Appendix :Uses and substitutions of Specialist Equipment

This document is the appendix of the general comment to the Restriction report on Per- and polyfluoroalkyl substances (PFAS) from
（Industrial Gas Detectors and Monitors Manufacturers Association）
submitted on 22. September 2023

Table of content

The characteristics and functions of PFAS

Summary

PFASs have many functions. The characteristics and functions of PFAS which are mainly used in Specialist equipment are described in this section.

PFAS has excellent properties such as, chemical resistance, electric insulation, heat resistance, repellency from water and oil, non-adhesion, weatherability, and others. PFASs are used where multiple of these properties are required simultaneously. We recognize that the ability to provide these various properties in a single material is the most important property of PFAS, and at present we do not have information on any other substance with this function other than PFAS.

Chemical resistance

Fluoropolymers compared to other general-purpose resins

	ETFE	FEP/TFE/FPA	FLPE	FLPP	HDPE	LDPE	PC	PETG	PP	PVC	TPE***
Acids, Dilute or Weak	E	E	E	E	E	E	E	G	E	E	G
Acids, **Strong/Concentrated	E	E	G	G	G	G	G	N	G	G	F
Alcohols, Aliphatic	E	E	E	E	E	E	G	G	E	G	E
Aldehydes	E	E	G	G	G	G	G	G	G	G	G
Bases/Alkali	E	E	F	E	E	E	N	N	E	E	F
Esters	G	E	G	G	G	G	N	G	G	N	N
Hydrocarbons, Aliphatic	E	E	E	G	G	F	G	G	G	G	E
Hydrocarbons, Aromatic	G	E	E	N	N	N	N	N	N	N	N
Hydrocarbons, Halogenated	G	E	G	F	N	N	N	N	N	N	F
Ketones, Aromatic	G	E	G	G	N	N	N	N	N	F	N
Oxidizing Agents, Strong	E	E	F	F	F	F	F	F	F	G	N

*Not for tubing chemical resistance (except PVC) **Except for oxidizing acids (See oxidizing agents, strong) ***TPE gaskets

Table 1 **Classes of Substances at 20° C, Chemical Compatibility Chart - LDPE, HDPE, PP, Teflon Resistance (calpaclab.com)** [1]

* Not for tubing chemical resistance (except PVC) ** Except for oxidizing acids (See oxidizing agents, strong) *** TPE gaskets

Excellent: 30 days of constant exposure causes no damage. Plastic may tolerate for 30 years.
Good: Little or no damage after 30 days of constant exposure for the regent
Fair: Some effect after 7 days of constant exposure to the reagent. The effect may be crazing, cracking, loss of strength or discoloration.
Not recommended: Immediate damage may occur. Depending on the plastic, the effect may be severe crazing, cracking, loss of strength or dis coloration, deformation, dissolution or permeation loss.

Type / Properties	Fluoroelastomer	Silicon rubber	Acrylic rubber	Nitrile rubber	Ethylene propylene rubber
	FKM	MQ, VMQ	ACM	NBR	EPDM
Specific gravity	1.8～2.0	1.0	1.0	1.0	0.9
Heat resistance	◎	◎	○	△	○
Low temperature resistance	△	◎	○	◎	◎
Electrical properties	○	○	△	△	◎
Solvent resistance	◎	◎	○	△	○
Flame resistance	◎	○	▲	▲	▲
Ozone resistance	◎	◎	◎	×	◎
Steam resistance	◎	○	×	△	○
Acid resistance	◎	○	△	○	◎
Alkaline resistance	◎	◎	△	○	◎
Oil resistance	◎	△	○	○	×
Permeability resistance	◎	▲	○	○	△

Table 2　Property Comparison of Fluoroelastomers (FKM) with Other Rubbers[1]

◎ : Excellent　○ : Good　△ : Fair　▲ : Marginal　× : Poor

"Cleanliness" is defined as the fact that fluoropolymers are not easily eluted by acids, alkalis, or solvents (chemical resistance), do not contain other materials such as plasticizers in the molding process, and do not contain products that would thermally decompose during the material molding process.

Ozone resistance

Ozone is known to degrade plastic materials in two ways:

A:　Substances with double bonds (C=C) in their structures (such as natural rubber, chloroprene rubber, butadiene rubber, etc.) undergo decomposition in which ozone reacts with the double bonds to produce ketones, when they come into contact with ozone.

