BDI

POSITION | SUBSTANCE POLICY | REACH

Restriction of PFAS

Evaluation of the envisaged restriction procedure

08. September 2021

1. General

Background/proposal on the restriction of PFAS

On 14 October 2020, the EU Commission adopted its Chemicals Strategy for Sustainability. In this strategy, the Commission presents a comprehensive package of measures to regulate the sub-class of per- and polyfluoroalkyl substances (PFAS). The declared aim is to restrict the use of PFAS and the placing on the market of products containing PFAS in the EU as far as possible. Exceptions are only to be made for essential uses, which are still to be defined as part of the restriction process.

The REACH competent authorities of the Netherlands, Germany, Denmark, Sweden and Norway have already started preparatory work on the preparation of a corresponding restriction dossier last year and published their intention to submit a PFAS restriction proposal on 15 July 2021. The exact scope of the PFAS restriction proposal has not yet been determined, but as things stand, it includes all substances with at least one aliphatic CF2 or CF3 group in the molecular structure. According to the current OECD list for PFAS, this definition includes at least 4,700 chemical compounds. However, since this list does not include all relevant substances, a much higher number of compounds can be expected in reality. The planned comprehensive restriction of PFAS is primarily justified by the high persistence of many representatives of the substance group. Other reasons cited are the high mobility and the bioaccumulation potential of some PFAS substances.

BDI fully supports the aim of the Chemicals Strategy for Sustainability to improve the protection of human health and the environment against risks from chemicals and at the same time to increase the competitiveness of EU industry. Within the framework of sustainable chemicals regulation, substances that pose unacceptable risks due to their properties and use profile should be restricted or regulated based on scientific assessments. However, the BDI rejects the broad regulation of entire groups of substances - in the case of PFAS, several thousand substances - irrespective of their actual risk. In this position paper, the BDI expresses its position on various aspects of the planned PFAS regulation.

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Aims of the position paper

The aim of the position paper is to present the significant impact on the entire industry of a comprehensive PFAS restriction. To ensure a uniform understanding, a practice-oriented classification of PFAS is first made in Part 1. On the basis of various overviews, we then explain in Part 2 which PFAS are used in which industrial sectors and branches, and articulate the significance of the substance group for innovations and technical developments in industry. Finally, we will take a few application areas as examples and explain the role that PFAS play in the implementation and achievement of efficiency and environmental goals as well as for future technologies.

There is explicitly no classification into essential and less essential applications in which PFAS are used. The reason for this is that such a classification represents an incalculable challenge and would have far-reaching negative consequences both for society and for Europe as a location for business. This will be demonstrated on the basis of the points mentioned above.

Furthermore, this position paper (Part 1) deals with fundamental aspects of the envisaged regulatory approach. The industry is particularly critical of the EU regulatory authorities desire to combine and restrict all PFAS in one group in order to simplify and accelerate the regulatory processes. This ignores the fact that the PFAS definition covers substances with different properties and that neither all PFAS are equally persistent nor equally mobile or bioaccumulative. The planned concept of merging all PFAS into one group of substances to be regulated will lead to great regulatory complexity in the implementation phase. Furthermore, almost risk-free chemicals are equated with substances of very high concern ("SVHC") which have properties that require regulation. Instead, EU policymakers should ensure that a differentiated approach is taken. This should take into account whether a PFAS substance poses an unacceptable risk to the environment or human health. Otherwise, there is a risk, for example, that chemicals that have a crucial role to play in helping our industries move towards a decarbonised economy will be driven out of the market.

The BDI is concerned that the restriction of PFAS as currently planned will be disproportionate and unrealisable. Moreover, it is feared that it will hinder the achievement of both economic goals and EU Green Deal objectives.

In summary, the main concerns are as follows:

- A general regulation of thousands of PFAS substances as one group does not have sufficient scientific basis and would therefore be disproportionate.
- The grouping of thousands of PFAS substances carries the risk that regulation would be too complex for enforcement authorities and thus not feasible.
- The PFAS regulatory approach being planned is contrary to generally accepted REACH principles, such as that there should only be restrictions in the case of unacceptable risks.
- The impact of broad PFAS regulation on industry and product diversity would be significant. A ban on the production and use of a broad range of PFAS, but also of specific PFAS, would considerably restrict the innovative capacity of German industry. Germany and the EU's economic goals as well as the goals of the EU Green Deal would be hindered or endangered.
- A lack of viable alternatives to PFAS substances means high socio-economic costs when trying to replace them.

- Due to the often highly complex international supply chains and the associated difficulty in analysing and preparing for the exact impact of a ban on many thousands of substances, there is a great risk of unforeseen disruptions to supply chains with all the associated economic impacts. A sufficient amount of time is needed to analyse the precise impact of the ban per substance; this time has unfortunately not been granted.

Types, properties and use of PFAS

Due to their unique property profile, PFAS are used today in a wide range of mainly industrial products, often because of their high thermal and chemical resistance and the fact that they have a very low surface tension and are thus water and oil repellent, as well as abrasion and wear resistant at the same time.

