solvent resistance is somewhat reduced.

Typical applications for polyester TGIC coatings are aluminum extrusions, automotive wheels, pole and pad-mounted transformers, air conditioners, fencing, gas cylinders, and lawn furniture.

Other Polyester-Based Powder Coatings

Several new crosslinking systems have been introduced into the powder coatings industry. Included in this group are melamines, glyco-urils, hydroxy alkyl amides, non-blocked isocyanates, and various glycidl-based compounds. While all types have not been universally accepted, many are being used in “niche” applications. Because of their relative newness, broad characterizations of their properties is premature. Suffice it to say that each offers a unique combination of advantages and disadvantages, which bring new possibilities to the powder coating market.

Acrylic Powder Coatings

Early attempts to use acrylic-based powder coatings were unsuccessful due to their inherent brittleness, lack of smoothness, and extreme problems with contamination of other powders. There has been a rebirth of acrylic technology in powder coatings as acrylic resin technology and acrylic powder formulation has improved. The most common acrylic-based technologies in use are: acrylic urethanes (hydroxyl functional resins), acrylic hybrids (acid functional resins), and glycidyl methacrylate acrylics (GMA) (epoxy functional resins).

Acrylic Urethane Powder Coatings

Acrylic urethanes require cure temperature and times (profiles) similar to polyester urethane powder coatings (minimum temperature 360°F / 182°C). In comparison to polyester urethanes, acrylics can offer better weathering, improved chemical resistance, and harder films (typical properties of acrylics). Like polyester-based urethanes, they offer very good smoothness at low film builds but, unlike polyester coatings, flexibility and impact resistance is usually poor. Similarly, acrylic urethanes may exhibit outgassing at film builds in excess of 3 mils (75 μ). Typical applications are plumbing fixtures, automotive wheels, vending machines, and aluminum extrusions.

GMA Acrylic Powder Coatings

GMA acrylic powders are distinguished from acrylic urethanes by their faster (or lower) cure profiles and improved weatherability. GMA-based powders also exhibit water-white clarity and are therefore well suited as clear topcoats on brass, chrome, and similar substrates in addition to their use as pigmented powder coatings. As with acrylic urethane powders, flexibility may be limited. GMA-based powders may be used at film builds above 3 mils (75 μ) as outgassing does not occur.

Typical applications are microwave cavities, automotive trim, wheels, and plumbing fixtures.

Acrylic Hybrid Powder Coatings

Acrylic hybrid powder coatings are similar to polyester hybrid coatings in that they combine a resin with an epoxy as the binder. Acrylic hybrids do offer slightly better weatherability than polyester epoxy hybrid coatings, but neither is considered to be outdoor durable. Acrylic epoxy hybrids can be formulated to give good mechanicals and flexibility. Acrylic hybrids are being used in applications, which include metal furniture and lighting fixtures.

Epoxy Powder Coatings

Epoxy-based powder coatings were the first thermosetting systems to become commercially available and are still widely used today. Although epoxy powders can be used in decorative applications where they are not subject to UV radiation, they are used primarily as functional coatings for substrate protection where inherent toughness, corrosion resistance, flexibility, and adhesion are required. Because of the large number of available epoxy resins and each resin's ability to react with a wide variety of curing agents, <u>nearly any combination of desired physical properties can be obtained.</u> With the proper selection of components (raw materials), epoxy-based (pure epoxies and hybrids) coating powders can be formulated to be **FDA** compliant for food contact applications. The primary limitations of epoxy-based coatings is their poor weatherability.

Functional Epoxy-Based Powder Coatings

As stated above, the terms functional and decorative, as applied to epoxy powders, may be misleading. However, with functional epoxy-based powder coatings, appearance is less of a consideration.

The two major uses of functional epoxies are electrical insulation and corrosion protection. They offer many design, cost, and production advantages over conventional insulating coating such as tape wrapping, phenolic sleeving, and polyester sheeting. Powder coatings conform exactly to each contour of the electrical parts, bonding to the surface to become permanent, integral insulation that is void-free and of low bulk. It is the nature of epoxies to provide outstanding properties and to retain these properties after long-term heat aging.

Epoxies are also used in a wide variety of corrosion protection applications. They provide low cost, low maintenance, and long lasting protection against most chemically aggressive atmospheres typically found in industrial environments. While most formulations offer similar resistance properties, epoxies can be formulated for severe conditions dictating a need for toughness, flexibility, impact resistance, low vapor permeability, and extreme temperature. Their enhanced adhesion and toughness accounts for the excellent mechanical properties and thermal shock resistance they provide.

Typical applications include pipe coatings, automobile alternators, plumbing fixtures, electrical meters, electrical motors, high voltage switchgear, PC boards, reinforcing bars (rebar), battery cases, etc.

Thin Film Decorative Epoxy Powder Coatings

As previously stated, decorative epoxy-based coatings provide the same protective qualities as functional coatings. But unlike their functional counterparts, appearance properties are better. As with all powder coatings, epoxy-based decorative powder coatings are generally formulated to specific requirements of a given application.

Epoxy Polyester Hybrid Powder Coatings

Hybrid coatings share many characteristics with standard epoxy-based powder coatings. The primary differences are improved resistance to overbake yellowing during cure, somewhat softer films, and slightly improved weatherability. Like epoxies, hybrid coatings are not considered suitable for exterior applications, even though their deterioration and discoloration when exposed to sunlight is slower than pure epoxies. Gloss loss due to sunlight exposure, corrosion resistance, flexibility, and impact resistance is similar to pure epoxies, but hybrids may have reduced chemical resistance.

Hybrid coatings are often used in the same applications as epoxies particularly when slight improvement in weathering and overbake stability is required. Typical applications are shelving, hot water heaters, office furniture, plumbing fixtures, power tools, fire extinguishers, and oil filters.

1. Taken from

Powder Coating The Complete Finishers Handbook,
Powder Coatings Institute, 1994