Annex 2 Application examples and PFAS essentiality in EEE functions in Annex 1

Application examples and PFAS essentiality in Electrical and Electronic Equipment functions in Annex1

Contents

1. Optical function and required properties

(1) Optical function

Essential for EEE (Electrical and Electronic Equipment) to control transmission, reflection, diffusion etc. of light.
For example, camera imaging and optical communication of fiber optic cables.

(2) Required properties for parts and components

- Low refractive index, high light transmittance, high durability

  e.g.) Lens (high sensitivity), image sensor (high sensitivity), LED antireflection coating (energy saving), optical fiber (high-speed transmission)

- Transparency/No absorption in visible light (approx. 380 to 770 nm) and water and oil repellency.

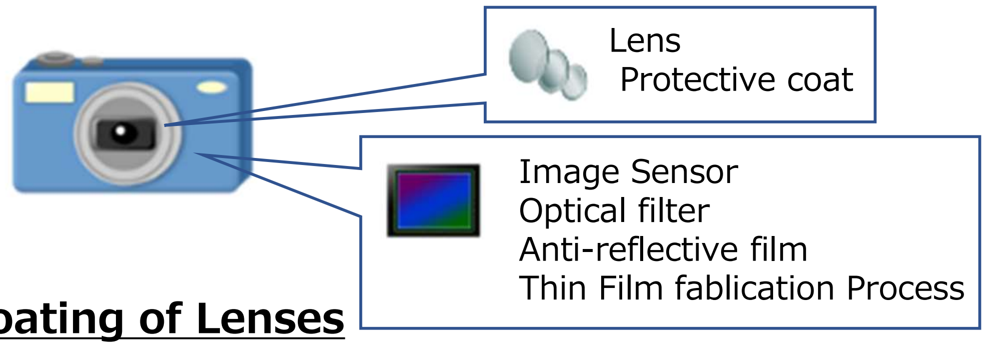
  e.g.) Protective coating for lenses (high durability), encapsulant for LEDs (high reliability, energy saving)

＊( ) indicates achievable performance

<Application examples>

[Digital camera, Surveillance camera, etc]

Parts in which PFAS is used



<u>Protective Coating of Lenses</u>

Light reflection occurs between objects with different refractive indices, and the greater the difference in refractive index, the greater the reflection. If light is reflected at the interface between air and lenses with different refractive indices, it will result in loss. Therefore, a layer with a low refractive index, which is intermediate between the refractive indices of air and lens, can prevent reflection and reduce loss. In addition, to protect the lens, stain resistance and durability through water and oil repellency are also essential.

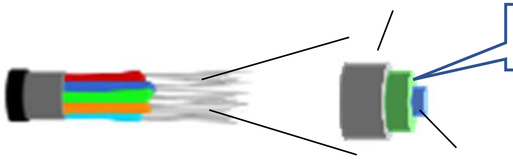
1. Optical function and required properties

<Application examples>

Parts in which PFAS is used

[Optical fiber]

Essential for high-speed communication and transmission functions



Cladding Material of Optical Fiber

Optical fiber has a concentric structure in which a core with a high refractive index is covered with a layer with a low refractive index called cladding, and light is confined and transmitted within the core. Losses occur when light is reflected at the interface between the coating material and core, which have different refractive indices. A layer with a low refractive index prevents diffuse reflection. Durability (heat, moisture, and scratch resistance) is also essential for the application.

1. Optical function and required Properties

(3) Required properties for materials and comparison with non-PFAS materials

Required properties for materials	Materials					Note
	Fluoro-Polymers*	Quartz glass	PMMA	Acrylic	Silicone	
Refractive index (n_d)	1.33～1.42	1.45	1.49	1.48	1.42	・When materials with different refractive indices are mixed, light is refracted and scattered at the interface between the substances, resulting in loss of transparency and cloudiness, so a single composition is necessary. ・For anti-reflection (high transmittance), a materials with a refractive index intermediate between that of air and that of lenses is desirable, especially for glass.
Water and oil repellent	○	×	×	×	△	
Flexibility	○	×	×	△	○	

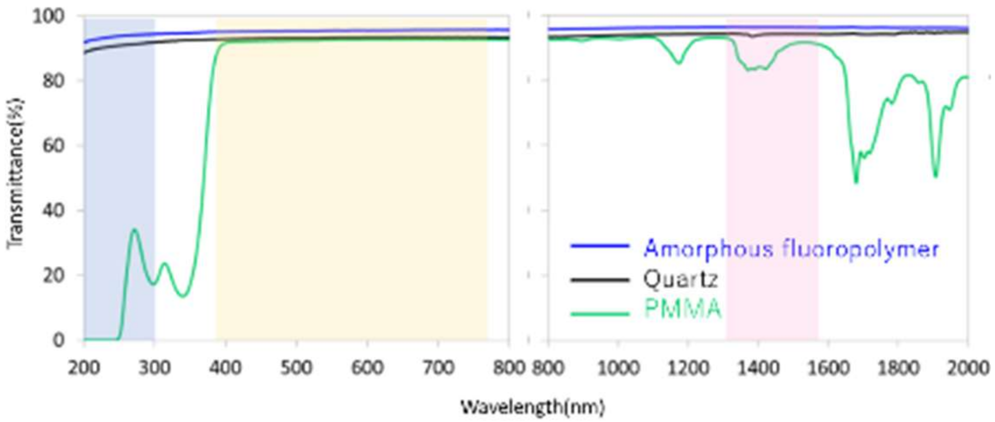
○=Excellent; △=Usable; ×=Not well suited for use

* PTFE,PFA,FEP,ETFE,PVDF

<Light transmittance versus wavelength>

High transmittance over a wide wavelength range

- No absorption (UV): UV LED encapsulant
- No absorption (visible light): Coating materials
- No absorption (near-infrared): Optical fiber for communication



＊Source: https://www.agc-chemicals.com/file.jsp?id=file/Cytop_tech14_EN.pdf

- Materials must have a low refractive index (intermediate between the refractive index of air and that of lenses) for optical applications, which are achieved by controlling the transmission, reflection, and diffusion of light. In addition, water and oil repellency and flexibility are also essential to ensure the reliability and durability of devices.
- These must be realized with a single material (A higher refractive index means that light is not focused (scattered) and the intensity of light is reduced, resulting in reduced sensitivity of the device.

There is no material other than fluoropolymers that can achieve a good balance of low refractive index, water and oil repellency, and flexibility (there is no alternative material).

1. Optical function and required properties

(4) Social impact when PFAS cannot be used (example)

1) Fluorine material cannot be used in the camera, resulting in poor imaging performance

- The lack of clarity of the camera lens reduces the security performance of surveillance cameras, and the larger size of the camera lens is required to compensate for the lack of clarity, which is counter to energy conservation.

  In addition, if water and oil repellent coatings cannot be applied to the camera lens, reliability will be reduced and product life will be shortened (frequency of replacements or exchanges will be required).

2) When fluorine material could not be used as cladding material for optical fiber

- Optical fiber is a waveguide for propagating light and supports high-speed communication and transmission functions as a transmission path for optical signals in the field of optical communications, an essential function of EEE. In the information society, demand for communication is increasing rapidly. The communication speed is reduced due to the deterioration of transmission loss (the speed is reduced in the Internet, where real-time communication is interfered with), and this will prevent the progress of digital communication in the future.
- If fluorine material cannot be used for the cladding material, the light confinement function in the core is reduced, so it is necessary to thicken the core or increase the number of single wires to increase light intensity. This also deteriorates the handling performance during installation and other operations. Furthermore, because the size of the light source will be changed, the entire optical system will need to be redesigned.
- In additional, the power consumption of the equipment will also increase, which is contrary to energy conservation.

2. High-speed communication/transmission function and required properties

(1) High-speed communication and transmission functions

EEE essential functionality to achieve high-speed, high-capacity communications by using high-frequency radio waves (low transmission loss) with telecommunications and infrastructure equipment.

