



PFAS **EXPLAINER**

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1. Introduction

Welcome to the **SEMI PFAS** information "Explainer". It is intended primarily to provide companies in the semiconductor manufacturing supply chain with some basic and some detailed information about PFAS. It focuses on components that are incorporated into semiconductor manufacturing equipment (sometimes known as "tools" in the semiconductor industry) and the equipment that is built into semiconductor manufacturing facilities. For an overview of the inputs, infrastructure and equipment used for manufacturing semiconductors, refer to [Appendix A. SEMICONDUCTOR MANUFACTURING PROCESS & SEMICONDUCTOR USES](#).

Semiconductor manufacturing equipment includes ingot saws, chemical mechanical polishing (CMP) systems, etch systems, chemical vapor deposition (CVD) systems, coater developers, lithography systems, ion implantation systems, wafer cleaning systems, metrology systems, prober/testers, and many others. Semiconductor facilities equipment includes: distribution and purification/treatment systems for water, process chemicals, cleanroom air, and manufacturing equipment emissions/exhaust; workpiece (wafer) transport and stocker systems; clean room wall panels; clean room clothing; and many other items. "Equipment" is used on this webpage to represent all of these products.

The term 'component' means an item acquired by an equipment manufacturer to make their product. A component can be as simple as a cable tie or as complex as a wafer handling robot system. An 'article' is essentially a piece of hardware that has at some time existed independently. Components are also articles. 'Part' has a broader meaning and is used for components, assemblies of components, and occasionally items within a component.

This Explainer was developed by the **SEMI PFAS** working group and is maintained under their oversight.

This guide aims to be as clear and concise as possible, while also explaining some of the important, but finer points in the PFAS discussion with sufficient detail. In the interest of making this information available as quickly as possible, some organizational clarity may have been sacrificed. The working group plans to restructure this information in the next few months to assist comprehension. If you have any concerns about the information on this page, or would like to offer some additional ideas for it, please contact ehs@semi.org

2. The PFAS Concern for Industry

The PFAS concern is related to a large family of substances that have certain types of bonding between fluorine and carbon atoms. It began with a focus on only a few substances (e.g., PFOA and PFOS) but has now expanded to a group of several thousand substances.

Some of the earliest PFAS substances were developed in the 1940's. Since then, the development of PFAS substances has grown exponentially. PFAS have enabled every aspect of our modern society from chemical processing and medicine to the millions of devices that comprise our massive computation and communications infrastructures.

In the 1950s, information that was not broadly available demonstrated health concerns with some early PFAS non-polymer substances. This was followed by more publicly available investigations into some of these same PFAS non-polymer substances that were poorly managed at the substance manufacturing sites and at factories where the substances were

used in the manufacture of other materials. This information revealed even more potential impacts of PFAS to human health and the environment.

Because of the strength of the fluorine-carbon bond, many PFAS can last a very long time in the natural environment, where they can accumulate at multiple points in the food chain. The longevity of many PFAS molecules, and the growing body of information about their negative impacts to human health and the environment has now led to global concerns, of varying degrees of seriousness, with all PFAS substances. The world is now faced with a very large group of substances that are embedded in every aspect of our modern society, most of which we have not investigated deeply, but all of which have been brought into question.

We must figure out how to responsibly limit, control, and investigate PFAS while defining and maintaining the uses that are essential.

3. Why Your Company Should Be Concerned

As a product supplier, the PFAS topic has an impact on the triple bottom line: People, Planet, and Profit. Beyond the health (people) and environmental (planet) concerns described elsewhere, the ongoing debate on PFAS can have a direct impact on the profitability of your company. Your ability to manufacture, sell, import, or export your products can be hampered by developing regulations that restrict PFAS in or require notification of their presence in your product. Additionally, your ability to acquire the materials and components used to make your products can also be affected.

Investigating and understanding where PFAS are present in your products and supply chain is critical in preventing or minimizing disruptions to your business. The large number of chemicals involved coupled with them being present in more substances and parts than you may be aware of dictates starting this investigation as early as possible.

Microelectronic devices are designed into almost everything we use in our modern lives. A central part of the microelectronics industry is the production of semiconductors, which are used to make microchips which control anything electronic from the smallest switches to huge datacenters, critical infrastructure, the transportation sector, and even the equipment that manufactures them. Learn more in [Appendix A. SEMICONDUCTOR MANUFACTURING PROCESS & SEMICONDUCTOR USES](#).

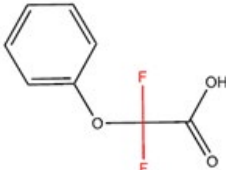
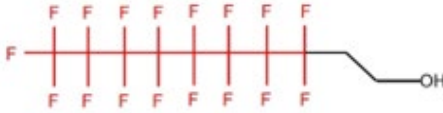
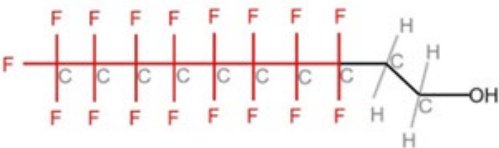
4. What are PFAS?

Generally speaking, “PFAS” stands for “per- and poly- fluoroalkyl substances”.

Within this broad group of substances, there are roughly 12 thousand that have been assigned a chemical abstracts service number (i.e., a CAS No.), and many more that have not.

The following might help explain the term more completely:

- » An alkyl substance has one or more molecular portions (‘moieties’) with a general carbon and hydrogen formula of C_nH_{2n+1} where n is any integer.
- » In a per-fluoroalkyl substance, all the hydrogen atoms in the alkyl moiety(ies) are replaced with fluorine.
- » In a poly-fluoroalkyl substance, at least one alkyl moiety is fully fluorinated (i.e., all the hydrogen atoms are replaced with fluorine) and at least one alkyl moiety is not fully fluorinated.
- » Though not explicitly referenced in the acronym, many PFAS definitions also admit substances with a single fully fluorinated methylene moiety with a general formula of C_nH_{2n}

A perfluoro alkyl substance	A perfluoro alkyl derivative considered to be a PFAS	A polyfluoro alkyl substance
 CAS No. 116-15-4	 CAS No. 24210-45-5	 CAS No. 678-39-7
In these molecular structure diagrams the red features are what make the molecule a PFAS. Carbon atoms are presumed at each line intersection. Each carbon atom will make four bonds. Hydrogen atoms are not shown, and fill a single bond location for all the carbon bonds not otherwise shown. Thus, CAS No. 678-39-7 could also be depicted as shown here.		

However, for any regulation, the term PFAS will have a slightly narrower meaning (refer to “PFAS Definitions” section, below).

PFAS should not be confused with “perfluoroalkoxy alkanes” (PFAs) which are a subset of PFAS.

PFAS should not be confused with “perfluorinated sulfonic acids” (PFSAs) nor with “perfluoroalkylsulfonates” (which regrettably have been referred to in literature from around 2009 with the acronym “PFAS”). Both chemical species are subsets of PFAS.

Fluoropolymers (such as PTFE, PVDF, and PFA) are substances with long chains of repeating molecular blocks that are all the same type, or a mix of two or three types, and which have a portion of the block that includes carbon atoms bonded to fluorine atoms. All fluoropolymers are PFAS.

A few of the non-polymer PFAS such as PFOA (perfluorooctanoic acid – $C_7F_{15}-CO_2H$), PFHxS (perfluorohexane-1-sulphonic acid – $C_6F_{13}-SO_3H$) and PFOS (perfluorooctanesulfonic acid – $C_8F_{17}-SO_3H$) have brought attention to the larger PFAS chemical family because of their persistence in the environment and hazard to human health.

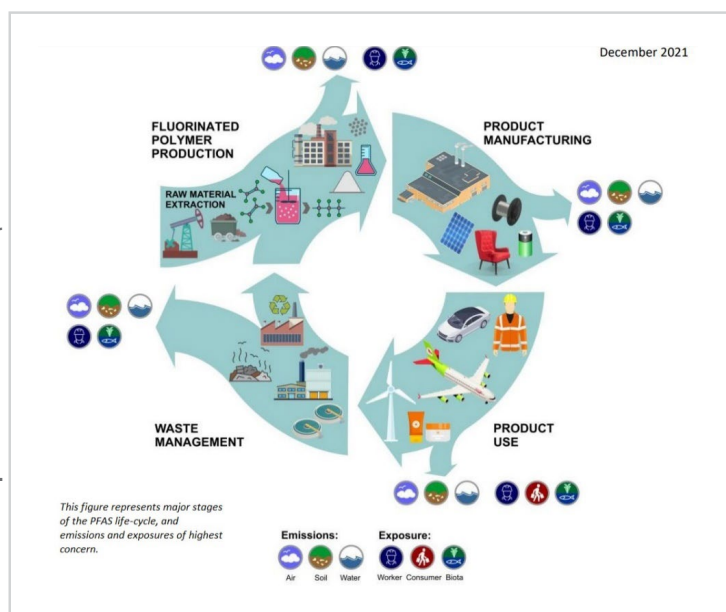
Many of the PFAS have a “backbone” of carbon atoms bonded together, each of which is bonded to one or more fluorine atoms – this structure has given rise to terms such as “long-chain” and “short-chain”.

