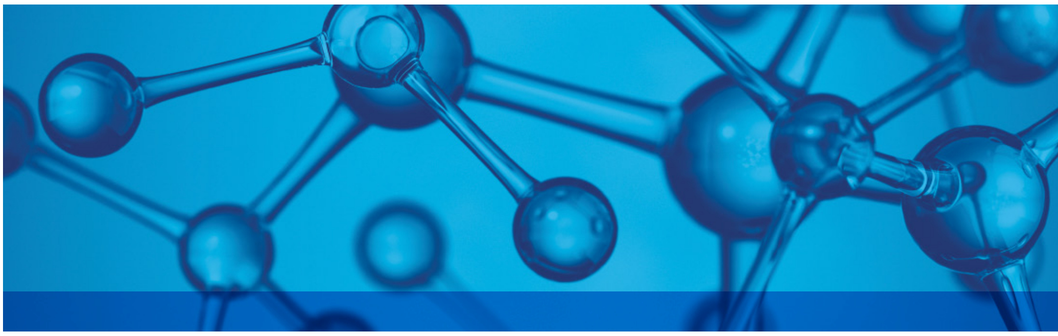

Ryton® PPS High-Temperature, Non-Stick, Corrosion-Resistant Coatings

Introduction

Ryton® PPS (polyphenylene sulfide) is a family of specialty polymers possessing properties desired in many coating applications. These include good electrical properties, excellent chemical resistance, and high heat resistance.

Ryton® PPS resin used for coatings is produced as a finely divided off-white colored powder having a modest molecular weight and high melt flow. This powder may be applied using slurry or electrostatic spray methods and the coatings are then fused and cured (cross-linking and/or chain extension) at temperatures (371°C, 700°F) well above the melting point of the polymer (285°C, 545°F). Heating the modest molecular weight resin below the melting point in the presence of air partially cures the resin to a lower melt flow. Then, depending on the degree of curing, the resulting resins may be selected for powder spraying, electrostatic spraying, flocking, or fluidized bed deposition methods typically used to apply thicker coatings.

Ryton® PPS Coating Resins

There are presently three grades of Ryton® PPS resins most commonly used in coating formulations.

Ryton® PR11 and Ryton® V-1

High melt flow, uncured PPS polymers typically used for thin coatings (0.013 to 0.051 mm, 0.5 to 2 mils). Use of these resins as coatings or components of coatings cured at temperatures above 371°C (700°F) is permitted by the FDA (21 CFR 177.2490) for coatings on articles intended for repeated food contact use.

Ryton® P-6

Moderate melt flow, partially cured PPS polymer typically used for thicker coatings (up to 0.25 to 0.30 mm, 10 to 12 mils).

A number of commercial manufacturers supply ready to use PPS coating formulations for specific purposes. These manufacturers provide their own application instructions, curing recommendations, and technical service.

Typical Slurry Formulations

PPS has an excellent affinity for a variety of fillers. If the filler can withstand the 371°C (700°F) curing temperature, it can probably be blended with PPS. Some typical examples of the many possible Ryton® PPS slurry formulations for specific purposes are listed below.

Industrial Release

100 parts	Ryton® V-1
33 parts	TiO_2
20 parts	PTFE
185 parts	Water
100 parts	Propylene Glycol
4 parts	Wetting agent (such as Triton® X-100)

This formulation is normally ball milled for 24 hours

Pigmented Coatings

100 parts	Ryton® V-1
16 parts	TiO_2
16 parts	Pigment
185 parts	Water
60 parts	Propylene Glycol
3.5 parts	Wetting agent (such as Triton® X-100)

This formulation is normally ball milled for 16 hours

Unpigmented Coatings

100 parts	Ryton® V-1
130 parts	Water
20 parts	Propylene Glycol
2 parts	Wetting agent (such as Triton® X-100)

This formulation is normally ball milled for 12 hours

Cobalt Oxide Primer

100 parts	Ryton® V-1
100 parts	Cobalt Oxide
300 parts	Propylene Glycol

This formulation is normally ball milled for 16 hours

Surface Preparation

The surface preparation is probably the most important factor in obtaining a good coating with PPS. This is true for most coatings that require baking at elevated temperatures. Although in some cases chemical treatment is sufficient preparation, the preferred method is grit blasting with a 60 to 120 grit medium. The grit should be fresh and free of contamination because contaminated blasting medium can deposit foreign material on the part surface that is difficult to remove. Any contaminant that will degrade at the curing temperature will produce an inferior coating.

Cleaning and Degreasing

Cleaning and degreasing of the parts is equally important to surface preparation. Any part to be coated with PPS should be thoroughly degreased. This can be accomplished by various methods such as vapor degreasing, solvent washing, sonic degreasing, and thermal degradation. Parts that have been exposed to cutting oils, rust inhibiting chemicals, and other preservatives should be degreased prior to grit blasting. It is also recommended that the part be degreased after a grit blasting operation. The recommended procedure for castings is to bake the parts at a temperature from 11°C to 28°C (20°F to 50°F) above the maximum expected curing temperature. This will degrade any oils and trapped gases that could cause holidays in the coating. This pre-bake should be done prior to grit blasting. In some cases, castings have some porosity. If this porosity is large, it is recommended that it be filled by welding or with some material that will withstand the baking temperature prior to coating with PPS. Care should be exercised in handling parts after cleaning so that body oils are not deposited on the part. If the parts must be handled, the use of clean cloth gloves is recommended.