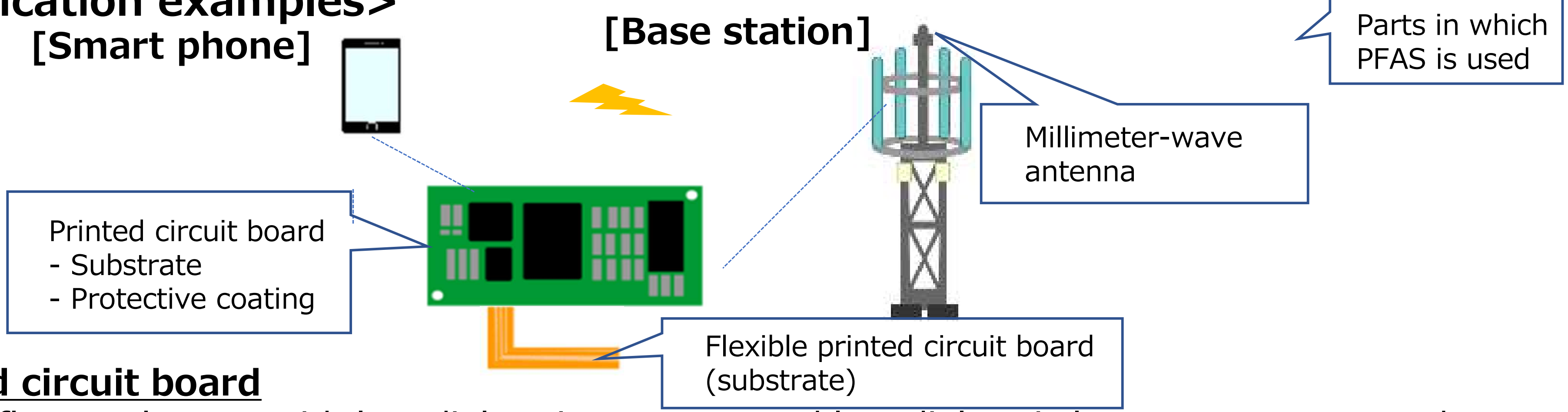
(2) Required properties for parts and components

- Low dielectric constant and dissipation factor at high frequencies and small frequency dependence. Furthermore, high reliability (heat resistance, flame retardance, and long life) is also essential. Therefore, all the performance must be satisfied at the same time.

e.g.) Printed circuit boards for high-speed transmission and millimeter wave radar such as 5G, coaxial cables, satellites and antennas in the millimeter wave band: (high-speed, high-capacity communication, high reliability and energy saving)

＊( ) indicates achievable performance

<Application examples>



<u>Printed circuit board</u>

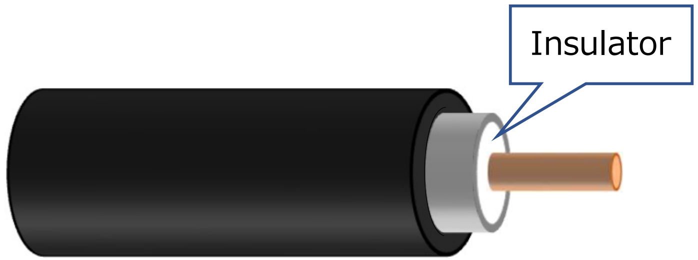
When fluoropolymers with low dielectric constant and low dielectric loss tangent are used as the substrate, the signal energy is not attenuated. This is due to the low rate at which part of the energy is lost internally as heat when current flows. In addition, flame resistance is essential for heat resistance and safety for component mounting. The long life required for base stations can be achieved at the same time, ensuring high reliability.

2. High-speed communication/transmission function and required properties

Parts in which PFAS is used

<Application examples>

[Coaxial cables (high-frequency wires)]



Coaxial cables (high-frequency wires)

The relative dielectric constant of the insulator must be close to that of air (relative dielectric constant: 1) to reduce transmission loss (attenuation of electrical signals due to heat). PTFE has a low relative dielectric constant of 2.1 and is both flame retardant and highly durable to ensure equipment reliability.

2．High-speed communication/transmission function and required properties

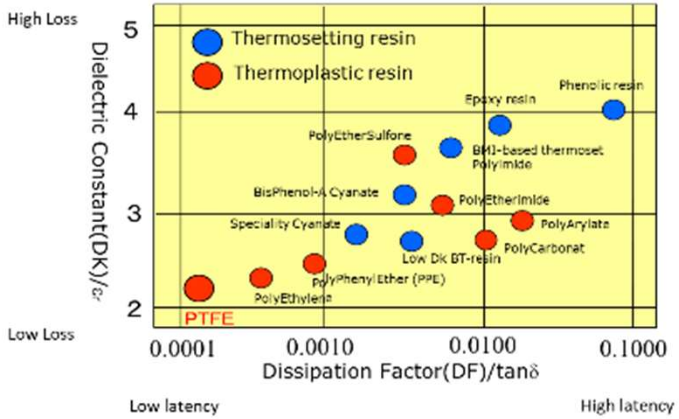
(3) Required properties for materials and comparison with non-PFAS materials

Required properties for materials	Fluoro-polymers*	FR-4 epoxy	Modified polyphenylene oxide（PPO)	Polyimides (PI)	Polyethylene (PE)	Liquid crystal polymer（LCP)	Note
Dielectric constant (ε)	2.1	4～5	3.5	3.2	2.3	2.9	When mixing different materials, inferior properties appear.
Dielectric tangent (tanδ)	0.0006	0.015	0.002	0.002	0.001	00035	
Thermal resistance Non-combustibility	◎	△	○	○	×	◎	

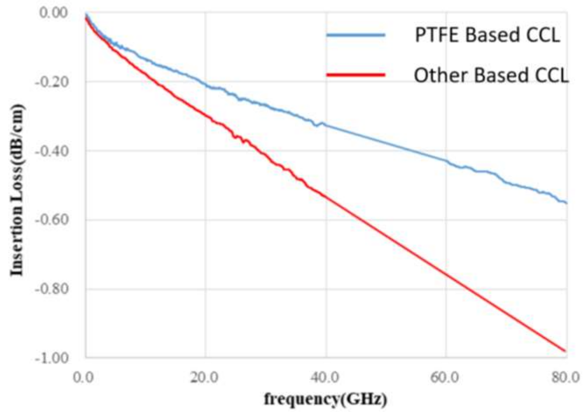
*PTFE,PFA,FEP

◎=Superior; ○=Excellent; △=Usable; ×=Not well suited for use

<Requirements and frequency characteristics of the equipment>



Characteristics of dielectric constant and dielectric tangent in resin materials



＊Source
Nippon Pillar Packing co.,Ltd.
https://www.pillar.co.jp/en/

Frequency dependence of transmission loss

・The use of high frequencies such as millimeter waves is essential for electrical and electronic equipment for high-speed and high-capacity communications, and transmission losses need to be as low as possible. The material must have a low dielectric constant, low dielectric loss tangent and low frequency dependence to reduce transmission losses at high frequencies (signal energy loss by heat). Furthermore, the high-frequency equipment needs to be highly heat-resistant and reliable, as it is used for millimeter-wave sensors in base stations and ADAS (Advanced Driver-Assistance Systems). These need to be realised in a single substance.

There are no materials other than fluoropolymers that combine low dielectric constant and low loss at high frequencies with high heat resistance and high reliability (no alternative materials).

2. High-speed communication/transmission function and required properties

(4) Social impact when PFAS cannot be used (example)

1) When fluoropolymers cannot be used for high-frequency substrates for smartphones and base stations

- High-speed and large-capacity communication is increasingly required in the information society, but if fluoropolymers cannot be used, transmission losses at high frequencies will increase and large-capacity communication (e.g., video communication) will be delayed. Furthermore, the board generates heat due to high transmission losses, leading to heat generation in the equipment. Therefore, the equipment needs to be designed for cooling (contrary to energy saving).
- Heat generated by the equipment also affects the product life of other components (e.g., capacitors) mounted on the board, thus shortening the life of the equipment (requiring more frequent replacement or exchange).

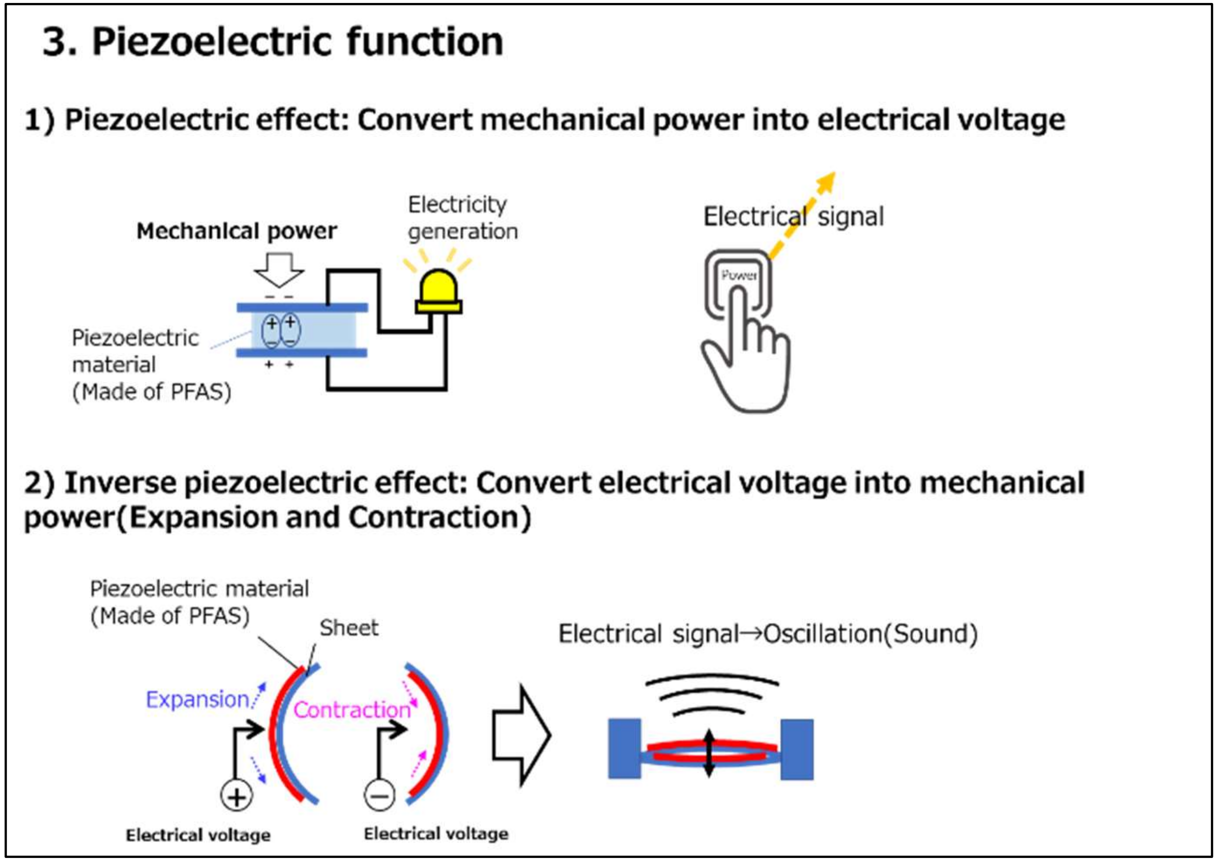
2) When fluoropolymers cannot be used for millimeter-wave radar substrates

