SYENSQO
ADVANCING HUMANITY

Maine Department of Environmental Protection
Syensqo Response to Proposed Rulemaking on PFAS in Products
January 28, 2025

On behalf of Solvay Specialty Polymers USA, LLC, member of the Syensqo group ("Syensqo"), we appreciate the opportunity to submit comments to the Maine Department of Environmental Protection concerning the amended proposed rule, Chapter 90, to establish criteria for currently unavoidable uses of intentionally added PFAS in products and to implement the sales prohibitions and notification requirements for products containing intentionally added PFAS but determined to be a currently unavoidable use pursuant to the amended 38 M.R.S. 1614.

Syensqo is a global leader in advanced materials and specialty chemicals. Our tailor-made range of products and constantly evolving research offers everyday sustainable market-based solutions for next-generation transportation, resource efficiency, consumer goods, healthcare, and industrial production to accommodate United States (U.S.) consumers' needs. Syensqo, through its predecessors, has been connecting people and scientific minds for 160 years. Innovation is at our core and part of our DNA. In the U.S., Syensqo employs nearly 5,000 people working in 43 sites across 20 states. While Syensqo does not directly operate any facilities in Maine, our customers use our products that are essential to the economy of Maine, including many key downstream applications not covered by Maine's proposed exemptions to the currently unavoidable use paradigm.

We are a science company with a remarkable past, aiming to reinvent the future with our technologies, particularly in the emerging clean energy markets. In that vein, in October 2022, Solvay Specialty Polymers, LLC (a subsidiary of Syensqo) was awarded a $178M grant from the Department of Energy (DOE) as part of an Infrastructure Investment and Jobs Act battery material funding program to produce a PVDF fluoropolymer production facility in Augusta, GA.[1] This facility has the potential to provide enough PVDF fluoropolymer to supply more than 5 million EV batteries per year at full capacity, and the project is expected to create more than 500 local construction jobs and 100 highly-skilled jobs. Once fully operational, our project is an American investment that will fill a significant domestic supply gap with all major feedstocks, including fluorspar (a designated critical mineral), coming from North America. Our PVDF also is stationary energy storage applications, and are key to ensuring low cost and reliable storage are available to developers. Both of these applications are necessary for Maine to achieve the state's statutory goal of net-zero GHG emissions by 2045. Moreover, PVDF is used in semiconductor manufacturing, chemical processing, and aerospace and defense and medical device applications.

---

[1] *See https://www.energy.gov/sites/default/files/2022-10/DOE%20BIL%20Battery%20FOA-2678%20Selectee%20Fact%20Sheets%20-%201_2.pdf*

While we appreciate Maine's step to remove the onerous "general notification requirement" that was previously scheduled to take effect Jan. 1, 2025, we continue to strongly oppose a "currently unavoidable use" construct being applied to the entire class of PFAS chemistry for the reasons outlined below. Further, the enclosed appendix outlines Syensqo's detailed analysis of the key downstream uses of our fluorinated products that have a critical and irreplaceable impact on society. As such, Syensqo respectfully requests that these products are specifically deemed "currently avoidable" and a full exemption for fluoropolymers manufactured without fluorosurfactant process aids.

I. *This type of restriction is incompatible with complex critical supply chains and economies of scale.*

Manufacturers of fluoropolymers (and other polymeric PFAS substances) need sufficient sales and volume to justify the immense capital and operation costs of an advanced chemical facility and remain cost competitive in a truly global market (that exists for advanced polymer chemistries). For example, if only fluoropolymer coatings for architectural applications are deemed "currently unavoidable," but these coatings that are used in a variety of industrial applications are not approved, the loss of overall demand would be significant to the manufacturer. Syensqo's facilities service a multitude of different industries for different applications. In many cases, we are multiple tiers removed from our products' end use as a material supplier. This dynamic extends across our entire portfolio of fluorinated products. Allowing only "currently unavoidable uses" in specific downstream sectors – rather than analyzing the risk profiles of specific PFAS chemistries – would severely endanger the supply of materials for the approved uses by the state. The demand of PFAS products from these small sub-sectors cannot support the weight of the entire industry nor support the economies of scale that we need to compete with non-domestic manufacturers, particularly those based in China.

The US Department of Defense specifically highlights this problem as a key national defense vulnerability in their recent, "Report on Critical Per- and Polyfluoroalkyl Substance Uses."

> "PFAS are critical to DoD mission success and readiness and to many national sectors of critical infrastructure, including information technology, critical manufacturing, health care, renewable energy, and transportation…
>
> Emerging environmental regulations focused on PFAS are broad, unpredictable, lack the specificity of individual PFAS risk relative to their use, and in certain cases will have unintended impacts on market dynamics and the supply chain, resulting in the loss of access to mission critical uses of PFAS. These market responses will impact many sectors of U.S. critical infrastructure, including but not limited to the defense industrial base. Collectively, international and U.S. regulatory actions to manage PFAS'

> environmental impacts and identify and eliminate PFAS from the market, and the resulting market changes, pose risks to DoD operations and the defense industrial base supply chain. In addition, impacts to the global PFAS supply chain will present risks to the DoD Foreign Military Sales program and to North Atlantic Treaty Organization interoperability."[2]

Ultimately, the market will adapt, and the supply of these critical materials will be available from foreign manufacturers who do not have the same environmental, labor, climate, and safety controls as U.S. suppliers. Moreover, it is highly likely that these critical supply chains will relocate to geopolitical adversaries and further disrupt domestic security for key manufacturing inputs.

II. *This regulation does not follow the science and fails to recognize key differences in PFAS chemistries*

Syensqo actively promotes the continued responsible and safe manufacture, use, and placement of products which are essential to U.S. industry and to the decarbonization of the global economy. We take the subject of PFAS very seriously, and health and safety are our top priorities.

The regulation currently does not recognize the distinct differences in PFAS chemistries, particularly with respect to fluoropolymers which present low hazards to human health and the environment. These chemistries are vital to the critical industries that are the foundation of our sustainable future, including hydrogen-based energy, semiconductor manufacturing, EV batteries, and aerospace and defense applications.

Specifically, fluoropolymers are molecules that are inert, relatively large and have "documented safety profiles; are thermally, biologically, and chemically stable, negligibly soluble in water, nonmobile, nonbioavailable, nonbioaccumulative, and nontoxic."[3] Moreover, some of these fluorinated substances are even completely insoluble, including FKM (a fluoroelastomer) and PFPE lubricants.

III. *Alternative assessments should recognize the responsible manufacturing of certain PFAS chemistries.*

Concerns about fluorochemistry have focused on the use of fluorosurfactant process aids used in the production of polymers.