B: When ozone exists in water, peroxy radicals are generated. Non-fluorine materials (eg polyethylene, polypropylene, etc.) deteriorate even if they do not have double bonds.

Fluoropolymers does not have decomposition pathways such as A and B even if it comes into contact with ozone, so it can be used for a long time without deterioration.

[1] https://www.daikinchemicals.com/library/pb_common/pdf/catalog/RC-1L.pdf translated from the document in Japanese. Last accessed on 14 July, 2023

Thermoplastic resin		Ozon Resistance
Soft vinyl chloride	PVC	○
Rigid vinyl chloride	PVC	○
Vinylidene chloride resin	PVdC	◎
ABS	ABS	△
Polyethylene	PE	△
Nylon	N	×
Acrylic resin	PMMA	△
Fluoropolymer resin	PTFE	◎
Phenolic resin	PF	△
Melamine resin	PVC	○
Furan resin	FF	○
Epoxy resin	EP	△
Unsaturated polyester resin	UP	×

Table 3 Comparison of ozone resistance properties of plastics

Repellency from water and oil / non-adhesion

Since the fluoropolymers have a small polarizability, the intermolecular force is small. Because of its characteristics, fluoropolymers have repellency and non-adhere properties on the surface.

In general, the repellency from various liquids is evaluated by the contact angle, and the larger the contact angle, the higher the repellency.

Contact angle θ

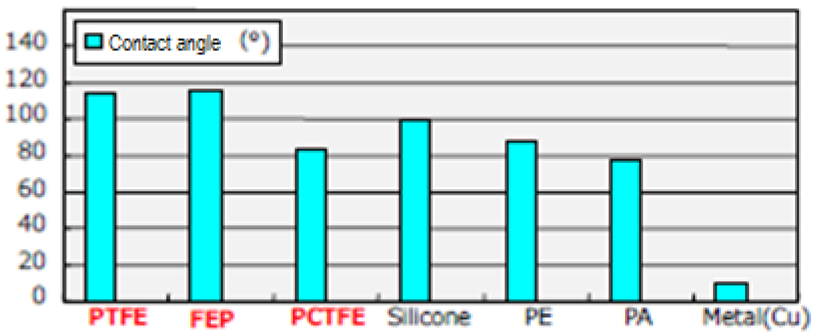

Figure 1 Contact angles with water

Adhesion energy refers to the amount of work required to pull a liquid contacting a solid away from the solid. The larger the contact angle, the smaller the adhesion energy. It means that a liquid in contact with a small adhesion energy solid easy to separate from the solid.[2]

Material name	Contact angle with water (°)	Adhesion energy (dyn/cm)
PTFE	**114**	**43.1**
FEP	**115**	**42.0**
Silicone resin	**90~110**	**47.8~72.7**
Paraffin	**105~106**	**52.7~53.8**
PE	**88**	**75.2**
PCTFE	**83**	**-**
PA	**77**	**97.7**
Phenolic resin	**60**	**109.0**
Copper(electropolishing)	**9.6**	**144.2**
Aluminium(electropolishing)	**4.6**	**145.0**

Table 4 Surface properties of various plastics and metals

This characteristic is sometimes called "mold releasability". It can also be expressed as antifouling because it does not easy to adhere.

Heat resistance

Fluoropolymers have high heat resistance as follows. They have higher heat resistance compared to other general-use resins

	Fluoropolymers						Other general-use resins	
Heat resistance : maximum operating temperature (C)	PTFE	PFA	FEP	ETFE	PCTFA	PVdF	PP	PVC
	260	260	205	150	120	120	100	60

Table 5 The heat resistance of Fluoropolymer [3]

Electric insulation

When the dielectric constant is low, the insulation in electrical components can be made thinner, leading to downsizing and weight reduction of the equipment. In applications where

[2] Japan Fluoropolymers Industry Association(2020), ふっ素樹脂ハンドブック, 14th edition. Page 34 Translated from Japanese.