- Millimeter waves are used in sensing technology to enhance safety in driving, for example in ADAS (Advanced Driver-Assistance Systems). If fluoropolymers cannot be used in substrates and antennas for high-speed millimeter-wave communications, instantaneous sensing isn’t possible due to the delay in radio waves, which significantly affects human safety. In addition, as vehicles are used in particularly harsh environments, high reliability characteristics (such as heat resistance, moisture resistance and long life) must be met at the same time.
- If millimeter-wave radars have short life, they will require maintenance and replacement within a short period of time, increasing waste and maintenance costs.

3. Piezoelectric function and required properties

(1) Piezoelectric function

Essential for EEE to the performance of crystalline materials in converting mechanical strain into voltage and voltage into mechanical strain.



3．Piezoelectric function and required properties

(2) Required properties for parts and components

- The material must have a high piezoelectric coefficient (the higher the coefficient, the better the response) that converts mechanical strain into voltage and voltage into mechanical strain, and must also satisfy processability and durability (high temperature and high humidity) at the same time.

e.g.) Touch panel, Sensor, Speaker, Headphones, Inkjet printer head :（Freeform、Cost reduction, high reliability）

＊(　) indicates achievable performance

<Application examples>

Pressure sensors for healthcare

Flexibility is essential in addition to piezoelectricity for pressure sensors that require installation on curved surfaces.（e.g. : Wrist-mounted pulse wave sensor）

This flexibility cannot be achieved with inorganic piezoelectric materials, and even with organic piezoelectric materials, only fluoropolymers can achieve high voltage coefficients and high reliability (heat and moisture resistance) in the operating environment as sensors. Since the organic piezoelectric material is in film form, high productivity and large area can be achieved, and low-cost sensors can be provided.

3．Piezoelectric function and required properties

(3) Required properties for materials and comparison with non-PFAS materials

	Organic type		Inorganic type		
Required properties for materials	Copolymers VDF with trifluoroethylene	Polylactic acid	Piezoelectric crystals	PZT (Ceramic piezoelectric materials)	PZT (Piezoelectric films)
Piezoelectric constant d_{33} (pC/N)	～40	7～12	2.0	100～600	100～600
Durability	○	△	◎	◎	○
Fabrication of thin films	◎	◎	×	×	◎
Pliability	◎	◎	×	×	×
Cost reduction	◎	◎	△	○	×

◎=Superior; ○=Excellent; △=Usable; ×=Not well suited for use

・They are inferior to inorganic materials in terms of piezoelectric constants and reliability. However, ceramic materials are generally brittle and difficult to process, making it difficult to form and process them as large-area, thin-film materials. Flexibility and large area, which can only be achieved with organic piezoelectric materials, and lower cost due to significant changes in the production process are important factors that cannot be realized with inorganic piezoelectric materials. Important Technologies Supporting Wearable Electronics

(4) Social impact when PFAS cannot be used (example)

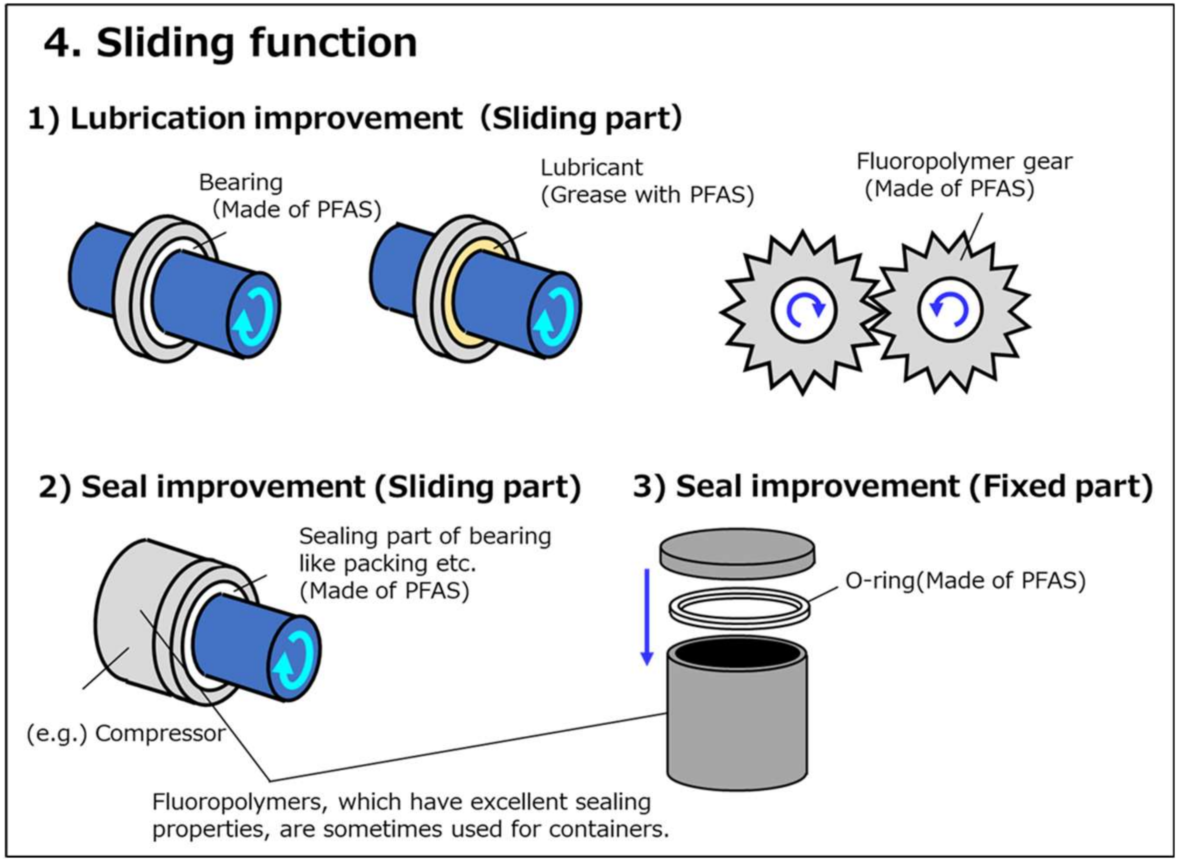
■ When fluoro resin could not be used for piezoelectric element as pressure sensor for biomedical

- In the healthcare field, there is a need for sensor devices that can more easily and accurately monitor daily vital information (heart rate, respiration, etc.) in a "non-constrained" manner without any hassle or feeling of being worn. Since these sensors are attached to the arm or body for measurement, they need to be curved in shape, lightweight, and sensitive so as not to interfere with daily life. The only organic piezoelectric material that satisfies these requirements is fluoro resin-based in terms of sensitivity.
- In order to live a long and healthy life, the need for sensors for health care, which are also used to manage physical condition, is increasing rapidly. For medical support, it will continue to be necessary to develop sensors that are inexpensive and can be used by anyone, and if PFAS cannot be used in this regard, the potential of future technologies will be destroyed.

4. Sliding function in mechanical section and required properties

(1) Sliding function

Essential function for EEE to control and ensure the smooth movement of driving parts or sealed parts, such as camera zoom lenses, motors, compressors, etc.



(2) Required Properties for Parts and components

- ■ Two or more high-reliability properties such as lubricity and flame retardance must be achieved simultaneously in one material.

  e.g.) Motors, bearings, gears, camera lenses, grease, lubricants (high durability, high reliability)
- ■ Two or more high-reliability properties such as flame retardance, chemical resistance, and water repellency, must be achieved simultaneously in one material.

  e.g.) Packing, O-ring (high durability, high reliability)

＊( ) indicates achievable performance

4. Sliding function in mechanical section and required properties

<Application examples>

[Camera]

Sliding functions in camera's mechanism section

Numerous sliding parts are required to work stably at high speed, with high precision, over a long period, and in harsh environments.

Cameras must satisfy functionality and performance requirements even in harsh environments such as extremely cold, deserts, and tropical regions. If substances derived from lubricant adhere to the lens or sensor, the image will be significantly affected. In addition, the recent trend toward reducing environmental impact requires longer product life. Considering these factors, the lubricants that can be used are limited to fluorine-based lubricants.

<Typical functions of a camera and the role of fluorinated lubricants>

① Autofocus lens drive unit

Image formed on the sensor surface by changing the distance between the lens and the image sensor surface

➡ **Instantly drive on the order of microns to achieve high-speed/high-precision focus adjustment**

② Shutter mechanism

Controls exposure time of image sensors down to a few thousandths of a second

➡ **Contribute to higher speeds and lower dust emissions for shutter blades and driving components**

③ Zoom mechanism

Use a rubber ring on the plastic tube to prevent dust from entering the zoom inside.