Primers for Ryton® PPS Coatings

For most materials that are to be coated with PPS, primers are not required for external coatings. Internal coatings for pipe, fittings, valves, etc., made from steel, cast iron, or stainless steel, require a primer for best adhesion. There may be other primers that will prevent oxidation of the substrate and promote adhesion, but the best materials tested to this point are:

- Corro Therm CT-33
- Sermetel W
- Cobalt Oxide

These primers should be applied and baked according to the manufacturers' instructions. Each of these primers has produced excellent adhesion of Ryton® PPS coatings. In addition, users have noted that Ryton® PPS bonds easily to zinc phosphate converted coatings on carbon steel (Battelle Report No. GRI-90/0219).

Copper is very difficult to coat with materials that must be cured at elevated temperatures or in cases where the part is subjected to elevated temperatures during operation. Copper oxidizes very rapidly and the oxide does not adhere to the substrate. The best results in coating copper have been obtained by either electroless nickel plating or silver plating prior to coating with PPS.

Other materials, such as aluminum, may be coated without primers or treatments other than grit blasting and degreasing.

Slurry Coatings

Water based slurries of PPS can be applied using most standard industrial type spray guns. Air pressures from 1.0 to 3.8 bar (15 to 55 psi) can be used depending on the particular equipment employed. The spray gun should be adjusted to produce a fine mist that will produce a wet film of 0.025 to 0.038 mm (1.0 to 1.5 mils). The slurry coated part may go directly into the oven for curing. Air drying or preheating is not required for Ryton® PPS slurry coatings. Multiple coats, except for formulations containing PTFE, can be applied by repeating the spraying procedure. Coating thickness up to 0.25 to 0.38 mm (10 to 15 mils) can be achieved by slurry spraying. The first coat should not be applied more than 0.038 mm (1.5 mils) thick, but the second and subsequent coats can be applied as thick as 0.064 mm (2.5 mils) without experiencing mud cracking. A thicker first coat will usually produce severe mud cracking. Slurry coated parts should be baked at a temperature of at least 371°C (700°F) for at least 30 minutes. A curing schedule for minimum and maximum time for various temperatures is provided below.

Electrostatic Coating

Electrostatic spraying can be done on either cold or hot surfaces. Listed below are steps for obtaining optimum coatings using both techniques.

Cold Electrostatic Spraying

1. The surface should be prepared by degreasing and grit blasting with clean grit, with care being taken not to contaminate the cleaned surfaces. Small, intricate, or ceramic surfaces should be preheated to 371°C (700°F) and then cooled to room temperature. This will form an oxide on the surface and the first coat will give better coverage.
2. Coat the surface evenly to a 0.051 to 0.076 mm (2 to 3 mils) maximum film thickness per pass.

3. Place the coated part in a circulating air oven at 371°C (700°F) until 5 to 10 minutes after the coating melts. Cool the part to room temperature, and then repeat this procedure until the desired thickness has been achieved.

4. Final cure at 371°C (700°F) should be approximately 45 minutes for coatings up to 0.13 mm (5 mils) thickness and 90 minutes for coatings of 0.13 to 0.25 mm (5 to 10 mils) thickness.

Hot Electrostatic Spraying

1. Use the same surface preparation as for the cold spraying technique specified above.

2. The initial coat (0.051 to 0.076 mm, 2 to 3 mils) should be applied at room temperature, and the part then heated to 371°C (700°F). Subsequent coats may then be applied hot. If the part does not have enough mass to retain sufficient heat to melt the PPS as it is applied, it is not suitable for hot spraying and should be cold sprayed.

3. When melting of the powder starts slowing down, place the part back in the oven to reheat it to 371°C (700°F) and then continue spraying. If the coating should sag or run, the coating is being applied too heavily, and thinner coatings should be applied.

4. Final cure at 371°C (700°F) should be approximately 45 minutes for coatings up to 0.13 mm (5 mils) thickness, 90 minutes for coatings of 0.13 to 0.25 mm (5 to 10 mils) thickness, and 120 minutes for coatings of 0.25 mm to 0.51 mm (10 to 20 mils) thickness.

Fluidized Bed Coating

This method will produce smooth, glossy finishes but is limited to thicker, heavier parts that will retain heat long enough to melt the resin and coat the part with the desired thickness. The part is heated in an oven to 371°C (700°F) then removed and immersed in the fluidized bed as quickly as possible. While in the bed, the part is kept in motion to ensure a uniform coating. One to three seconds of immersion is generally sufficient to yield a 0.13 to 0.25 mm (5 to 10 mils) coating. After removing the part from the fluidized bed, the excess un-melted powder is removed by air or vibration. The coated part is then immediately placed in a circulating air oven before the coating surface cools. The coating should then be baked at 371°C (700°F). Multiple coats are recommended to ensure pinhole free coatings. After the first coat and while the item is hot from baking, the dipping and baking operation should be repeated.