---

[2] *See https://www.acq.osd.mil/eie/eer/ecc/pfas/docs/reports/Report-on-Critical-PFAS-Substance-Uses.pdf*

[3] *See Korzeniowski, S.H.; Buck, R.C.; Newkold, R.M.; El Kassmi, A.; Laganis, E.; Matsuoka, Y.; Dinelli, B.; Beauchet, S.; Adamsky, F.; Weilandt, K.; et al. A Critical Review of the Application of Polymer of Low Concern Regulatory Criteria to Fluoropolymers II: Fluoroplastics and Fluoroelastomers. Integr. Environ. Assess. Manag. 2023, 19, 326–354.*

SYENSQO
ADVANCING HUMANITY

> "The objective of this analysis is to evaluate the evidence regarding the environmental and human health impacts of fluoropolymers throughout their life cycle(s). Production of some fluoropolymers is intimately linked to the use and emissions of legacy and novel PFAS as polymer processing aids. There are serious concerns regarding the toxicity and adverse effects of fluorinated processing aids on humans and the environment." [4]

Over the last several years, we have invested millions of dollars to advance our technology where we now produce all of our fluoropolymers in the U.S. without the use of fluorosurfactants. Fluorosurfactants are non-polymeric process aids that help ingredients work together in manufacturing some fluoropolymers and historically included PFOA and PFOS, that are among the PFAS substances under the most intense spotlight. We were able to develop a next generation, more sustainable range of specialized fluoropolymers without the use of fluorosurfactants while keeping the unique properties of these products, as required for special applications.[5]

A recent November 2023 scientific review specifically analyzed how the industry has responded to these claims amid new regulatory actions globally on "essential use"/"currently unavoidable use"/etc.,

> "Because they are concerned about the negative aspects of the fluorinated polymerization aids (FPAs or surfactants) currently used to replace PFOA, FP [fluoropolymer] manufacturers have been overcoming the great challenge to produce FPs free from FPAs…*FPs produced without any FPAs should be exempt for all uses across all industries including consumer applications as they raise no risk to the environment or to mammal and human health, in addition to the fact that FPs also match the PLC [polymer of low concern] criteria."*[6] (Emphasis added.)

The supply of fluoropolymers for critical product supply chains is currently a delicate balance between market demand and regulation. A full exemption for fluoropolymers that are responsibly manufactured for industrial uses represents a path forward to address environmental, national security and economic competitiveness priorities.

Alternatively, should the Maine DEP continue with the "currently unavoidable use" construct that solely focuses on downstream uses, we request that additional categories

---

[4] *See Lohmann, Rainer, Ian T. Cousins, Jamie C. DeWitt, Juliane Glüge, Gretta Goldenman, Dorte Herzke, Andrew B. Lindstrom, et al. 2020. "Are Fluoropolymers Really of Low Concern for Human and Environmental Health and Separate from Other PFAS?" Environmental Science & Technology 54 (20): 12820–28.* https://doi.org/10.1021/acs.est.0c03244.

[5] *See* https://www.syensqo.com/en/innovation/science-solutions/pfas

[6] *See Améduri B. Fluoropolymers as Unique and Irreplaceable Materials: Challenges and Future Trends in These Specific Per or Poly-Fluoroalkyl Substances. Molecules. 2023 Nov 13;28(22):7564. doi: 10.3390/molecules28227564. PMID: 38005292; PMCID: PMC10675016.*

be created for more critical industries that are not covered under the proposed regulations' exemption categories.

As mentioned in the section above, our enclosed annex outlines Syensqo's detailed analysis of the key downstream uses of our fluoromaterial products that have a critical and irreplaceable impact on society, and we request that Maine DEP consider all categories listed for an exemption. Below are a list key industrial applications and products that we request Maine DEP consider for additional exemptions:

- **Automotive** - Within the automotive sector, fluoropolymers find application in several key technical components, such as gaskets, hoses, joints, O-rings, seals, cords, cables, or sleeves. Additionally, they are applied in articles that constitute part of components used in automotive, such as membrane in the fuel cell or bearing shafts in air conditioner compressors. Fluoropolymers are used in the transport sector primarily due to their resilience, broad thermal and chemical resistance and low friction properties, as well as due to their resistance to swelling and permeability. Without an exemption, nearly every automobile currently manufactured would not be able to be sold in Maine.
- **Aeronautics** - Fluorpolymers and Perfluoropolyethers are widely used in the aerospace industry for their general ability to withstand harsh conditions, with some sub-uses and end-applications similar to the ones described for the automotive sector. Indeed, in the aeronautic sector FPs are widely used as gaskets, hoses, joints, O-rings, seals, cords, cables, or sleeves inside the aircraft. The current proposed Chapter 90 "Products Containing PFAS" draft language exempts "A product required to meet standards or requirements of the FAA, the National Aeronautics and Space Administration (NASA), the United States Department of Defense (DOD) or the United States Department of Homeland Security (DHS)." However, this exemption would not cover specific products that are used in the aerospace and defense industry, but are not explicitly certified by each of these federal agencies. Syensqo and its customers manufacture numerous upstream fluoropolymer products that are used in defense and aerospace applications such as fighter jets, or engine and structural parts for civilian and commercial aircraft. With the proposed "currently unavoidable use" construct, airports and airfields in Maine will find many of their necessary service and spare parts unavailable due to the lack of a specific FAA certification on many aerospace products containing fluoropolymers.
- **Batteries and E-mobility** - Batteries are essential for powering a wide range of applications, from smartphones and power tools to mission-critical assets like data centers and nuclear power plants. They are critical enablers of the growth of electric vehicles, e-bikes, and e-scooters, contributing to economic development and job creation. Additionally, batteries play a vital role in powering machines such as drones, rockets, and satellites, as well as providing energy storage for electrical grids. Without an exemption from Maine DEP, critical fluoropolymer products will be banned from usage in high density batteries, which would force manufacturers to switch back to

inefficient, less advanced chemistry batteries. As consumers continue to demand higher range EVs and longer lasting consumer batteries, an exemption for batteries is necessary to ensure strong demand to continue to electrify our economy.

- **Renewable Energy** - Nearly every innovative clean energy generation source, from solar, wind, nuclear, geothermal, hydropower, energy storage, and carbon capture all rely on fluoropolymers in their products for protective coatings, sealing, and lubrication to ensure efficient and safe operation. Without an exemption for the energy industry, developers and utilities in Maine would find nearly all of their necessary clean technologies banned. Meanwhile emerging technologies such as green hydrogen use fluoropolymers in membranes used in electrolysis as well as in hydrogen storage and transport applications, such as valves, sealing and pipes. Green hydrogen is a key future technology for decarbonization, especially for hard-to-abate industrial applications that require heat generation. Hamstringing Maine utilities and developers would only increase demand for price-volatile and GHG-heavy energy sources like natural gas and petroleum and would ultimately reduce grid reliability and hurt Maine ratepayers.
- **Industrial application (e.g., lubricants, sealant)** - Sealing devices and materials serve a crucial role in the safe containment of fluids in several markets, including but not limited to automotive, aerospace, pharmaceuticals, industrial and mineral extraction. Industrial sealings are used to contain media inside hardware and the seal materials must withstand the environmental conditions of the application. Using a lower performing lubricant would result in a shorter lifetime, higher costs due to the more frequent replacements and in some cases an increase of the safety-risk. Without an exemption, Maine companies who rely heavily on many of these industrial products would find many of their industrial equipment banned.
- **Electronics** - While semiconductors and its manufacturing equipment are exempted, many key parts that impact the waterproofing and performance of consumer electronics would not be covered by the exemption categories. Other fluoropolymer uses in electronics include the treatment medium for touchscreen glass, which protects the touch screen glass from fingerprints and degradation from skin oils. A lack of an exemption would drastically reduce the quality and longevity of many electronic products, which would likely result in the products ending up in the waste stream.

While the currently exempted product categories do give some manufacturers of critical products regulatory certainty, the exemptions do not recognize the reality that fluoromaterials are used in industrial applications. Maine needs to proactively exempt the currently non-exempted critical product supply chains and industry categories listed above to ensure consumers and industry have access to the critical products that they need. Lastly, we respectfully request that Maine DEP recognizes that many key products, like the ones we listed above, have no viable alternative and thus should not potentially have their exemption revoked in the future. Having regulatory certainty is crucial for further domestic investment in these critical product supply chains.