➡ **Ensure smooth operation and improves water repellency.**

④ Buttons, dials, etc.

High precision/stable operation, high wear resistance, long product life

➡ **No effects on electrical components and contribute to stable operation and long product life.**

⑤ Aperture blades

The multiple blades that make up the aperture mechanism must be positioned with high precision.

➡ **Provides lubricity and high durability to the blade to ensure reliable operation.**

Cameras require high-speed, high-precision drive/operation and long-life characteristics in harsh environments ⇒ Use of lubricants is essential

4. Sliding function in mechanical section and required properties

(3) Required properties for materials and comparison with non-PFAS materials

1) Articles: Bearings, Gears, Rolls, Sealing materials (Packing, O-rings, etc.)

＊Please see also “6. Safety and safety functions”

■ **Resins**

Properties	Fluoropolymer	Other Resins						
	PTFE	PE	PVC	POM	PC	PS	PP	ABS
Organic solvent resistance	◎	○	△	○	△	×	○	×
Acid resistance	◎	○	○	×	△	×	△	△
Alkali resistance	◎	◎	◎	○	×	○	○	○
Flammability	not catch fire	Extremely slow	Natural fire extinguishing	slow	Natural fire extinguishing	slow	slow	slow
Dynamic friction coefficient (ud)	0.09	0.13	0.25	0.18	0.45	0.47	0.37	0.48
Surface energy (dyn/cm)	18	31	39	36	42	36	29	42
Water absorption (ratio %)	<0.01	<0.01	0.04~0.75	0.22～0.25	0.15～0.18	0.03～0.1	<0.01	0.2～0.6

◎=Superior; ○=Excellent; △=Usable; ×=Not well suited for use

- **There is no material other than fluoropolymers that can simultaneously satisfy multiple properties such as flame resistance and chemical resistance in addition to lubricity.**

↓

- Fluoropolymers are more expensive than commonly used materials, and therefore they are not used blindly. They are only used selectively in applications where they cannot be substituted under severe conditions, even in required properties for safety and safety functions that are essential for EEE. (There is no alternative material because of selective use.)

4. Sliding function in mechanical section and required properties

■ Rubbers

Properties	Fluoroelastomers		Synthetic rubbers			
	FKM	FEPM	Silicone	EPDM	CR	NBR
Heat resistance max use temperature,℃	230	230	230	150	100	120
Chemical resistance	○	○	△	△	○	○
Ozone resistance	◎	◎	○	○	×	×
Cold resistance	△	△	△～○	△～○	△～○	△
Electrical insulation (Dielectric constant ,ε)	△ (3～4)	△～○ (2.5～3.5)	△ (3.2～10)	△～○ (2.5～3.5)	× (7.5)	× (15～20)
Combustibility	◎	◎	△ Chemical resistance is reduced by flame retardant	△ Chemical resistance is reduced by flame retardant	○	△
Gas permeability (cc·cm/cm^2·sec·atm)	1	1	400	15	15	3

◎=Superior; ○=Excellent; △=Usable; ×=Not well suited for use

- **Fluoroelastomers have overwhelmingly excellent chemical resistance, ozone resistance, and insulation properties in addition to heat resistance and flame resistance, compared to other rubber. They also have excellent gas barrier properties (the smaller value, the less gas permeates.), so they are used in sealing materials (packing) that also require heat and chemical resistance and cannot be substituted.**

↓

- Fluoroelastomers are also more expensive than commonly used materials, and therefore they are not used blindly. They are only used selectively in applications where they cannot be substituted under severe conditions, even in required properties for safety and safety functions that are essential for EEE. (There is no alternative material because of selective use.)

4. Sliding function in mechanical section and required properties

2) Preparations: Greases, Lubricants, Protective coating materials

a. Lubricating components

Properties	Fluoropolymer	Molybdenum disulfide	Graphite
Light load lubricity	○	×	×
non-conductive	○	○	×
Polite resistance	○	×	×

○=Excellent; ×=Not well suited for use

b. Solvents

Properties	Fluorosolvent	Petroleum oil	Silicone oil
Chemical Attacks on Plastics	Low	high	low
Generation of volatile gases	low	low	high
Risk of contact failure	not	not	Yes
Temperature viscosity change	low	high	low
flammability	not	Yes	not

Major compositions : a. Lubricating components + b. Solvents
➡ Fluoropolymers + Fluorosolvents is best

- **Only "fluoropolymers and fluorinated solvents" have lubricity, thermal stability, and no negative effects on components (i.e., there are no alternatives).**

4. Sliding function in mechanical section and required properties

(4) Social impact when PFAS cannot be used (example)

1） If fluorine material cannot be used in the cameras, the functional degradation will occur.

- Furthermore, EU customers will not be provided with high-performance cameras year after year. Cameras that are significantly less capable than the current ones will likely miss or fail to record key moments in news, sports, events, etc., and will have a significant impact on their coverages with photos and videos in EU.
- If the camera lens cannot be coated with a sliding function coating, it will lead to a decrease in reliability and shorten the product life. (Frequency of replacements or exchanges will be required).
- The performance of mechanical sections such as focusing and zooming is reduced, making it difficult to capture fast-moving subjects.

2） If fluoropolymers cannot be used for safety and high reliability components such as O-rings and packings,

- The safety of electrical and electronic equipment cannot be guaranteed, which in turn places people and the environment in an unsafe situation. Such components are widely used in sections that must simultaneously meet high reliability (safety) requirements such as heat resistance, insulation, flame resistance, and solvent resistance, especially in equipment for professional use. Examples include industrial equipment such as EEE and other production equipment (heating furnaces, molding machines, robots, semiconductor manufacturing equipment, etc.), infrastructure equipment, medical equipment, and analytical instruments.
- If fluoropolymers with excellent water repellency and lubricity cannot be used, the waterproof performance of EEE cannot be guaranteed and product life will be shortened.
- Since fluoropolymers with excellent solvent and chemical resistance cannot be used, it is difficult to meet the required performance, especially in medical devices, analytical instruments, and semiconductor manufacturing equipment, which are likely to come in contact with chemicals and solvents, due to lack of reliability and frequent maintenance replacement, which also affects the life of the equipment.
- Lack of equipment reliability not only leads to increase of waste, but also significantly affects work safety in professional use.

5. Display function (Liquid crystal) and required properties

Please refer to Japan Electronics and Information Technology Industries Association (JEITA).
And please consider excluding the battery since it is essential for electrical and electronic equipment.

6. Safety and safety functions and Required properties

(1) Safety and safety functions

Basic and as prerequisite elements and functions for EEE to ensure safe use of equipment and to minimize damage in the event of fire, etc.

(2) Required Properties for Parts and components

- Two or more high-reliability properties, such as heat resistance, flame retardance, chemical resistance and high airtightness (low gas permeability) must be achieved simultaneously in a single material.

e.g.) Cables, Tapes, Protective coatings, Encapsulants and Tubes (safe and reliable)

- Prevent dripping of resin components to minimize damage in the event of a fire (enhance flame retardant property)

e.g.) Equipment such as PCs and smartphones, Enclosures for power supplies, batteries, etc., Components that make up parts (Safety)

*( ) indicates achievable performance

<Application examples>

[Cables, tapes (for insulation and sealing), and liquid transport tubes used in manufacturing equipment]

<u>Cables, tubes, tapes, etc. (Covering ,Protective Material)</u>

Insulation (low dielectric constant), bendability (flexibility), flame resistance, and resistance to heat and cold are essential for cables, and chemical resistance is required depending on the environment in which the cable is used. In particular, only fluoropolymers simultaneously achieve the high safety requirements of heat resistance, chemical resistance, insulation, and flame retardance.

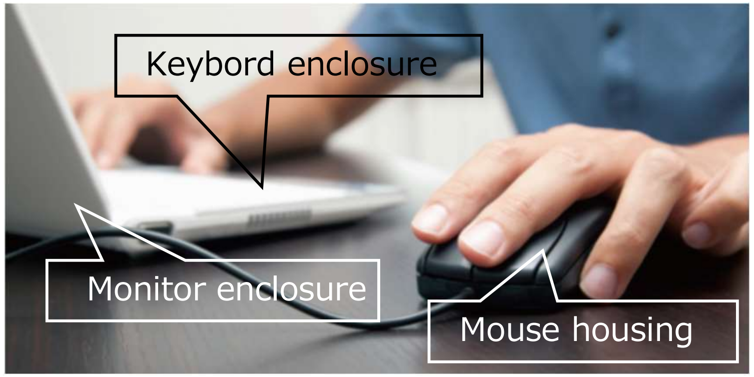
6．Safety and safety functions and Required properties

<Application examples>

[Anti-dripping agent]

Parts in which PFAS is used

e.g. : Personal computer (equipment housing)



e.g. : TV (equipment housing)

Anti-Dripping agent

Resins used for housings for TVs, PCs, etc. must be certified to UL94 (the Standard for Safety of Flammability). Especially for resins that require a high flame retardance above V-0 grade, it is necessary to prevent the generation of burning particles that can lead to ignition, and an anti-drip agent is indispensable. In order to increase the melt tension of low-viscosity resin, the anti-drip agent itself must have extremely high melt viscosity and be high flame-retardant, and only PTFE achieves these requirements.