[3] DAIKIN INDUSTRIES, LTD. (2009) ダイキン フッ素樹脂ハンドブック, Page 4

downsizing and weight reduction are necessary, it is an essential feature

	Fluoropolymer				Fluorine rubber	
	PTFE	FEP	PFA	ETFE	FKM	FEPM
Dielectric constant	◎ 2.1			○ 2.3～2.8	△ 3～4	△～○ 2.5～3.5
	Non-fluoropolymer				Non-fluorine rubber	
	PVC	PEEK	TPI (Thermoplastic Polyimide)	Polyolefin	Silicone rubber	EPDM
Dielectric constant	△ 4～6	△ 3.2～4.5	△ 2.8～3.2	△～○ 2.3～4	△ 3.2～10	△ 2.5～3.5

Table 6　The dielectric constants of various resins

Low friction, self lubrication

Friction coefficient of fluorine resin is lower than that of other resins. It is because polarizability

(Mobility of electrons in an electric field) of C-F bonding is low (0.68) and the intermolecular force is weak. (Reference: polarizability of C-Cl bonding is 2.59) [4]

Types of plastic	Plastic / Plastic	Plastic / Steel	Steel / Plastic
PTFE	0.04	0.04	0.10
PE	0.10	0.15	0.20
PS	0.50 *)	0.30	0.35
PMMA	0.80 *)	0.50 *)	0.45 *)

*) indicates occurrence of stick-slip motion.
Measurement condition: Bowden-Laden type measurement equipment, load: 9.8-39.2N, sliding speed: 0.01cm/s
Plastic/Steel indicates sample material/pin material
PE: polyethylene PS: polystyrene PMMA: polymethylmethacrylate

Table 7　Comparison of friction coefficient among PTFE and other materials[5]

As an example of low friction, Table8 shows friction coefficient of PTFE.

Type	ASTM test method	Measurement condition		Unit	PFA	PTEF	FEP
Coefficient of static friction	-	Against polished steel		-	0.05	0.02	0.05

Table 8 Comparison of static friction coefficient among PFA, PTFE and FEP[6]

[4] Japan Fluoropolymers Industry Association(2020), ふっ素樹脂ハンドブック, 14th edition. Page 9 Translated from Japanese.

[5] Japan Fluoropolymers Industry Association(2020), ふっ素樹脂ハンドブック, 14th edition. Page 24 Translated from Japanese.

[6] DAIKIN INDUSTRIES, LTD. (2009) ダイキン フッ素樹脂ハンドブック, Page 53

One of the characteristics related to friction is “self lubrication”. The molecules of PTFE separate from molding of PTFE due to friction. The molecules in crystals of PTFE separate easily because intermolecular forces are weak. PTFE moves and attaches to the friction mating surface and generates friction between them. It lowers friction coefficient. [7]

Gas barrier properties/Gas permeation properties

Fluoropolymer film are less steam permeability.

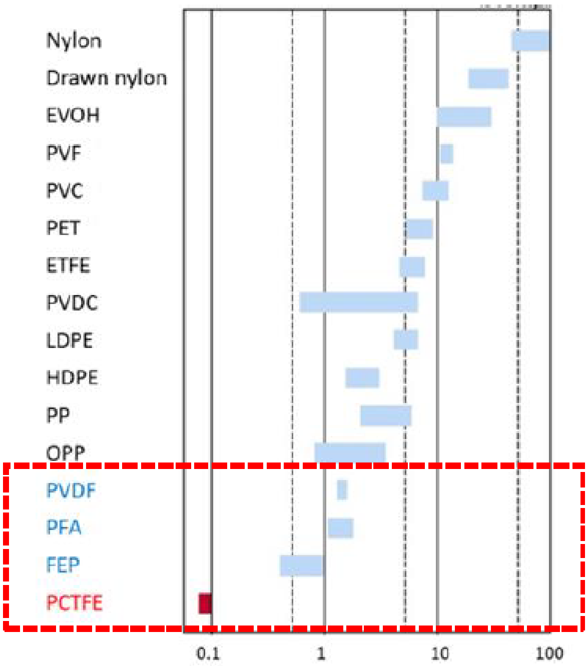

Figure 2 The degree of steam permeability [8]

steam permeability (g/m^2/d)

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[7] Japan Fluoropolymers Industry Association(2020), ふっ素樹脂ハンドブック, 14th edition. Page 24 Translated from Japanese.

[8] DAIKIN INDUSTRIES, LTD. (2009) Daikin Fluoropolymers Handbook，Page 109

Fluorine elastomers are less atmospheric (nitrogen, oxygen) permeability.