5. Why Are PFAS Being Regulated as a Group?

Early PFAS regulations focused on single PFAS or small groups of PFAS such as the EU POPs regulation PFOA restriction. More recently, however, jurisdictions are developing regulations that have the entire PFAS family in scope (with varying definitions). The reasons that authors have given for this large expansion of scope includes the following points:

Note: SEMI and the members of the SEMI PFAS working group have not confirmed whether these assertions are true, nor taken a position on whether they are sufficient to warrant broad-spectrum PFAS restriction.

- » PFAS are persistent (PFAs have lifetimes in the thousands of years) and bio-accumulative. Long term accumulation increases the risk of harm. Top predators in the food chain (including humans, whales, bald eagles) have highest PFAS levels in their blood and tissues.
- » PFAAs (perfluoroalkyl acids and perfluoroalkyl-ether acids such as PFOA), a subset of PFAS, are well absorbed in animals and transport to organs with high blood flow. They can occupy sites on multiple receptors, proteins, and cell interfaces – resulting in cancers, changes in hormone and immune system function, and adverse developmental effects. Approximately 85% of PFAS are PFAA precursors.
- » The early control on well-known PFAS “bad actors” (such as PFOS) has resulted in regrettable substitution with shorter chain PFAS. In other words, the alternative substances used to replace the targeted bad substance turned out have just as many (or more) negative impacts as the original substance.
- » Shorter chain PFAS are quite mobile in the environment, permeating through the soil, and more easily accumulate in plants than longer chain PFAS.
- » Fluoropolymers are believed to release low molecular weight PFAS and other hazardous substances throughout their lifecycle. Low molecular weight PFAS are used as raw materials or additives in fluoropolymer production and can (and are known to have) been released into the environment and human water supplies. Further, greenhouse gases can be formed during some types of FP production, contributing to global warming.



- » Although incineration can destroy PFAS, it has been found that incineration is often performed at temperatures that are too low or for durations that are too short for complete destruction of PFAS.
- » Fluoropolymers are generally comprised of very long molecules that cannot interact with biological systems, but some molecules that are technically fluoropolymers are very short (e.g. having fewer than 10 monomers) and so are biologically active.
- » Fluoropolymers can be a source of microplastics. (Note: this is true of most polymers, whether they are PFAS or not)
- » Perfluoroalkanes and perfluoroalkylamines (subsets of PFAS) are generally biologically inert, but they can be very potent greenhouse gases.
- » Less than 1% of all PFAS have been tested for their hazardous effects. Testing one chemical at a time will cause substantial delays in the effort to protect health and the environment.

Sources for this information:

1. record of the Hearing of the ASSEMBLY COMMITTEE ON ENVIRONMENTAL SAFETY AND TOXIC MATERIALS, Bill Quirk, Chair – Date of Hearing: April 26, 2022, [LINK](#)
2. “Scientific Basis for Managing PFAS as a Chemical Class”, Carol F. Kwiatkowski, et al., : Environ. Sci. Technol. Lett. 2020, 7, 532–543, [LINK](#)
3. “Are Fluoropolymers Really of Low Concern for Human and Environmental Health and Separate from Other PFAS?”, Rainer Lohmann, et al., Environ. Sci. Technol. 2020, 54, 12820–12828, [LINK](#)

Other discussions of PFAS:

4. “Commission Staff Working Document / Poly- and Perfluoroalkyl Substances (PFAS)”, European Commission SWD (2020) 249 Final, Brussels, 14.10.2020, [LINK](#)
5. “Fluorinated polymers in a low carbon, circular and toxic-free economy / Technical report”, Wahlström, M. & Pohjalainen, E. (editors) et al., European Environment Agency – European Topic Centre on Waste and Materials in a Green Economy (ETC/WMGE) & European Environment Agency – European Topic Centre on Climate Change Mitigation and Energy (ETC/CME), Eionet Report – ETC/WMGE 2021/9, [LINK](#)
6. “Reconciling Terminology of the Universe of Per- and Polyfluoroalkyl Substances: Recommendations and Practical Guidance Series on Risk Management No.61”, Organisation for Economic Co-operation and Development (OECD), ENV/CBC/MONO(2021)25, 9 July 2021, [LINK](#)

6. Semi PFAS Mission Statement

- » SEMI and its member companies recognize the legitimate concerns about PFAS. PFAS are an integral part of our modern lives. SEMI member companies are dedicated to the responsible use of PFAS in the semiconductor industry where it is essential to the interests of a well-functioning society, and to removing PFAS from the industry on a practicable timeline for non-essential uses.
- » It appears that many jurisdictions are aiming to restrict the use of PFAS and to require the reporting of PFAS imports without a complete understanding of how dependent common technologies are on PFAS substances, how PFAS fill a very unique (and currently essential) technical niche, and how pervasively PFAS are used in semiconductor production, semiconductor manufacturing equipment, the full semiconductor industry supply chain, and in technology in general. At this time semiconductor chips and related devices cannot be produced without PFAS being available at multiple points in the supply chain and for multiple use-cases in the supply chain. We see similar dependencies on PFAS in medical, automotive, consumer electronics, aviation, and other sectors.

7. The Semiconductor Manufacturing Industry Responds

PFAS have enabled technological development in the semiconductor industry for many years. It is important to understand the basic ways in which PFAS are present in the semiconductor manufacturing process.

1. PFAS can be present in the chemicals directly used to manufacture semiconductor and related devices such as in photoresist liquids, etch chamber gases, as well as the containers that hold them.
2. PFAS can be present in the equipment directly used to manufacture semiconductors, such as in the high purity water distribution systems in a semiconductor manufacturing factory or in a lithium battery used for data back up in a metrology tool. There are thousands of other use cases.
3. PFAS can be present in the semiconductor and related devices that are the output of the manufacturing process such as in the plastic case of a microprocessor chip.
4. PFAS can be present in the equipment used to make components and chemicals that in turn are used directly in semiconductor manufacturing such as in a CNC machine used to produce silicon components for wafer plating systems, in a chemical purification system used to produce high purity hydrogen for EUV exposure systems.

Among these basic ways there are hundreds (if not thousands) of use-cases that are each repeated thousands of times throughout the individual components and products used in the industry - resulting in hundreds of thousands to millions of individual design-instances.

A few PFAS (such as PFOA and PFOS) have already been restricted in many jurisdictions, but not equally so. The semiconductor industry has stopped all direct use of these PFAS in jurisdictions where they are restricted and continues to investigate the deeper supply chain to ensure compliance.

In light of the developing interest in restricting all PFASes and requirements to report PFAS content in products, investigations for viable, safe, long-term PFAS alternatives have accelerated and resulted in some successes.

The semiconductor industry's activities include the following:

» A SEMI working group, formed originally to understand concerns with and uses of the PFOA group of PFAS substances, has expanded into a PFAS working group

focused on European regulations and the many US States and Federal laws that have recently passed or are in development. Among other outputs, this working group has provided a sector response to the EU public consultation for the proposed, broad-spectrum PFAS restriction under the EU REACH Regulation. (Reference entry ID 4304 in the ECHA collection - held in Table/Part 13 [LINK](#))

» A Semiconductor PFAS Consortium has formed under the umbrella of the Semiconductor Industry Association both to educate the world about the uses of PFAS in semiconductor manufacturing, and to investigate alternatives. Reference semiconductors.org/pfas. The Semiconductor PFAS Consortium has developed many whitepapers towards these goals (see more information at the bottom of this webpage).

» The World Semiconductor Council (WSC) has had long standing commitments to move away from PFOA and other PFAS. **Reference** www.semiconductorcouncil.org.

8. Consider Joining the SEMI PFAS Working Groups

SEMI working groups are comprised of staff from many SEMI member companies and are guided and assisted by SEMI staff. If you would like to join SEMI or the SEMI PFAS working group, please contact EHS@semi.org.

9. The Semiconductor PFAS Consortium Whitepapers

The Semiconductor Industry Association (SIA) has formed a Semiconductor PFAS Consortium to investigate and document the uses of PFAS in the semiconductor industry, and to develop information about which use-cases are essential and which use-cases could be fulfilled by an alternative, non-PFAS, substance. The main 2023 output of the Semiconductor PFAS Consortium are a series of whitepapers.

One of the whitepapers, known as the “Rina whitepaper” but titled as “The Impact of a Potential PFAS Restriction on the Semiconductor Sector” summarizes this information as it is understood up to approximately 2023. It can be downloaded [from here](#).

Other PFAS focused whitepapers available from the same link are:

- » “Background on Semiconductor Manufacturing and PFAS”
- » “PFAS-Containing Surfactants Used in Semiconductor Manufacturing”
- » “PFOS and PFOA Conversion to Short-Chain PFAS-Containing Materials Used in Semiconductor Manufacturing”
- » “PFAS-Containing Photo-Acid Generators Used in Semiconductor Manufacturing”
- » “PFAS-Containing Fluorochemicals Used in Semiconductor Manufacturing Plasma-Enabled Etch and Deposition”

- » “PFAS-Containing Heat Transfer Fluids Used in Semiconductor Manufacturing”
- » “PFAS-Containing Materials Used in Semiconductor Manufacturing Assembly Test Packaging and Substrate Processes”
- » “PFAS-Containing Wet Chemistries Used in Semiconductor Manufacturing”
- » “PFAS-Containing Lubricants Used in Semiconductor Manufacturing”
- » “PFAS-Containing Articles Used in Semiconductor Manufacturing”
- » “The Impact of a Potential PFAS Restriction on the Semiconductor Sector”
- » “Response to “Safer and Effective Alternatives to Perfluoroalkyl-Based Surfactants in Etching Solutions for the Semiconductor Industry””
- » “The Socio-economic Impact of a Potential PFAS Restriction on the Semiconductor Value Chain in Europe”

Additional whitepapers will be listed here, as they become available.

