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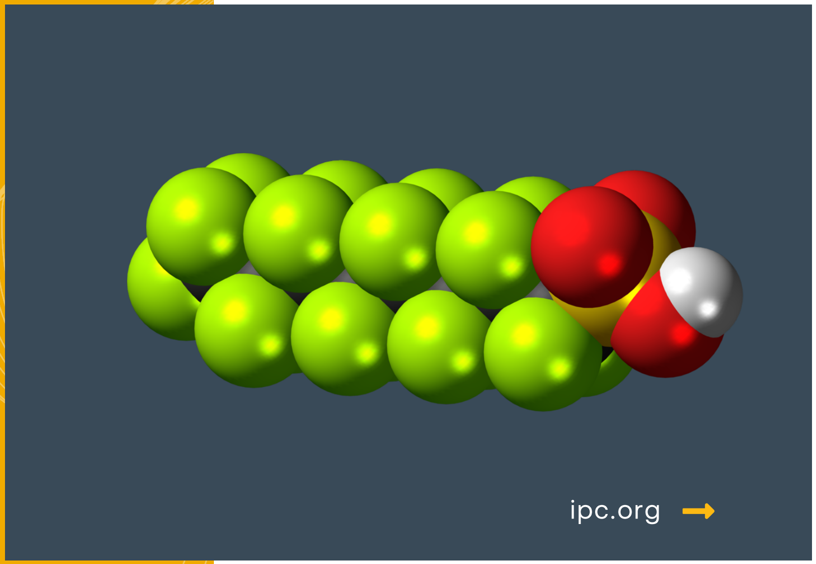
Preliminary Findings: PFAS Use in the Electronics Industry

Screening study commissioned by IPC and completed by Matthew Chalkley, Consultant, on July 31, 2020



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Please review the preliminary findings from the screening study.

Did the study accurately capture the uses of PFAS in electronic products?

How would you rank the criticality of PFAS to the performance of the electronic products?

Point of Contact is Kelly Scanlon, IPC Director of Environment, Health, and Safety Policy and Research

Summary

> Screening study aims:
  - Analyze legislative approaches across different jurisdictions;
  - Understand the PFAS-containing electronic products and manufacturing processes.

> With an increasing number of PFAS substances being developed (4,730 already identified by the OECD and set to increase), the complex nature of these substances and the fact many are used across the electronics industry, this screening study recommends that on behalf of their membership, IPC continues to research, collaborate with other stakeholders (including semiconductor and fluoropolymer industry associations), and provide advocacy for all members, especially for members that may not be as engaged or fully understand of the potential implications of PFAS legislation and regulation to their businesses.

What are PFAS?

> Per- and polyfluoroalkyl substances (PFAS) are a group of 4,730 man-made chemicals (OECD, 2018), the two most well-known of which are perfluorooctanoic acid (PFOA) and perfluorooctane sulfonic acid (PFOS). PFAS are used in a wide variety of consumer products and industrial applications because of their unique chemical and physical properties, including oil and water repellence, temperature and chemical resistance, and surfactant properties*.

> Buck et al**. specified PFAS as a subset of fluorinated substances is the highly fluorinated aliphatic substances that contain 1 or more C atoms on which all the H substituents (present in the nonfluorinated analogues from which they are notionally derived) have been replaced by F atoms, in such a manner that they contain the perfluoroalkyl moiety C_nF_{2n+1}–.