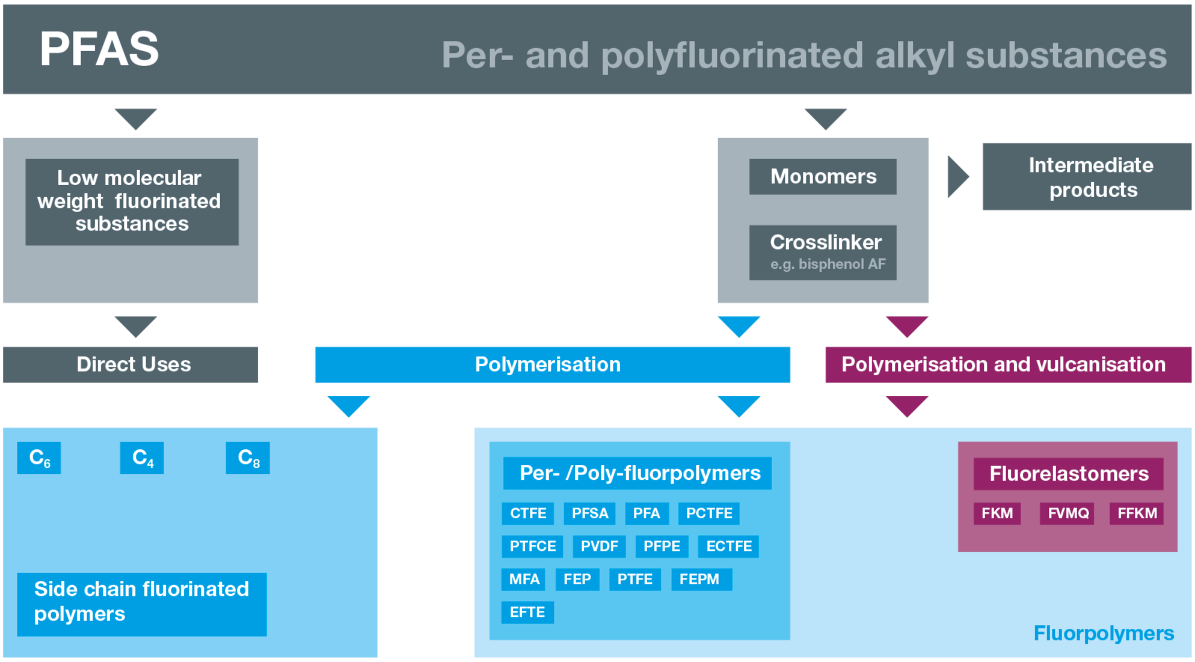
Depending on the size of the molecule and the chemical structure, the chemical, physical and ecotoxicological properties and thus the hazard potential of the representatives of this very extensive group of substances differ considerably: PFAS can be gaseous, liquid or solid; some are water-soluble; some are mobile, others bioaccumulate, some are toxic, others are physiologically harmless and many are persistent in the environment.

In the past, some PFAS have repeatedly been released into the environment, have accumulated in soil and water and can now also be detected in the human body. In recent years, the industry has already made considerable efforts and established comprehensive environmental protection measures in production. Toxic and particularly harmful substances from the PFAS group (e.g. PFOA and PFOS) have been substituted and production processes have been changed. As the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) reports on its website (www.bmu.bund.de) and as analyses of the German federal environmental sample bank show for some compounds, the exposure of the population to PFOS (perfluorooctane sulfonic acid, C8) and PFOA (perfluorooctanoic acid, C8) has also decreased significantly in recent decades. The measured values were highest in 1986. Today the measured values are approx. 10 % for PFOS and about 30 % for PFOA compared to the values at that time. This trend is mainly due to the success of the considerable investments made by companies in the EU. The primary sources of emissions to the environment (e.g. from aerosols in Teflon production, fire extinguishing foams or fire training areas, etc.) are already recorded and controlled in the member states and are largely eliminated (or are in the process of being eliminated) through continuous technological development and dynamic operator obligations to comply with the state of the art in the EU.

There is no doubt, however, that PFAS are needed for many high-tech applications (such as special protective clothing or essential innovations like fuel cells with suitable membrane technology). Moreover, it is not foreseeable which future applications will rely on the unique properties of fluorochemical-based polymers. If PFAS are banned in the EU for many important applications, this will not change the extensive need for products with the advantageous properties of PFAS applications. Future innovation and development of PFAS technology will be important but will no longer be possible in the EU.

For a better understanding of the diversity of the substances PFAS can be differentiated into the following subgroups (see Figure 1):

Figure 1: **Systematic presentation of the different PFAS categories (with characteristic examples of substances)**



Quelle: BDI

Fluoropolymers with the subgroup of **fluoroelastomers** include fully (per-) and partially (poly-)fluorinated plastics. These are generally high-performance plastics whose chemical backbone consists of carbon atoms and which have a high proportion of fluorine atoms in their chemical structure. Their high resistance to extreme temperatures, aggressive chemicals and wear, as well as the physiological harmlessness of fully fluorinated types define their areas of application, such as anti-stick coatings for products (e.g. plain bearings in the process industry) or medical products (e.g. catheter hoses or oil- and fuel-resistant seals).

The basis of many high-performance lubricants are liquid perfluoropolyethers, which are also a class of compounds within the fluoropolymers. They are mainly used under extreme conditions (very high temperatures, chemically aggressive environments) and for lubricating machines in the food sector, as they are non-toxic.

Side chain fluorinated polymers (SCFP), which have a comb-like structure and in which the fluorine atoms are located in the side arms of the polymers, also belong to the fluoropolymers. A frequent field of application for this class of polymers is the oil-, dirt-, water- and chemical-repellent finishing of surfaces. Side-chain fluoropolymers are also used as coating materials for a variety of components in electrical and electronic devices.

In addition, there is the large and extremely diverse group of gaseous and liquid low-molecular organic fluorine compounds. Here, too, a distinction is made between perfluorinated and polyfluorinated types. Gaseous representatives are used, among other things, as coolants (F-gases) and as insulating gases in gas insulated switchgears (GIS). Many liquid low-molecular PFAS are surface-active and therefore serve as surfactants and wetting agents (e.g. in fire extinguishing foams and as a component of release agents) but also as auxiliary chemicals in a wide variety of processes (e.g. in the semiconductor industry or fluoropolymer synthesis). The basic building blocks of fluoropolymers, the fluorinated monomers, also belong to this group of substances.