SYENSQO
ADVANCING HUMANITY

Lastly, Maine's misguided focus on all types of PFAS undermines Maine's statutory goal to achieve state GHG neutrality by 2045.

Maine's goal to eliminate GHG emissions by 2045 is both ambitious and achievable if, and only if, the energy industry is allowed to continue the use of fluoropolymers. Within the current proposed rule, no exemptions exist for energy generation and storage systems. Much of our current and future renewable energy systems rely heavily on fluoropolymers in the manufacturing process and finished products. Hydrophobic coatings on solar glass and weatherproof backsheets, PVDF in EV batteries and stationary energy storage systems, and components within onshore and offshore wind turbines would all be banned under the "currently unavoidable use" construct.[7] For many of these products, like PVDF separators in EV battery and energy storage products, continued innovation will require greater usage of fluoropolymers, not less, to achieve the efficiency and safety standards demanded by customers and consumers.[8]

As written, the current proposed language does not create any carve outs for renewable energy systems, and energy developers and utilities would find themselves cut off from accessing necessary renewable energy solutions. Without these key technologies, Maine would not be able to decarbonize its grid and roads to meet its statutory requirements, and would continue its reliance on liquefied natural gas and other fossil energy. Furthermore, with New England continuing to close current and prevent future natural gas infrastructure, ratepayers in Maine will continue to see increased costs for basic utility functions without renewable resources bridging the gap.

We encourage the Maine DEP to take all measures to implement this statute while maintaining regulatory certainty and U.S. competitiveness in critical product supply chains. It is vital that non-problematic fluoromaterials are not only allowed in commerce, but have sufficient demand and the regulatory certainty to maintain cost-competitiveness. Thank you for your consideration of our comments.

Very truly yours,

David A. Cetola
Vice President, Global Government Affairs
Syensqo Group
dave.cetola@syensqo.com

[7] https://www.americanchemistry.com/chemistry-in-america/chemistries/fluorotechnology-per-and-polyfluoroalkyl-substances-pfas/pfas-critical-to-renewable-energy
[8] *See https://www.uschamber.com/assets/documents/Essential-Chemistries_-Providing-Benefits-Across-the-U.S.-Economy.pdf*

ANNEX

Introduction

Fluoropolymers (FPs) and Perfluoropolyethers (PFPEs) are known to have an extremely high thermal, oxidative and chemical stability. Most of the technical knowledge about the stability of FPs and PFPEs is related to test conditions which simulate their use (often by accelerated tests); conditions that are in general harsher than the environmental conditions that a FP can experience if released into the environment (e.g. landfill). FPs are thermally, biologically, and chemically stable, barely soluble in water, immobile and insoluble in organic solvents.

FPs are the only materials that simultaneously possess heat resistance, weather resistance, chemical resistance, water repellency, lubricity, and unique optical/electrical properties, and they have become indispensable materials in many fields, including the energy field (fuel cells and lithium-ion batteries), semiconductor field (clean members, etching gas), electrical and electronic communications field (wire cladding and liquid crystal materials), transportation field (cars, airplanes, railroads), oil & gas industry field and medical field (catheters, protective clothing).

Many sectors of use of FPs – such as aerospace and transportation, construction, medical devices, electronics, food processing, and water and wastewater treatment - are regulated by strict standards to ensure the highest level of safety and performance. Other industrial sectors require a high level of protection for both the workplace and the environment. For instance, in the chemical processing sectors, it is necessary to prevent any leakage of hazardous chemicals from pipelines, vessels, pumps and valves. FPs coatings and sealings are often considered the only suitable option to reach the highest level of safety in this application field.

FPs find application in medicine and biomedical fields, where biocompatibility and inertness are key properties. FPs are also applied in medical diagnosis and cure, from nuclear magnetic imaging (due to high F content and short T1 and long T2 relaxation time), drug delivery, and tissue engineering. FPs are also used to enhance the effectiveness of PDT (Photo Dynamic Therapy). Moreover, an important application of FPs is in the development of membranes for blood separation, or as the base polymer matrix for implantable devices. Other examples of essential medical equipment include cables with FP insulation are suitable for very high frequency signals, which is essential for transmitting huge amounts of data generated by MRI, PET, and CT scans. Additionally, FPs are biocompatible according to ISO 10993, which means that they can be placed in physical contact with patients' skin. Most potential alternatives have not been certified as biocompatible.

Additionally, due to their molecular weights with controlled viscosities along with very high purity levels, these materials are an excellent choice for membranes covering a broad range of porosity and shapes. Indeed, FPs find application in water purification/filtration for drinking water and for wastewater treatment. Syensqo's FPs are used to make microfiltration and ultrafiltration flat sheet and hollow fiber membranes for a wide range of bioprocessing and medical filtration applications. For instance, PVDF (Solef®), ECTFE (Halar®), PTFE (Algoflon®) and PFSA (Aquivion®) are applied under different forms (e.g. pellet, powder, membranes or dispersions) in membranes and filtration systems.

The fluoropolymers mainly used for lubrication purposes are Polymist and Algoflon®, used as friction and wear additive or grease thickener, and PFPE oils (Fomblin®), used on its own or as base oil in grease formulation or in combination with PFAS-based solvent as carrier/deposition. Due to its compatibility/solubility in PFPE lubricants, functionalized PFPEs, Fomblin® PFPE and Fluorolink® PFPE, can be used as additives in PFPE oil, PFPE based grease/paste or in combination with PFAS-based solvents to impart corrosion protection to metallic part such as, no limited to, rolling bearings. PFPE based lubricants are used in a broad range of applications in which the harsh condition makes it impossible for other materials to reach the desired performance and the safety requirements. PFPE-based lubricants combine the low coefficient of friction with excellent resistance to chemicals and extreme temperatures (-80°C to over 270°C), while at the same time being non-flammable, allowing for extended durability in use. In addition, PFPE-based lubricants being non-toxic, odorless, dielectric, offering excellent compatibility with materials (plastics, elastomers) and resistance to high pressure oxygen (liquid & gas) provide safety in use in multiple sectors.

Overall, FPs and PFPEs are a versatile group of substances used in a very broad range of applications. For most of the applications and sectors they represent the state-of-the-art materials thanks to their unique combination of properties. Their performance together with their extreme durability has made these products ubiquitous in many industrial sectors.

As detailed in our separate submissions accompanying this one, the analysis of alternatives concludes that these currently remain the sole suitable materials for applications requiring resilience to extreme temperatures, adverse chemical agents, mechanical stress, and resistance to oil and water, or a low coefficient of friction.

The relevant product family names and HTS codes are listed below. However, these are only representative of our products which are considered raw materials to finished articles and not the finished articles themselves that downstream users produce.

ALGOFLON®/POLYMIST® PTFE (Polymers of tetrafluoroethylene) - HTS 3904610090
HYLAR®/SOLEF® PVDF (Homo- and co-polymers of vinylidene fluoride) - HTS 3904695000, 3911902500
TECNOFLON® Fluoroelastomers (Copolymers of vinylidene fluoride/hexafluoropropylene/others) - HTS 3904691000
AQUIVION® PFSA (Copolymer of tetrafluoroethylene and perfluorosulfonylvinylether) - HTS 3904695000

SYENSQO
ADVANCING HUMANITY

HALAR® ECTFE (Copolymers of ethylene and chlorotrifluoroethylene) - HTS 3904695000
GALDEN®, FLUOROLINK®, FOMBLIN® Perfluoropolyethers - HTS 3907290000
There are other product HTS codes that contain PTFE and/or other PFAS that are an integral part of the composition. Due to the short time period for response this list may not be exhaustive: 391190250, 3908907000, 3208900000, 3907300000, 3910000000, 3911902500, 3911904500, 3921904090, 6815120000, 6815130000, 7019120080, 7019519090, 7019694021 and 7019901100.