Table 9 Comparison of gas permeability of elastomer[9]

Material	Temperature degree Celsius	He	H_2	O_2	N_2	CO_2	CH_4	C_2H_2	C_3H_8
Vinyl methyl silicone rubber (VMQ)	25	N/A	400	400	200	1600	N/A	N/A	10000 or more
	50		570	500	280	1550			
Ethylene propylene rubber (EPDM)	25	N/A	N/A	16.5	5.90	79.2	N/A	N/A	91.2
	50			46.6	13.7	183			246
Perfluoro-elastomer (FFKM)	25	10.3	8.25	2.5	8.1	28.7	3.3	N/A	N/A
Styrene butadiene rubber (SBR)	25	17.5	30.5	13	4.8	94	N/A	N/A	N/A
	50	42	74	34.5	14.5	195			
Vinylidene fluoride fluororubber (binary FKM)	25	2.95	4.6	1.0	0.8	3.9	0.6	N/A	N/A
Vinylidene fluoride fluororubber (Ternary FKM)	25	2.64	4.13	1.7	0.7	1.6	0.4	N/A	N/A
Chloroprene Rubber (CR)	25	N/A	10.3	3.0	0.89	19.5	2.5	N/A	N/A
	50		28.5	10.1	3.55	56.5	9.8		
nitril-butadiene rubber (Mid-high NBR)	25	9.32	12.1	2.94	0.81	23.5	N/A	18.9	26.9
	50	23.4	33.7	10.5	3.58	67.9		68.3	78.3
nitril-butadiene rubber (High NBR)	25	5.2	5.42	0.73	0.18	5.67	N/A	8.25	11.2
	50	14.2	17.0	3.5	1.08	22.4		19.8	33.1
butyl rubber (IIR)	25	6.4	5.5	0.99	0.25	3.94	0.6	1.28	N/A
	50	17.3	17.2	4.03	1.27	14.3	3.2	5.82	

($\times 10^{-8}$ cc, cm/cm^2,sec,atm)

[9] DAIKIN INDUSTRIES, LTD. (2009) Daikin Fluoropolymers Handbook, Page 78

Property of Gas Permeability

Property			Standard Test method	Unit	FEP film
Gas Permeability	Gas permeability coefficient	N_2	ASTM D1434	㎤・cm/㎠・s・atm	120×10^{-10}
		O_2			370×10^{-10}
		H_2			$1,080 \times 10^{-10}$
		CO_2			970×10^{-10}
		CH_4			66×10^{-10}
		C_2H_4			44×10^{-10}
	Water-vapor permeability		JIS Z0208	g/㎡・24h	1.6
	Water Absorption		ASTM D570	%・24h	<0.01

Table 10 Gas Permeability of FEP film[10]

Fluoropolymers permeate small molecular gases, such as oxygen and nitrogen, conversely, large molecular gases do not permeate. Fluoropolymer properties are used in permeate membranes for measurement and analysis.

Gas	Gas Permeability		
	FEP	PTFE	Low Density Polyethylene
N_2	1.2×10^{-8}	1.1×10^{-8}	0.74×10^{-8}
O_2	3.7×10^{-8}	3.2×10^{-8}	2.2×10^{-8}
CO_2	9.7×10^{-8}	8.9×10^{-8}	9.6×10^{-8}
CH_4	0.66×10^{-8}	—	2.2×10^{-8}
CH_3	0.66×10^{-8}	—	5.2×10^{-8}
C_3H_8	0.11×10^{-8}	—	7.2×10^{-8}
C_2H_4	0.48×10^{-8}	—	—

Temperature: 25 degree Celsius(77°F) Units: cm^3 (ST P) cm/cm^2・atm

Table 11 Comparison of gas permeability of various materials[11]

[10] DAIKIN INDUSTRIES, LTD. (2009) Daikin Fluoropolymers Handbook, Page 78

[11] DAIKIN INDUSTRIES, LTD. (2009) Daikin Fluoropolymers Handbook, Page 80

Low refractive index

Amorphous fluoropolymer resin has high transmittance. This is utilized for optical components and optical fibres.