Part 2 of this position paper explains which PFAS are currently used in which sectors, why they are urgently needed and how they can be used safely.

Evaluation of the envisaged restriction approach

Application of the group approach to the restriction of PFAS

From the point of view of German industry, a blanket restriction of the entire PFAS substance group without a differentiated, substance- and application-specific risk assessment and solely due to the persistence of many PFAS is not appropriate. In order to ultimately achieve a sustainable overall balance of resource conservation and environmental impact, a restriction is only justified in cases where the risks to humans and the environment cannot be controlled.

It should be taken into account that the category of PFAS encompasses substances with different properties and that not all PFAS are equally persistent, mobile or bioaccumulative. This puts almost risk-free chemicals on an equal footing with substances of very high concern ("SVHC") with properties that require regulation. As part of a differentiated approach, it must be urgently ensured that only substances whose use poses an unacceptable risk to the environment or human health are banned. Otherwise, there is a risk that chemicals that play a crucial role in innovative technologies will be driven out of the market.

In addition, legal regulations already exist for certain substances from the extensive family of fluorocarbon compounds in the POP Regulation and under REACH (e.g. PFOS, PFOA). In the context of the regulation of these compounds, their properties, restrictions and exemptions have already been discussed extensively. This discussion should not be repeated. In addition, there would be double regulation, e.g. in the area of refrigerants (F-gases), as their use is already regulated by the F-Gas Regulation (EU) No. 517/2014.

Application of the "essential uses" concept to PFAS

The concept of "essential uses" will play a key role in the overall restriction process for PFAS. This concept is also a fundamental element of the EU Commission's chemicals strategy. The PFAS restriction is to be the "model" for this within the framework of the chemical's strategy. According to the concept of "essential uses", only those uses that are indispensable - i.e. "essential uses" - are to be excluded from a group ban on the "most harmful chemicals". The concrete criteria for "essential uses" are to be defined at EU level based on the Montreal Protocol's definition of the ban on ozone-depleting substances. According to the Montreal Protocol, a use is "essential" only if it is necessary for health or safety or critical for the functioning of society and there are no environmentally and health compatible alternatives.

In addition to the concept of "essential use", the EU Commission has announced in the Chemicals Strategy for Sustainability that it wants to speed up restriction procedures to ban hazardous substances in consumer products and to apply the "generic approach to risk assessment" as a standard option.

The BDI is critical on both the concept of "essential use" and the "generic approach to risk assessment". By extending the scope of restrictions based on the precautionary principle, the Commission would abandon the proven principle of substance-specific risk-based assessments. An extended application of the precautionary principle is not justified from an industry point of view and contradicts the regulatory system of the REACH Regulation, which is designed to regulate substance-specific unacceptable risks. We therefore advocate the retention of the risk-based approach to assessment for the regulation of chemicals in the EU. In the future, too, it must be possible to use hazardous substances if they can be used safely and do not pose an uncontrollable risk. Only in this way is it possible to maintain the diversity of substances and thus the innovative strength and future viability of European industry.

Furthermore, a discussion on "essential uses" is premature at this stage. Rather, the benefits to society as a whole of a risk-based approach should be discussed and emphasised. Basically, the question arises whether the concept of "essential use", which was developed for a very limited group of substances with proven fatal global effects on the ozone layer, can be transferred to such a large group of substances, of which precise knowledge of the associated hazards and risks is available only for some substances and others are known to have no harmful properties at all.

We also perceive a danger that restricting entire groups of substances to "essential uses" would violate the principle of proportionality. According to this principle, only such measures may be taken that are suitable and necessary for the achievement of the objective (here: health and environmental protection) and do not lead to disproportionate effects. This excludes prohibiting uses that do not lead to relevant exposures, even if they are not considered "essential". These include, for example, uses of PFAS as process chemicals, intermediates under strictly controlled conditions, and substances in closed systems that can be disposed of properly. Furthermore, it does not seem necessary to ban the entire group of PFAS except for essential uses. Individual environmental protection measures and disposal strategies can be used to prevent their entry into the environment. Restricting the permitted use solely to uses that are necessary for the functioning of society (a concept that is hardly tangible) would exclude uses that are of great benefit to society (e.g. by increasing the durability and energy efficiency of products and articles).

Fundamentally, the political limitation to essential applications leads to an inhibition of future developments, as it is not an objective scientific method and does not allow for planning security. What is considered non-essential today has no chance of being developed within the context of essential applications at all at a later date, as internal company compliance requirements would prevent research and development in this area. If the EU wants to continue to be a driver of innovation together with its industry, such a static concept cannot be effective.

Importance of PFAS for innovative technologies and products

In order to avoid misregulation and subsequent amendments, restrictions on PFAS must be examined and implemented carefully and gradually. Complex chemical compounds for specific applications cannot be regulated simply and comprehensively without causing considerable obstacles and damage to Europe as a centre for technology and business. It is imperative that regulation also assesses the risk and necessity of use and cannot be limited to intrinsic substance properties alone, which in some cases do not even apply to all PFAS.

The industrial use of PFAS has significantly contributed to the further development of technologies and thus, for example, to the improvement of climate protection. The service life of components has been increased and maintenance intervals reduced, through PFAS-incorporating designs which improve resource-efficiency and use less mass. PFAS are therefore an essential building block for today´s innovative strength of industry and will continue to be so in the future. This development would be set back by a broad ban on PFAS-based applications and products. Non-European manufacturers and their technological developments as well as sales and market shares would receive an unassailable boost and lead, as entire production chains would no longer be possible in Europe.