10. Types of PFAS Regulations

There are many PFAS regulations in effect and in development and trends are arising in the topics the regulations target. Some regulations target one topic and others cover several topics. The topics include:

PFAS in waterways and drinking water.	PFAS in consumer cleaning products	PFAS in consumer medical products (e.g. dental floss).	PFAS in farmland.
PFAS in food packaging.	PFAS in fire-fighting foams.	PFAS in pesticides.	PFAS in animal health products.
PFAS in textiles.	PFAS in cosmetics.	PFAS in bottled-water bottles.	PFAS in industrial food preparation equipment.
PFAS in general products.	PFAS in ski wax	PFAS in cookware.	PFAS in baby products

There are also regulations which focus subsets of the larger PFAS family. These include regulations restricting PFOA, PFOS, PFHxA, Fluorinated Greenhouse Gases, and many others.

11. PFAS Regulation Examples

Listed here are a few of the PFAS regulations that the SEMI PFAS working group has been monitoring, and in some cases, seeking amendments through advocacy.

Status	Summary	Link
Proposed	1. An EU REACH Annex XVII restriction on the general use of PFAS. As currently proposed, it would likely shut down the semiconductor industry in the EU (and many other industries).	Link
Proposed	2. A new US TSCA PFAS reporting and recordkeeping regulation. As currently drafted it requires a company to look back to 2011 and reporting on any PFAS substances manufactured (including import) between then and now.	Link
In Effect	3. A US Maine statute (LD1503) requiring the reporting of products containing PFAS and prohibiting such product from 2030 unless the Department of Environmental Protection (DEP) deems it to be a “currently unavoidable use”. Regulations for the statute have been drafted but not released. The statute has generated a lot of concern and there are several amending bills in process to change the statute.	Link
Proposed	4. A US Minnesota statute () requiring the reporting of products containing PFAS	
Proposed	5. A US Massachusetts statute (S.1356) requiring the reporting of products containing PFAS	Link
Proposed	6. A US New York statute (A03571) requiring the reporting of products containing PFAS	Link

In Effect	7. An EU REACH Annex XVII restriction (entry 68) on the general use of a PFAS subset - perfluorocarboxylic acids containing 9 to 14 carbon atoms in the chain (C9-C14 PFCAs), their salts and C9-C14 PFCA-related substances. Such substances could be present as additives or process residues in polymers or as constituents of semiconductor process chemicals.	Link
Proposed	8. An EU REACH Annex XVII restriction on the general use of a PFAS subset - perfluorohexane sulfonic acid (PFHxS) including its salts and related substances.	Link
Proposed	9. An EU REACH Annex XVII restriction on the general use of a PFAS subset - undecafluorohexanoic acid (PFHxA), its salts and related substances. Such substances could be present as additives or process residues in polymers or as constituents of semiconductor process chemicals.	Link
In Effect	10. Beginning as an EU REACH Annex XVII restriction but moved into the EU Persistent Organic Pollutants (POPs) regulation, a restriction on the general use of perfluorooctanoic acid (PFOA), its salts and PFOA-related compounds. Such substances could be present as additives or process residues in polymers or coatings. They are likely no longer present as constituents of semiconductor process chemicals.	Link
In Effect	11. A US TSCA Significant New Use Rule (SNUR) on general use of a PFAS subset - Long-Chain Perfluoroalkyl Carboxylate and Perfluoroalkyl Sulfonate Chemical Substances (LCPFAC). It is a list-based restriction which includes PFOA a several similar substances and has many use-case exemptions.	Link
In Effect	12. Beginning as an EU REACH Annex XVII restriction but moved into the EU Persistent Organic Pollutants (POPs) regulation, a restriction on the general use of Perfluorooctane sulfonic acid and its derivatives (PFOS). Such substances are likely no longer present as constituents of components or semiconductor process chemicals.	Link
Proposed	13. A US TSCA SNUR on PFAS listed as “Inactive” in the TSCA chemical inventory.	Link
In Effect	14. A Singapore PFOA restriction. “plastics” and “lubricants” are excepted, but not adhesives. Company case-specific exceptions can be granted after NEA review and approval.	Link
Vetoed	15. A US California statute (AB2247) requiring the reporting of products containing PFAS	Link

There are many other PFAS regulations related to drinking water, firefighting foams, cosmetics, etc.

Regulations related to fluorinated greenhouse gases (Fgases or GHGs) and ozone depleting substances (ODSs) might also have PFAS in scope and so are a kind of PFAS regulation but are not included in the above list.

Semiconductor manufacturing and related semiconductor chemical and equipment manufacturing facilities might also be subject to wastewater regulations which include consideration of PFAS.

12. PFAS Concentrations of Regulatory Interest

In the above regulations, the concentration of regulatory interest (CRI) varies from complete bans on PFAS (i.e., no intentionally added concentration of PFAS is allowed) to concentrations on the order of 25 parts per billion (0.0000025%) for a single PFAS substance or several hundred parts per billion (ppb) for the sum of all PFAS substances.

As an example, the broad spectrum European PFAS restriction being proposed for the REACH regulation has a base restriction as follows for a substance, mixture, or article:

- “i. 25 ppb for any PFAS as measured with targeted PFAS analysis (polymeric PFASs excluded from quantification)
- ii. 250 ppb for the sum of PFASs measured as sum of targeted PFAS analysis, optionally with prior degradation of precursors (polymeric PFASs excluded from quantification)
- iii. 50 ppm for PFASs (polymeric PFASs included). If total fluorine exceeds 50 mg F/kg the manufacturer, importer or downstream user shall upon request provide to the enforcement authorities a proof for the fluorine measured as content of either PFASs or non-PFASs.”

In consideration of concentrations, it is important to note that the denominator of the concentration can also vary. In Europe, regulations applicable to components usually are for “articles” which, in accordance with the 2015 “once and article always an article” interpretation of the European Court of Justice, roughly means any individual part of the component that has ever existed separately in commerce – a simple potentiometer can be composed of 20 or so individual articles. In the United States the EPA uses the term “article” to mean the item as it is placed on the market – the same potentiometer would be considered as one single article.

Regulations aiming to limit the amount of PFAS in water supplies have levels that are much lower – in the parts per trillion.

13. The SEMI PFAS Investigation Definition

As members of SEMI in collaboration with the Semiconductor Industry Association strive to identify PFAS being used in the semiconductor industry, we have been using a fairly broad definition of PFAS that is aligned with the definition used in the PFAS Consortium “Background on Semiconductor Manufacturing and PFAS” whitepaper: -

All chemistries and materials that contain molecules with $-CF_2-$ and/or $-CF_3$

This aligns with the broader definitions present in US state PFAS regulations. It is not necessarily the definition the industry thinks is most appropriate. It contains some of the different PFAS definitions that can be found in existing and developing regulations.

14. A Listing of PFAS

There is no single list of PFAS in accordance with this definition. However, the United States EPA has a “list of lists” of PFAS available at <https://comptox.epa.gov/dashboard/chemical-lists/PFASMASTER>. Some PFAS are listed on more than one of the 10 lists shown there. In total, there are more than 12,000 unique substances among the lists. It is not clear which PFAS definition the EPA uses for their lists, but it is likely to be narrower than the PFAS definition used by SEMI and by most US states.

[Appendix E. PFAS FLUOROPOLYMERS NAMES](#) and [Appendix F. PFAS TRADE NAMES](#) contain more information on the names of PFAS substances.

15. PFAS-Containing Components

Both SEMI and the Semiconductor PFAS Consortium have working groups that have been investigating the use of PFAS (or PFAS sub-sets) in hardware (also known as ‘articles’) for many years. The following picture illustrates, at a very high level, the types of articles in which PFAS can be found.