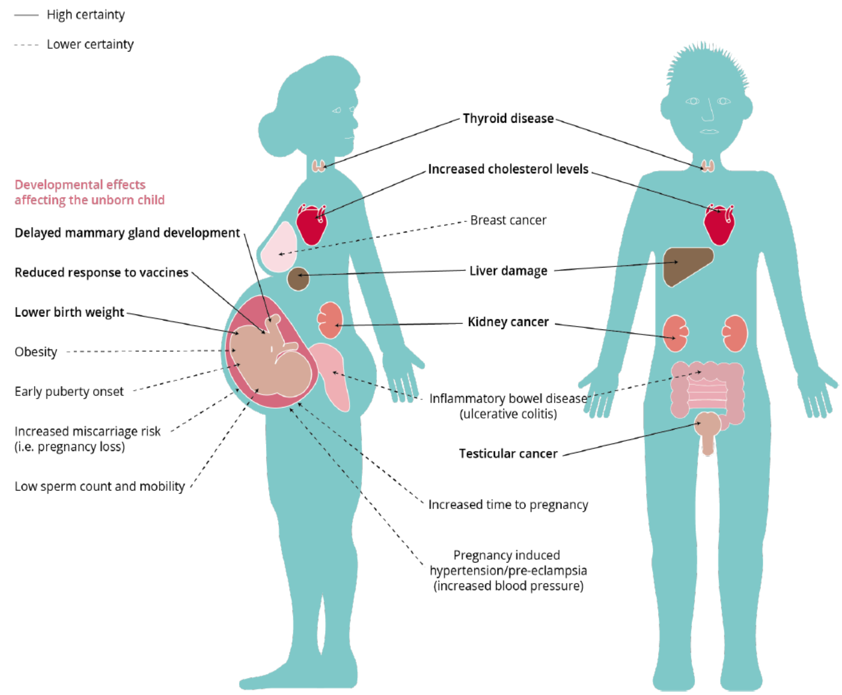
> PFAS can be long-chain, short-chain or side-chain fluorinated polymers.

* https://www.eea.europa.eu/themes/human/chemicals/emerging-chemical-risks-in-europe
** R. C. Buck, J. Franklin, U. Berger et al., "Perfluoroalkyl and polyfluoroalkyl substances in the environment: terminology, classification, and origins," Integrated Environmental Assessment and Management, vol. 7, no. 4, pp.

Why are PFAS a Concern?

> PFAS are sometimes referred to as **‘Forever Chemical’** due their persistence and are, or degrade to, persistent chemicals that accumulate in humans, animals and the environment. This adds to the total burden of chemicals to which people are exposed (Evans et al., 2016*) and increases the risk of health impacts. Of the relatively few well-studied PFAS, most are considered moderately to highly toxic, particularly for children’s development**

Effects of PFAS on human health



Sources: US National Toxicology Program, (2016); C8 Health Project Reports, (2012); WHO IARC, (2017); Barry et al., (2013); Fenton et al., (2009); and White et al., (2011).

- https://www.sciencedirect.com/science/article/pii/S0048969715309785

** https://www.eea.europa.eu/themes/human/chemicals/emerging-chemical-risks-in-europe

Screening Study Methodology

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> Several data and information gathering approaches were employed during the study including:

- Access information available in the public domain
- Post an article requesting information from LinkedIn and circulated across IPC's social media platforms e.g. website, Twitter, etc.
- Request information from attendees at IPC's monthly Environmental, Health and Safety Committee meeting
- Request information from attendees at IPC's European Government Relations Committee meeting
- Conference call with Product Stewardship experts industry to discuss use of fluoropolymers in products, with emphasis on PTFE
- Contact the fluoropolymers Product Group of PlasticsEurope
- Review European and U.S. legislative and non-legislative activities

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UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