Without the use of PFAS, new future-oriented and sustainable technologies for private and industrial applications are not possible according to current knowledge (see Part 2). The placing on the market of certain products containing PFAS with high safety relevance and key functions in industrial applications would also no longer be possible in the EU.

In this respect, it should be emphasised once again that German industry supports regulations that prevent PFAS from entering the environment. However, a general ban on all applications with PFAS seems unsuitable for achieving this goal, as it would endanger, or even make impossible, the development of future technologies which have a high innovation potential within Europe.

2. Practical examples

Affected sectors and areas of application

Per- and polyfluorinated substances are used in many industries, especially when resistance to high temperatures, to wear or high chemical inertness are required. PFAS are therefore not replaceable by alternatives in many areas of application. They are used to achieve increased efficiency and resource-saving in manufacturing processes, as well as to increase the service life and reliability of products. PFAS thus make a decisive contribution to the durability and safety of products. PFAS enable many innovative technologies that contribute to a sustainable European economic system. In many areas, PFAS are necessary to comply with official regulations, especially in safety-relevant areas in production plants. Only PFAS such as Teflon and PVDF are sufficiently pure and inert to manufacture high-tech products.

It is often the inconspicuous components that are key for the functionality of products, such as seals or membranes, in which PFAS are used. These "key components" are not only needed in the products themselves, but also in the manufacture, transport or positioning of other products, and this across all industries. In almost all industrial sectors, lubricants are used on moving parts to minimise friction and thus also to minimise energy losses. These have to withstand extreme conditions and remain functional over the entire service life (e.g. of industrial plants), which is made possible by the use of PFAS.

PFAS are also widely used in important future technologies such as lithium-ion batteries, fuel cells, hydrogen technologies or innovative medical devices, which will play a central role in achieving sustainability and environmental protection goals, as well as in healthcare. As no suitable alternatives exist for these applications, PFAS are essential to achieve the goals of the EU Green Deal and to further increase the sustainability and efficiency of products and technologies. In the area of food contact and medicine, PFAS provide the necessary hygiene by allowing the use of appropriate cleaners and minimising residues on the material.

The following table gives an overview of the affected industries and exemplary applications of PFAS.

Table 1: Use of PFAS in various industrial sectors

Industrial sector	Exemplary application
Automotive industry	Components and systems containing PFAS are an integral part of current and future vehicle technologies; neither battery electric and fuel cell drives nor automated driving functions work without PFAS.
Electrical industry	Due to the variety of products, PFAS are used in the electrical industry in a wide range of applications, e.g.: ▪ Cable sheathing for sensor systems in process engineering plants ▪ Sliding and sealing systems in production plants and motors ▪ Coating materials for a wide range of components in electrical and electronic equipment ▪ Insulating gases as a substitute for SF_6 (which is one of the most harmful greenhouse gases) ▪ Spark gaps for the realisation of smallest dimensions (due to the very good insulating effect in combination with high thermal resistance) ▪ Lubricants to increase the reliability of electrical connections (e.g. in modern transport systems and industrial plant engineering) ▪ Electrode components of lithium-ion and lithium-primary batteries, which serve as energy sources in numerous electrical devices ▪ Other applications in power generation, semiconductor manufacturing, kitchen appliances, medical technology and the heating industry (see below).
Power generation	The use of fuels in engines or turbines requires a high resistance of the materials (of hoses and seals) e.g. to very high and very low temperatures, to fuels and oils containing alcohol and non-alcohol.
Renewable energies	In connection with the Green Deal and the reduction of CO_2 emissions, the storage of sustainably generated electrical energy (e.g. through photovoltaics and wind power) will play an increasingly important role. This concerns both stationary storage (e.g. in houses with photovoltaic systems) and in vehicles (electromobility). In this context, both lithium-ion batteries and fuel cells are becoming increasingly important. Both lithium-ion batteries and fuel cells require PFAS which cannot be replaced by other substances in these applications.
Semiconductor manufacturing	Due to their high technical functionality and chemical properties PFAS-containing special formulations are used in photolithography, which is the central step in semiconductor production. Per- and polyfluorinated gases are used in the semiconductor industry for etching processes to structure wafers and to clean production equipment. For micromechanical semiconductor components (MEMS), fluoroalkylsilanes are used as an anti-stick coating of the moving microstructures in the chip to prevent functional failures caused by these structures sticking together.

	In various production facilities in the semiconductor industry, materials containing PFAS are necessary as components and as vacuum or liquid seals for permanent use in aggressive environments (reactive gases or chemicals, plasma, high temperatures).
Food and beverage industry	In the area of food contact, PFAS offer the prerequisite for the necessary hygiene because they allow the use of partly aggressive cleaners and minimise residues on the material (with simultaneous approval as a food contact material).
Aerospace	PFAS play a major role in safety-relevant components, e.g. regarding the durability of products.
Mechanical and plant engineering	In various machines, for example, PFAS-containing seals are used, which in addition to the sealing function also keep frictional resistance low, e.g. in rotating objects such as injection moulding machines, presses or excavators, and are used under extreme conditions in safety-relevant components. PFAS-containing seals, but also coatings, play an important role in many other product areas, such as pumps that convey various media. For mechanical engineering, many applications mentioned under other sectors such as the electrical industry, power generation, the lubricant industry, the food industry or air conditioning technology are also essential.
Medical technology	The hygiene standards in medical production but also in the use of medical products themselves are very high. The materials used in the products must not be damaged during cleaning processes. In addition to the hygiene aspect, the physiological harmlessness of many PFAS (polymers, especially PTFE) is a major reason for their use in the field of medical products without a viable alternative.
Lubricant industry	PFAS-based lubricants save energy and CO_2 emissions and conserve resources through extreme durability (lifetime lubrication) that cannot be achieved otherwise. Their use is also indispensable for lubrication in aggressive environments (aggressive chemicals/extreme temperatures).
Textile industry	Technical textiles and safety clothing as well as medical textiles are subject to various requirements, e.g. in the area of water, oil, dirt and chemical repellent and temperature resistant properties, which can only be achieved with PFAS.
Heating, air conditioning and refrigeration technology	The refrigeration circuits of various heating, air conditioning and refrigeration products are based on hydrofluoroolefine (HFO) refrigerants. These refrigerants are not harmful to the ozone layer and have a low greenhouse potential. They are a result of the implementation of the European F-Gas Regulation (EU 517/2014) and are essential for safe and efficient operation of the systems.