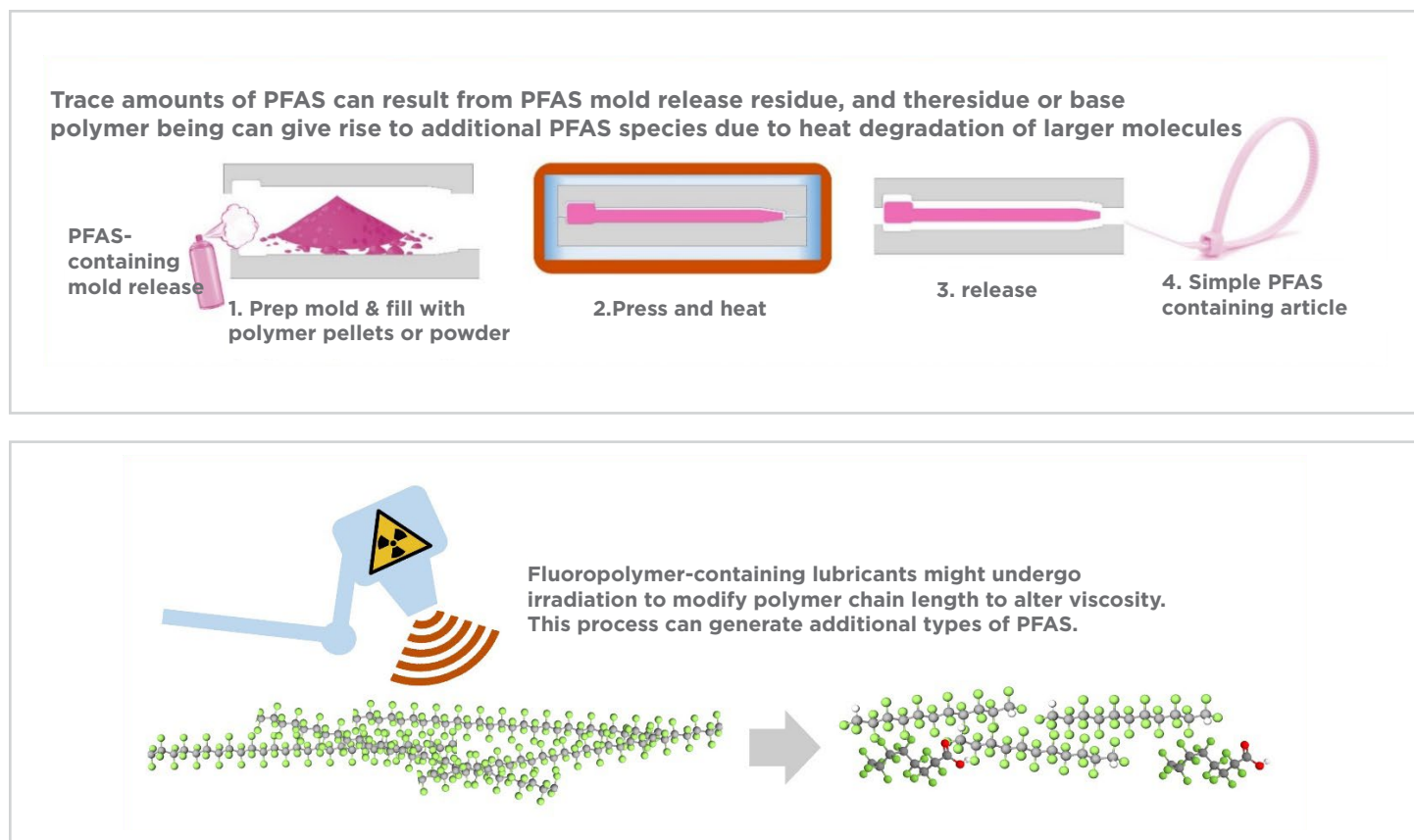
- » Mention of an article type in this figure means it is likely that the article type contains PFAS, it does not mean every article of the type contains PFAS.
- » Three examples of containerized PFAS-containing mixtures are shown (indicated with blue dots) to emphasize the fact that adding a PFAS substance or PFAS-containing mixture such as grease or refrigerant into (or onto) an article will make that article a PFAS-containing article. However, containerized substances and mixtures are usually regulated distinctly from articles.

PFAS can be the major constituent of an article, and it can be an additive to other PFAS polymers, and even non-PFAS polymers. [Appendix G. PFAS ADDITIVES TO PFAS & NON-PFAS POLYMERS](#) contains more information about additives. [Appendix H. PFAS IN ELECTRONIC COMPONENTS](#) contains information about some specific PFAS that have been found in electronic components.



16. Unusual Cases

Small amounts of a variety of PFAS substances can arise in articles, mixtures, and substances from various industrial processes. The contribution of new PFAS might initially be dismissed as too small to matter, but careful consideration should be given to the fact that concentrations of regulatory interest can be as low as a few parts per billion. Here are a couple examples:



17. Other PFAS Materials

As noted in the articles figure above, heat transfer fluids, fluorinated greenhouse gases, and lubricants can be PFAS. PFAS can also be ozone depleting substances.

» FGases / GHGs

Certain fluorinated greenhouse gases (sometimes called “F-gases” or “GHGs”) are also in scope of regulations focused on the gas’s global warming potential such as the European F-gas regulation (Regulation 517/2014 – soon to be replaced, number TBD) or the United States AIM Act. It is possible that the F-gas-focused regulations have more relaxed restrictions than relevant PFAS-focused regulations.

» HTFs

Some heat transfer fluids, particularly polyfluoro polyethers (PFPEs) are PFAS. One example is CAS No. 69991-67-9, “1-Propene,1,1,2,3,3,3-hexafluoro-, oxidized, polymerized” which is sold under the trade name of “Galden HT-55” and “Fomblin Y”. There are many other PFPEs.

» Lubricants

Some lubricants are PFAS. They can be PFAS because fluoropolymers (which are solid at use temperatures) are present as micro-powders, such as PTFE, in the lubricant mixture, or because liquid PFAS are present in the lubricant mixture as some perfluoro polyethers or polyfluoro polyethers (both use the acronym PFPEs). Some micropowder PTFE based lubricant trade names are 3-In-One and WD-40. PFPE based lubricants include MolyKote HP-300 grease, and Fomblin M/Z oils. Some lubricants combine these two technologies, such as Krytox EG (electrical grade) 2000.

» ODSs

Some of the PFAS substances (such as chlorotrifluoromethane – CF_3Cl) are also regulated as ozone depleting substances (ODSs) and are in scope of regulations focused on ODS concerns such as the EU’s ODS regulation (Regulation 1005/2009 – soon to be replaced, number TBD). This is an example of where the details of PFAS definition matter. Because chlorotrifluoromethane has a Cl attached to the same carbon as the fluorine, it would not be in scope of the EU’s proposed general PFAS restriction, but it would be in scope of the state of Maine’s PFAS definition (see PFAS Definitions, above).

18. PFAS Alternatives & Use Cases

When considering the use of an alternative, non-PFAS, chemical in an application in which PFAS is currently used, it is very important to focus on a particular use-case or set of use-cases. Based on experience to date, there is no alternative that can replace a PFAS chemical in all use-cases – and this concept applies on a per-article-type basis.

For example, it may be feasible to replace PTFE cable ties used inside controllers, with lower ambient temperatures, with cable ties made from nylon. However, it is probably not feasible to use nylon cable ties to replace PTFE cable ties being used to secure wires inside a low-pressure process chamber.

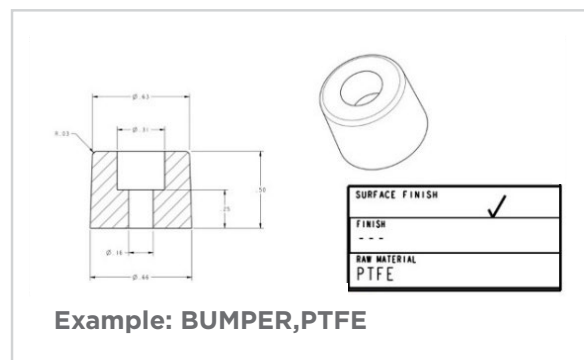
19. Equipment Component Groups

When considering components and PFAS, it can be useful for equipment manufacturers to organize their components into 3 fundamental groups:

Group 1 - Fabricated components designed by the equipment manufacture to contain PFAS

The equipment manufacturer designs the component and specifies a PFAS substance as a material, or a PFAS containing mixture (e.g., paint) as a finish. Fabricated components are also known as FAB parts.

These are likely the easiest use-cases to find, provided the material and finish fields are searchable in a drawing database. If drawings stored only as image, or materials and finishes are random text the file, manual reading of each drawing will be needed.



Group 2 - Off the shelf components with PFAS overtly revealed

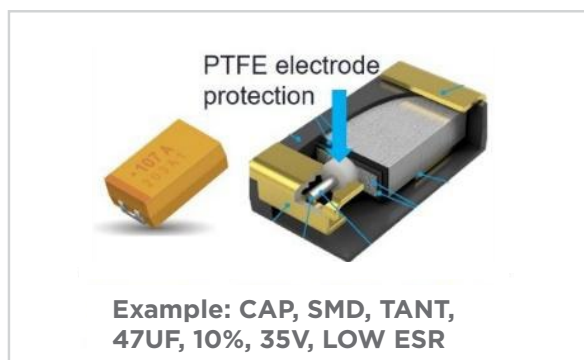
The equipment manufacturer selects the component off the shelf (OTS) such as from a catalogue or website. The component description or other prominent information indicates at least one PFAS is present in the component.

These are easy to find for at least determining the component is a PFAS-containing component but does not necessarily reveal all PFAS. For example, the PVDF PFAS used for the main part of this sensor could contain a PFAS fire retardant, or wiring inside the sensor could contain PFAS.

Group 3 - Off the shelf components with PFAS undisclosed

The equipment manufacturer selects the component off the shelf (OTS). PFAS is present in the component, but it is not prominently disclosed (e.g., it is not revealed in the product description).

These are the most difficult to find and control. It will require careful and detail-oriented information along all levels of the supply chain to find these uses of PFAS that are undisclosed at the component level.



20. PFAS in Chemical Safety Data Sheets

When investigating the presence of PFAS in chemicals (also known as substances or mixtures) in containers, or presence of PFAS at the very early stages of an article's supply chain, such as blocks of polypropylene, Safety data sheets (SDSs) are usually relied upon as the source of information. The SDS for a fluoropolymer could indicate ">99% PTFE" which is clearly >99% PFAS.

A caveat is that the SDS might not indicate PFAS process residues or additives also present, but at ppb level concentrations. This is because, up until recent years, most PFAS have not been considered hazardous – or have any other characteristic for which applicable SDS regulations would require disclosure. Or, if they were designated hazardous, they were not present in a quantity that required disclosure. The same is true for fluoroelastomers which are mainly one type of PFAS but can contain other PFAS at ppb levels unreported in an SDS.