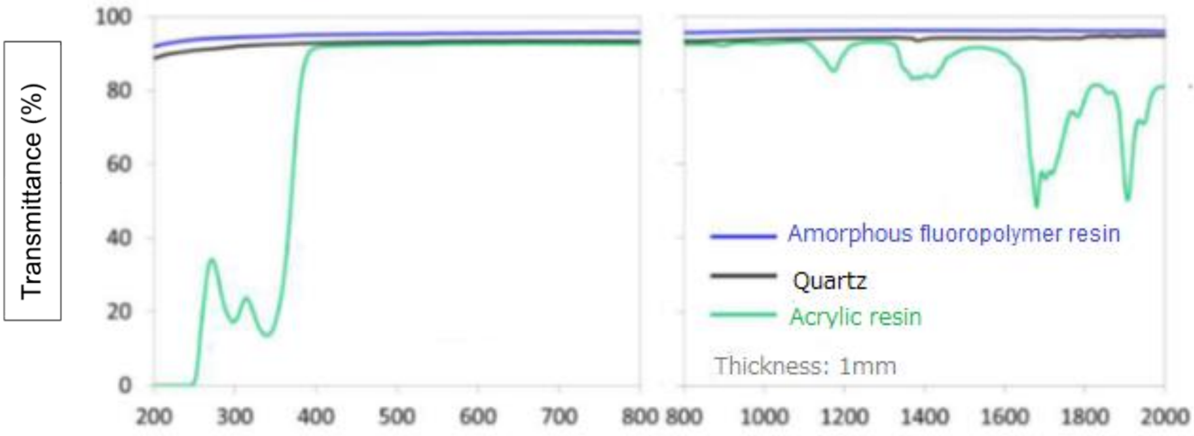


Figure 3 Comparison of transmittance [1]

Weatherability

Fluoropolymer resin has high weatherability and can be used outdoors. It does not react to sunlight such as ultraviolet rays. It is not susceptible to oxidizing effects of atmospheric oxygen and other substances (see “chemical resistance”). It can be used in a wide temperature range from low to high (see “heat resistance”). It has high water repellency and does not absorb water, so it is not affected by humidity changes. It can be said that fluoropolymer resin has high weather resistance because it has the above points.

Table 12 Fluoropolymer resin weatherability comparison [12]

	Fluoropolymer resin						General resin	
	PTFE	PFA	FEP	ETFE	PCTFE	PVdF	PP	PVC
Weatherability	◎	◎	◎	◎	◎	◎	×	×

◎ Excellent, ○ Good △ Not very good ▲ Needs attention × Not good

Regarding the graph below, it can be seen from the accelerated weatherability test with the Sunshine Weather Meter that the gloss retention rate decreases by no more than 10% even after 4000 hours of exposure. [13]

[12] DAIKIN INDUSTRIES, LTD. (2009) ダイキン フッ素樹脂ハンドブック, Page 4

[13] https://www.kyoeishoji.co.jp/business/chemical/fusso_toryo.html translated from the document in Japanese. Last accessed on 21 July, 2023