EUROPEAN COMMISSION

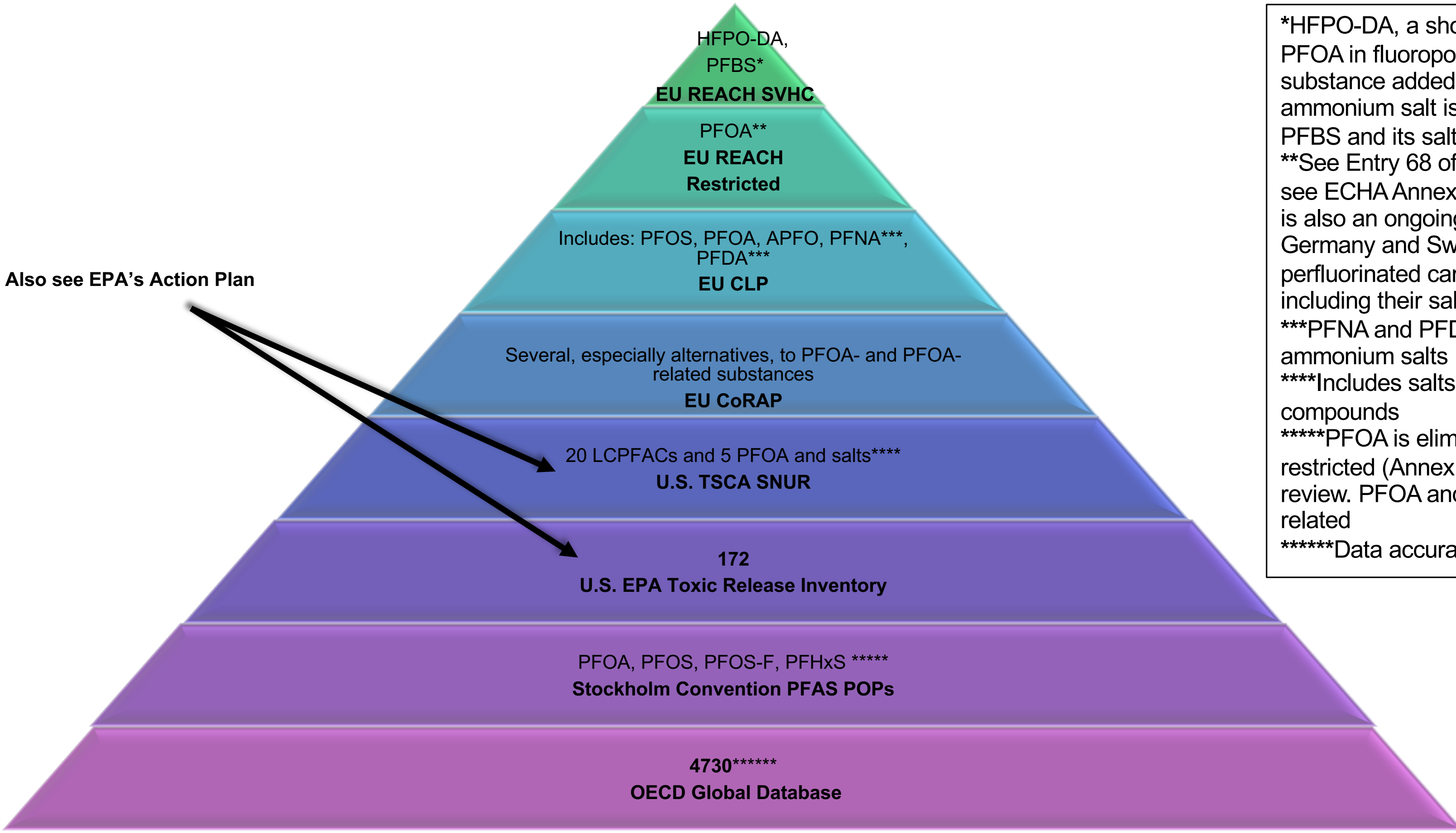
OECD

Legislative and Regulatory Findings

The landscape is complex and there is no harmonization among jurisdictions. Navigating such a landscape will be challenging to the producers and manufactures of electronic products, especially those with global presence or that manufacture, export, import, or place products on different jurisdictions.

Regulatory Landscape Snapshot

Also see EPA's Action Plan



*HFPO-DA, a short-chain PFAS substitute for PFOA in fluoropolymer production, was the first substance added to the Candidate List. Its ammonium salt is commonly known as GenX. PFBS and its salts, a replacement of PFOS.
**See Entry 68 of Annex XVII to REACH, Also see ECHA Annex XV Restriction Report - There is also an ongoing restriction proposal by Germany and Sweden for the following perfluorinated carboxylic acids: C9-14 PFCAs, including their salts and precursors
***PFNA and PFDA include its sodium and ammonium salts
****Includes salts and precursors compounds
*****PFOA is eliminated (Annex A); PFOS is restricted (Annex B); and PFHxS is under review. PFOA and PFHxS include Salts and –related
******Data accurate as of circa May 2018

Legislative and Regulatory Findings

> Legislation – Complex and Evolving!