21. Testing For PFAS

Testing might also be a consideration for investigating the presence of PFAS (especially PFAS process residues or additives in fluoropolymers and fluoroelastomers) , but this also presents challenges.

Most importantly, regarding components, there is no nationally recognized test method available for broad spectrum PFAS that can determine the concentration (i.e., quantitative analysis) of each PFAS in any particular part (or article) of a component. There are quantitative tests available for blood, water, or soil, but not for solid matrix items.

Some laboratories offer testing services on solid matrix items for some PFAS subsets using custom modifications on PFAS test methods intended for other purposes (such as detecting PFAS in water). The better tests begin with reducing the object under test to smaller particles to increase the surface area to extract the PFAS molecules from. But none of these tests are very accurate. A negative result (i.e., no PFAS) from such a test cannot truly rule out the presence of PFAS, and any results value that is provided is likely well below the actual amount of PFAS that is present.

It is also important to keep in mind that as a laboratory processes a PFAS plastic or rubber polymer for testing, non-polymer PFAS can be produced (essentially portions of the PFAS polymer chain breaking off into smaller molecules). Laboratory processes that have a potential to do this include mechanical grinding, ultrasonic sonication, and heating. It is also possible that PFAS present in the laboratory equipment and process vessels can impact the test outcome.

22. Material Disclosure Protocols

There are many ways that material information can be exchanged in the supply chain.

- » Safety Data Sheets (SDSs) are one way to do this, but they are generally only applicable to materials when they are exchanged as base, raw materials. SDS criteria are laid down in various national regulations such as EU REACH Annex II, and the US Hazard Communication System Appendix D. (Refer also to 21. PFAS IN CHEMICAL SAFETY DATA SHEETS)
- » Standard material data exchange formats of several types are available. They are based on substance lists. These include:

- IEC 62474, “Material Declaration for Products of and for the Electrotechnical Industry” which is supported by two public access databases known as the Declarable Substance List (DSL) and the Reference Substance List (RSL) – [Link](#). The former has an entry for “Per- and poly-fluoroalkyl substances (PFAS)” derived from the US State of Maine legislation, using their broad PFSA definition – “substances that include any member of the class of fluorinated organic chemicals containing at least one fully fluorinated carbon atom”. The latter provides examples of substances in a particular chemical family. There are only 629 substances listed in RSL for PFAS. Some fluoropolymers are included in the list. The operative threshold for the Maine requirement is given as “intentionally added”. These databases will be updated from time to time as additional PFAS regulations come into force. More targeted PFAS regulations, such as the EU POPs PFOA restriction, are also covered.
- IPC 1752, “Materials Declaration Management Standard” – [Link](#) – which is presented in two revisions: Revision A and Revision B, each of which has had a few amendments. IPC 1752A establishes a standard XML reporting format for material declaration data exchange between supply chain participants and supports reporting of bulk materials, components, printed boards, sub-assemblies, and products. The IPC-1752B standard helps companies who want to collect data from their supply chains in a format matching the data requirements of the EU “SCIP” database. The structure of the IPC-1752B standard mirrors the ECHA SCIP database submission format. IPC 1752A defines 4 classes of declaration (A thru D) related to 5 chemical list appendices (B thru F) that are publicly available in a single document ([Link](#)). The chemical [Appendix F](#) mirrors the IEC 62474 list – but it might not be synchronized in time.
- ChemSherpa ([Link](#)), is a Japanese-based reporting scheme which aims to include the entire supply chain of a product from the very upstream substance producers to mixture producers to part manufacturers and then to component product manufacturers. There is specialized, publicly accessible data entry support tool provided from the ChemSherpa website and a collection of manuals and training materials in several languages.
- » Full Material Declaration (FMD). While the above chemical information exchange standards are driven by a finite list of substances that various regulations require to be reported, a full material declaration is intended to be a report of all the substances that might be present in a component. The challenge with this approach is to be very clear about how articles will be considered in the FMD declaration and with what content precision each article will be reported. Recall that a single component, such as potentiometer, can have 10’s of fundamental articles as well as substances and mixtures that are also added at the component level, likewise, the PFAS concentrations of regulatory interest can be expressed as in parts per billion of each article. An FMD report that only goes to 0.1% of the reported component weight will not provide enough information for most PFAS restriction and reporting regulations.
- » Custom method – There are many information gathering efforts going on these days to understand the impact of, and respond to, proposed and existing broad-spectrum PFAS reporting and restriction laws. The standardized material disclosure protocols might not cover all the PFAS necessary. Therefore, a custom PFAS inquiry protocol might be needed for use in your supply chain. This should be undertaken with careful consideration. Companies in the supply chain, particularly suppliers of less complex assemblies, are likely to be more familiar with standard protocols. A custom protocol will require them to understand new concepts and use different response methods, which can give rise to response errors of various types. If a custom protocol is created it is best to develop one with the goal of simplifying respondent reply efforts, but based as much as possible on an existing standard protocol, and if possible, in collaboration with other companies in a similar industry sector to limit the variety of inquiries in the supply chain.

23. Inquiries Into Your Supply Chain

Given the above challenges in relying on SDS or test for information on PFAS, a significant source of information, and likely the main source of information, will have to be direct inquiry. The following are some recommendations for undertaking supply chain inquiries and controls for PFAS in the components you acquire to make your product.

1. Have a list of all the components, substances, and mixtures, by part number, that go into making your product.
 - » Recall that ‘component’ simply means something you acquire that goes into the product you provide. A component might be a single, simple article, a complex assembly, an amount of adhesive, or paint that is applied to part of your product.
 - » Be aware of whether materials contribute to your product that are not listed in your bills of material (BoMs) – for example do assembly drawings call for adhesives, or stock hardware “as needed” in assembly drawing notes.
 - » Consider all related labels, manuals, cases, packaging, and shipping brackets/braces – they are part of the overall product you are supplying.
 - » Consider all relevant standard options and non-standard requests for the product.
2. Sort your list of components into those for which you control the material and finish specifications (i.e., fabricated parts – FAB parts), and those for which you do not control the material and finish specification (i.e., Off the shelf parts – OTS parts).
 - » Carefully consider assemblies made for you by a contract manufacturer. In some cases, you might control the bill of materials completely, and in others your vendor might have some say in how components of the assembly are sourced.
 - » Carefully consider items that might be defined by special purchase agreement with a supplier – such as a custom variation on a standard power supply – these might contain a combination of your material requirements with their material requirements.
 - » Modify your lists as need in response to your ongoing design changes.
3. For OTS components, develop a survey process for your direct suppliers to gather and store required PFAS information.
 - » Your Enterprise Resource Planning (ERP) system might have an item master where you can collect information.
 - » There are many 3rd parties that offer supplier survey services and related databases that can provide quantity roll-up for bills of material.
 - » You can provide a link to this webpage as one aspect of the information you provide in your survey.
 - » Keep in mind that if you have different OEM sources for the same item, they could contain

different types and different quantities of PFAS – be prepared to store their survey data separately, but account for the selection of one or another in your total product considerations.

- » Be very clear about some key concepts in your survey information, such as:
 - What “zero” content means (for example, because of previous regulatory work, such as dealing with EU RoHS, some suppliers consider “less than 0.1%” to be the same as a “zero content”).
 - The difference between “none present” and “none intentionally added”
 - The component’s manufacturing date range, or serial number range, for which the data is relevant.
 - Should your suppliers report only information they have received from their own supply chain, or should they actively survey their supply chain.
 - If threshold measurements are important, make sure the denominator for those measurements is clear. For example, you might have to explain the difference between the European REACH interpretation of article versus the EPA interpretation.
 - Packaging materials for components are also in scope of the inquiry – you might forward completely packaged component to your own customers or field service operations as replacement parts.
- 4. For FAB components, you will most likely have to modify the materials and finish specifications in your drawings.
 - » If the component must be made from a fluoropolymer or fluoroelastomers (which are PFAS but might ultimately be allowed greater use considering developing PFAS restriction laws) be sure to consider the possibility of process residues and additives in the material and specify accordingly. For example, “PVDF made without PFAS processing aides and additives”.
 - » Ensure that finish specifications are based on well-defined and well-understood materials and processes. Paints and other coatings can contain polymer and non-polymer PFAS.
 - » While using a generic chemical description for the material or finish specification gives your supplier some flexibility, using a specific material trade name specification that you have fully investigated could give you greater control.
 - » If your component fabrication drawing calls for some sort of marking, such as marking with your part number, be sure the ink is specified in line with your PFAS goals. Inks can contain polymer and non-polymer PFAS.
 - » If the fabricated component requires cleaning or similar processing, be very clear about what substances should be used in the process. Recall that PFAS concentrations of regulatory interest can be as low as several parts per billion. Even residual cleaning solutions on a small part could have a compliance impact.
 - Try to avoid having fab drawings that call for additional parts (e.g., by means of notes on the drawing) in their construction. Use a bill of materials for such a structure. In any case, make sure the material and finish specification blocks clearly state all materials and finishes required to make the component.