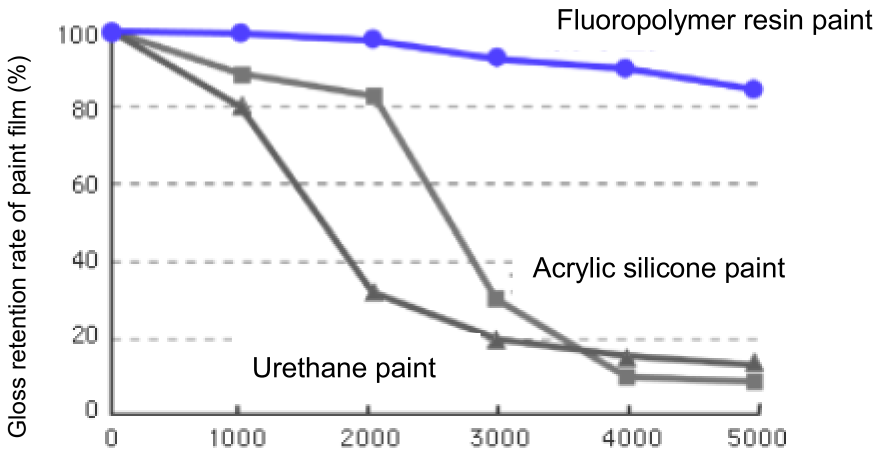


Figure 4 Accelerated weatherability test of paint

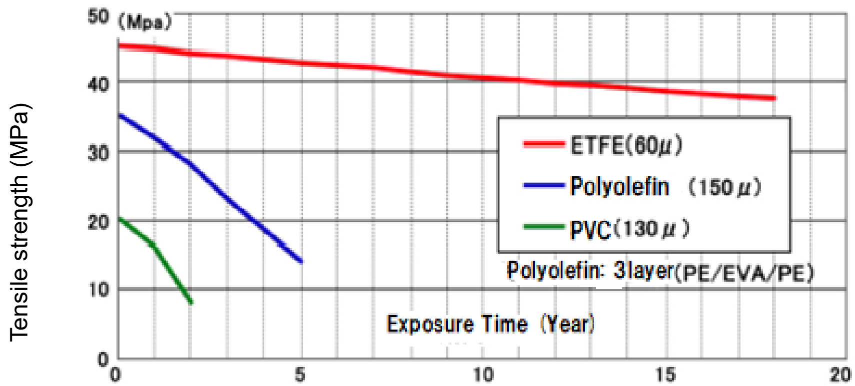


Figure 5 Outdoor exposure test Comparison of tensile strength between ETFE and other materials [14]

Durability

It means that it can be used for a long time. Due to its high chemical resistance and high weatherability, PFAS can achieve high durability.

Resistance to creep / Compression set

When a constant load is applied to a polymeric material, creep occurs, in which deformation progresses over time. Similarly, compression set occurs where the deformation does not recover when the force is removed. Both properties are known to be correlated. When rubber materials are used in elastic applications such as packings or diaphragms, it is required to

[14] https://www.taiyokogyo.co.jp/feature/etfe_film.html translated from the document in Japanese. Last accessed on 21 July, 2023

minimize the effects of both properties.

Experimental examples of "30% creep time (Hour)" for major rubber materials are shown below. Creep is known to be worse at higher temperatures, Experiments have shown that FKM and silicon exhibit good properties.

	50 degree Celsius	70 degree Celsius	100 degree Celsius	120 degree Celsius	150 degree Celsius
NR	190	103	3.8	–	–
SBR	1250	203	14	–	–
CR	4200	550	45	7.4	–
NBR	3900	380	41	12.2	–
IIR	–	–	2.7	–	–
FKM	–	–	1650	305	180
Silicon	–	–	–	1550	190

Table 13

Quoted from the journal of “the Society of Rubber Science and Technology, Japan”, 1960(Vol33), P882-892, “Stress relaxation and creep properties of various vulcanized rubbers”.

Examples of compression set test results are shown below. In general, it is difficult to quantitatively compare materials because the measured values differ depending on the compounding and hardness of the rubber. Here, the compression set of the materials was compared by comparing the minimum value of each material in the database. FKM and silicon showed relatively good properties, showing the same tendency as creep.

	Compression set JISK6301 100 degree Celsius×70h
NR	–
SBR	Min 20%
CR	Min 23%
NBR	Min 9%
IIR	–
EPDM	Min 23%
FKM	Min 11%
Silicon	Min 6%

Table 14

The minimum value of each material was quoted from the data described in "Material Database / Organic Materials" (1989), The Nikkan Kogyo Shimbun”.

Uses of PFAS in Specialist Equipment

Summary

PFAS are a very important group of substances for Specialist Equipment, which depends on these uses to maintain safety, as they are highly effective in chemical resistance, Repellency from water and oil, and electric insulation.

PFAS polymer resins are two to ten times more expensive than other commodity plastics. There is no use other than where the equipment does not work without the use of PFAS.

General electronics components are not covered in this document. However, since our equipment also uses common electronic circuit parts, we also use parts common to information equipment and general consumer EEE. For usage and non-substitutable information for such parts, please refer to Japan 4EE Opinion RCOM21, No.4543 and additional Opinion Information and Non-Substitutable Information to be submitted in September 2023. Semiconductors are also used in our products. Many PFASs are used in semiconductors and semiconductor manufacturing equipment. Comments on most of the items in this section have been submitted by industry associations that specialize in the respective items. We hope that dossier submitters consider the manufacturer's opinions.

PFAS applications

【1】Sealingmaterials(Fluoropolymer O-rings) /No alternative technologies

【2】coating(Fluororesin coating) /No alternative technologies

【3】filteringmembrenes(PTFE,FEP,ETFE,PFA,PCTFE) /No alternative technologies

【4】cutting parts(PTFE,PFA) /No alternative technologies

【1】Sealingmaterials(Fluoropolymer O-rings)

parts description

・Packings, gaskets, and O-rings

Packings and gaskets exist to connect and seal by placing/placing them between parts. As an example, they are used in piping and pipe connections. Gases and liquids that pass through pipes leak out through the smallest gaps, and packing gaskets exist to prevent this. Packing in the narrow sense is used for power system parts, and those used for non-moving parts are called gaskets. Various innovations have been made in molding and realizing functions, such as spiral gaskets made of alternating layers of thin metal strips and PTFE sheets, and wrapped gaskets made of 0.4~0.8 mm hot PTFE, covering gaskets of metal or other materials.