Table 2 below provides an overview of the types, properties and diverse uses of selected PFAS as well as the requirements for the substances used. In the following, we will use selected application examples to describe the role that the use of PFAS plays in particularly innovative technologies and applications. In this context, we will focus on future technologies and applications that are important for achieving efficiency and environmental goals as well as for future developments.

Table 2: Overview of the types, properties and multiple uses of PFAS

Selection of key components	Selection of sectors/applications/products	Properties/requirements in relation to the materials used
Fluoropolymers (Per-/Polyfluoropolymers (fully or partially fluorinated polymers and fluoroelastomers) Per-/Polyfluoropolymers have a carbon backbone, fully or partially fluorinated and are: Inert, fabric repellent, temperature resistant, chemical resistant, abrasion resistant, pressure resistant and have mechanical resistance. Elastomers due to their deformability are also used in applications where, in addition to the properties mentioned above, the material is subjected to different pressures during pressure absorption and release.		
▪ Seals ▪ Hoses ▪ Cable insulation ▪ Components for chemical process technology ▪ Sliding bushes ▪ Solid components to ensure the technical switching function ▪ Sealing rings ▪ Filters e.g. from the per-/polyfluoropolymers e.g. PTFE, CTFE, FEP, ETFE, MFA, PFA and Fluorelastomers e.g. FKM, FFKM, FVMQ	Production, transport, storage, treatment, preparation of liquids, gases and solids Affected products are e.g.: ▪ Machines or process plants for production ▪ Pumps for transport ▪ Motors for drive or ▪ Tanks for storage	Requirements for the materials: Resistance to acids and bases; resistance to solvents and physical effects (heat, cold, abrasion, etc.). **Food/drinking water:** ▪ Fulfilment of hygienic requirements for materials in the area of drinking water and food contact ▪ Resistance to aggressive cleaning agents (e.g. hydrogen peroxide in aseptic applications) and fatty foodstuffs. ▪ Prevention of aroma carry-over (due to their inert properties, perfluorinated materials do not take on the aroma of the filling material) **Fuels:** ▪ Resistance of materials in internal combustion engines to various fuels (including those containing alcohol) ▪ Resistance of materials in turbines to fuels and low-viscosity oils in combination with very low temperatures (- 60 °C) **Lubricating oils and hydraulic fluids:** ▪ Resistance to engine and gear oils as well as hydraulic fluids at often high temperatures and simultaneous wear resistance due to low friction coefficients in dynamic sealing applications **Wastewater:** ▪ Resistance to fluctuating composition with extreme pH values

		Gases/flue gases: ▪ Gas tightness in combination with very high or very low temperatures and extreme chemical conditions. ▪ Resistance at high temperatures and in the presence of aggressive gases
	Medical devices that have contact with the human body (implants, endoscopy, catheters, dialysis, respirators, anaesthesia equipment), care and surgical textiles).	▪ Resistance to concentrated oxygen and anaesthetic gases ▪ Hygiene requirements ▪ Biological compatibility must be present
	▪ NOx sensors/catalytic converters/sensors ▪ SCR heating cable for the Adblue supply lines ▪ BVA (Brake wear indicator) ▪ Cables (e.g. in the gearbox, often immersed in hot, aggressive gearbox oil) ▪ Windscreen washer system heater to prevent freezing of the windscreen washer system	▪ Reliability with large mating cycles ▪ Requirements for low contact resistance, chemical resistance, temperature resistance and mechanical friction reduction
	▪ Wet chemistry ▪ Process plants ▪ Railway technology ▪ Production engineering ▪ Kinematic chains	▪ Resistance to high temperatures ▪ Resistance to chemicals ▪ Requirements for low contact resistance and mechanical friction reduction
	Gearboxes and Motors	Fluoroelastomers (e.g. FKM) have the following properties in sealing rings compared to alternative materials such as nitrile butadiene rubber (NBR): ▪ better temperature and chemical resistance ▪ better wear resistance at high speeds ▪ high resistance to environmental influences such as ozone radiation ▪ Higher ageing resistance and lower maintenance intensity
Membranes Proton conducting material e.g. out of PTFE, PFSA and Gas diffusion layers e.g. out of FEP	▪ Fuel cells ▪ Electrolysis cells ▪ Breathable protective membranes	▪ Highest requirements for chemical and thermal resistance ▪ Requirements for gas tightness ▪ Use of sealing materials in fuel cells that seal gas and water paths and must withstand all chemical and thermal conditions in the cell