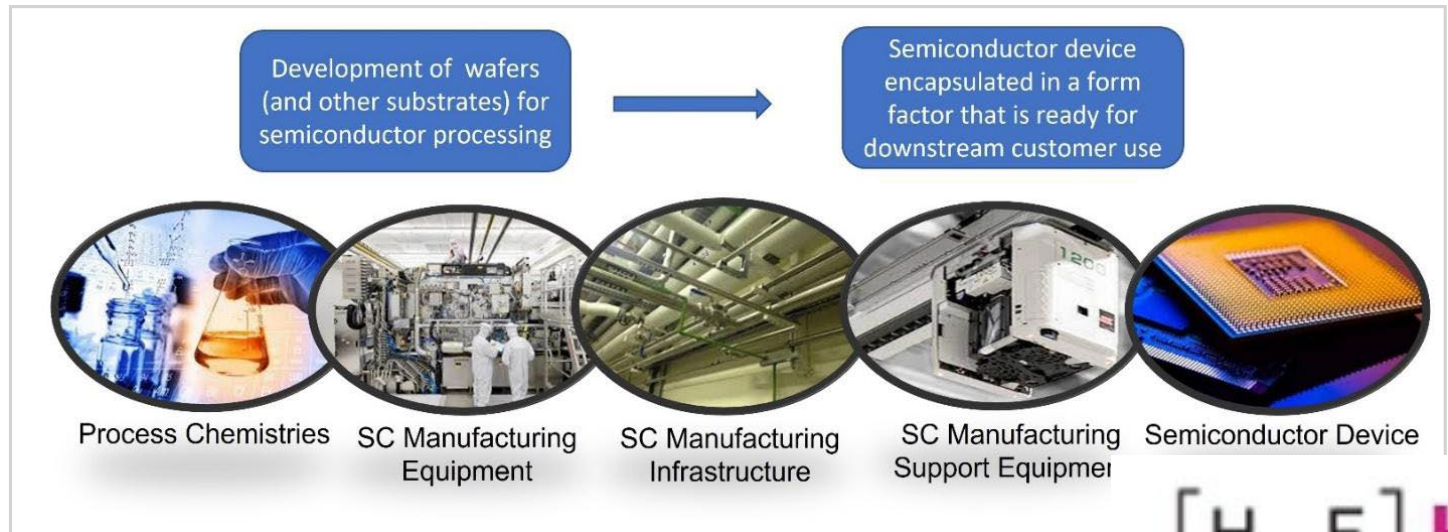
5. You are likely a supplier to someone else, so also develop a PFAS profile for your products.
 - » Consider how variations in component source or component fabrication date might impact your product representation (for example, you might need to state a range of possible PFAS quantity in your output).
 - » Consider how standard options and NSRs will be represented.
 - » The packaging materials used for your product are also of concern and might have to be passed on by your customer to their customers or service operations (e.g., as a replacement part). List packaging materials in a separate group.
 - » At a minimum, your downstream customers will likely have an interest in which PFAS is present in your product, where they are in your product (described in terms of the EU interpretation of “article” and with enough information to locate the article within the product), and for what reason the PFAS is present in each article.
 - » If possible, it will be very helpful to express any information you can about when certain uses of PFAS can be replaced with alternative substances or when the product will be PFAS free – or replaced by an equivalent PFAS free product.

24. Supplier EHS/Compliance Staff

As you consider gather information from your supply chain, keep in mind that many companies do not have resources allocate for complex regulatory issues such as PFAS reporting and restrictions, particularly considering the variety seen in existing and pending legislation. This might be an aspect to bring into your supplier qualification process. Certainly, invite all your suppliers to review this information page.

Appendix A. Semiconductor Manufacturing Process & Semiconductor Uses

The Semiconductor Manufacturing Process includes all the direct and indirect equipment and materials required to manufacture semiconductor “chips” and similar devices such as solar panels, light emitting diodes (LEDs), flat panel displays (FPDs), semiconductor sensors, and microelectromechanical systems (MEMS).



SEMICONDUCTORS ENABLE EVERYTHING DIGITAL AND SHAPE OUR FUTURE



Semiconductor technology development and production fuels future economic growth in artificial intelligence, machine learning, autonomous driving, cloud and edge computing, high-performance computing, 5G, smartphones, and more.

Appendix B. Varying PFAS Definitions

Unfortunately, the many PFAS regulations do not share a common definition for PFAS, although there are some technical commonalities. A few of the more noteworthy definitions are shown here. Note that within the same jurisdiction (and even within the same jurisdiction agency) the definitions are not always the same.

The fluoropolymer PVDF is particularly problematic. The ideal formula of PVDF is a polymer chain comprised of sequential CH₂-CF₂ units, such that no two linked carbons are fluorinated, as such it is outside the SCOPE of some EPA regulations. However, in the real-world polymerization PVDF defects can occur such that the ideal “head to tail” alignment of the CH₂-CF₂ links is disrupted with “head to head” and “tail to tail” link defects. The EPA has suggested, therefore, that PVDF (or at least the defect portions of PVDF) are in scope of their definition.

Definition Source	Definition
Proposed EU REACH general PFAS restriction.	Any substance that contains at least one fully fluorinated methyl (CF ₃ -) or methylene (-CF ₂ -) carbon atom (without any H/Cl/Br/I attached to it). [The definition has this further scope qualification – it is not clear if it is legally considered part of the PFAS definition or not.] A substance that only contains the following structural elements is excluded from the scope of the restriction: CF ₃ -X or X-CF ₂ -X', where X = -OR or -NRR' and X' = methyl (-CH ₃), methylene (-CH ₂ -), an aromatic group, a carbonyl group (-C(O)-), -OR'', -SR'' or -NR''R'''; and where R/R'/R''/R''' is a hydrogen (-H), methyl (-CH ₃), methylene (-CH ₂ -), an aromatic group or a carbonyl group(-C(O)-)
Proposed EU REACH general PFAS restriction.	Any substance that contains at least one fully fluorinated methyl (CF ₃) or methylene (CF ₂) carbon atom (without any H/Cl/Br/I attached to it).
EPA proposed PFAS reporting rule.	1. Any chemical substance or mixture that structurally contains the unit R-(CF ₂)-C(F)(R')R''. Both the CF ₂ and CF moieties are saturated carbons. None of the R groups (R, R' or R'') can be hydrogen. EPA proposed SNUR for inactive chemicals. i. R-(CF ₂)-CF(R')R'', where both the CF ₂ and CF moieties are saturated carbons; ii. R-CF ₂ OCF ₂ -R', where R and R' can either be F, O, or saturated carbons; and iii. CF ₃ C(CF ₃)R'R'', where R' and R'' can either be F or saturated carbons.
State of Maine PFAS reporting and restriction statute	Substances that include any member of the class of fluorinated organic chemicals containing at least one fully fluorinated carbon atom.
New York state proposed PFAS reporting and restriction statute	Substances that include any member of the class of fluorinated organic chemicals containing at least one fully flourished [sic] carbon atom.

Some PFAS regulations have a scope limited to specific list of PFAS substances, such as the US Toxic Substances Control Act (TSCA) Significant New Use Rule (SNUR) for Long-Chain Perfluoroalkyl Carboxylate and Perfluoroalkyl Sulfonate Chemical Substances (LCPFAC) at 40CFR721.10536.

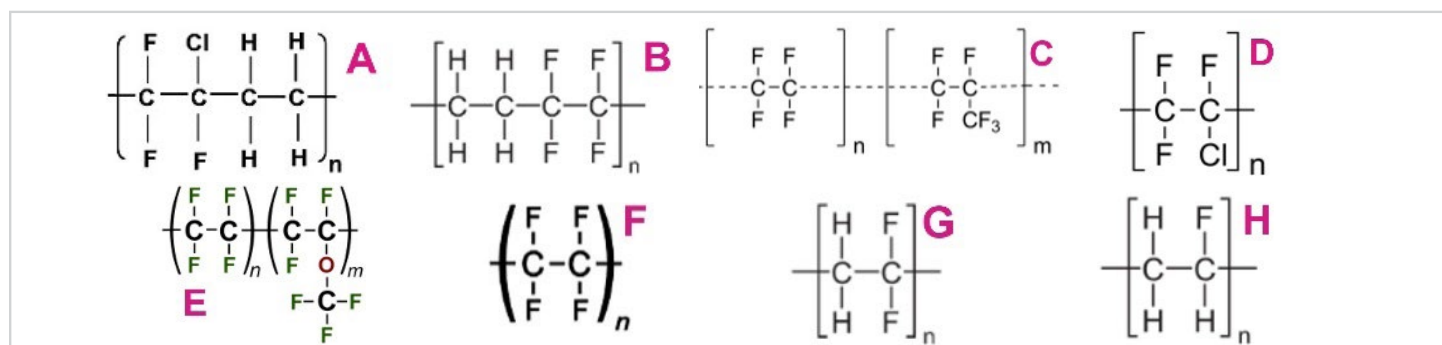
Appendix E. PFAS Fluoropolymer & Fluoroelastomer Names

As mentioned above, fluoropolymers are PFAS. Fluoroelastomers are also PFAS. When researching the use of PFAS in components, a manufacturer might find that the material specification block of their drawings indicates a fluoropolymer trade name rather than the generic name. For example, it might indicate, “Teflon” or “Eفالon” rather than PTFE or “15% Glass Filled PTFE”. Therefore, it is important to be familiar with the trade names of fluoropolymers and fluoroelastomers as well as their generic names.

The following are several generic fluoropolymer and fluoroelastomer names, followed by some trade names.