Batteries and E-mobility

Batteries are essential for powering a wide range of applications, from smartphones and power tools to mission-critical assets like data centers and nuclear power plants. They are critical enablers of the growth of electric vehicles, e-bikes, and e-scooters, contributing to economic development and job creation. Additionally, batteries play a vital role in powering machines such as drones, rockets, and satellites, as well as providing energy storage for electrical grids.

FPs are largely used in the energy sector, covering a wide field of applications, including conventional energy generation and renewables technologies. Specifically, they find extensive application in the production process of Li-ion batteries, where FPs constitute essential components.

Batteries consist of two electrodes, a separator and an electrolyte. Each electrode consists of an active material mass which is coated onto a current collector. As chemical resistance and tolerance to a high range of working temperatures are crucial for batteries, PFAS, and in particular FPs, are used in key components for all high performance and lithium battery technologies, mainly in active material masses, electrolytes, valves, gaskets, washers, membranes, and coatings.

As reported by RECHARGE[9] batteries are a main enabler for the transition towards low-emission mobility, decarbonised energy generation and digitalisation and contribute to generate significant economic growth and provide jobs for millions of people. Due to their unique properties, both polytetrafluoroethylene (PTFE) and polyvinylidene difluoride (PVDF – both homopolymer and copolymer) are used as binder materials in the active material masses in electrodes in a wide range of battery technologies.

PVDF binders have several roles inside the battery, they help to disperse the active material and the conductive additive in the solvent during the fabrication process; they hold the active material and the conductive additive together and connect them to the current collector, ensuring the mechanical integrity of the solid electrode without significantly impacting electronic or ionic conductivity; they act as an interface between the composite electrode

[9] Europe's industry association for advanced rechargeable and lithium batteries

and the electrolyte. As mechanical degradation of electrodes is believed to be one of the key mechanisms that limits battery life, binders with excellent properties are a key component to maximizing battery life. PVDF has several unique enabling properties, such as chemical and electrochemical stability which are essential properties to enable the binder to function for long periods and over numerous cycles without degradation of the battery. PVDF is the only proven material that can sustain a large voltage range from 0 to 5V at industrial scale for various battery designs and high-capacity cells. This stability guarantees its safe use in the electrochemical environment of the lithium cell. The insolubility of PVDF in the liquid electrolyte is advantageous for lithium-ion batteries because it provides stability and prevents the binder material from leaching into the electrolyte, which could negatively impact the performance and safety of the battery. Additionally, PVDF enhances mechanical properties, including stiffness, toughness and hardness as well as good adhesion to the active material, the conductive additive, and the current collector. PVDF ensures the flexibility of electrodes. The positive electrode binder must be able to withstand the forces that result from the expansion and contraction of active materials during charge/discharge cycles; thermal stability is also important, both for the high temperatures commonly used for electrode fabrication and also for operation of the battery at various temperatures; good dispersive capabilities are important to help distribute the slurry evenly over the current collector during fabrication. PVDF binders, due to the C-F bond properties, offer higher stability due to their resistance to oxidation compared to non-fluorinated binders. They can also prevent self-discharge by inhibiting some electrochemical reactions and thus improve the energy density as well as lifespan of the battery. PVDF stability avoids degradation of the polymer during the use stage, and potential emissions to the environment. Internal studies conducted at Syensqo demonstrated that no changes in PVDF structure were observed after recycling end-of-life PVDF compared to virgin PVDF. Recycling of lithium-ion batteries is a rapidly growing industry, which is vital to address the increasing demand for metals, and to achieve a sustainable circular economy. Currently, relatively little information is known about the environmental risks posed by LIB recycling. Many other binder materials have been evaluated as replacements for PVDF. However – based on the current status of development - all other materials have been found to oxidize at the high voltage at the positive electrode. Syensqo's batteries solutions portfolio consists of products such as PVDF (Solef®) for binders and separator coatings. Syensqo also provides high-performance polymers, such as PTFE (Hyflon®), for cell gaskets and battery modules to reduce weight and improve battery safety.

The relevant product family names and HTS codes are listed below. However, these are only representative of our products which are considered raw materials to finished articles and not the finished articles themselves that downstream users produce.

ALGOFLON®/POLYMIST® PTFE (Polymers of tetrafluoroethylene) - HTS 3904610090
HYLAR®/SOLEF® PVDF (Homo- and co-polymers of vinylidene fluoride) - HTS 3904695000, 3911902500

TECNOFLON® Fluoroelastomers (Copolymers of vinylidene fluoride/hexafluoropropylene/others) - HTS 3904691000

Availability of alternatives
The only type of rechargeable battery which does not use PFAS is lead-acid batteries. However, it must be pointed out that lead-acid batteries have low energy density and cannot serve the various and technologically complex sectors that currently use PFAS in batteries. Indeed, PFAS-based batteries serve applications where a variety of performances are required, amongst which are high energy, high power, very long life, superior reliability, ability to withstand extreme temperatures. Lead-acid batteries have limited capacity in these respects and cannot be considered as suitable alternatives.
Additionally, it is deemed that for the following uses, as of today, there are no available alternatives:

- PVDF as the binder of the active material masses
- PTFE as the binder of the active material masses
- Use of PFAS as electrolytes
- PTFE & FEP in gaskets & washers in chemically aggressive environments
- PFA, VDF, HFP, FKM in gaskets in high performance batteries which require very thin high-performance gaskets
- PTFE in oxygen permeable membranes in Zinc air batteries
- PTFE / PVDF in solid electrolyte/ gel polymer in solid-state batteries

Hydrogen

The emerging hydrogen technologies rely heavily on FPs, including membranes used in electrolysis (proton exchange membranes – PEM, alkaline electrolysers – AEL, anionic exchange membrane electrolysers – AEMEL), compressors used in biomass gasification and biogas or methane reforming, as well as in hydrogen storage and transport applications (valves, sealing and pipes).

Electrolysers are a crucial technology for green hydrogen production using electricity from renewable sources. It is a new technology which is projected to grow rapidly worldwide in the coming years.

In the hydrogen industry, electrolysers and fuel cell applications are fundamental technologies that rely on FPs as key materials for their production. Other demanding complementary industrial processes are also essential for the development of the hydrogen economy. Ultimately, fuel cells, electrolysers and those industrial processes are heavily reliant on the use of FPs. As mentioned, the hydrogen industry has great potential to provide a decarbonization pathway for energy-intensive industries, such as the steel industry, acting both as feedstock and fuel source.

Syensqo's offer to the hydrogen industry includes high-performance FPs including Aquivion®, which find use from the core to the stack, to the plant. Common applications include membranes, electrode binders, hydrogen gaskets, diaphragms, enclosures, hydrogen cell frames and end plates, in addition to uses in thermal management and air systems. FPs are also key materials in Carbon Capture, Utilisation and Storage (CCUS) technologies and hydrogen end use applications, spanning from mobility uses to industrial off-takers, such as ammonia or steel production.

The relevant product family names and HTS codes are listed below. However, these are only representative of our products which are considered raw materials to finished articles and not the finished articles themselves that downstream users produce.