- Globally PFOS and PFOA are identified as PFAS for restriction and prohibition
- OECD – Lists 4,730 PFAS
- Stockholm Convention* – PFOS (Annex B – Restricted), PFOA (Annex A – Elimination); PFHxS under review
- U.S. Congress, bills contain authorizing language for funding to support PFAS-related projects and studies including health studies; as of end of July 2020:
  - Water Resources Development Act, H.R. 7575
  - National Defense Authorization Act, S. 4049 and H.R. 6395
  - FY21 House Appropriations, Interior and Environment Minibus, H.R. 7608
- U.S. Environmental Protection Agency (EPA) PFAS Action Plan – uses combination of regulatory and voluntary approaches, including TSCA SNURs, PFOA Stewardship Program, and TRI, for
  - Setting MCLs for PFOS and PFOA**
  - Assessing other PFAS: PFDA, PFNA. PFHxA, PFBA, GenX***

* Includes specific PFAS, its salts and related substances
** in drinking water, evaluate designating PFOA and PFOS as hazardous substances, issue groundwater cleanup guidances for PFOA and PFOS, and develop toxicity values for GenX and PFBS
*** perfluorodecanoic acid (PFDA), perfluorononanoic acid (PFNA), perfluorohexanoic acid (PFHxA), perfluorohexanesulfonate (PFHxS), and perfluorobutanoic acid (PFBA); GenX (hexafluoropropylene oxide dimer acid (HFPO-DA) fluoride)

Legislative and Regulatory Findings

- U.S. EPA Toxics Release Inventory (TRI)
  - As of June 2020, 172 PFAS added
- U.S. EPA Toxic Substances Control Act (TSCA) Significant New Use Rule (SNUR)
  - Requires notification for Significant New Uses
  - These uses will be reviewed by the EPA
  - Designated ongoing uses exempted
  - PFOS already included
  - 20 LCPFAC and 6 PFOA substances identified
  - Final Rule Published July 27, 2020

Legislative and Regulatory Findings

- SNUR
  - > Exemption still in place for fluoropolymer dispersions and emulsions, and fluoropolymers as part of articles
  - > The manufacture, import or processing of certain LCPFAC substances is recognized as ongoing for use in
    - Antireflective coating
    - Photoresists
    - Surfactant used in photomicrolithography
    - Other processes used to produce semiconductors or similar components of electronic miniaturized devises
  - > A chemical substance subject to the SNUR is only 'unintentionally present' at the point of manufacture, it is already exempt from reporting as the importer of the imported purity
  - > Comments/Concerns*
    - A more precise definition of 'surface-coating' is required e.g. does it cover the overall finish of an article
    - Even with this clarification, notification prior to importing a component (article) or piece of complex equipment based on potential presence of LCPFAC might be considered burdensome
    - No *de minimis* exemptions were included to account for trace amounts of PFAS

* https://chemicalwatch.com/135113/compliance-challenge-looms-with-tsca-notification-requirements-for-pfas

Legislative and Regulatory Findings

- EU Community Rolling Action Plan (CoRAP)
  - ECHA and the Member States developed risk-based criteria for the selection of substances for the CoRAP
  - Prioritises substance for evaluation over a three-year period
  - Evaluation aims to clarify a concern that the manufacture and/or use of these substances could pose a risk human health and the environment
  - Several PFAS (especially alternatives to PFOA- and PFOA- related substance) are listed in the draft for evaluation over the next years
- EU Classification, Labelling and Packaging Regulation (CLP)
  - Based on UN Globally Harmonised System (GHS)
  - Purpose to ensure high level of protection of health and environment, and free movement of substances, mixtures and articles
  - Requires manufactures, importers and downstream users of substances or mixtures to classify, label and package their hazardous chemicals appropriately before placing them on the market
  - Annex VI, includes the following PFAS: PFOS, PFOA, Ammonium pentadecafluorooctanoate (APFO), perfluorononan-1-oic acid (PFNA) and its sodium and ammonium salts; nonadecafluorodecanoic acid (PFDA) and its sodium and ammonium salts.

* https://echa.europa.eu/information-on-chemicals/annex-vi-to-clp

Legislative and Regulatory Findings

- EU REACH
  - Adopted to improve human health and the environment
  - Restrictions are normally used to limit or ban the manufacture, placing on the market (including imports) or use of a substance, but can impose any relevant condition, such as requiring technical measures or specific lables
  - PFOA, its salts and related substances are listed at entry 68
    - Shall not be manufactured or placed on the market as substances on their own from 4 July 2020.
    - Shall not, from 4 July 2020, be used in the production of, or placed on the market in:
      - another substance, as a constituent;
      - a mixture;
      - an article,
    - in a concentration equal to or above 25 ppb of PFOA including its salts or 1 000 ppb of one or a combination of PFOA-related substances.
  - PFOS was originally included in REACH Annex XVII restricted substance list . After PFOS was added to the Annex B of the Stockholm Convention in 2009, the European Commission removed PFOS from REACH Annex XVII and added it to the Annex I of the Regulation (EC) No 850/2004 of the European Parliament and of the Council on persistent organic pollutants. PFOS is now regulated as a persistent organic pollutant (POP) in EU.

