

How to Choose a Fluoropolymer

William A. Miller

Fisher|Moore

Introduction

Since their introduction, polymers have competed with metals, brick, glass, rubbers, FRP and other materials to provide corrosion protection in the chemical, semiconductor, food and pharmaceutical industries. The increasing demand for greater purity, particularly in the semiconductor and pharmaceutical industries, has made it difficult for metals and the existing types and procedures to meet the needs of many industry standards.

Fisher|Moore, recognizing the various industrial applications for improved purity and chemical resistance, developed high-build coatings for these applications. The company currently provides linings and coatings that include using the following materials:

- 1- PFA – perfluoroalkoxy
- 2- FEP – fluorinated ethylene propylene
- 3- ETFE – ethylene tetrafluoroethylene
- 4- ECTFE – ethylene chlorotrifluoroethylene
- 5- PVDF – polyvinylidene fluoride
- 6- PP – polypropylene
- 7- PE – polyethylene

Technical Development

Expanding on the high-build coating concept with both fluoropolymer and polyolefins, Fisher|Moore developed the techniques of high-build (>60 mil) coatings to compete with sheet lining. The advantages of the high-build coatings over sheet lining are:

- 1- No seams, eliminating major sites for bio-film build-up
- 2- No welds that can fail in time due to thermal cycling
- 3- Lower labor content in fabrication
- 4- Less dependent on the individual worker skill required during the welding of the sheet
- 5- Higher product purity – no adhesive residues that can be extracted through the installed sheet.

Primer Development

Fisher|Moore developed our own thermally stable primers to ensure excellent adhesion of the coating being applied to the metal substrate. The thermally stable primer permits application of multiple coats of the coating powder and the required oven heat cycles to fuse the powder without loss of adhesion or degradation.

Resin Heat Stabilizers

A significant number of powder coating materials are designed by their manufacturers for thin film coatings, without effective stabilizers. The heat stabilizers are not required for the few oven cycles normally involved with these materials. This effectively prevents the use of these powder-coating materials for



Tighter environmental laws are spurring use of fluoropolymers as anticorrosive linings in process vessels (left) and large diameter piping (right).



high-build coatings since the first coat will eventually start to degrade after multiple oven cycles because of the lack of an effective heat stabilizer in the polymer.

Fisher|Moore recognized the need for effective heat stabilizers to permit the application of high-build coatings with a wide range of materials.

Advantages of High-Build Coatings

The advantages of high-build coatings are:

- 1- Drastically reduces permeation through the coating and possible corrosion of the metal substrate.
- 2- Lowers the metals content of the fluid being handles due to the reduction of the permeation, substrate corrosion, and back migration of corrosion products.
- 3- Extends the life of the coating when exposed to an abrasive media.
- 4- Thick coatings can be repaired by welding if mechanically damaged. Thin coatings (<20 mil) must be stripped and recoated if repairs are not possible.
- 5- Thick coatings operate better under pressure/vacuum cycling than thin coatings.
- 6- Cost of a thick coating is not directly proportional to the coating thickness. Longer on-line performance is achieved at only a small additional cost with high-build coatings. Less maintenance is an important benefit.
- 7- No welds exist with a high-build coated vessel in comparison to one that is sheet-lined. Welds in sheet-lined vessels are a known point of failure.

Coating Selection

The selection of the proper coating material is based on:

- 1- Chemical exposure
- 2- Permeability of the coatings to the materials to be processed
- 3- Pressure if handling gaseous materials
- 4- Purity, FDA and USDA requirements
- 5- Maximum operating temperature
- 6- Abrasives, if present
- 7- Cost

Property comparison

The important properties to be considered of a coating are as follows:

Material	Specific Gravity	Melting Point °F	Max use temperature °F	Hardness Shore	Chemical Resistance	Abrasion Resistance	Powder Cost
PFA	2.15	580	500	D-64	Excellent	Poor	Expensive
FEP	2.15	500	400	D-55	Excellent	Poor	Expensive
ETFE	1.74	473-536	310	D-63-72	Excellent❶	Excellent	Moderate
ECTFE	1.68	430	300	D-75	Excellent❶	Excellent	Moderate
PVDF	1.77	320	265	D-75-80	Excellent❷	Excellent	Moderate
PP	0.9	311	210	D-58	Good❸	Good	Low Cost
PE	0.96	221	140-160	D-44	Good❹	Good	Lowest Cost

❶ - Attacked by strong oxidizing agents and hot amines

❷ - Resistant to acids and bases; dissolved by polar organics

❸ - Resistant to acids and bases; attacked by strong oxidizing agents

❹ - Resistant to dilute acids and bases; attacked by strong oxidizing agents

PFA – Perfluoroalkoxy

PFA is a copolymer of tetrafluoroethylene (TFE) with a perfluoroalkoxy monomer (PFA). This has a 590°F melting point and a continuous use temperature of 500°F. Specific gravity of PFA is 2.15 g/cm³. PFA has better mechanical properties than PTFE or FEP. Chemical resistance is excellent, even similar to PTFE. PFA can be applied by Fisher|Moore to a coating thickness of greater than 80 mils. The coating is expensive because of the high powder cost, high specific gravity of the powder and the high temperature of processing. Rotomolding and powder coating grades are available.

PFA is extensively used in the semiconductor applications due to both chemical resistance and low extractables (high purity). FDA compliant grades are available for pharmaceutical applications.