6． Safety and safety functions and Required properties

(3) Required properties for materials and comparison with non-PFAS materials

■Resins

Properties	Fluoropolymers				Other Resins			
	PTFE	FEP	PFA	ETFE	PVC	PEEK	PI（Film)	Polyolefin resin
Heat resistance Continuous use temperature,℃	260	200	260	150	60～105	180～200	150～200	90～125
Chemical resistance	◎	◎	◎	○	△	△ Oil-proof and Acid resistance NG	○	△ Solvent resistance NG
Flex resistance	○	○	○	◎	△ impact resilience	△ Too rigid	△ Too rigid	△
Cold resistance	○	○	◎	○	△	△～○	○	△～○
Electrical insulation (Dielectric constant, ε)	◎ (2.1)	◎ (2.1)	◎ (2.1)	○ (2.3～2.8)	△ (4～6)	△ (3.2～4.5)	△ (2.8～3.2)	△～○ (2.3～4)
Flame retardancy (Limiting oxygen index)	◎ (>95vol%)	◎ (>95vol%)	◎ (>95vol%)	○ (31vol%)	◎ (45vol%)	○	◎	△ Chemical resistance is reduced by flame retardant

◎=Superior; ○=Excellent; △=Usable; ×=Not well suited for use

・Fluoropolymers have overwhelmingly excellent chemical resistance and insulation properties in addition to heat resistance and flame retardance. Since they also have a very low dielectric constant, they have excellent insulating properties per thickness, leading to thinner base materials, which in turn leads to smaller and lighter electrical and electronic equipment (energy saving).

↓

・Fluoropolymers are more expensive than commonly used materials, and therefore they are not used blindly. They are only used selectively in applications where they cannot be substituted under severe conditions, even in required properties for safety and safety functions that are essential for EEE. (There is no alternative material because of selective use.)

6. Safety and safety functions and Required properties

■Rubbers

Properties	Fluoroelastomers		Synthetic rubbers				
	FKM	FEPM	Silicone	EPDM	EVA	CR	NBR
Heat resistance max use temperature,℃	230	230	230	150	200	100	120
Chemical resistance	○	○	△	△	△	○	○
Cold resistance	△	△	△～○	△～○	△	△～○	△
Electrical insulation (Dielectric constant ,ε)	△ (3～4)	△～○ (2.5～3.5)	△ (3.2～10)	△～○ (2.5～3.5)	−	× (7.5)	× (15～20)
Combustibility	◎	◎	△ Chemical resistance is reduced by flame retardant	△ Chemical resistance is reduced by flame retardant	×	○	△
Abrasion resistance	◎	◎	△～×	○	○	◎～○	◎
Gas permeability ($cc \cdot cm/cm^2 \cdot sec \cdot atm$)	1	1	400	15	◎	15	3

◎=Superior; ○=Excellent; △=Usable; ×=Not well suited for use

・Fluoroelastomers, like fluoropolymers, have overwhelmingly excellent chemical resistance, ozone resistance, and insulation properties in addition to heat resistance and flame resistance, compared to other rubber. They also have excellent gas barrier properties (the smaller value, the less gas permeates.), so they are used in sealing materials (packing) that also require heat and chemical resistance and cannot be substituted.

↓

・Fluoroelastomers are also more expensive than commonly used materials, and therefore they are not used blindly. They are only used selectively in applications where they cannot be substituted under severe conditions, even in required properties for safety and safety functions that are essential for EEE. (There is no alternative material because of selective use.)

6. Safety and safety functions and Required properties

(4) Social impact when PFAS cannot be used (example)

1） <u>If fluoropolymers and fluoroelastomers cannot be used for safe and highly reliable components such as cables, protective tubes, sealing materials, and pipe,</u>

- The safety of electrical and electronic equipment cannot be guaranteed, which in turn places people and the environment in an unsafe situation.
- Such components are widely used in sections that must simultaneously meet high reliability (safety) requirements such as heat resistance, insulation, flame resistance, and solvent resistance, especially in equipment for professional use (They are also used around engines of automobiles and other vehicles). Examples include industrial equipment such as EEE and other production equipment (heating furnaces, molding machines, robots, semiconductor manufacturing equipment, etc.), infrastructure equipment, medical equipment, and analytical instruments. Lack of equipment reliability also affects equipment life, including frequent maintenance and replacement, leading to increase of waste and, of course, a significant impact on work safety in professional use.

6. Safety and safety functions and Required properties

2） <u>If PFAS cannot be used as an anti-drip agent,</u>

- Resins used for housings of TVs, PCs, and other products, as well as resins used around power supplies and heat-producing component in electrical components, may be required by law to be certified to UL94; the Standard for Safety of Flammability. In order to satisfy these standards, the addition of flame retardants is definitely needed.　Especially for resins that require a high flame retardance above V-0 grade, it is necessary to prevent the generation of burning particles that can lead to ignition, and an anti-drip agent is indispensable.
- In some cases that halogenated flame retardants are regulated by law, and inorganic flame retardants and phosphate ester flame retardants must be used, however, inorganic flame retardants require the addition of large amounts of flame retardants to achieve sufficient flame retardant effects, resulting in a loss of resin properties. On the other hand, phosphate ester flame retardants are limited to resins (that easily carbonize with oxygen) due to the flame retardant mechanism (formation of carbonized layer during combustion). Flame-retardant resins made from a polymer alloy of polycarbonate and styrene resin (PC/ABS) with a phosphate ester flame retardant are widely used in Home appliances and Office Automation equipments. However, phosphate ester flame retardants plasticize resins, causing them to drip more easily, so PTFE (a fibrillated fluoropolymer increases the melt tension of low viscosity resins and has an anti-dripping effect) must be added as a flame retardant aid in order to achieve V-0 grade. The addition of an anti-drip agent can also reduce the amount of flame retardant used.

7. Functional surface and required Properties

(1) Functional surface

Essential functions for EEE, such as water-repellent, oil-repellent, non-adhesive, solvent-resistant, moisture-resistant, and weather resistant on surfaces touching with substances for the purpose of stain-proofing and protecting equipment.

(2) Required properties for materials used in parts and materials

- A newly high strength film which is heat resistant, solvent resistant, and water/oil repellent is formed on the surface of the base material.

  ⇒ Baking coating of resin (powder coating) _Adding new functions where there is a requirement for film thickness and high durability. Base materials are limited to metals, ceramics, glass, etc. due to processing temperatures, and cannot be applied to plastics.

  e.g.) Inner surface treatment of cooking appliances (high durability, safety), iron (high durability, high quality), Machines and Equipment (high durability, safety)

- In order to protect the functionality of equipment, a thin film is given to the surface of the base material to provide not only stain resistance but also weather resistance, moisture resistance, insulation properties, etc.

  ⇒ Application coating : A film is formed by foaming and drying at room temperature, so it can be applied to a wide range of base materials.

  e.g.) Touch panel protection (high durability), exterior protection of outdoor equipment (high durability), substrate circuit protection (high durability, safety)

7. Functional surface and required Properties

Parts and materials using PFAS

<Application example>

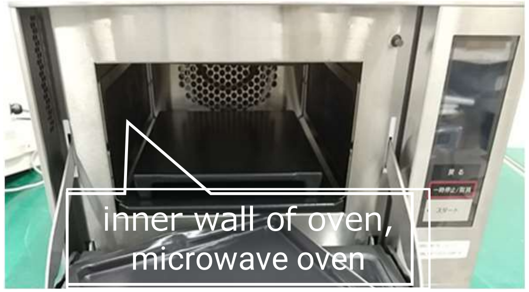
[Cooking appliances]

Automatic Bread Maker

Innerpot of Automatic Bread Maker

Parts

Microwave oven



Inner pot and surface treatment of cooking appliances: Fluoropolymers baking coating (liquid coating and powder coating)

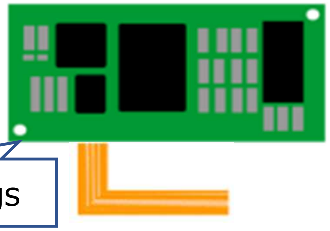
Inner pots and surface of cooking appliances require functions such as heat resistance to bear cooking temperatures, Antifouling for food baking and cleanliness, and anti-bacterial measures. In order to realize these functions at the same time, fluoropolymers baking coating is applied. Baking coating is a method of forming a film by applying fluoropolymers powder such as PTFE to a heat-resistant base material like metal, ceramic, or glass and heating , melting it to form a coating. In addition, it is the only material and method that can simultaneously ensure water and oil repellency, acid resistance, and non-adhesiveness, which are the characteristics of fluorine material. Particularly in the case of the Automatic Bread Maker, it is essential to use a material that allows the baked bread to be removed from the container without burning. And also particularly in the case of a microwave oven, it is necessary to use a material that does not affect electromagnetic waves for safety reasons. It’s because fluoropolymers is baked on, it does not peel off by scratching and dissolve in water, oil, or seasonings, so it can be used safely for the life of the device, contributing to the reduction of waste during long-term use. In addition, fluorine treatment of cooking appliance prevents food from burning, which is said to be carcinogenic, and thus greatly contributes to human health.