AQUIVION® PFSA (Copolymer of tetrafluoroethylene and perfluorosulfonylvinylether) - HTS 3904695000
HYLAR®/SOLEF® PVDF (Homo- and co-polymers of vinylidene fluoride) - HTS 3904695000, 3911902500
TECNOFLON® Fluoroelastomers (Copolymers of vinylidene fluoride/hexafluoropropylene/others) - HTS 3904691000
HALAR® ECTFE (Copolymers of ethylene and chlorotrifluoroethylene) - HTS 3904695000

Availability of alternatives

Electrolysers and fuel cell applications represent pivotal technologies for the hydrogen industry, strongly reliant on the use of FPs. Due to the high specialized material technologies, the industry has thus far not identified any alternative materials that could substitute FPs in the current applications. No alternative is foreseen today or in the near future for the substitution of FPs in the key application of hydrogen technology, thus making the use of FPs crucial for a transition towards climate neutrality. As reported by Chi Hoon Park et al[10], there have been researches ongoing on sulfonated hydrocarbon membranes for medium-temperature and low-humidity PEM fuel cells (PEMFCs) as potential alternatives to fluorinated materials. However, as concluded by the authors of the study, although properties and performance of these materials may be seen as promising, their durability is generally regarded as poor, due to the oxidation by oxygen radicals. Additionally, at the current development stage, the technology is not mature enough to be considered for industrial application.

Although certain indicators of performance of non-PFSA membranes can suggest their relevance from an alternative standpoint, these non-PFSA membranes (such as hydrocarbon) in electrolyser applications have failed to demonstrate a pathway to commercial lifetimes (>50,000h for electrolyser applications) or at relevant temperature (>79°C). The timeframe required for developing and implementing an alternative must as

[10] Sulfonated hydrocarbon membranes for medium-temperature and low-humidity proton exchange membrane fuel cells (PEMFCs) - ScienceDirect

well be closely considered: as reported by Hydrogen Europe[11], suitable chemistry would need to be found to accommodate for this major barrier. If, and only if, suitable chemistry (with overall reduction of risk through lifecycle) was to be identified one day, deployment cycles are in 10-year timeframes, with a minimum of 5-year demonstration period with reasonable scale, i.e. adding another 15 years on top of the time required to find the substance.

Automotive

Within the automotive sector, FPs find application in several key technical components, such as gaskets, hoses, joints, O-rings, seals, cords, cables, or sleeves. Additionally, they are applied in articles that constitute part of components used in automotive, such as membrane in the fuel cell or bearing shafts in air conditioner compressors.

The automotive industry's International Material Data System (IMDS), taken in Q1, 2022, provide a clear overview on the impact and utilization of PFAS and PFAS-based articles in the automotive industry:

- Nearly 8 million automotive parts contain PFAS substances.
- Over 5 million of these parts contain FPs and fluoroelastomers.
- The largest reported PFAS is PTFE , which is used in nearly 4 million automotive parts.
- PTFE counts for nearly 50% of the total reported PFAS in automotive parts and more than 70% of fluoropolymer uses.
- Fluoropolymer use impacts hundreds of automotive applications, which will need to be evaluated.

FPs are used in the transport sector primarily due to their resilience, broad thermal and chemical resistance and low friction properties, as well as due to their resistance to swelling and permeability. It is important to remark that many components based on FPs are in fact instrumental to the vehicle emission control (CO_2 and NO_x) and to the reduction of the fuel consumption. In conclusion, due to their physicochemical properties, FPs reduce evaporative emissions contributing to a cleaner environment.

The number of applications of FPs and PFPEs in the automotive sector is very extensive, a non-exhaustive list of applications is provided here:

- Components of electrical vehicles, such as electric motors, cables for electrical gears and Li-ion batteries
- In every Li-Ion battery, PVDF is used as binder in the cathode and separator coating and often even as key material for the separators and FKM gaskets are largely used as well
- Wires and cables for energy and data distribution (for communication and systems' control) in land vehicles

[11] European association of the Hydrogen Industry

- Cables in land vehicle catalysts and NOx, oxygen and lambda sensors which monitor the vehicles emissions and carbon footprint, contributing to emission control.
- Land vehicle wheel bearing seals and in general seals protecting automotive bearings.
- FKM seals in combustion engines, water and oil filters, shock absorbers, cooling systems, turbochargers, gearboxes and transmissions, E-axles, crankshafts, clutches.
- Low permeability FKM layers in the Fuel hoses and filler neck hoses, air Ducts (Turbo chargers) and Exhaust gas recirculation hoses used for the engine efficiency and the emission reduction. Both systems need FKM as the inner layer.
- Perfluorinated ionomers are used as membrane and electrode binder materials in fuel cell catalyst coated membranes (CCMs) and membrane electrode assemblies (MEAs) which are components in fuel cell stacks in fuel cell engines-in automotive.
- Sensors (pedal, battery, oil, radar, rain-light, ABS NOx, Oxygen, Temperature)
- Ionomers, specialized FPs with ionic properties, are used in ion exchange membranes (IEMs) that provide mechanical and chemical stability while delivering high proton conductivity. IEMs are critical components in fuel cells, while other FPs find use in batteries, sensors and circuits that are enabling the evolution of the transportation industry.
- Lubrication of sintered metal bearings in A/C electric fan, rolling bearing, electrical contacts & switches, fuel tank sensors, throttle valves, EGR - Exhaust Gas Recirculation valves, sunroof sealing, electronic window motors, spark plug boots, HVAC plastic gear boxes, ABS systems, weatherstripping.
- Lubrication of plastics & elastomers for Aid assembly during the manufacturing of the car.

PFPEs are widely used in the automotive sector as lubricants since combining a unique set of properties in a wide temperature range (low & high) and offering safety (non flammable, no failure due to stress cracking in contact with plastics & elastomers). Moreover, PFPEs are used in the automotive sector as "lifetime" lubricants and the use of alternative lubricants may bring a reduction in sustainability. PFPEs have peculiar properties (such as, among other low friction properties, durability, hydrophobicity, temperature/heat resistance, chemical stability) that make them irreplaceable in specific lubrication applications.
PFPEs lubricants are essential for the automotive industry since they take on different functionalities in different parts of the vehicle, e.g. low friction, heat/temperature resistance, durability, chemical stability, long lasting functionality. These functionalities of the PFPEs are in many cases simultaneously needed and no alternative lubricant can take over all this in once. As the PFPEs with those functionalities are relatively expensive they are only used in very specific cases, e.g. in harsh conditions where no other alternatives can be used (high temperature differences, a product/part cannot be replaced easily and in case several of above-mentioned functionalities must be fulfilled simultaneously). In addition, non PFPE based lubricants would lead to higher costs for the customer due to increasing maintenance frequency (regreasing/relubrication).

Syensqo portfolio of high-performance materials used in the automotive sector features Tecnoflon® FKM, used in the production Engine seals, transmissions, Exhaust Gas recirculation systems, sensors, Turbo systems, brakes , and Fomblin® PFPE which is used in the production of brake systems and transmission.

The relevant product family names and HTS codes are listed below. However, these are only representative of our products which are considered raw materials to finished articles and not the finished articles themselves that downstream users produce.

