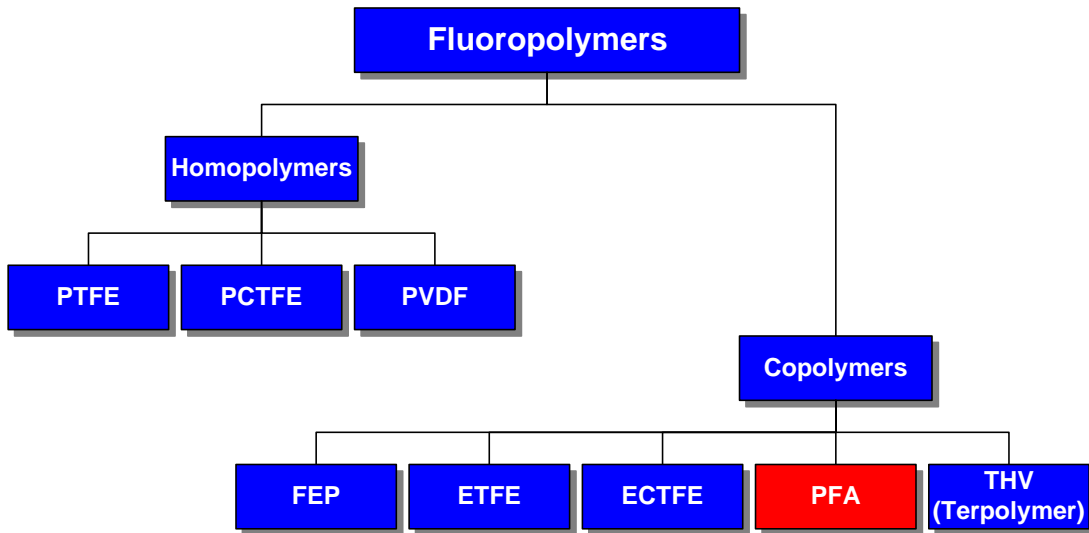


Focus on: PFA

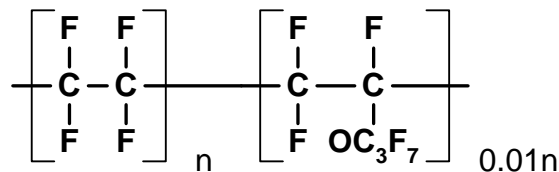
Introduction

This month the focus is on another melt-processable member of the fluoropolymer family, PFA or perfluoroalkoxy copolymer. As with last month's focus on FEP, PFA is a copolymer of the structure -A-B-A-B-A-B- (where A and B are different repeating units) and fits into the fluoropolymer family as shown below.



PFA in the fluoropolymer family.

PFA is a partially fluorinated copolymer of tetrafluoroethylene (TFE), the base material for PTFE, with a perfluoroalkoxy monomer (PFA). In the case of PFA the TFE and PFA do not combine in a ratio of 1:1 to give the straight -A-B-A-B-A-B- format, but combine in a ratio of 1:0.01 to give a copolymer of the format -A-A-A-A-A-B-A-A-A-A-A-B where there are approximately 100 A monomers for every B monomer. The chemical structure of PFA as shown below:



The structure of PFA

As with all fluoropolymers, the structure of PFA is semi-crystalline giving it not only a distinct and sharp melting point but also generally better mechanical properties than those of the amorphous type of polymers such as the polyolefins.



PFA was first produced by DuPont in 1972 (Teflon® PFA) and is melt-processable. In many ways PFA is similar to FEP but generally has better mechanical properties at higher temperatures. It has a higher maximum service temperature than FEP that is very similar to that of PTFE. PFA combines many of the best attributes of PTFE and FEP and is considered by some to be the best melt-processable fluoropolymer alternative to both.