PFOS reference:
https://www.chemsafetypro.com/Topics/Restriction/PFOS_EU_restriction_limit_PFOS_and_REACH_annex_XVII.html

Legislative and Regulatory Findings

- EU REACH
  - > The identification of a substance as a Substance of Very High Concern (SVHC) and its inclusion in the Candidate List can trigger certain legal obligations for the importers, producers and suppliers of an article* that contains such a substance
  - > Producers and importers have to notify to ECHA the substances listed on the Candidate list which are present in their articles, if both the following conditions are met:
    - The substance is present in their relevant articles above a concentration of 0.1% weight by weight.
    - The substance is present in these relevant articles in quantities totalling over one tonne per year.
  - > Companies have to notify no later than six months after the inclusion of the substance in the Candidate List.
  - > In June 2019 and January 2020, two PFAS groups were identified as SVHCs based on their persistence, mobility and toxicity, which were considered to pose a threat to human health and wildlife when exposed through the environment (including through drinking water). These groups are:
    - 2,3,3,3-tetrafluoro-2-(heptafluoropropoxy)propionic acid, its salts and its acyl halides (HFPO-DA), a short-chain PFAS substitute for PFOA in fluoropolymer production, was the first substance added to the Candidate List. Its ammonium salt is commonly known as GenX.
    - perfluorobutane sulfonic acid (PFBS) and its salts, a replacement of PFOS.

*REACH defines an article as an object which during production is given a special shape, surface or design that determines its function to a greater degree than its chemical composition.

Legislative and Regulatory Findings

- Grouping
  - There are various approaches to grouping PFAS has in order to determine risk mitigation actions
  - Several approaches/definitions to group PFAS have been discussed by industry and are based on:
    - Essential Use, Safe by Design, or PFAS class
      - Essential Use: Montreal Protocol* Definition - A controlled substance qualifies as essential only if:
        - It is necessary for the health and safety—or is critical for the functioning—of society (encompassing cultural and intellectual aspects)
        - There are no available technically and economically feasible alternatives or substitutes that are acceptable from the standpoint of environment and health
      - Production and consumption, if any, of a controlled substance for essential uses is permitted only if:
        - All economically feasible steps have been taken to minimize the essential use and any associated emission of the controlled substance
        - The controlled substance is not available in sufficient quantity and quality from the existing stocks of banked or recycled controlled substances
      - In a position paper AmCham EU**, believes the concept of essential use to the PFAS restriction process is premature, and may set a precedent that will have unintended consequences. The current call for evidence does not stipulate identified risks per use. Instead, it collects information on a number of uses. Applying this concept to such a large class of chemicals for the first time is a very ambitious task that does not exclude the possibility of unjustified restrictions being concluded and a lack of enforceability.

* https://ozone.unep.org/treaties/montreal-protocol/essential-use-exemptions
** https://www.amchameu.eu/position-papers/reach-restriction-essential-use-criteria-context-socio-economic-impact-analysis-when

Legislative and Regulatory Findings

- Grouping
  - Safe by Design**
    - Safe by Design is alternative approach that could by employed as a grouping strategy for PFAS
    - The concept of 'safe by design' aims to address safety issues during the, research and development, and design phases of production. This is done to reduce the need for substitution at a later stage
  - Grouping by PFAS class***
    - In a paper on grouping PFAS, AmCham EU state that as PFAS are a large and chemically diverse group of approximately 4,730 substances, these substances are not the same and should not be regulated as one group unless there is adequate and sufficient scientific evidence that this approach can be justified based on the principles of read across highlighted in REACH guidance
    - Grouping by class may classify inert solids, liquids, salts, and gases in a single class where intrinsic properties such as vapor pressure and environmental partitioning are enormously varied

** https://newsletter.echa.europa.eu/home/-/newsletter/entry/from-substitution-to-safe-design
*** https://www.amchameu.eu/position-papers/grouping-pfas-regulation-distinct-pfas-classes-scientifically-superior

PFAS Uses in Electronics

In addition to the already-documented uses in semiconductors, fluoropolymers such as PTFE are used in some printed circuit board materials and in insulation materials for cables in electronics equipment.