(Non-stick) coatings	▪ Plain bearing ▪ Housing ▪ Tubes ▪ Hoses ▪ Conveyor belts	▪ Requirements for chemical, mechanical and thermal resistance ▪ Requirement for a friction-reducing effect ▪ Fulfilment of hygiene requirements
Lubricants and lubrication, bearings, gears, compressors electrical contacts e.g. out of PTFE, PFPE	Contact lubrication is used in a wide range of industries: ▪ Mechanical engineering ▪ Automotive industry ▪ Food production ▪ Gas/oxygen production ▪ Textile industry ▪ Shipping industry ▪ Chemical industry ▪ Aviation ▪ Medical technology ▪ Electrical contact technology	To minimise friction and thus minimise energy losses, lubricants are used on all moving parts. The lubricants must withstand extreme conditions and meet the following requirements: ▪ Substances must be non-toxic and non-flammable. ▪ Resistance to decomposition must be guaranteed for years. ▪ Resistance to high and low temperatures (note pour point). ▪ Resistance to aggressive media must be guaranteed. ▪ Resistance to high mechanical loads must be guaranteed. ▪ Substances must be compatible with the requirements of food and medical technology. ▪ Ensure lubrication over the entire life of a bearing or any other product. ▪ Increasing the number of mating cycles and extending the service life of electrical contacts.
Electrode material, Cooling hoses e.g. out of PVDF, PTFE	▪ Lithium-ion batteries ▪ Lithium primary batteries ▪ Fuel cells ▪ HV transformers	▪ Prerequisite for efficient and long-lasting lithium batteries and fuel cells through high material resistance in the electrochemical environment
Insulation panels e.g. out of PTFE	▪ Spark gaps of surge protection devices	▪ Realisation of extremely compact designs due to the very good insulating properties and thermal resistance
Solid lubricants e.g. out of PTFE/PFPE	▪ Use in high vacuum applications	▪ The reason for using PTFE in lubricants for high vacuum applications is the vapour pressure curve. The lubricants are still liquid at low pressures.
Side chain fluorinated polymers (SCFP) SCFP have fluorinated polymer side chains on a carbon backbone and are inert and substance-repellent		
Textiles	▪ Protective textiles ▪ Technical textiles ▪ Filtration media ▪ Medical textiles	▪ Materials must have oil-, dirt-, water- and chemical-repellent properties. ▪ Barrier against bacteriological, viral and other biological influences
Coatings	▪ Electric and electronic components/devices	▪ inert, fabric repellent, good dielectric properties

Low molecular fluorinated compounds		
Surfactants and wetting agents	▪ Release agents ▪ Paints and varnishes ▪ Paper and packaging	▪ Surfactants and wetting agents are partly surface-active and partly reactive ▪ Requirements for a wide range of physical, chemical and electrical properties
Waterproofing sprays		▪ Fulfilment of fabric and water repellent properties
Extinguishing foams	▪ Extinguishing fires, e.g. in large mineral oil storage tanks and their containment areas.	▪ Use of simultaneously oil- and water-repellent surfactants ▪ High flow rate, high range and good temperature resistance of the foam required
Process materials	▪ Additives for the production of fully and partially fluorinated polymers	
Use in the photo-lithography process of the semiconductor industry	▪ Central process step in the semiconductor industry	▪ The technical requirements of the photolithography process are a specific combination of surface properties, with specific refractive indices and chemical and thermal resistance.
Fluoralkylsilanes	▪ Anti-stick coatings for micromechanical components (MEMS, especially sensor chips) in the semiconductor industry	▪ Minimisation of surface energy, adhesion forces and friction to reliably prevent the microstructures from sticking together (stiction) during the entire product life. ▪ At the same time, high temperature stability of the anti-adhesion layer (> 400 °C during processing). ▪ Hydrophobisation of surfaces in MEMS products with contact to the surrounding medium (e.g. microphones)
Per- and polyfluorinated gases (insulating gases, process gases)	▪ Electrical industry, medium and high voltage switchgear, etching and cleaning processes ▪ e.g. in the production of solar cells, printed circuit board and semiconductor industry	▪ Requirements for very good dielectric properties with low greenhouse potential (substitute for SF6) ▪ Use as etching gases (e.g. for structural etching and for chamber cleaning of coating machines) due to the unique combination of performance and occupational safety in the specific release of the fluorine atoms required for the etching reaction
Wetting agent e.g. 4H-PFOA	▪ Use in chrome baths	▪ 4H-PFOA is a substitute for perfluorooctanoic acid (PFOA), which is restricted by the POP Regulation. Compared to PFOA, F atoms have been replaced by H atoms.

Refrigerants e.g. R1234 yf	▪ Use as a refrigerant for heat pumps, air conditioning and refrigeration applications. ▪ Used in refrigeration and by heating equipment manufac-turers.	Tetrafluoropropene known as R1234 yf (HFO Blends) from the substance group of hydrofluoro-olefins (HFO) fulfils the following properties: ▪ low global warming potential ▪ low atmospheric residence time; decom-position products (TFA) possibly persis-tent, but high background level of natural origin. ▪ Normally, refrigerant is not released, but largely recovered and recycled. ▪ Alternative refrigerants with low GWP are explosive, therefore associated with increased risk, especially in the domestic environment.
Monomers Monomers are intermediates without the use of which the production of polymers (fluoropolymers, side-chain fluorinated polymers) would not be possible.		

Selected application examples

Protective textiles in the field of personal protective equipment (PPE) for fire brigades, security and rescue forces and in the medical sector.

Protective textiles for the protection of employees in action are used by the police, customs, the Federal Border Guard, the fire brigade and the Federal Armed Forces, but also in private institutions such as security services or aid organisations (e.g. in Germany the Federal Agency for Technical Relief (THW)). Among other things, chemical protection suits are used to avert danger in the event of accidents and environmental incidents. Special protective equipment is also necessary for workers in the chemical industry or fishermen.