Properties

The general properties of PFA are typical of other semi-crystalline high performance thermoplastics:

- Excellent clarity and flexibility
- Maximum service temperature of 260°C/500°F
- Combines the best attributes of PTFE and FEP
- Chemically resistant to all common solvents
- Maintains mechanical strength at high temperatures
- Available in high purity grades
- Chemically inert
- Low gas permeability
- Smoother surface texture
- Ultra-low levels of ionic extractables
- Gamma, EtO, e-beam and autoclave sterilizable
- Flame resistance rating of UL 94 V-0

Physical and Mechanical

The physical and mechanical properties of PFA are generally similar to those of PTFE although in some cases they exceed it (i.e. tensile strength at yield and flexural modulus). The surface finish of PFA is smoother than that of either PTFE or FEP and the flex life is also generally better. However, the abrasion resistance of PFA is generally less than that of PTFE.

Typical mechanical and thermal properties are given in the Table below.

Property	Approximate Value of Natural Polymer
Tensile strength (@23°C)	27 MPa
Tensile Modulus (@1% strain @23°C)	0.5 - 0.6 GPa
Elongation at Break (@23°C)	310 - 360%
Flexural Strength (@23°C)	No Break



Izod Notched Impact Strength (@23°C)	17 J/m²	
Coefficient of friction (dynamic)	0.21	
Heat Deflection Temperature	73°C/163.4°F	
Low Temperature Toughness	-268°C	
Coefficient of Thermal Expansion	@20°C	120 - 180 µm/m-°C
	@100°C	140 - 180 µm/m-°C
	@250°C	250 µm/m-°C
Long Term Service Temperature	260°C/500°F	
Melting point	305°C/581°F	
Specific Gravity	2.15	
Water Absorption	Less than 0.05% (50% rh)	
Transparency	Transparent	

Thermal and flammability

PFA is also one of the few plastics that is both suitable for high and low temperature applications and can be used over the range of temperatures -268°C/-450°F to 260°C/500°F. This is very similar to the working temperature range of PTFE but PFA has the advantage of being melt-processable.

The fire behavior of PFA is also excellent and PFA has no difficulty in achieving UL 94 V-0 for flame resistance. The Limiting Oxygen Index (LOI) for PFA is greater than 95, which means that there must be over 95% oxygen present to support free combustion (air only contains approximately 21% oxygen and therefore a material with an LOI of greater than 21 will probably not support burning in an open air situation).

Even when PFA does burn, the heat of combustion is extremely low, the amount of smoke released is minimal, and the decomposition gases have very low corrosiveness, therefore minimizing the major factors in the damage caused by real fires with cable and building related products.



Electrical

PFA has excellent dielectric properties such as high volume and surface resistivity. These properties are relatively constant with changes in temperature, but are somewhat less than those of PTFE and FEP. These dielectric properties make PFA suitable for applications such as the insulation of communications cables or components for electronic devices where low dissipations are needed at high frequencies.

Chemical resistance

PFA is not fully fluorinated, and as a result, the chemical resistance of PFA is slightly less than that of the fully fluorinated polymers PTFE and FEP.

Despite this, the chemical resistance of PFA is still excellent and the material has few known solvents. As a general rule PFA is preferred to FEP when extended service is required in hostile environments, and this is particularly true in conditions that might induce stress cracking.

PFA is suitable for food contact and is FDA compliant (FDA 21CFR.177.1550), and is also used extensively in the pharmaceutical industry.

PFA is also appropriate for medical applications. It is biocompatible to USP Class VI (non-toxic, non-hemolytic and non-pyrogenic) and PFA products can be sterilized by gamma, EtO, e-beam, or autoclaving.

PFA has good weathering resistance to sunlight, ozone and general weathering, and tests in Florida show no measurable property changes after 20 years.

Optical

PFA has a high transparency and low haze with good transmittance in both the UV and visible wavelengths. PFA also has one of the lowest refractive indexes of all polymers (1.34) and products are extremely clear and transparent.

PFA can be colored almost any color but only inorganic pigments can be used due to the high processing temperatures required.