PFAS Uses in Electronics

- With 4,730 PFAS identified, their use in the electronics industry is extensive
  - However, PFAS incorporated as articles in products or used in the processing of articles, is limited to a relative subset of electronic product subcategories
- There is some evidence of Long-chain PFAS being replaced with either Short-chain or Side-chain alternatives
- PFAS, including some F-gas, are used in semiconductors, these uses are well-documented
- This screening study determined that PFAS are used in the following electronic products (other than PFAS use in semiconductors)
  - Wire and Cables (insulation) and Cable Assemblies
  - Printed Circuit Boards (PCBs)
  - Other products, like liquid crystal displays

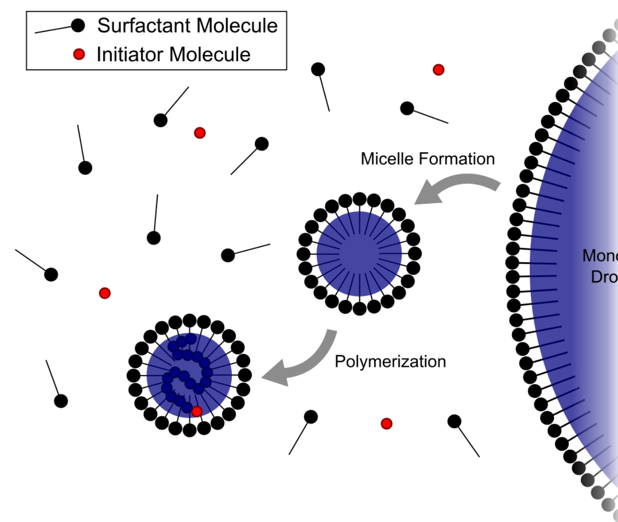
PFAS Uses: Wire and Cables

- A type of PFAS (fluoropolymers) are used for insulating cables in variety of electrical and electronic applications
- Fluoropolymers can be fluoroplastics and fluoroelastomers and include, PTFE, PFA, ETFE, FEP, and others
- These PFASs substances are selected for there properties:
  - Operation at high temperature
  - Resistance to corrosion
  - Water and oil resistant
  - Low dielectric constant – excellent electrical insulator
  - Flame retardant
  - Flexible, high stress crack resistance, UV resistance, long-life
- Fluoropolymer insulated wire and cables can be used in harsh environments and where high-volume data transmission is required e.g., automotive, medical equipment, data centers

Fluoropolymers in Wire and Cables

- The strength of the carbon-fluorine bonds prevent the compounds from easily degrading
- Fluoropolymers are an important enabling technology for society* and enables innovation and progress e.g., IoT
- They have a well-established safety profile and meet the accepted (OECD) criteria to be considered **"polymers of low concern"**, indicating that they do not present a significant concern for human health or the environment*
  - They are large, stable, inert polymeric molecules that are too large to cross biological membranes and therefore do not present significant concerns*
- PFOA can be used in the manufacture of fluoropolymers and fluoroelastomers in the polymerization process, as a surfactant in the emulsion
  - If used, the majority of the PFOA is removed at the end of the polymerization process, but some may remain as residue**