Common fluoropolymers and fluoroelastomers – Generic Names (all are PFAS)				
--- Fluoropolymers ---				
Acronym	Name	CAS number	Ideal Molecular Formula	Index
ECTFE	Ethylene Chloro Tri Fluoro Ethylene	25101-45-5	$(CF_2-CFCl-C_2H_4)_n$	A
ETFE	Ethylene Tetra Fluoro Ethylene	25038-71-5	$(C_2H_4-C_2F_4)_n$	B
FEP	Fluorinated Ethylene Propylene	25067-11-2	$((C_2F_4)_n + (C_2F_3-CF_3)_m)$	C
PCTFE	Poly ChloroTri Fluoro Ethylene	9002-83-9	$(C_2F_3-Cl)_n$	D
PFA	Per Fluoroalkoxy Alkane	26655-00-5	$((C_2F_4)_n + (C_2F_3-(O-CF_3)_m)$	E
PTFCE	See PCTFE			
PTFE	Poly Tetra Fluoro Ethylene	9002-84-0	$(C_2F_4)_n$	F
PVDF	Poly Vinyl iDene Fluoride	24937-79-9	$(CH_2-CF_2)_n$	G
PVF	Polyvinyl fluoride	24981-14-4	$(C_2H_3F)_n$	H

Molecular Structure Models



---Fluoroelastomers---	
FKM	» Fluoroelastomers do not have specific CAS numbers nor definite molecular structures. » 'FKM' and 'FFKM' are not acronyms, they are material designations from the ASTM D1418 standard. They are also classified in ISO/DIN 1629 as 'FPM' and 'FFPM'. FKM / FPM are 'fluoroelastomers' and FFKM / FFPM are 'perfluoroelastomers'. » FKMs are made from a mixture of 6 monomers (VF – vinylidene fluoride, HFP – hexafluoropropylene, TFE – tetrafluoroethylene, PMVE – perfluoro methyl-based vinyl ether, E – ethylene, P – propylene) and two main 'curing' systems which result in 5 types of FKMs. » FFKMs are basically made from two monomers and an additional 'cure site monomer.'
FFKM	
FPM	
FFPM	
FVMQ	Fluorovinylmethylsiloxane

Appendix F. PFAS Trade Names

The following list of trade names also demonstrates that the inventor of a particular fluoropolymer product might license out the manufacture and/or sale of the product to another company.

You can also see that some of trade names represent very large families of fluoropolymers of types, sometimes with many sub-grades in the family.

Example Fluoropolymer & Fluoroelastomer Trade Name

This information is from <https://www.matweb.com/search/AdvancedSearch.asp>. The product names were selected randomly to demonstrate various trade names and that some tradenames represent different type of fluoropolymers. Some of the products listed here are no longer available.

» 350 PFA Copolymer – Chemours	Rodgers
» 450HP PFA – Afton Plastics	» Arlon DiClad 880 PTFE/Woven Fiberglass Laminate – Rodgers
» 800 GoldEnd® Tape – Chesterton	» Avalon® 89 PTFE – Greene Tweed
» ACLAR® SupRx 900 CTFE – Honeywell	» CENTROFLON PVDF – CENTROPLAST
» Adalon® 252 PTFE, 28% Glass Fiber – Adamas	» Chemlam® TR6 Value Industrial Laminate – Saint-Gobain
» Adalon® 826 PTFE, 50% Stainless steel – Adamas	» CHFM 025 Perfluorosulfonic Acid Proton Exchange Membrane (PFSAPEM) – Shandong Dongyue Shenzhou New Material Co
» Ajedium™ Film-- Halar® 500LC ECTFE – Solvay	» Clariflex® TFE/VF2/HFP – Westlake Plastics
» Algoflon® F 7 PTFE, Powder – Solvay	» DAI-EL® T-530 Thermoplastic Fluoroelastomer – Daikin
» APSOplast® FEP Fluoro plastic – Angst+Pfister	» Dyflor® EE PVDF – Evonik
» APSOplast® PTFE Fluoro plastic – Angst+Pfister	» Dyneon™ 1645 PTFE Powder – 3M
» Aquivion® E87-05 Perfluorosulfonic Acid (PFSA) – Solvay	
» Arlon 22122R079 Silicone-FEP Film Laminate –	

- » Dyneon™ PVDF 60512/0000 Polyvinylidene Fluoride – 3M
- » Dyneon™ THV 610GZ Fluoroplastic Granules – 3M
- » ENSIKEM® PVDF – Ensinger
- » ES HiFill® ECTFE GF25 25% Glass Filled – Techmer
- » ESD 3281 ETFE Carbon Fiber - Static Dissipative – RTP Company
- » Evolite™ F1050 Thermoplastic PVDF/Carbon Fiber Composite – Solvay
- » Fibracon® PTFE + 15% Carbon – Röchling
- » FLAMETEC™ HALAR® 901 ECTFE - Vycom
- » Fluon® C-88AP ETFE – AGC
- » Fluon® P-802UP PFA – AGC
- » FluorLoop® CH08/0001 PVDF – Solvay
- » Fluoro T® 611 Thermoplastic Grade PTFE Additive – Shamrock Technologies
- » Fluoroloy® A30 High Performance PTFE/Glass Seal Material – Saint-Gobain
- » Fluorosint® 135 PTFE and PPS Blend – Mitsubishi
- » GORE™ 800 PTFE Universal Pipe Gasket – W. L. Gore
- » Guarniflon FEP
- » Guarniflon PTFE G200
- » GYLON® 3500 PTFE Gasketing, Silica Filler – Garlock
- » Halar® 1400LC ECTFE – Solvay
- » Halar® High Performance E-CTFE Film – Honeywell
- » Hyflon® AD 40L Perfluoropolymer – Solvay
- » Hylar® 301S PVDF – Solvay
- » KF Polymer 1300 PVDF – Kureha
- » KLINGER® top-chem-2000 PTFE Gasketing – Klinger Thermoseal
- » Kynar Flex® 3030-50 PVDF – Arkema
- » Kynar® ADX FLEX 281 PVDF – Arkema
- » Lakinor® U PVDF – Adamas
- » LUBRICOMP™ Compound 5CL23 PVDF – SABIC LNP™
- » Michem® Glide 37 Nonionic PTFE dispersion – Michelman®
- » Murflor® PTFE – Murtfeldt
- » Nafion™ N324 perfluorosulfonic acid (PFSA) cation exchange membrane
- » NanoFLON® P 51A Thermoplastic Grade PTFE Additive – Shamrock Technologies
- » Nelco® NX9320 PTFE Laminate, Woven-Glass Reinforced – Park Aerospace
- » NEOFLON® AP-230 PFA – Daikin
- » NEOFLON® EP-506 Extrusion Grade ETFE – Daikin
- » Norton® PFA Fluoropolymer Film – Saint-Gobain
- » Novec™ FC-4430 Fluorosurfactant – 3M
- » Ofluorine D-1 PVDF Lithium Ion Battery Binders (DF-2) – Shanghai
- » POLITEF® (PTFE) – Polimersan Plastics
- » Polycom 460 PTFE, 10% Ekonol® – AGC
- » Polymist® XPP 511 R PTFE, Powder – Solvay
- » Polystone® PVDF – Röchling
- » Reproflon PTFE – Mikro-Technik
- » RT/duroid® 5870 Glass Microfiber Reinforced PTFE High Frequency Laminate – Rodgers
- » RTP 3105 PFA Glass Fiber 30% – RTP Company
- » Rulon® AR Bearing/Seal PTFE – Saint-Gobain
- » RULON® J PTFE – Manifattura Cattaneo
- » SIMONA® 010024460 PVDF 740 – SIMONA America
- » Solef® 3108/0903 PVDF – Solvay
- » Solvadura™ 08/1001 PVDF – Solvay
- » STAT-KON™ Compound 5E003M PVDF – SABIC LNP™
- » Symalit® 1000 ETFE – Mitsubishi

- » Tarnow™ TARFLEN SG-1 PTFE – Azoty
- » TECAFLON™ PVDF – Ensinger
- » Tedlar® SP TUA10AH9 Polyvinyl Fluoride Film – DuPont
- » Teflon® Sanitary Gasket – Process Technologies Inc
- » Teflon™ 532-6118 Permeation Resistant ETFE Industrial Coating – Chemours
- » Teflon™ 532G-13032 Abrasion Resistant PFA Coating – Chemours
- » Teflon™ 959G-205 Industrial coating primer – Chemours
- » Tefzel® HT-2160 Static Dissipating Semiconductive Resin – Chemours
- » Thermocomp® FP-EC-1004 ETFE Copolymer, Carbon Fiber Reinforcement – LNP
- » THERMOCOMP™ Compound 2C003 ETFE Copolymer – SABIC LNP™
- » Tisoflon® 10 AD Polytetrafluoroethylene Coated Glass Fabric – Isoflon
- » Tyflor™ 1000 Sanitary Gasket – Process Technologies Inc
- » Tygon® Furon® 400 High-Purity PFA Tubing – Saint-Gobain
- » Valvelon® 3500 PTFE Sealant – Chesterton
- » Vespel® CR-6100 Carbon-Reinforced Fluoropolymer – DuPont
- » Viton™ VTR-1001A fluoroelastomer
- » Waywodec® ABS/PVDF – Röchling
- » ZOTEK® F OSU Semi-Rigid PVDF Foam – Zotefoams

Appendix G. PFAS Additives to PFAS, Non-PFAS Polymers

One of the more important concepts to keep in mind is that non-PFAS polymers can have PFAS additives, and perhaps even residual PFAS processing aids (chemicals used in the production of the base polymer material). Because of this some non-PFAS polymers will be in scope of PFAS regulations. For example, PFBS (perfluoro butane sulfonic acid) is sometimes present in polycarbonates as a flame retardant.