This requires numerous highly innovative special products with a combination of different properties: The textiles often have to be simultaneously non-flammable, water-, oil-, chemical- and dirt-repellent. These properties must remain undiminished during the entire period of use and even after several industrial washes. The finish required for the longevity of the textiles makes an important contribution to sustainability. The combination of a water, oil, stain and chemical repellent finish can only be achieved with fluorinated polymers. No fluorine-free alternatives are yet available for the combination of an oil-, stain- and chemical-repellent finish.

PFAS continue to be indispensable in many medical applications. Every operation in Europe must be performed covered. In Germany alone, more than 19 million patients are treated each year, of which about 40 % are operated on, according to Destatis. For example, membrane laminates are used for reusable medical products such as surgical gowns and drapes, as well as close-meshed microfilament fabrics, which must be equipped with PFAS to prevent the penetration of certain liquids that occur in the operating theatre. There is no adequate alternative to C_6 or C_8 textile auxiliaries to achieve the appropriate performance of these fabrics. Consequently, the entire sector of reusable surgical textile products in Europe is affected. Also plasters, which are offered as medical devices, are partly equipped with PFAS (C_6 chemicals). This applies in particular to plasters and plaster fabrics that are offered rolled and must also function at warm ambient temperatures.

Sun protection systems (e.g. awnings, sun sails, textile building envelopes) that are protected against weather influences and biological infestation in the long term prevent rooms from heating up, avoid the need for energy-intensive cooling and thus reduce energy consumption. They thus make a significant contribution to climate protection and to achieving the European climate targets.

Filtration media (exhaust air and wastewater purification, clean rooms, pollen filters, etc.)

Filter media for dust separation in industrial processes are required for numerous important industries, from aluminium to cement production, from waste incineration to energy generation and also in the food industry. The requirements, especially for the mechanical and chemical resistance of the filter media, are high, as they must provide their function undiminished over a long period of time in order to protect people and the environment from emissions. In order to maintain the filter effect even against different and changing pollutant flows, the filter is impregnated. A fluorine-free substitute for impregnation is currently not available in the same quality, and the service life of alternative impregnated systems is significantly shorter.

Semiconductor

The use of PFAS-containing special formulations in the central process step of semiconductor manufacturing, photolithography, is essential due to their high technical functionality and chemical properties. PFAS-containing process chemicals are, for example, photoresists and anti-reflective coatings that are used in photolithography to create the structures on the silicon wafer. PFAS components are used in low concentrations (typically less than 1%) in these special formulations. Photolithography processes are repeated several times (up to 60 times, depending on the technology) throughout the semiconductor manufacturing process, each time before applying further layers to create structures that, taken together, eventually form the transistors and interconnects of the finished microchips on the silicon wafer.

The use of fluoroalkyl silanes is essential for certain micromechanical semiconductor components (MEMS), especially MEMS accelerometers, due to their unique properties (formation of very thin layers with extremely low surface energy and correspondingly low adhesion forces combined with very high temperature stability). Anti-sticking coatings based on fluoroalkyl silanes enable the fabrication of very precise sensors of small size with the required reliability. Such MEMS acceleration sensors are indispensable for automotive safety systems (airbag, ESP driving dynamics control) as well as for automated driving and other vehicle assistance systems. They are also used in a variety of consumer electronics applications (smartphones, tablets, wearables).

PFAS-containing process chemicals (PFHxA-related substances) remain in the finished product in some specific applications (MEMS, CMOS image sensors in automotive and medical technology, cameras, mobile phones, computers), but are encapsulated.

Perfluorinated and polyfluorinated gases are used in the semiconductor industry for etching processes to structure wafers and for cleaning production equipment.

The semiconductor industry has installed risk and safety management measures (e.g. closed production facilities) to prevent the release of chemicals at all stages of the manufacturing process. Waste containing PFAS from photolithography is usually collected on site and disposed of properly.

There are no known alternatives for PFAS-containing special formulations in photolithography that have the same unique properties. Due to the high purity requirements in the production process, the use of fluoropolymers in the production equipment is necessary.

The continued availability of PFAS in the production process is a fundamental prerequisite for the manufacture of semiconductors as a key technology and thus essential for the existing production supply chains (e.g. automotive) and the future innovation capability in Europe.

Lithium-ion Batteries

Rechargeable lithium-ion batteries, especially for use as traction batteries in vehicles, must meet high demands in terms of service life, charging speed, high energy density and permanent charging capacity. The materials used in lithium-ion batteries are therefore carefully selected so that they are stable at different outside temperatures and high currents or energies. Fluorocarbon compounds are indispensable for meeting these requirements due to their stability.

A long service life of the lithium-ion batteries and thus the long-term stability of the materials used are also crucial with regard to the secondary use of traction batteries as stationary energy storage systems, as envisaged in the Green Deal and the new EU Battery Regulation currently being drafted.

The durability of the materials used also plays a decisive role for lithium primary batteries, which are often permanently installed in electrical devices and provide energy for runtimes of up to 20 years.

There are currently two main PFAS applications in modern Lithum-ion batteries:

1. PVDF (polyvinylidene fluoride) and PTFE (polytetrafluoroethylene) as binders for coating the cathode with active materials such as metal oxides.

2. Fluoro-organic additives in the electrolyte to improve the service life of the battery cell.

Emissions of PFAS compounds into the environment occur exclusively during malfunctions or accidents. The PFAS compounds are used in the production of the battery cell in closed facilities, are encapsulated in the battery cell during the use phase and are decomposed during recycling and the resulting fluorine compounds are removed via gas scrubbers.