TECNOFLON® Fluoroelastomers (Copolymers of vinylidene fluoride/hexafluoropropylene/others) - HTS 3904691000
FOMBLIN® Perfluoropolyethers - HTS 3907290000
HYLAR®/SOLEF® PVDF (Homo- and co-polymers of vinylidene fluoride) - HTS 3904695000, 3911902500
ALGOFLON®/POLYMIST® PTFE (Polymers of tetrafluoroethylene) - HTS 3904610090
AQUIVION® PFSA (Copolymer of tetrafluoroethylene and perfluorosulfonylvinylether) - HTS 3904695000
There are other product HTS codes that contain PTFE and/or other PFAS that are an integral part of the composition. Due to the short time period for response this list may not be exhaustive: 391190250, 3908907000, 3208900000, 3907300000, 3910000000, 3911902500, 3911904500, 3921904090, 6815120000, 6815130000, 7019120080, 7019519090, 7019694021 and 7019901100.

Availability of alternatives
It has been widely commented by various stakeholders in the automotive sectors (e.g. ACEA, Ford, Tesla, KAMA, JAMA, FPG etc) that there is no actual viable alternative for several FPs applications. In particular, it has been noted that no viable alternatives exist for the dynamic seals in the gearbox. Lubricating fluids used in gearboxes (ATF) do contain special additive packages for the reduction of wear, increasing service intervals, increasing resistance to micro-pitting and they are all chemically aggressive for the non-fluorinated candidate sealing materials, such as AEM, ACM, HNBR or NBR. Immersion tests at 130°C and 150°C for a period of 1000h in gearbox fluids show that only FKM seals can maintain the sealing properties and ensure the safety and the warranty of the automotive transmissions.
While the alternatives maturity is not fully clear to the actual automotive manufacturers, the wide variety of applications described above suggest that to achieve the same properties granted by the use of FPs this substitution could affect the very design of these applications making their validation and implementation much more complex. As an example, the substitution of the air conditioning gasses would need to redesign the entirety of the mobile air conditioning system, and with it the entirety of the vehicle.
Regarding PFPEs, currently no substances are available taking over the whole bundle/package of functionalities of PFPE in lubricants. Additionally, it is not possible to estimate any costs for alternatives as no alternatives are available on the market to

substitute PFPE in lubricants in our products which takes over all the functionalities mentioned prior. Therefore no cost comparison is possible.

Aeronautics

FPs and PFPEs are widely used in the aerospace industry for their general ability to withstand harsh conditions, with some sub-uses and end-applications similar to the ones described for the automotive sector. Indeed, in the aeronautic sector FPs are widely used as gaskets, hoses, joints, O-rings, seals, cords, cables, or sleeves inside the aircraft.

Other uses within the aerospace industry include:

- Safety wires used in aircraft engines in high temperature areas. In addition, conventional manual flight controls have been replaced by an electronic system which has as primary benefit weight reduction. PTFE as insulation provides excellent electrical resistance combined with fire resistance and low smoke.
- FPs are widely used in commercial and military airplanes, due to their excellent thermal stability that helps insulate the cables that run through the aircraft, their superior resistance to aging, radiation and fire and their chemical compatibility, which allows the safe and durable flow of fuel and other aircraft fluids.
- Components such as seals, hoses and wiring needed to withstand extreme temperatures and aggressive chemicals in aircraft. Aircraft equipment must be resistant to many chemicals including jet fuel, engine lubrication oils, hydraulic fluids, rocket propellants and oxidizers. They must be able to do so at extreme (both very high and very low) temperatures. Fluoroelastomers seals allow all the equipment to withstand these aggressive substances increasing their lifetime, resulting in lower emissions and higher safety standards.

Aircraft interiors may also be coated with FP film, to facilitate safety, cleaning and anti-fouling over a long-life span. The FP coating also offers fire-retardant properties. FP parts in the aircraft must be able to withstand exposure to harsh chemicals, such as oils and fuels, including biofuels which may contain high levels of alcohol (methanol, ethanol) and environmental conditions (humidity, soil / dirt). Their high chemical compatibility ensures the right level of performance and safety of all the critical parts (engine, fuel systems, emission control systems, thermal management, transmissions).

The space community has come to rely on PFPE-based lubricants, whose characteristics (low outgassing, low temperature performance, outstanding stability in the presence of oxygen) offer long-life lubrication for equipment functioning in space for years unattended with no opportunity to relubricate. Some applications include:

- Lubrication of the Space Shuttle: wing flap and tail rudder/speed brake actuators, hydraulic system, cargo bay doors/bay lift arm, crew seat adjustments gears and the oxygen system.
- Lubrication of Space Suit: breathing pack and arm/leg joints bearings.

- Lubrication of Hubble Space Telescope: optical adjustment bearings and gears.
- Lubrication of Space Station: oxygen system, docking hardware, treadmill, instrument bearings, valves and switches.

PFPEs are also widely used as lubricants and coating materials in the aerospace industry.

Regarding Syensqo's product portfolio, we offer various solutions that support the aerospace industry and aircraft OEMs with a range of beneficial performance and process capabilities. Among others, our products include a selection of specialty polymers indicated for aerospace propulsion solutions, such as:

- Ajedium® film (made from Halar® ECTFE) offers excellent adhesion to composite substrates and superior aesthetic surfaces. It is used as protective layer on the engine acoustic ring panel against the aggression of the harsh environment typical of the entrance of an aircraft engine;
- Tecnoflon® Fluoroelastomers (FKM) and Perfluorelastomers (FFKM) - These highly resilient synthetic rubbers retain critical properties in chemically aggressive environments at extreme temperatures. Tecnoflon® FKM and FFKM are also highly resistant to UV light and ozone and perform best in O-rings and seals for hydraulic systems.
- Composite Materials are used in aerospace, security and defense products.

The relevant product family names and HTS codes are listed below. However, these are only representative of our products which are considered raw materials to finished articles and not the finished articles themselves that downstream users produce.

TECNOFLON® Fluoroelastomers (Copolymers of vinylidene fluoride/hexafluoropropylene/others) - HTS 3904691000
HALAR® ECTFE (Copolymers of ethylene and chlorotrifluoroethylene) - HTS 3904695000
There are other product HTS codes that contain PTFE and/or other PFAS that are an integral part of the composition. Due to the short time period for response this list may not be exhaustive: 391190250, 3908907000, 3208900000, 3907300000, 3910000000, 3911902500, 3911904500, 3921904090, 6815120000, 6815130000, 7019120080, 7019519090, 7019694021 and 7019901100.

Availability of alternatives

The situation on alternatives for the aeronautics sector is mostly similar to that of the automotive sector – where no alternatives to FPs and PFPEs are currently viable. Moreover, in the Aerospace sector, the implementation of new alternatives would need much more time. Indeed, in this particularly high-tech and heavily regulated environment, finding and deploying safe alternatives to FPs will take much longer. With no known suitable replacements for PTFE as insulating material, and given the number of critical implications it covers, it is fair to conclude that phasing out those substances may take a similar amount of time, if not longer.

SYENSQO
ADVANCING HUMANITY

The Aerospace, Security and Defence Industries Association of Europe (ASD) has provided[12] a precise description of all the uses that are relevant for the Aerospace industry and for which no alternatives are available.

Semiconductors

The semiconductor industry serves several end-use markets including automotive electronics, computing & data storage, consumer electronics, industrial electronics, wired communications and wireless communications. Semiconductor devices are essential components of electronic devices and are at the center of technological advancements and an enabling technology for a number of key applications that make a significant contribution to society.

FPs possess a unique set of characteristics that are required for many of the critical articles and the use is often required by safety and insurance guidelines. FPs are also required to prevent particle generation which is detrimental to semiconductor production yield.