FEP – Fluorinated ethylene propylene

FEP is a copolymer of tetrafluoroethylene (TFE) and hexafluoroethylene (HEP). This material is available in powdered grades for rotomolding and powder coating. Melting point is 530°F and the continuous use temperature is 400°F. Chemical resistance is similar to PTFE and PFA. Mechanical properties such as cut through and abrasion resistance are poorer than PTFE and PFA. FEP can be applied by Fisher|Moore to coating thicknesses of greater than 80 mils. The coating is expensive because of the high powder cost, high specific gravity and the high temperature of processing.

FEP is extensively used in the semiconductor and pharmaceutical applications due to the excellent chemical resistance, low extractables (high purity), and FDA compliance.

ETFE – Ethylene tetrafluoroethylene

ETFE is a copolymer of ethylene (E) and tetrafluoroethylene (TFE). It has a specific gravity of 1.74 g/cm³, a melting point of 520°F and a continuous use temperature of 310°F. It is a tough material with excellent cut through, abrasion resistance and impact properties. It is resistant to most chemicals except some strong oxidizing agents and hot amines. Powder grades are available for powder coating and rotomolding. Grades are available that have very low extractables making it suitable for semiconductor applications. These grades are also FDA and USP Class VI compliant. Surface smoothness is typically less than 2 micro inches after coating.

ECTFE – Ethylene chloro trifluoroethylene

ECTFE is a copolymer of ethylene (E) and chlorotrifluoroethylene (CTFE). ECTFE has a specific gravity of 1.68 g/cm³, the lowest density of the fluoropolymers. It has a melting point of 430°F and a continuous use temperature of 300°F. It is a tough material with excellent cut through, abrasion resistance and impact properties. It is resistant to most chemicals except strong oxidizing agents and hot amines. Grades are available for powder coating. The permeation resistance of ECTFE to many chemicals is superior to other fluoropolymers. ECTFE has only a limited range of FDA compliance. Extractable levels are higher than with ETFE.

PVDF – Polyvinylidene fluoride

PVDF is a polymer made by the polymerization of vinylidene monomer. It has a specific gravity of 1.77 g/cm³, a melting point of 280-340°F depending on the grade and a continuous use temperature of 265°F. It is a tough material with excellent cut through and abrasion resistance properties. PVDF polymers, while resistant to strong acids and bases, are readily dissolved by polar organics. This is the lowest cost fluoropolymer and is the most widely used fluoropolymer in the semiconductor, chemical, and pharmaceutical industries. Grades are available that meet FDA and USDA requirements.

PP – Polypropylene

PP is a polymer made by the polymerization of the propylene monomer. The coating grades of PP have a specific gravity of .99 g/cm³, a melting point of 311°F and a continuous use temperature of 210°F maximum. It is a tough material with excellent cut through and abrasion resistant properties. PP is resistant to strong acids and bases but not to the same temperatures as the fluoropolymers. It is attacked by strong oxidizing agents. Extractable levels are not as low as with fluoropolymer materials. The powder cost is lower than any fluoropolymers.



Polyolefin coatings offer low TOC's, no adhesives and higher purity at a lower cost than conventional rubber linings.



PE – Polyethylene

PE is a polymer made by the polymerization of the ethylene monomer. The coating grade of PE has a specific gravity of .96 g/cm³, a melting point of 221°F and a maximum use Temperature of 140-160°F. The PE coatings are softer with poorer abrasion resistance than the materials previously discussed. It is attacked by strong oxidizing agents. Extractable levels are not as low as with fluoropolymer materials. This is the lowest cost high-build coating material.

High-build PE coatings are an excellent replacement for rubber lining. Higher Product purity and longer life with no seams are the significant advantages for the high-build coating.

Applications of High-Build Coatings

There are currently seven major polymers that Fisher|Moore applies as high-build coatings. Rarely does one occupy an application to the complete exclusion of all other materials. Each specific application must be considered before selecting a material for use.

- 1- Mixed beds
- 2- Water storage tanks
- 3- Pumps
- 4- Piping
- 5- Chemical storage tanks
- 6- Valves
- 7- Chemical day tanks
- 8- Filter housings
- 9- Wet bench components
- 10- Vacuum degasifiers
- 11- Agitators
- 12- CMP components

Future Growth

Future growth of high-build coatings will come about from:

- 1- Increasing cost of stainless steel and high nickel alloys
- 2- Increasing problems in the disposal of other less chemically resistant plastics after they have been exposed to hazardous materials and

absorbed some of the hazardous materials. Fluoropolymers tend to absorb fewer materials.

- 3- Requirement of certain industries for reduced metal content to improve yield and quality.
- 4- Requirements of certain industries for higher product purity preventing the use of plastic materials with high levels of extractable organics.

Despite competition from metals and other materials, high-build coatings continue their expansion into semiconductor, pharmaceutical, chemical and process industry applications. The balance of excellent chemical resistance, high purity and good mechanical properties ensure that this trend will continue.

High-build coatings will be the option of choice, in our opinion, when compared to sheet lining and rotolining for chemical protection.

The Author

William A. Miller was the manager of commercial development for the fluoropolymers at Ausimont, USA Inc., a major supplier of fluoropolymer materials. He has more than 30 years of fluoropolymer experience in research and development, technical service and applications. Mr. Miller has a B.E. in chemical engineering from Villanova University, an M.S. in chemical engineering from Notre Dame and an M.S. in engineering management from Newark College of Engineering (now the New Jersey Institute of Technology).

In 1996, Mr. Miller left Ausimont USA and joined Fisher|Moore where his tasks include research and development of new applications for polymers and marketing duties throughout the United States.