The following table shows some common types of additives that used in polymers, taken from UL 746A (Polymeric Materials – Short Term Property Evaluations) Table 9.1. Of course, not all these additives are expected to be PFAS. Examples are given of known PFAS additives

Types of Polymer Additives (known PFAS types shown as examples)				
Acid Acceptor (Scavenger)	Impact Modifier	Lubricant or Release Agent	Coupling Agent	Plasticizer e.g., ACR-ENP-1, fluoroalicyclic oligomer
Antimicrobial	Conductive Material	Processing Aid or Dispersing Agent	Drip Inhibitor	UV stabilizer e.g., 5-(3-Fluoro-2-methylphenyl)-3-methylphenol CAS 1262001-16-0
Copolymer	Antioxidant	Blowing Agent	Nucleating Agent	Monomers (unreacted)
Crosslinking Agent e.g., Rhenofluor	Antistatic Agent	Catalyst	Filler e.g., PTFE	Metallic Pigment
Curing Agent	Compatibilizer	Colorant/Pigment (organic & inorganic)	Reinforcement	Smoke suppressant
Flame Retardant e.g., PFBS (Rimar salt) in polycarbonates	Halogen Scavenger	Carbon black (Colorant)	Heat Stabilizer	
Other polymer (in polymer blend)	Low Wear Additive	Corrosion Inhibitor	Hydrolytic Stabilizer	

Appendix H. PFAS In Electronic Components

As reported in a June 2023 blog post ([link](#)), the GreenSoft Technology company conducted a search in their Full Material Declaration (FMD) database. Their search found one or more of 56 PFAS in 7,000 parts in the database. Those PFAS are listed in the following table. This might be indicative of the more common PFAS, besides fluoropolymers, that could be present in general electronic components

PFAS found by GreenSoft in components		CAS*
1	Ethene, 1,1,2,2-tetrafluoro-, homopolymer	9002-84-0
2	1-Propene, 1,1,2,3,3,3-hexafluoro-, polymer with 1,1,2,2-tetrafluoroethene	25067-11-2
3	Pentadecafluorooctanoic acid	335-67-1
4	Propane, 1,1,1,2,2,3,3-heptafluoro-3-[(1,2,2-trifluoroethenyl)oxy]-, polymer with 1,1,2,2-tetrafluoroethene	26655-00-5
5	1-Hexene, 3,3,4,4,5,5,6,6,6-nonafluoro-, polymer with ethene and 1,1,2,2-tetrafluoroethene	68258-85-5
6	Perfluoro compounds, C5-18	multiple
7	Potassium 1,1,2,2,3,3,4,4,4-nonafluorobutane-1-sulphonate	29420-49-3
8	Norflurane	811-97-2

9	1-Propene, 1,1,2,3,3,3-hexafluoro-, polymer with 1,1-difluoroethene	9011-17-0
10	2-Propenoic Acid, 2-[Methyl[(Nonafluorobutyl)Sulfonyl]Amino]Ethyl Ester, Telomer With Methyloxirane Polymer With Oxirane Di-2-Propenoate and Methyloxirane Polymer With Oxirane Mono-Propenoate	1017237-78-3
11	1-Hexanesulfonic acid, 1,1,2,2,3,3,4,4,5,5,6,6,6-tridecafluoro-	355-46-4
12	Ammonium pentadecafluorooctanoate	3825-26-1
13	Tetrafluoroethylene	116-14-3
14	Heptacosafuorotetradecanoic acid	376-06-7
15	1-Hexanesulfonic acid, 1,1,2,2,3,3,4,4,5,5,6,6,6-tridecafluoro-, lithium salt (1:1)	55120-77-9
16	4,4'-[2,2,2-trifluoro-1-(trifluoromethyl)ethylidene]diphenol	1478-61-1
17	Pentacosafuorotridecanoic acid	72629-94-8
18	1-Propene, 1,1,2,3,3,3-hexafluoro-, polymer with 1,1-difluoroethene and 1,1,2,2-tetrafluoroethene	25190-89-0
19	Henicosafuoroundecanoic acid	2058-94-8
20	Oxetane, 2,2,3,3-tetrafluoro-, homopolymer, fluorinated	113114-19-5
21	Tricosafuorododecanoic acid	307-55-1
22	Propane, 2-(ethoxydifluoromethyl)-1,1,1,2,3,3,3-heptafluoro-	163702-06-5
23	1-Octanesulfonic acid, 1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8,8-heptadecafluoro-, ammonium salt (1:1)	29081-56-9
24	Butane, 1-ethoxy-1,1,2,2,3,3,4,4,4-nonafluoro-	1337538-18-7
25	Butane, 1,1,1,2,2,3,3,4,4-nonafluoro-4-methoxy-	163702-07-6
26	Ethene, 1,1,2,2-tetrafluoro-, polymer with ethene	25038-71-5
27	1-Propene, 1,1,2,3,3,3-hexafluoro-, oxidized, polymd.	69991-67-9
28	Propane, 2-(difluoromethoxymethyl)-1,1,1,2,3,3,3-heptafluoro-	163702-08-7
29	Triethoxy(3,3,4,4,5,5,6,6,7,7,8,8,8-tridecafluorooctyl)-silane	85857-16-5
30	1-Propene, polymer with 1,1,2,2-tetrafluoroethene	27029-05-6
31	Ethene, 1-chloro-1,2,2-trifluoro-, homopolymer	9002-83-9
32	Ethyl perfluorononan-1-oate	30377-52-7
33	Mixture of S,S,S',S'-Tetraphenylthiobis(4,1-phenylene)disulfonium dihexafluoroantimonate and diphenyl(4-phenylthiophenyl) sulfonium hexafluoroantimonate	159120-95-3
34	Ethene, 1,1,2,2-tetrafluoro-, oxidized, polymd.	69991-61-3
35	Pentanoic acid, 4,4-bis((gamma-omega-perfluoro-C8-20-alkyl)thio) derivs., compds. with diethanolamine	71608-61-2
36	Poly[oxy(trifluoro(trifluoromethyl)-1,2-ethanediyl)], .alpha.-(1,1,2,2,2-pentafluoroethyl)-.omega.-[tetrafluoro(trifluoromethyl)ethoxy]-	60164-51-4
37	1-Butanesulfonamide, 1,1,2,2,3,3,4,4,4-nonafluoro-N-(2-hydroxyethyl)-N-methyl-	34454-97-2
38	1-Octanesulfonamide, N-[3-(dimethyloxidoamino)propyl]-1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8,8-heptadecafluoro-	178094-69-4
39	ETFE	25038-71-5
40	Ethene, fluoro-, homopolymer	24981-14-4

41	Heptadecafluorooctanesulphonyl fluoride	307-35-7
42	Poly(difluoromethylene), .alpha.-(cyclohexylmethyl)-.omega.-hydro-	65530-85-0
43	pentadecafluorooctyl chloride	335-64-8
44	Phosphonium, triphenyl(phenylmethyl)-, salt with 4,4'-[2,2,2-trifluoro-1-(trifluoromethyl)ethylidene]bis[phenol] (1:1)	75768-65-9
45	Poly(oxy-1,2-ethanediyl), .alpha.-hydro-.omega.-hydroxy-, ether with .alpha.-fluoro-.omega.-(2-hydroxyethyl)poly(difluoromethylene) (1:1)	65545-80-4
46	(2-carboxylatoethyl)(dimethyl) [[4,4,5,5,6,6,7,7,8,8,9,9,10,10,11,11,12,12,13,13,14,15,15,15-tetracosafuoro-2-hydroxy-14-(trifluoromethyl)pentadecyl]amino]propyl]mmonium	93776-15-9
47	1,1,1,2,2,4,5,5,5-nonafluoro-4-(trifluoromethyl)-3-pentanone	756-13-8
48	1-Propene, 1,1,2,3,3,3-Hexafluoro-, oxidzed, polymd., reduced, hydrolized reaction products with ammonia, mittlere Molmasse 3000 g/m	370097-12-4
49	3-ethoxy-1,1,1,2,3,4,4,5,5,6,6-dodecafluoro-2-(trifluoromethyl)-hexane	297730-93-9
50	Diammonium 4,4,5,5,6,6,7,7,8,8,9,9,10,10,11,11,11-heptadecafluoro-2-hydroxyundecyl phosphate	94200-45-0
51	Ethene, 1,1,2,2-tetrafluoro-, polymer with 1,2,2-trifluoro-2-(trifluoromethoxy)ethene	26425-79-6
52	Ethene, 1-chloro-1,2,2-trifluoro-, polymer with ethene	25101-45-5
53	Pentafluoroethane	354-33-6
54	Pentane, 1,1,1,2,2,3,4,5,5,5-decafluoro-	138495-42-8
55	Perfluoroethane	76-16-4
56	Propane, 1,1,1,3,3,3-hexafluoro-	690-39-1
*CAS Registry Numbers were provided by the SEMI "PFAS Explainer" maintenance team. Notify EHS@semi.org if you think there is an error.		

Appendix I. Document Revision Notes

The following are notes of the most significant changes to the document. The more recent changes are nearer the top of the table

Revision	Date	Notes
2	2024, May	Conversion to single document, with minor content changes.
Original	2023, July	First release as collection of web pages.