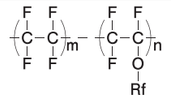
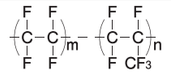
FLUOROCARBON POLYMERSCOATING

Since 1938 when Dr. Roy J. Plunkett, a chemist at DuPont, discovered TFE (Tetra Fluoro Ethylene polymer), it has been widely used in coatings, moldings, impregnation material, and films under the DuPont Teflon® brand. Teflon® is a registered trademark of DuPont. This trademark may be used only under license from DuPont in the United States.

Fluoropolymers are, unlike other industrial materials, (1) resistant to extreme temperatures, (2) resistant to chemicals and corrosion, (3) adhesion resistant, (4) abrasion resistant, (5) unique in their electrical properties, and (6) non-flammable. These polymers can be applied to many uses from small bearings and nuts & bolts to large equipment for the aero-space industry.

The steps used to apply fluoropolymer coating vary depending on the type of base material, use, and on the type of fluoropolymer coating. Typically, those steps are degreasing, surface treatment, coating, drying, and baking in that order.
The surface treatment usually involves blasting the base material with alumina powder to make the surface rough. In some cases, chemical conversion is also used.
Often the coating is applied as a liquid spray as is often done with standard paint, but dip coating, dip spin coating, roll coating, and spin flow coating may also be used depending on the base material. Powdered coating is applied by electrostatic powder coating or electrostatic immersion coating.
The final step is baking, which gives the coating the desired characteristics.
The base material (the coated object) can be metal, such as aluminum, stainless steel, etc., or glass, ceramic, or other substances. Depending on the type of coating, baking temperature varies between 165℃~427℃.

Types of fluoropolymer

Types	Structural Formula	Melting Point (℃)	Continuous use temperature (℃)
PTFE (Polytetrafluoroethylene)		327	260
PFA (Perfluoroalkoxy)		300~310	260
FEP (Fluorinated Ethylene Propylene copolymer)		250~270	204

The following is a list of characteristics of recently-launched fluoropolymers.

	Property	unit	ASTM method	PTFE	PFA	FEP	ETFE	PVDF	ECTFE	PCTFE	PVF
Physical	Melting point	℃		327	300-310	260	270	156-170	245	220	203
	Specific gravity	—	D792	2.14-2.20	2.12-2.17	2.12-2.17	1.70	1.75-1.78	1.68-1.69	2.1-2.2	1.38~1.57
Mechanical	Tensile strength	MPa	D638	27~34	24~34	22~13	45	34~43	48	31~41	82
	Elongation	%	D638	200~400	300	250~330	100~400	80~300	200~300	80~250	115~250
	Comp. strength	MPa	D695	12	17	15	49	67~96		31~51	
	Impact strength (Izod)	J/m	D256A	160	Not destroyed	Not destroyed	Not destroyed	160~370	Not destroyed	130~140	
	Hardness (Rockwell)	—	D785	—	—	—	R50	R79~83	—	R75~95	
	Hardness (Shore)	—	D2240	D50~65	D64	D60-65	D75	D65~70	D55	D75~80	
	Flexual modulus	GPa	D790	0.55	0.66	0.65	1.4	2.0~2.5	0.66~0.69	1.3~1.8	
	Tensile modulus	GPa	D638	040~0.55	—	0.34	0.82	1.3~1.5	1.6	1.0~2.1	1.9
	Dynamic friction coefficient		(0.7MPa 3m/min)	0.10	0.20	0.30	0.40	0.39	—	0.37	
Thermal	Thermal conductivity	W/m·K	C177	0.25	0.25	0.25	0.24	0.10~0.13	0.16	0.20~0.22	0.14~0.17
	Specific heat	10^3J/kg·K	D240	1.0	1.0	1.2	1.9~2.0	1.4	—	0.92	1.0
	Linear expansion coefficient	10^{-5}/K	D696	10	12	8.3~11	5.9	7~14	8.0	4.5~7.0	7.1~7.8
	Ball pressure temp	℃	—	180	230	170	185	—	—	170	
	Load Deflection temp. 1.8MPa	℃	D648	55	50	50	74	87~120	77	—	
	Load Deflection temp. 0.45MPa	℃	D648	121	74	72	104	149	116	126	
	Max working temp	℃	(No load)	260	260	204	150~180	150	165~180	177~200	100
Electrical	Volume resistivity	Ω·cm	D257 (50%RH,23℃)	$>10^{18}$	$>10^{18}$	$>10^{18}$	$>10^{16}$	2×10^{14}	10^{18}	1.2×10^{18}	1.2×10^{14}
	Breakdown strength (short time)	KV/mm (3.2mm)	D149	19	20	20-24	16	10	20	20-24	
	Dielectric constant 60Hz	—	D150	<2.1	<2.1	2.1	2.6	8.4	2.6	2.2-2.8	8.2~8.5
	Dielectric constant 10^3Hz	—	D150	<2.1	<2.1	2.1	2.6	8.4	2.6	2.3-2.8	6.2~6.7
	Dielectric constant 10^6Hz	—	D150	<2.1	<2.1	2.1	2.6	6.43	2.6	2.3-2.5	6.2~7.0
	Dielectric dissipation factor 60Hz	—	D150	<0.0002	<0.0002	<0.0002	0.0006	0.049	<0.0005	0.0012	0.3
	Dielectric dissipation factor 10^3Hz	—	D150	<0.0002	<0.0002	<0.0002	0.0008	0.018	0.0015	0.023-0.027	
	Dielectric dissipation factor 10^6Hz	—	D150	<0.0002	0.0003	<0.0005	0.005	<0.015	0.009-0.017		
	Arc resistance	sec	D495	>300	>300	>300	75	50-70	18	>360	
Durability, others	Water absorption 24h	%	D570	<0.01	<0.01	<0.01	0.029	0.04-0.06	0.01	0.00	<0.5
	Flammability 3.2mm thickness	—	(UL-94)	V-0	V-0	V-0	V-0	V-0	V-0	V-0	HB
	Limiting oxygen index	%	D2863	>95	>95	>95	30	44	60	>95	23
	Direct sunlight impact	—	—	none	none	none	none	none	none	none	none
	Acid			◉	◉	◉	◎	○	◎	◎	△
	Alkali			◉	◉	◉	◎	○	◎	◎	○
	Solvent	—		◉	◉	◉	◎	△	◎	○	△