Semiconductor devices (also known as "chips", or "integrated circuits") are essential components of electronic devices. Semiconductor devices are extremely complex to manufacture. This requires the utilization of process chemicals, manufacturing equipment, and manufacturing facility infrastructure which may contain PFAS substances. PFAS, and specifically FPs, provide specific and unique capabilities within semiconductor process chemistries, semiconductor manufacturing equipment and facilities, as well as the electronic products they drive. Without PFAS, the ability to produce semiconductors and the facilities and equipment related to and supporting semiconductor manufacturing would be put at risk. FPs are essential components for the electronics and semiconductor sectors, having several applications because of their durability in a broad spectrum of extreme conditions (temperature, pressure, chemicals, mechanical stress, high energy plasma, high vacuum). They are considered essential by most manufacturers of electronic equipment, as alternative materials cannot meet the necessary specifications and could have higher risks compared to FPs.

FPs are broadly used in cables and wires, as they are the only materials that can withstand very high temperatures, exposure to chemicals, as well as mechanical stress. Their very good flexibility is another factor contributing to the popularity of FPs as cable jacketing.
Additionally, FPs resins and coatings grant speed and low latency to communication equipment used in the recently developed 5G technology.

FPs and PFPEs are used in the semiconductors sector in the following forms:

- Articles (FP pipes, ducts, fittings, valves, parts, seals) used in semiconductors manufacturing plants infrastructure, for ultrapure water systems, exhausts, chemical

[12] ASD submission to 2nd Stakeholder Consultation on EU REACH PFAS Restriction

delivery systems where a high degree of cleanliness and precision is required, while ensuring long lasting and safe operation.

- Heat transfer fluids (PFPE) used in chillers for their wide temperature range of operation, electric properties minimizing process interferences, non toxicity, non flammability, and non contaminant impact on the chips.
- Test fluids (PFPE) used in test equipment for immersion testing, thermal shock testing and thermal cycling thanks to their wide temperature of operation, electric properties and outstanding material compatibility.
- Lubrication fluids (PFPE) and grease component (PFPE/PTFE paste) used in vacuum pumps for bearings and gear box lubrication for harsh condition processes (high temperature, harsh gasses and chemicals, high vacuum) thanks to their low outgassing, wide temperature range of operation, non toxicity, non flammability, and non contaminant impact on the chips.
- O-rings, seals, flanges (FP) used in processing tools for sealing applications thanks to their low outgassing properties, resistance to chemicals and high energy plasmas, wide temperature range of operation
- As formative / protective coating on electronic parts and semiconductors to protect from harsh conditions. Printed circuit boards are an example, with numerous extensions, of where such a coating can be applied.
- FP components in hard disk drives can also extend the life of those parts that need a high dielectric strength.
- In vapor phase soldering equipment where PFPEs fluids bring precise temperature control, thus increasing yield and also enabling replacing lead-based technologies.
- In sealing that can protect sensitive electronic components from external agents, such as moisture, acids or alkalis. This use also includes gaskets, O-rings and other sealing equipment or lining of tubing / pipes and other fluid-handling equipment, e.g., in *in vitro* diagnostic devices or cooled / refrigerated devices, to prevent leakage that could impair the function of the electronic component.
- As insulation and jacketing of cables used in devices, allowing these to operate at higher temperatures and harsher conditions for longer.

Many Syensqo products play a pivotal role in the semiconductors industry including ECTFE (Halar®), PTFE (Polymist®), PVDF (Solef®), amorphous FPs (Hyflon®) and PFPE (Fomblin® and Galden®).

<u>Halar® ECTFE</u>

Halar® lightweight, semi-crystalline, and melt-processable fluoropolymer offers complete chemical resistance to the full range of semiconductor chemicals and solvents. Halar® ECTFE exhibits a unique structure that enables an unparalleled combination of physical and mechanical benefits, in addition to abrasion, temperature, and fire resistance. With ultra-pure grades and a broad range of melt viscosities, Halar® ECTFE is an exceptional solution in many semiconductor processing applications, such as duct coatings and structural parts for wet cleaning equipment.

Galden® -PFPE

These inert, dielectric and high-performance heat transfer fluids offer low evaporation rates and low viscosity with boiling points ranging from 55°C to 270°C and an end-use temperature of up to 290°C. Because Galden® HT PFPE excels in a wide range of temperatures, specifically as heat transfer fluid with high boiling temperature for chillers, these solutions contribute to semiconductor devices that withstand highly aggressive operating conditions. Galden® HT PFPE products feature extremely low surface tension, low evaporation losses, and enhanced compatibility with a range of materials for effective wetting in almost all conventional sealing and gasket materials.

Fomblin® PFPE

The Fomblin® PFPE family of inert fluids offer low evaporation weight loss, excellent chemical inertness, and high-temperature resistance for semiconductor applications that require the highest-quality vacuum. These fluids exhibit excellent lubrication properties, outstanding compatibility with a broad range of materials, no flash or fire point, exceptional radiation stability, and high dielectric properties. Fomblin® PFPE achieves superior performance with low molecular weight variation, controlled viscosity, and extremely low vapor pressure in essential applications like lubrication for vacuum pumps.

Solef® PVDF

Solef® is a pure, non-reactive thermoplastic specially designed for semiconductor components and has been the go-to piping material for ultra-pure water systems in semiconductor fabs since the 1980s because of its high purity and low leachable. Solef® PVDF offers intrinsic chemical stability and fire and oxidation resistance to withstand some of the most aggressive environments without degradation.

Tecnoflon® FFKM

This family of fluoroelastomers is specifically designed for demanding applications, like seals and O-rings, in semiconductor processing. Tecnoflon® FFKM grades exhibit extremely high thermal resistance up to 340°C and are resistant to nearly all semiconductor chemicals. Additionally, these fluoroelastomers are formulated with superior strength, high purity, and good plasma resistance for excellent performance in long service life applications.

The relevant product family names and HTS codes are listed below. However, these are only representative of our products which are considered raw materials to finished articles and not the finished articles themselves that downstream users produce.

HALAR® ECTFE (Copolymers of ethylene and chlorotrifluoroethylene) - HTS 3904695000
GALDEN®, FOMBLIN® Perfluoropolyethers - HTS 3907290000
HYLAR®/SOLEF® PVDF (Homo- and co-polymers of vinylidene fluoride) - HTS 3904695000, 3911902500

TECNOFLON® Fluoroelastomers (Copolymers of vinylidene fluoride/hexafluoropropylene/others) - HTS 3904691000

Availability of alternatives

Data on alternatives for the application of FPs in the semiconductors sector do not find consensus among various stakeholders. While some alternatives could be already available on the market, it is worth mentioning that, for semiconductors, no drop-in substitution is feasible. Every use and application has to be re-engineered in order to evaluate if the new material will fulfill the specific requirements.

The European Semiconductor Industry Association (ESIA) has reported[13] that the semiconductor industry has been researching PFAS-free alternatives for 25 years. There may be some instances where substitution is possible. However, in most applications, no alternatives to FPs have thus far been identified. For instance, in most photolithography applications, PFAS-free materials have been found to be not technically feasible or ineffective. For many applications in the semiconductor industry it would be necessary to reinvent potential PFAS-free alternatives. Identifying and implementing is a lengthy process that involves academic research, material supplier research, development (validation), scale-up, and subsequent efforts by the semiconductor manufacturer for demonstration (verification), integration, implementation, and scale-up to high-volume manufacturing. Even though all PFAS uses have their specific challenges and timelines for development, it will take 15 to more than 20 years to develop PFAS-free alternatives for most of the photolithography uses.