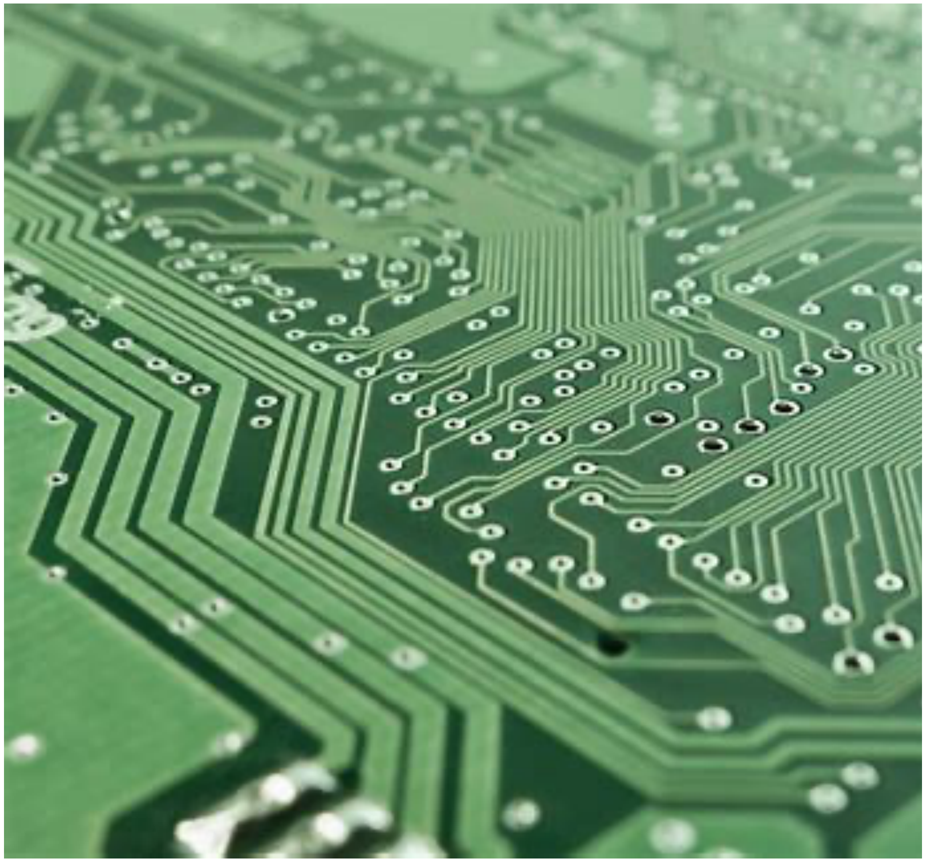
Polymerization Process



* https://fluorocouncil.com/important-update-about-fluorocouncil/
** https://blog.semi.org/semi-news/topic/semi-pfoa-working-group

PFAS Uses: Printed Circuit Boards

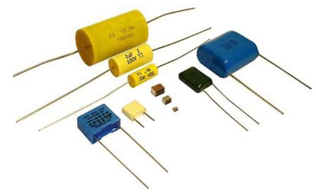
- PFAS fluoropolymers are used as a fiber-reinforced fluoropolymer layer in Printed Circuit Boards (PCBs)
- Examples include, PTFE and PFA
- Benefits include:
  - Low dielectric constant
  - Heat resistance
  - Chemical resistance
  - Non-stick and low frictional properties
  - Water and oil repellent
  - Low dissipation fact
- Can be used in Rigid, Flexible and Hybrid PCBs
- Fluoropolymer use is preferable over traditional FR-4 laminate material for high frequency and microwave applications



PFAS Uses: Other Electronic Products

> Other products, manufacturing processes, and components that use PFAS include:

- High Temperature Film Capacitors
- Liquid Crystal Displays*
  - Provide the liquid crystal with a dipole moment
  - Polymeric PFAS provide moisture sensitive coating for displays
- Light management films in flat panel displays*
  - Reduced static electricity build-up and dust attraction during fabrication
- F-Gases used in the manufacture of LCDs**
- Fluoropolymers used as materials in:
  - Lithium (Li) ion batteries***
  - Renewable Energy – photovoltaic panels
  - Fuel cell membrane electrode assemblies****
- Fluoropolymers are used as additives in certain polymer resins to help with flow control



* **An overview of the uses of per- and polyfluoroalkyl substances (PFAS)**
Juliane Glüge,[a*] Martin Scheringer,[a] Ian T. Cousins,[b] Jamie C. DeWitt,[c] Gretta Goldenman,[d] Dorte Herzke,[e1, e2] Rainer Lohmann,[f] Carla A. Ng,[g] Xenia Trier,[h] Zhanyun Wang[i]
** https://www.epa.gov/sites/production/files/2015-07/documents/supplier_profiles_2013.pdf
*** https://onlinelibrary.wiley.com/doi/10.1002/pola.28551
**** https://www.energy.gov/eere/fuelcells/parts-fuel-cell

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