This technology is also used in machinery and equipment for durability and safety purposes because, unlike general coatings, it can form coatings of several tens of micrometers or more.

7. Functional surface and required Properties

<Application example>

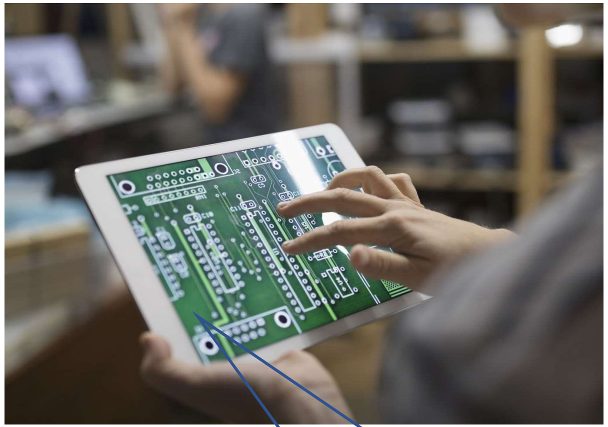
[Printed circuit board]



Surface coatings

[touch panel]

When used as a coating or protective film on the surface of a touch panel, it must also satisfy the properties required in "Optical Properties (1. Optical Functions)".



Parts and materials using PFAS

・Surface coatings
・Protective films

<u>Protective coating of printed circuit board : applied coating</u>

Printed circuit boards are the core of electrical circuits and are used in all kinds of electrical and electronic equipment. And environment these devices are used vary widely. In particular, for mobile devices such as smartphones and cameras, outdoor equipment, and in-vehicle equipment, measures must be taken to prevent migration caused by condensation owing to sudden temperature changes (such as moving from a cold outdoors to indoors), humidity caused by rain, etc. It is necessary to take measures to ensure reliability and safety, such as measures against short circuits due to sticking dust and measures against solvents to prevent leakage from electrolytic capacitors, batteries, etc. In addition to being water and oil repellent, fluorine materials are stain and moisture resistant, and have high solvent resistance and insulation properties that do not cause contact error. Therefore, there is no alternative material with equivalent performance, so fluorine materials are only for protective coatings for printed circuit boards.

7. Functional surface and required Properties

(3) List of required properties for materials and general physical properties

■ Resin baked coating (powder coating) ）

Properties	Fluoropolymer	Epoxy resin	Polyester resin	plating	DLC
Heat resistance max use temperature,℃	～350℃	～200℃	～230℃	◎	◎
Abrasion resistance	○	△	△	○	○
Water and Oil-repellent property	○	×	×	×	×
Chemical resistance	○	○	×	○	○
Weather resistance	○	×	○	○	○
Note	Since the film thickness is 30 μm or more, the base material with high strength and excellent durability is limited, and a dedicated factory (dedicated supplier) is required.			When the means are changed, the performance as an inorganic film can be secured, but the surface wetting performance is NG.	

○=Excellent; △=Usable; ×=Not well suited for use

- Powder coating has characteristic of high strength and durability of the coating film, and is often used for home appliances, industrial equipment, medical equipment, automobile parts, etc. fluoropolymers are excellent in all performances, but because of their high heat resistance, the treatment temperature during processing is high, and they are also expensive as materials, so they are appropriately selected and used according to the purpose.
- Fluoropolymers is often used in home appliances, especially in kitchen equipment. As alternative technology there is DLC, plating, but these films do not have water and oil repellency, so they do not meet the required properties.
- In the case of Fluoropolymers, they have not only baked coating but also chemical resistance, so it does not leach into water or oil, and has no environmental impact.
- Ensuring durability through high coating film strength extends product life and contributes to waste reduction.

7. Functional surface and required Properties

■Application coating

Properties	Fluoropolymers		Silicone	Acryl	Urethane
	Resin-type	Modified silane-type			
Heat resistance	○	○	○	×	×
Abrasion resistance	○	○	△	×	○
Water and Oil-repellent property	○	○	○～△	×	×
Moisture resistance	○	○	×	△	△
Electrical insulation	○	○	△ (Risk of contact failure by low-molecular weight siloxane)	○	○
Chemical resistance	○	○	○	△	△
Weather resistance	○	○	○～△	×	△
Light permeability	○	○	△	○	△

○=Excellent; △=Usable; ×=Not well suited for use

・Fluorine materials satisfy most of the performance requirements, but they are very expensive, so they are used only in carefully selected cases when multiple performance requirements must be satisfied at the same time. Therefore, because it is used out of necessity, it is used in applications in which other materials cannot be substituted.
・Adding functions and modifying surfaces by coatings is used to improve durability, ensure safety, and prevent failures of equipment use, extend product life and contribute to reducing waste.

↓

・Fluoropolymer is more expensive than common materials, so fluorine materials should not be used thoughtlessly. It is necessary to achieve multiple required performances at the same time, and it should be used carefully only in applications where it cannot be replaced (fluorine materials are essential so there is no alternative material).

7. Functional surface and required Properties

(4) Social impact when PFAS cannot be used (example)

1） When fluorine resin cannot be used for cooking equipment

- The inner pot and inner walls of cooking equipment are heat resistant to withstand cooking temperatures, stain resistant to prevent food from burning and to ensure cleanliness. Antibacterial measures are necessary.
  In order to realize these at the same time, a fluororesin baking coating is applied.
  Because the fluororesin is baked on, it does not peel off due to scratches, etc., and does not dissolve in water, oil, or seasonings, so it can be used safely for the life of the device, contributing to the reduction of waste during long-term use. PFAS-coated kitchen utensils prevent food from burning and thus helps avoiding unnecessary health risks associated with burned food (carcinogenicity).

- Powder coating is performed at dedicated factories (suppliers), so eliminating it out of the blue would deprive suppliers of their livelihood. Also, if the process (plating, DLC) is changed to powder coating, a large investment will be required due to the supply-demand balance, and it will not be possible to replace it immediately because it also requires dedicated factories (suppliers).

7. Functional surface and required Properties

2）When fluororesin cannot be used for printed circuit boards

- Printed circuit boards are the core of electrical circuits and are used in all kinds of electrical and electronic equipment, and the environment in which they are used depends on the environment in which they are used.
  A wide variety. In particular, mobile devices such as smartphones and cameras, devices installed outdoors, and devices installed in cars may be exposed to sudden temperatures.
  Migration countermeasures against condensation due to temperature changes (such as moving from cold outdoors to indoors) and humidity due to rain, etc.
  Countermeasures against short circuits due to adhesion of dust, etc., countermeasures with solvents in case of liquid leakage from electrolytic capacitors, batteries, etc. It is necessary to take measures to ensure reliability and safety. In addition to being water and oil repellent, fluorocarbon materials are stain and moisture resistant, and have high solvent resistance and insulation properties that do not cause contact abnormalities. Therefore,
  there is no alternative material with equivalent performance, so fluorocarbon materials is essential for protective coatings on printed circuit boards.
- It has been discovered that a substance related to PFHxA is used as a coating agent for printed circuit boards.
  In May 2022, SEAC's final draft of the PFHxA restriction study concluded that "Functional coatings used in electrical and electronic equipment shall not be applied until XXXXXX [7 years after entry into force]" as a conclusion of the socio-economic impact assessment.
  Based on this result, we believe that functional coatings that use substances related to PFHxA should be unconditionally exempted.

8. Semiconductor and required Properties

"Regarding the use of PFAS in the semiconductor industry, we strongly request the 13.5 years derogation presented by ECHA. In addition, as there are many cases where there is no prospect of a replacement product at present, it is fully expected that a replacement product cannot be developed within the 13.5 years period. Therefore, we request that a system be established to apply for derogation for 13.5 years or longer."

Many reports have been published on semiconductors, focusing on PFAS. Please obtain them from the following URL and consider them.

PFAS - Semiconhttps://www.semiconductors.org/pfas/ductor Industry Association (semiconductors.org)

- The Impact of a Potential PFAS Restriction on the Semiconductor Sector

Case Study
- PFOS and PFOA Conversion to Short-Chain PFAS Used in the Semiconductor - Manufacturing
- PFAS-Containing Surfactants Used in Semiconductor Manufacturing
- PFAS-Containing Photo-Acid Generators (PAGs) Used in Semiconductor Manufacturing

White Paper
- Background on Semiconductor Manufacturing and PFAS
- PFAS-Containing Fluorochemicals Used in Semiconductor Manufacturing Plasma-Enabled Etch and Deposition
- PFAS-Containing Heat Transfer Fluids (HTF) Used in Semiconductor Manufacturing
- PFAS-Containing Materials Used in Semiconductor Manufacturing Assembly Test - Packaging and Substrate Processes
- PFAS-Containing Wet Chemistries Used in Semiconductor Manufacturing
- PFAS-Containing Lubricants Used in Semiconductor Manufacturing
- PFAS-Containing Articles Used in Semiconductor Manufacturing

9. Thin film device production process and required Properties

The manufacturing process for thin film devices is the same process as for semiconductors and MEMS.
Therefore, as part of semiconductors, the same requirements must be exempted.
Many reports have been published on the requirements for the process in semiconductors, so please review them and consider them.