Advantages and Limitations

Advantages	Limitations
1. Melt-processable fluoropolymer	1. Higher cost in relation to some other polymers
2. Improved mechanical properties at high temperatures in comparison to FEP	2. Reduced chemical and dielectric properties in comparison to PTFE
3. Very good high and low temperature performance for all mechanical properties	3. Processing requires specially treated equipment to avoid corrosion of equipment
4. Excellent electrical performance at high temperatures	4. Processing requires suitable machines to cope with high melt viscosity



5. Excellent chemical resistance over a wide range of temperatures	
6. High transparency with good transmittance of both UV and visible wavelengths and a very low refractive index (1.34)	

Processing

As a melt-processable fluoropolymer, PFA can be processed by most of the traditional plastics processing methods, and the material is used extensively for injection molding, extrusion, powder coating, compression molding, transfer molding and other molding techniques.

As a general rule PFA is easy to process due to its high thermal stability. The polymer properties are not affected by long residence times but as with most fluoropolymers, processing requires high temperatures to melt the resin and the processing machinery used must be suitable for high temperatures and high melt viscosities.

Processing Method	Applicable for PFA
Injection molding	Yes
Extrusion (profiles, films, sheet, tubing, heat shrink tubing, and cable coating)	Yes
Powder coating	Yes
Compression	Yes

PFA Grades

PFA is produced in a variety of grades depending on the processing method to be used for the material. Specific grades are available for injection molding, extrusion, powder coating, compression molding and transfer molding.

Glass fiber filled grades of PFA are also available to give significant increases in heat deflection temperature and tensile strength compared to the standard unmodified grades. These increases are, however, at the expense of reduced elongation at break and notched Izod impact strength.

Finishing

PFA is available as semi-finished products in rod, tube, sheet and other formats suitable for further machining.

PFA semi-finished products can be machined using conventional machine tools to give a good finish for prototype evaluation or small run production. PFA machines easily and accurately using conventional machine tools with carbide or diamond tipped tooling. Speeds and feeds should be slow (as with any plastic material) to prevent excessive heat build up in the part.



Typical Applications

PFA is used in many similar applications to those of FEP and PTFE but is particularly suitable for applications where there are high degrees of chemical, thermal and mechanical stress.

Typical applications are:

- Semiconductor and pharmaceutical industries due to excellent chemical resistance and low extractables (high purity)
- Chemical process industries for coating of cables, tubes, pipes, fittings, pumps and valves
- Laboratory products
- Wire and cable insulation for computers and electronics systems
- Insulating bushings
- Release applications

Zeus Capabilities

Zeus processes PFA to produce a variety of extruded products such as:

- High Purity tubing
- Heat Shrink and Dual Shrink tubing
- Lay-Flat tubing
- Special profiles
- Monofilament reinforced tubing
- Multi-lumen tubing
- Convoluted tubing
- Roller covers

All of these products can be produced to extremely tight tolerances and can be modified by the inclusion of additives such as bismuth (for radio-opaque tubing), glass (for increased heat deflection temperature and tensile strength), carbon, pigments, or other special additives.

Summary

PFA was not the first melt-processable fluoropolymer but represented a major step forward in the fluoropolymer family. PFA was the first material to combine the best attributes of PTFE and FEP and is considered by some to be the best melt-processable fluoropolymer alternative to PTFE.

How Zeus can help

With a technical inside and outside sales force backed up with engineering and polymer experts, Zeus is prepared to assist in material selection and can provide product samples for evaluation. A dedicated R&D department staffed with PhD polymer chemists and backed with the support of a world-class analytical lab allows Zeus an unparalleled position in polymer development and customization.

Since 1966 Zeus has been built upon the core technology of precision extrusion of high temperature plastics. Today, with a broad portfolio of engineered resins and secondary operations, Zeus can provide turnkey solutions for development and high-volume supply requirements.



Contact us

- Visit us online at <http://www.zeusinc.com> for more information about our products and capabilities.
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- Email the editor of the *Zeus Polymer Minute* directly at editor@zeusinc.com
- Request technical info or support at support@zeusinc.com