Source: Modern Plastics Encyclopedia 97 supplemented with data from DuPont
Note: ◉Superior ◎Very good ○Good △Usable

Unique properties of fluoropolymer coating not found in other resin coatings

Non-adhesive

Most substances do not adhere to fluoropolymer coating even when the layer of coating is very thin. However, in some cases, when ultra adhesive resistance is required or when low viscous material is used, such as with epoxy resin dies that require good mold release, FEP series or PFA series coating is must be used to avoid pinhole formation.

Extreme temperature resistance

PTFE series, PFA series, and a composite PTFE/PFA are not only heat resistant, but also withstand cold temperature. These series can be used at 300℃ for short periods of time. Normal operating temperature ranges from 260℃ to -240℃. FEP series can be used continuously up to 204℃.

Nonstick

Fluoropolymer coatings have a low coefficient of friction, which is generally between 0.05 and 0.15 depending on the load and sliding speed.

Unique electrical properties

Fluoropolymer resins have the best electrical properties among all plastics. Electrical insulation properties, low dielectric loss, and arc resistance along with heat resistance make fluoropolymer resins an interesting material for use in electronic components. FEP series, PFA series, and compound coatings are suitable for electrical purposes. However, coatings must be applied carefully to avoid pinhole formation.

Abrasion resistance

Excellent abrasion resistance even for heavy loads can be achieved by using a modified coating comprising the good non-stick properties of fluoropolymer and an organic binder resin. For copier fuser rolls, mixing & rolling equipment, food processing equipment, and other uses with moderate load, a PTFE/PFA composite will provide both excellent non-adhesion and non-abrasive properties.

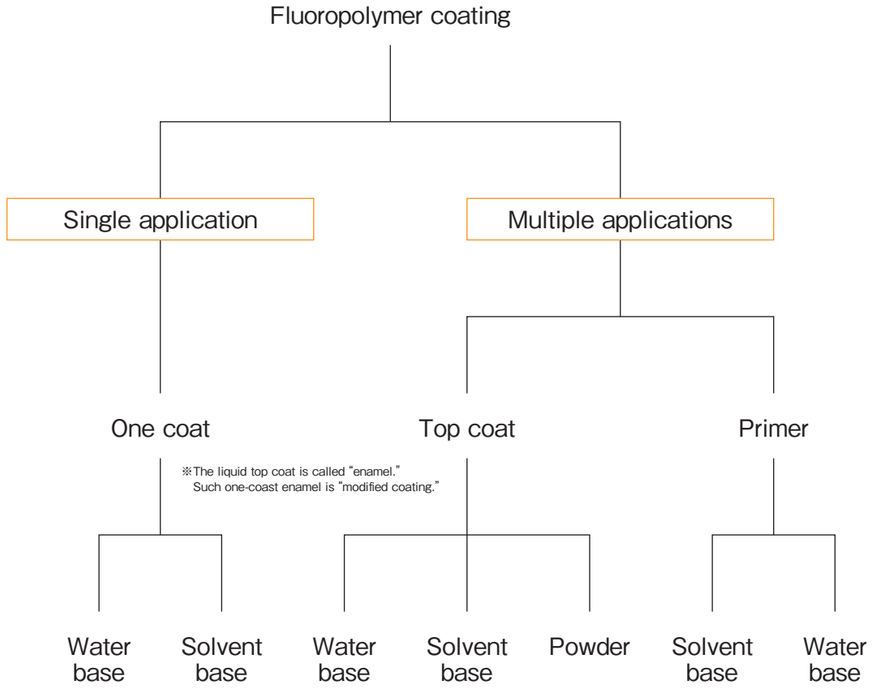
Chemical resistance

Fluoropolymers are unaffected by nearly all chemicals, however a thick coating is required to avoid pinholes that may easily form if only a thin layer of coating is applied. The osmotic force of strongly permeable chemicals must be taken into consideration whenever such chemicals are used. A thick coating of FEP or PFA is effective to resist corrosion. A modified coating may be used for protection against certain chemicals. PTFE series is not effective against corrosion as pinholes are likely to form.

Nonwetting

The surface of fluoropolymer coating repels oil and water without becoming wet from nearly all industrial fluids. Coated surfaces seldom become dirty. If necessary, surfaces can be easily cleaned reducing equipment downtime, saving energy, and increasing productivity.

Fluoropolymer coatings can be categorized as follows



Typical steps for applying fluoropolymer coating

Grade of coating and other conditions vary,so please consult Furukawa Agency Co., Ltd for details.