Fuel cells/electrolysis cells

PFAS are used in various key components in fuel cells and electrolysis cells. This includes, for example, the proton exchange membrane, gas diffusion layer and sealing materials for gas, water and air paths.

The proton exchange membrane consists mainly of PFSA-like ionomers with a reinforcement of PTFE. PFSA is the proton-conducting material in the fuel cell membrane and electrode and enables the electrical transport of protons in the electrodes and membranes. This separates reactants and gases and ensures the electrical isolation of the half-cells. The proton membrane is the main functional unit and thus absolutely necessary for the functionality of a polymer electrolyte fuel cell. In the gas diffusion layer, PTFE and FEP are used as hydrophobic agents to stabilise the water management and to separate the water circuits in the individual cells of a fuel cell stack. PFAS are also used to seal the chambers within the fuel cell. Here, chemical and thermal stability are particularly important.

Currently, no alternatives are available for use in these key components, since, for example, only PFSA ionomers have reached technological maturity for use in proton exchange membranes for these functions in the harsh environment of a fuel cell.

In gas diffusion layers, PTFE and FEP are needed as electrochemically stable binders that can withstand the acidic conditions near the catalyst or membrane of a fuel cell. The superior electrochemical stability of PTFE under different conditions in a fuel cell is of particular relevance here. There are currently no alternatives for this either.

Pressurised metered dose inhalers for the treatment of lung diseases

Pressurised metered dose inhalers are used for the targeted administration of medicines via the lungs. For these highly effective drugs, precise dosing in the microgram range is necessary. In addition, this form of administration with propellant gas allows children and elderly patients to inhale life-saving medicines, among other things. Many patients would not be able to take other forms of delivery due to their lung disease.

In these pressurised metered dose inhalers, PFAS are contained in the propellant gas and in the internal coating of the aluminium pressure container. During patient application, the propellant gas generates a fine distribution of the drug active ingredient and transports it into the lungs. At the same time, the pressure must not cause any damage to the lungs. Only fluorinated propellants have this property. The internal fluoropolymer coating prevents reaction of drug with the aluminium container and assure the correct drug delivery dose.

Food sector

PFAS and especially PTFE are used in numerous components and assemblies, in systems and equipment for the production and preparation of food. In most cases, this is due to the special material property combination of high temperature resistance and approval for food contact. The combination of high temperature resistance/lubrication effect is the reason for its use in seals and plain bearings.

An important application of PTFE is its use in hoses and pipes for transporting liquids. These liquids are, for example, drinking water, coffee, milk and also steam. Some of these transported liquids are under a pressure of up to 12 bar in normal operation and must be able to withstand pressures of up to 20 bar in the event of a fault. The operating temperature can be assumed to be between 0 °C and 160 °C in normal operation. In case of need, temperatures of up to 200 °C can occur. In some cases, there is even a combination of 20 bar and 200 °C. PTFE has proven to be an ideal material for such applications. But also, in the area of food contact, PTFE materials are characterised by their very good compatibility in contact with food. At present, there are no alternative materials for safe use in contact with food. Switching to other materials would result in an earlier failure of the components.

Heat Pumps

To achieve the European climate targets, the switch from fossil fuels to electrically driven heat pumps is one of the decisive measures. With the implementation of the F-Gas Regulation (EU 517/2014) in recent years, there has been an almost complete switch of components and equipment concepts to new synthetic refrigerants (HFOs). Additional restrictions on the use of refrigerants via PFAS regulation would make it impossible to achieve the EU climate targets for 2030.

In Europe, there is a broad wave of renovation in the building sector. Especially multi-family houses are in focus. The heat pump industry has just started to implement heat pumps in this sector and has adapted the necessary properties and performance sizes of the products for use in these buildings. To ensure safe and efficient operation of the heat pumps, the use of HFOs is necessary.

The widespread use of natural refrigerants as an alternative cannot currently replace the use of HFOs for technical reasons due to safety requirements and the desired efficiency requirements.

Paints and varnishes

Fluoropolymers, especially PTFEs, are also used in paints, varnishes and printing inks. They help to give the coatings important properties such as scratch and abrasion resistance as well as thermal and chemical resistance, which are essential for the specific end uses. Some of the compounds are only used in very small quantities but are of great technical importance. This applies to the areas of powder coatings, industrial coatings, automotive, corrosion protection and printing inks, among others.

Safety-relevant fasteners (e.g. screws, nuts, washers, clips, etc.), whose functionality can only be guaranteed by coatings with fluoropolymers according to the current state of the art, are used, for example, in the assembly of chassis and tyres. The coating ensures that the required defined assembly condition (including pretensioning force and clamping force) is fulfilled so that the connection maintains its function and the necessary safety. Fluoropolymer coatings are also essential for the function of seatbelt restraint systems, for example in cars. They prevent the belt from sticking to the components in the event of an accident due to the high thermal energy that occurs, thus guaranteeing that the belt remains functional. Furthermore, this coating ensures that the belt buckle can still be operated and opened under load after an accident.

In the case of printed products, especially in offset printing, various problems and qualitative impairments can occur without suitable rub protection. On the one hand, visible rubbing problems occur in the printed product, for example scratches, "smudging" and ink being deposited on surfaces that are actually unprinted. These rubbing problems can impair the quality of the printed product to such an extent that it can no longer be sold, which can cause considerable financial damage. On the other hand, contamination and deposits also occur in the press and in finishing, especially on chill rollers, formers and spiral bars, which lead to significantly more waste and result in increased, often very time-consuming and solvent-intensive cleaning.

Impressum

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