Those with a circular/round cross section are called O-rings.

In addition to PTFE, fluoropolymer rubbers such as FKM and FFKM are also used for this application.



Fig. Packings, gaskets, O-rings

【2】coating(Fluororesin coating)

A surface treatment in which the surface or inner surface of a base material is covered with a fluoropolymer is called a coating or lining. A relatively thick covering is often referred to as a lining, while a thin covering is often referred to as a coating. There are various methods such as molding, bonding a sheet to the base material, bonding powder, or covering with a liquid. Fluoropolymers used include PTFE, PFA, PCTFE, FEP, and ETFE.

Coatings and linings are applied to parts in contact with fluids. The parts include the inner surface of the piping and parts in contact with the fluid.

parts description

・Flame arrestor(sintered metal) surface

Sintered metal flame arrestor is used to prevent the internal gas sensor element from becoming an ignition source. Surrounding gas reaches the sensor element through fine gaps in the sintered metal, but when water is adsorbed on the sintered metal, the flow path of the gas narrows. Therefore, in order to prevent water adsorption and corrosion on sintered metal, a fluorine coating is applied for the purpose of adding repellency from water and chemical resistance.

・Inside the metal nipple

Fluorine coating is applied to the inside of the metal nipple which is part of the gas flow path for the purpose of adding non-adhesion in order to prevent the gas concentration from decreasing due to the adsorption of highly adsorptive gases.

Repellency from water

The flame arrester (sintered metal) is given water repellency by applying a fluorine coating to prevent clogging due to water adsorption and corrosion.

Non-adhesion

Fluorine coating is applied to parts of metal pipes that cannot be used due to insufficient strength of fluororesin pipes, such as when it is necessary to cut threads to fix them.

Chemical resistance

Fluorine coating is applied to the parts used in the gas flow path to provide chemical resistance. Fluorine coating can be used in acids, alkalis, organic solvents, ozone, and oils.

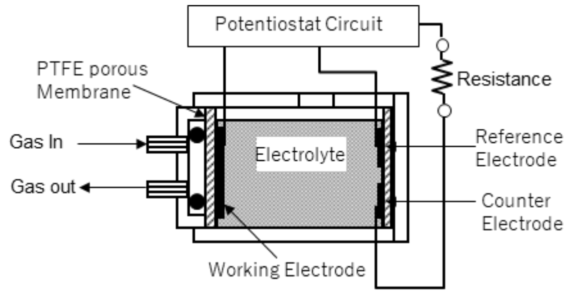
【3】filteringmembrenes(PTFE,FEP,ETFE,PFA,PCTFE)

Membrane filters are to remove and separate specific substances or objects from fluids. A wide variety of materials are used. If fluorine compounds are necessary, PTFE, FEP, ETPE and PFA are frequently used.

electrode film

electrode film of Electrochemical gas sensor

PTFE porous membrane Electrochemical gas sensor

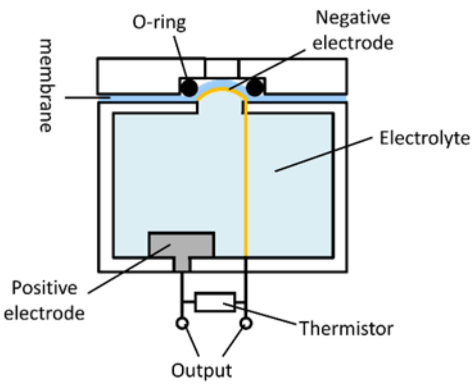


1. Electrochemical gas sensor is constituted by a working electrode formed on a PTFE porous membrane, a reference electrode, a counter electrode, electrolyte and a housing which is holding other components.
2. Every electrode is connected to a potentiostat circuit and the working electrode is implied fixed potential to that of the reference electrode.
3. The PTFE porous membrane is in contact with atmosphere which may contain intended gas to be detected.
4. The gas to be detected goes through by diffusion in the membrane and reaches the interface of the working electrode and the electrolyte.
5. The gas is electrochemically oxidized or reduced.
6. The oxidized or reduced reaction involves transfer of electrons between chemical species and the working electrode, hence current flows in the circuit.
7. The current is measured to determine the concentration of the gas to be detected

The following properties are required for the membrane used in this application.
There is currently no other material that possesses these properties at a level that can be used in products.