PFAS - Semiconhttps://www.semiconductors.org/pfas/ductor Industry Association (semiconductors.org)

- The Impact of a Potential PFAS Restriction on the Semiconductor Sector

Case Study
- PFOS and PFOA Conversion to Short-Chain PFAS Used in the Semiconductor - Manufacturing
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- PFAS-Containing Articles Used in Semiconductor Manufacturing

10. Passive electronic components, manufacturing process and their required Properties

◆Passive electronic components

Passive components are essential components in the electrical circuits of electrical and electronic equipment that protect semiconductors, filter electrical signals, and attenuate, store, and release electrical energy.

<Application example>

1) Electrode formation process with safety function for film capacitors

■What is a Film capacitor?

Film capacitors are capacitors that use plastic film as the dielectric and are one of the essential passive components in the circuit configuration of electrical and electronic equipment.

[Example of appearance of Film capacitors]

[Applications]

It is widely used in home appliances, game machines, measuring devices, medical devices, solar power generation, mobile phones, etc.

With the electrification of automobiles, the use of electric cars in automotive applications has expanded.

10. Passive electronic components, manufacturing process and their required Properties

■Safety function of film capacitor

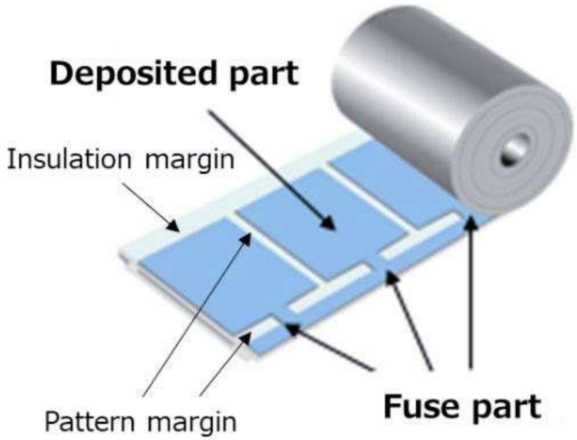

Fig. Internal electrode structure of film capacitor

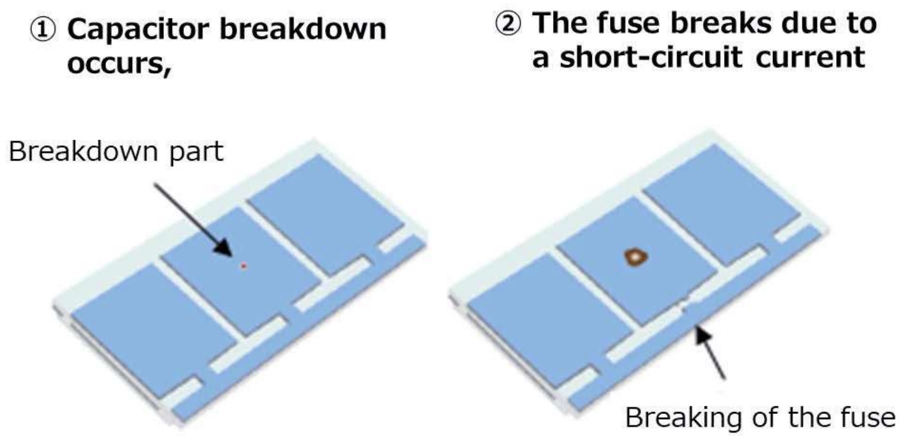

Fig. Safety function of film capacitor by fuse

For film capacitors, it is necessary to separate the deposited electrodes with a "pattern margin" and install an internal electrode pattern (fuse) to protect against overvoltage and overcurrent, and to install an "insulation margin" to ensure insulation between different electrodes.

This fuse is indispensable for the safety function of film capacitors. When a local breakdown occurs, the fuse breaks due to a short-circuit current, and the cell where the breakdown occurs due to the breaking of the fuse is electrically cut off from other cells to maintain the overall function of the capacitor.

In film capacitors, PFPE, a type of PFAS, is used in the manufacturing process when forming pattern margins and insulation margins.

In particular, the use of high voltage is increasing in applications for electrification of automobiles.
In order to ensure the safety of equipments, film capacitors must have safety fuses.

10. Passive electronic components, manufacturing process and their required Properties

■Safety function of film capacitor

Manufacturing process of film capacitor using PFPE

To form a fuse, PFPE oil is deposited on a plastic film (oil masking with PFPE), followed by metal deposition. Because no metal is deposited in the oil-masked area, fuses and insulation margins are formed. It is necessary to make the area without metal deposition as thin as possible because it becomes a loss part without generating capacitance. In addition, since the fuse part must be formed as thin as possible in order to enhance the operability, the dimensional accuracy of the order of 0.01 mm is required for oil masking by PFPE (refer to figure below). This technology can only be achieved with highly water-repellent/oil-repellent fluorinated compounds, and no other useful alternative materials exist.

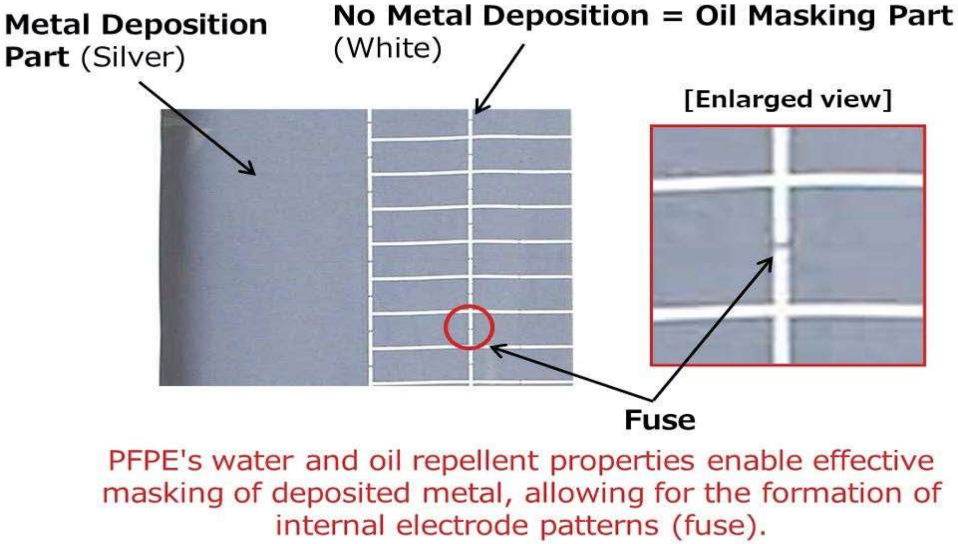

Fig. Appearance of the internal electrode pattern (fuse)

PFPE oil achieves high temperatures during metallization process which takes place under vacuum. Most of the properties of this oil are relevant for process itself and final product performance.

- A non-outgassing oil with a low evaporation loss is required for evaporation under vacuum.
- Chemical stability, non-corrosive, electrical insulation and high dielectric strength are mandatory properties due to this oil is in contact with the main part of film capacitors, which is the metallized film (metallized film = dielectric base film + metal layer).
- Thermal stability, heat resistance at extreme temperatures and non-flammability are also properties required for the oil considering the evaporation process.

Forming a fuse with oil masking using PFPE

10. Passive electronic components, manufacturing process and their required Properties

■ Concerns about substitution

As disclosed in the patent(平3-59981), when paraffin oil or silicone oil is used as an oil other than PFPE (perfluoroalkyl polyether) to form margins, deposited metal may also adhere to the masked margins. This causes problems with the insulation function, which is the original purpose. In addition, bleeding occurs at the boundary between the vapor deposition part and the margin part, and the margin itself becomes discolored, making it impossible to form patterns and fuses with high precision. In addition, bleeding occurs at the boundary between the vapor deposition part and the margin part, and the margin itself becomes discolored, making it impossible to form patterns and fuses with high precision.

At present, there is no prospect of a technology or material that can replace the oil masking performance of PFPE. Therefore, restrictions on PFPE in the film capacitor manufacturing process should be exempted.