Powder Spraying (Flocking)

Flocking can only be done on a hot part. After the proper surface preparation, degreasing, or priming has been done, the part should be preheated to 371°C to 427°C (700°F to 800°F). The PPS powder is then sprayed with a flocking gun onto the part to a thickness of 0.25 to 0.38 mm (10 to 15 mils). If a thicker coating is desired, it is preferable to apply two or more coats with a 30 to 45 minute cure between coats. Applying the coating too thick in one pass can produce blistering in the coating. To produce a smooth, glossy PPS coating, the powder should be sprayed on the part only as long as it readily melts. The addition of powder that does not melt will result in a rough, gritty coating. The powder coated part should be returned to the curing oven as soon as possible, at least prior to the part cooling to below the melting temperature of PPS (285 °C, 545 °F). Cooling the uncured coated part below the melt point could result in the coating cracking. The coating should be cured according to the curing schedule given below, which depends on the coating thickness and the temperature selected.

Coating Properties

Typical properties of Ryton® PPS coatings are shown in Table 1 and Table 2. Further information on the properties and chemical resistance of Ryton® PPS coatings is provided in the accompanying technical reprint.

Table 1: Properties of polyphenylene sulfide coatings

Property	PPS:TiO_2, 100:33	PPS:TiO_2:PTFE, 100:33:10
Hardness, pencil	2H	2H
Mandrel bend, 180° 4.85 mm (3/16")	Pass	Pass
Elongation, %, ASTM D522	32	32
Reverse impact, in·lbs (J)	160 (18.1)	160 (18.1)
Abrasion resistance, Taber, CS-17 wheel, mg/1000 rev.	50	57
Chemical resistance	Excellent	Excellent
Thermal stability	Excellent	Excellent

Table 2: Long term stability of polyphenylene sulfide coatings in air at 260°C (500°F)

	Weight Loss [%]	
Exposure Time [hours]	PPS:TiO_2, 100:33	PPS:TiO_2:PTFE, 100:33:10
24	0.003	0.02
100	0.06	0.07
500	0.18	0.21
1000	0.50	0.34
1182	0.47 (cracked)	0.31
1686	-----	0.95 (cracked)

Curing Schedule

Curing of PPS coatings is dependent on the coating thickness, temperature and time. The following is the recommended curing schedule:

Thin coatings – 0.025 to 0.05 mm (1 to 2 mils)

Temperature	Minimum Time	Maximum Time
316°C (600°F)	16 hours	72 hours
342°C (650°F)	6 hours	48 hours
371°C (700°F)	30 minutes	12 hours
399°C (750°F)	20 minutes	8 hours
427°C (800°F)	5 minutes	2 hours
454°C (850°F)	3 minutes	30 minutes

Thick coatings – 0.25 mm (10 mils)

Temperature	Minimum Time	Maximum Time
316°C (600°F)	-----	72 hours
342°C (650°F)	12 hours	48 hours
371°C (700°F)	1.5 hours	12 hours
399°C (750°F)	1 hour	6 hours
427°C (800°F)	34 minutes	2 hours

These times for curing PPS coatings do not include the heating time required to bring the part to the curing temperature. The time required to bring the part to this temperature must be added to the cure time. The following are some representative times required to heat substances to 371°C (700°F):

Pipe
Length: 5 inches (12.7 cm) **30 minutes**
Diameter: 10.2 cm (4 inches)
Weight: 2.04 Kg (4.5 lbs)

Open steel box **1 hour**
Sides: 20.3 cm (8 inches)
Wall Thickness: 2.54 cm (1 inch)
Weight: 10.4 Kg (23 lbs)

Steel Plate
Diameter: 17.8 cm (7 inches) **2.5 hours**
Thickness: 10.2 cm (4 inches)
Weight: 19.5 Kg (43 lbs)

For parts with large variation in thickness, it may be desirable to use a thermocouple on the heaviest section to determine when the part has reached the curing temperature.

Ryton® PPS Applications

The case histories of successful applications of Ryton® PPS coatings are much too numerous to list in this paper. It has been successfully used in many applications (many in high temperature, highly corrosive environments) such as pipe couplings, pumps, valves, tanks, reactors, sucker rods, oil well tubing, fan drive discs, coil insulation in motors, masking insulation on electrodes used for electrowinning metals, and many, many others. In addition, it has been recommended that PPS coatings be more completely evaluated over extended periods in heat exchangers in typical condensing furnaces (Battelle Report No. GRI-90/0219). Another good application for PPS is for cookware non-stick coatings. This is presently the largest single use for PPS coatings.

If there is a problem where high temperature and/or corrosion are encountered, then Ryton® PPS coatings will probably be the answer.

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