Regarding the use of fluoroelastomers (FKM) and perfluoroelastomers (FFKM) as sealing agents during semiconductor manufacturing process, SEMI (global industry association representing electronic manufacturing and design supply chain) has evaluated[14] various PFAS-free alternatives, namely ethylene propylene diene monomer (EPDM), silicone rubbers, aryl ketone polymer (PEEK) and hydrocarbon elastomers. None of the alternatives assessed were able to meet all functionalities assessed, i.e. wafer contamination, chemical compatibility, safety/environmental protection and impact on the manufacturing process – showing how PFAS-free alternative to FKM and FFKM in the uses above outline is currently not available.

There are no known viable alternatives to lubricants used in the semiconductor production process as well as used in the photolithography process.

---

[13] ESIA submission to Stakeholder Consultation on EU REACH PFAS Restriction

[14] SEMI Assessment of Proposed Alternative Fluoroelastomers for Sealing

Industrial application (e.g., lubricants, sealant)

Sealing devices and materials serve a crucial role in the safe containment of fluids in several markets, including but not limited to automotive, aerospace, pharmaceuticals, industrial and mineral extraction. Industrial sealings are used to contain media inside hardware and the seal materials must withstand the environmental conditions of the application.

FPs and PFPEs are ubiquitous in every industrial plant. FPs are typically used in sealants, coatings on valves and piping, gaskets, personal protective equipment/ clothing, refrigerants, membranes, filter materials and membranes, foams, greases/ lubricants, mold release, conveyor belts, O-rings, columns/ internals, diaphragms, processing aids, etc. Without these materials and pieces of equipment, industrial plants can no longer operate. PFPEs lubricants are used in lubricant applications across various sectors, where they provide a low coefficient of friction that is important for the machineries and for all other equipment to function as required. The FPs mainly used for lubrication purposes are PFPE oils and PTFE micropowders. PFPEs are used as lubricating oil on its own, or in formulation with functionalized PFPEs for example to enhance corrosion resistance of the lubricated metal parts. In addition, PFPE-based lubricants are resistant to chemicals and to high pressure oxygen (liquid & gas) providing safety in use in oxygen equipment such as valves, pumps and compressors for the chemical industry. PFPE-based grease offer high temperature (> 200°C) and corrosion resistance in several bearing applications such as, not limited to, corrugator paper machines. The unmatched high temperature resistance of PFPE-based grease makes it the lubricant of choice for the tire mold lubrication, adequate lubrication of the segments during the tire manufacturing / vulcanization step, reducing downtime and maintenance. PTFE micropowders are used as additives in lubricating greases and coatings. They are used when a low friction coefficient (-75°C to over 270°C) is needed in a broad range of temperature. They can also be used in inks for various applications and in various coatings and paints, where abrasion resistance is required. As such FP lubricants are used across a broad range of applications, including the chemical sector, automotive and transportation in general, industrial machinery and the semiconductor industry, especially where high temperatures are expected, due to the high heat resistance of FPs. They can also be used as additives in waxes, inks, paintings, thermoplastics, elastomers, synthetic oils, and greases. The family of high-performance lubricants, Fomblin® PFPE offers unmatched performance in several industrial applications. These inert FPs are a material of choice for lubricants for industrial electronics, as they are engineered specifically for applications where heat, chemicals, solvents, corrosion, flammability and service life pose notable lubrication challenges. Sealants FPs are widely used in industrial settings as molded sealing components to prevent leakage of hazardous or infectious agents in industrial processes, FPs sealants are used to meet extreme operating conditions (heat, corrosion, pressure, etc.) without which equipment could not guarantee the safety and reliability of industrial infrastructures. It is worth mentioning that many of the sectors where FPs based sealings are used are heavily regulated so any change to the materials used would need many years to be accepted and regulated. Sealants play a role in increasing the efficiency of energy and industrial infrastructures, as well as preventing methane and CO2 leakages. Sealing devices are also critical to green technologies such as CCUS and Hydrogen. Our portfolio of diverse materials for industrial coatings and sealings includes industry-proven solutions to guarantee enhanced quality, protection and durability. Our portfolio of trusted specialty polymer solutions feature brands such as Hylar® PVDF, Polymist® and Algoflon® L PTFE Micronized Powders and Halar® ECTFE.

The relevant product family names and HTS codes are listed below. However, these are only representative of our products which are considered raw materials to finished articles and not the finished articles themselves that downstream users produce.

FOMBLIN® Perfluoropolyethers - HTS 3907290000
HYLAR®/SOLEF® PVDF (Homo- and co-polymers of vinylidene fluoride) - HTS 3904695000, 3911902500
ALGOFLON®/POLYMIST® PTFE (Polymers of tetrafluoroethylene) - HTS 3904610090
HALAR® ECTFE (Copolymers of ethylene and chlorotrifluoroethylene) - HTS 3904695000
TECNOFLON® Fluoroelastomers (Copolymers of vinylidene fluoride/hexafluoropropylene/others) - HTS 3904691000

Availability of alternatives

Finding an alternative that has similar properties to FPs lubricants and PFPEs lubricants is challenging for many applications. In general, using a lower performing lubricant would result in a shorter lifetime, higher costs due to the more frequent replacements and in some cases an increase of the safety-risk. None of the alternatives that have been suggested would be able to fit all the functionalities achieved by using FP and PFPEs lubricants. Moreover, it has to be noted that many of the proposed alternatives could pose a more severe risk to human health and to the environment than the FPs and PFPEs that they would substitute.

Oil and Gas

FPs are widely used in the oil and gas industry, which involves the transfer of aggressive chemical agents, such as oils, acids and petroleum and gas products, and is also exposed to harsh environmental conditions.
Oil and gas drilling requires the use of “downhole” fluids that contain aggressive additives. In addition, the pumped liquids contain a broad mix of compounds that can degrade piping and pumping equipment. The drilling equipment can also be exposed to high temperatures and pressures.
FPs are used in the sealings for pipes, valves and joints and as inner liners and coatings for piping and high-pressure hoses, due to their high chemical and heat resistance. Other examples of equipment using FPs includes exploration seals, on/off and control valves for fluids, pumps, actuators and control accessories.

Similarly, FPs low permeation rate also makes FPs an ideal material for seals, valves and pumps for gas transfer and storage equipment, as they minimize leakage.
They are also used as insulation and jacketing of cables used in drilling as well as in surface and downhole cables and subsea cables for offshore installations. Use of FPs in cables allows for the cables' downsizing, making them more suitable for downhole applications (e.g., data logging, trace heating and ESP power cables).
Syensqo's Fomblin PFPEs products have a temperature resistance up to 290 °C, significantly above the usual operational temperatures in Oil&Gas applications, making them the products of choice for this particular sector.

The relevant product family names and HTS codes are listed below. However, these are only representative of our products which are considered raw materials to finished articles and not the finished articles themselves that downstream users produce.

HYLAR®/SOLEF® PVDF (Homo- and co-polymers of vinylidene fluoride) - HTS 3904695000, 3911902500
TECNOFLON® Fluoroelastomers (Copolymers of vinylidene fluoride/hexafluoropropylene/others) - HTS 3904691000

Availability of alternatives

Several downstream users have reported that, for what concerns the O&G sector, no feasible alternative to FPs based gasket and O-rings exist on the market, so a very long period of time would be needed to allow the implementation of an alternative inside the oil&gas industry.
The use of less safe materials for both the downhole liquids and sealing equipment /gaskets and O-rings) would result in higher risk of leakages and environmental spills.