(4) 特公 平 3−59981

7

では、上記した転写ロールの他に、噴霧塗布手段が好適に用いられるほか、装置的な制約の許す範囲で各種印刷手段も用いられる。更に、蒸着はベルジャーを用いたバッチ方式により行うこともできる。蒸着方式としては、狭義の真空蒸着のほか、各種スパッタリングも可能であり、それに応じて真空度も、例えば10^{-1}〜10^{-6}Torrと巾広い範囲が選択可能である。更にフイルムあるいはシート状基材への蒸着は片面に限らず、両面に実施してもよいことは云うまでもない。

以下、代表的な実施例、比較例により、更に具体的に本発明を説明する。

オイル供給装置6として、転写ロールの代りに、スリット状開口部を有する中空パイプ状噴霧塗布装置を用いる以外は、第1図に示したような、オイルマスク方式の半連続式蒸着機を用い、＊

8

＊オイルの種類を変えて蒸着を行つた。基材フイルム2としては、ポリエチレンテレフタレートのフイルム（厚み2μ、巾500㎜、長さ20000ｍ）を用い、その片面にフイルムの巻取り速度240ｍ／minでAlを蒸着した。蒸着機A内のオイル供給装置設置部の真空度は約10^{-2}Torr、Al蒸着される近辺の真空度は1〜3×10^{-4}Torrであつた。オイルは8㎜間隔毎に巾1㎜でフイルム面に蒸気として噴出付着させた。またAl蒸着部の表面抵抗は1.7Ω／口（膜厚として約400Å）になるようにした。

異なるオイルを使用して得られたコンデンサ用金属化フイルムについて、巻取られたロール状態でのマージン部における金属付着量および金属化フイルムの蒸着部とマージン部との境界のボケを目視観察した結果は第1表の如くであつた。

第　1　表

オイルの種類		マージン部における金属の付着状態(色)	ボ　ケ
名　称	平均分子量		
パーフロロアルキルポリエーテル(n=14)	2500	なし(白色、テープマスクと同等)	なし
流動パラフイン(1)	310	有(やや薄ねずみ色)	あり小
流動パラフイン(2)	420	有(やや薄ねずみ色)	あり大
ジメチルシリコーン	800	大(黒褐色)	マージン部着色のため観察不能

更にメタノールを含浸させたガーゼでマージン部を拭きとつて発光分析にかけたところ、流動パラフインおよびジメチルシリコーンを使用したものからはAlが検出されたが、パーフロロアルキルポリエーテルを使用したものからは検出されなかつた。

上記第1表からわかるように、オイルマスク方式によるマスキングの効果はオイルの種類によつて大きな差があり、パーフロロアルキルポリエーテルの特異性が極めて明確である。

次いで、パーフロロアルキルポリエーテルの各種フイルムに対するAl蒸着のマスキング効果を見るために、ベルジャー型蒸着試験機を使用して実験した。パーフロロアルキルポリエーテル（平均分子量2500）を綿棒に含浸させて各種のフイルムに巾約5㎜の綿状に塗布し、フイルムのオイル塗布面にAlを蒸着した。比較のため、ポリエチレンテレフタレートフイルムについてのみ、流動パラフイン（平均分子量310）を塗布したものも実験した。

蒸着後のフイルムについて、オイル塗布部へのAlの付着状態およびオイル塗布部の外周の乱れを観察した結果を第2表に示す。

Only PFPE meets all the requirements for film capacitor foil metallization: thermal and chemical stability, low evaporation loss, non-corrosion, electrical insulation, high dielectric strength and heat resistance at extreme temperatures.

10. Passive electronic components, manufacturing process and their required Properties

2) Electrode formation process of Electric Double Layer Capacitor (EDLC)

- Electric Double Layer Capacitors (EDLCs) one of the essential passive components in the circuit configuration of electrical and electronic equipments. EDLCs are used as power storage devices in backup power supplies for electrical and electronic equipment, leveling of output fluctuations in renewable energy, and energy regeneration systems for automobiles.
- Electrode formation for EDLC (used as binder)

⇒ High dispersibility in activated carbon, chemical and electrical stability, and high reliability (heat resistance and durability) can be secured, and the characteristics of EDLC are stabilized, so the performance and reliability of the backup power supply can be guaranteed.

[Application example : Backup in case of vehicle power failure]

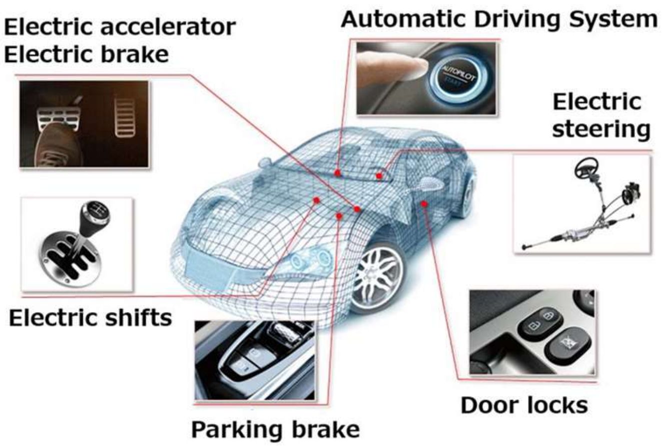

Fig. Examples of use in automotive applications

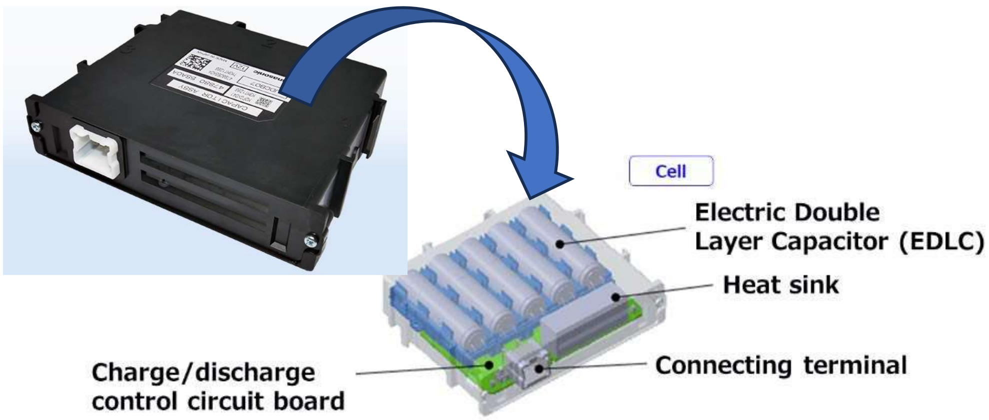

Fig. Backup power supply (power storage device) configuration

10. Passive electronic components, manufacturing process and their required Properties

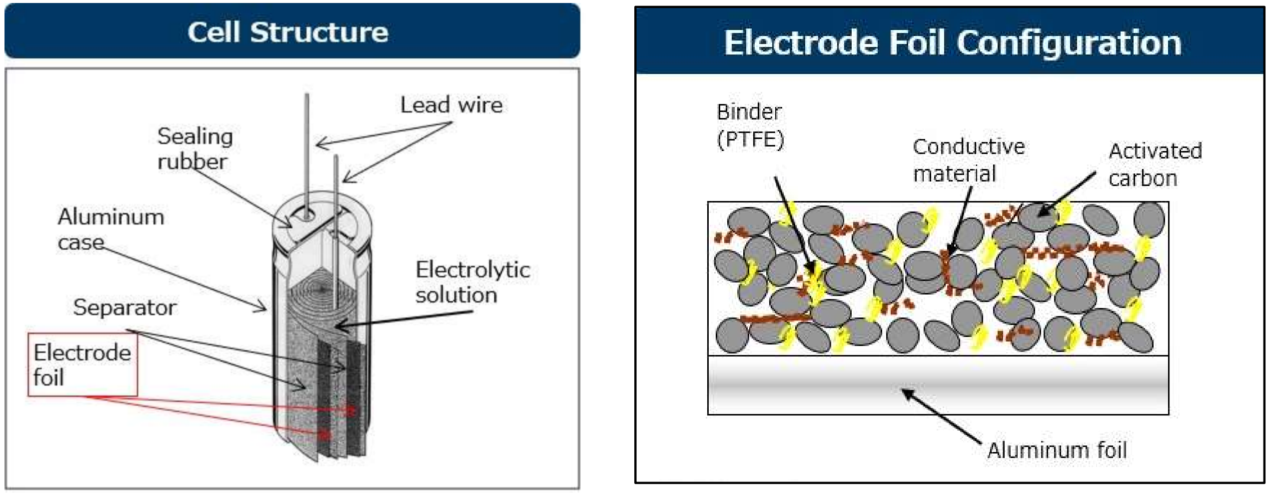

Fig. Cell structure and electrode foil configuration of EDLC

<PTFE Binder>

PTFE bonds activated carbon and aluminum foil. Fibrillated PTFE can hold activated carbon in small amounts

Electrodes are required to store a large amount of electric charge and realize high-speed charge/discharge, while at the same time they are required to have durability and reliability against vibration and impact. As with lithium batteries, the binder must have chemical stability that can withstand electrolytes, durability against electrochemical oxidation/reduction, and heat resistance. In addition, in order to achieve low resistance, it is necessary to form an electrode using a small amount of binder. PTFE is the only binder that simultaneously satisfies these required properties (there are no alternative materials).

11. Energy supply (Battery, Fuel cells, Solar cells) and required Properties

Please refer to the energy sector.
And please consider excluding Energy supply (Battery, Fuel cells, Solar cells) since it is essential for electrical and electronic equipment.

Please refer to the submissions by

- **Battery Association of Japan (BAJ)**
- **Japan Electrical Manufacturers' Association (JEMA)**
- **The Advanced Rechargeable & Lithium Batteries Association RECHARGE**

12. Refrigeration, Air-conditioning and heat pump sector RACHP (Refrigerant) and required Properties

Please refer to Fluorinated gases section and separate Panasonic HVAC submission.
And please exclude fluorinated gases for electrical and electronic devices.
This is because fluorinated gases are essential for electrical and electronic equipment in the manufacturing process and in the operation of the equipment.

Please refer to the submissions by

- **PANASONIC HEATING & VENTILATION AIR-CONDITIONING EU**
- **Japan Refrigeration and Air Conditioning Industry Association (JRAIA)**

Finally,
please also refer to the submissions by the following industry associations regarding the importance ("essentiality") of PFAS in supporting the functionality of electrical and electronic equipment.

- **Japan Auto Parts Industries Association(JAPIA)**
- **Japan Electronics and Information Technology Industries Association (JEITA)**