・Gas permeability
The membrane must have gas permeability at atmospheric pressure.
・Water resistance
The membrane must have sufficient water resistance not to leak electrolyte.
・Corrosion resistance
The membrane must have corrosion resistance. Examples of corrosive gases are NOx, SOx, halogen and halogen halide.
・Chemical resistance
・Heat resistance
The membrane must have sufficient heat resistance over 150℃ to coat electrocatalyst.
・Non-adsorptive
The membrane must have sufficient non-adsoptive. If the gas to be detected is adsoabed on the membrane, the gas can't go through the membrane,or it takes time to go through the membrane.

Galvanic oxygen sensor



1. Oxygen gas in the sample reaches through the membrane into the sensor.
2. The oxygen gas taken in is reductively decomposed at the cathode. A current flows according to the oxygen amount taken in.
3. The current is read as a voltage through a resistor such as a thermistor.

The following properties are required for the membrane used for this application.

・Gas permeability

The measurement target gas is taken into electrodes. Without sufficient oxygen permeability, measurement is not possible even in terms of no pressures. Among fluorine compounds, FEP has better oxygen permeability than other polymeric membranes.

・Chemical resistance

The membrane is also used in an environment where various gases (acid, alkali, organic solvents, etc.) contact at all times. Chemical resist products, which do not deteriorate even under these environment and do not elute components of filteringmembrenes in contact with any sample, are required.

・Water resistance

The membrane must have sufficient water resistance that water does not permeate electrodes.

・Weather resistance

The membrane does not change in an exposure test for 10 years as a material.

【4】cutting parts(PTFE,PFA)

(Example of finished products: diaphragm galvanic oxygen sensors, oxygen detectors)

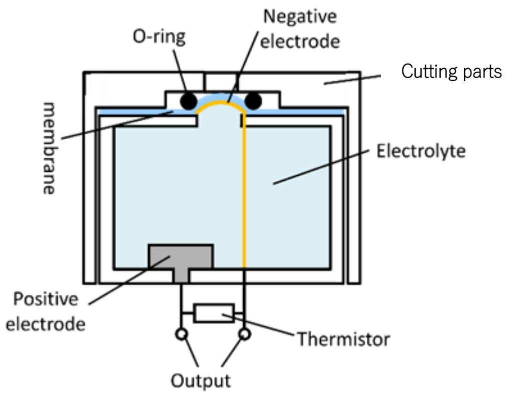
parts description

It is a part manufactured by cutting a block of resin. Because it is a small-lot production product, it is produced by cutting that does not require mold costs. Another reason for cutting is that there are places where sealing properties are required.

Here, I will touch on the machined parts used in the casing of the galvanic oxygen sensor. There are various materials, but we will describe the case where PTFE and PFA, which have higher chemical resistance, are used.

Fig. Example of Fluoroplastic Cutting Parts

Structure and measurement principle of galvanic cell type oxygen sensor



1. Oxygen gas in the sample reaches through the membrane into the sensor.
2. The oxygen gas taken in is reductively decomposed at the cathode. A current flows according to the oxygen amount taken in.
3. The current is read as a voltage through a resistor such as a thermistor.

Fluoropolymer casing are required when parts require chemical resistance. There is a need to measure oxygen concentration even in places where acids, alkalis, and organic solvents are always present. In this application, it is necessary to have chemical resistance such that it does not deteriorate even when it comes into contact with various gases (acids, alkalis, organic solvents), does not elute components even when it comes in contact with any sample. Also, as a material, it is necessary to have weather resistance properties such as not changing in a 10-year exposure test and not softening or deforming in the surrounding environment of -40 to 70 °C.
If you try to perform the same function with other materials, for example, phenolic resins and polyamide resins can be mentioned as resins that are resistant to acetone as a general organic solvent, but phenolic resins are resistant to strong alkalis. Polyamide-based resins cannot be used as a substitute because they do not have durability against strong acids.