Introduction

Despite concluding that there was an unclear substitution potential for electronics, the Dossier Submitters decided not to put the industry forward for derogations regarding the proposed PFAS Restriction.

As a consequence, there are several electronics uses that if they are not within the scope of a derogation(s), this will put the industry at a severe competitive disadvantage within the EU. Intel therefore requests that the following derogations be added to the EU PFAS restriction.

Cable/Connectors

The electronics industry utilises fluoropolymers in multiple functions such as cable jackets, insulation material, anti-friction coatings, covers etc. Fluoropolymers are only chosen when other polymers cannot meet the technical or performance requirements needed. Fluoropolymers such as PTFE, PTFE co-polymer, FEP etc. are utilised over other substances as they provide the following properties for cable and connector design:

- Low dielectric constant and dissipation factor – this property is required for low capacitance and coaxial cables.
- Thermal stability - high/low temperature resistance is needed for safety and long service life.
- Low flammability/flame resistance – fluoropolymers are unique amongst substances in that no additional flame retardants are needed (reduces the use of halogenated flame retardants), have high melting points, low rates of heat release and low smoke generation.
- Flexibility – no plasticizers are needed (reduces the use of ortho-phthalates).
- Low coefficient of friction – fluoropolymers have the lowest coefficients of friction of any solid materials.
- Chemical inertness/resistance – anticorrosion, can be used in the presence of solvents, oil, oxidizing agents, UV light and other environmental agents over a broad temperature range.
- Stress-crack resistance – fluoropolymers like any other polymers can be exposed to stress cracking from a variety of sources. These can involve solvent, environmental

and thermal cracking. However, fluoropolymers have excellent stress-crack resistance that aids in their duration.

- Low moisture absorption – fluoropolymers are hydrophobic and resistant to hydrolysis; the typical properties and dimensional stability remain unchanged even after long immersion in water which is good for cables/connectors for outdoor use.

There are no other chemicals that can provide all of these critical properties in combination in a standalone substance for cables/connectors.

Capacitors

PFAS is used in several materials such as electrodes (anode), masking, seals, coatings, insulators, and paste materials. The typical PFAS includes PTFE, PTFE co-polymer, Poly(difluoromethylene), .alpha.-(cyclohexylmethyl)-.omega.-hydro- (CAS# 65530-85-0), etc. The properties they provide include:

- highly reliable seal against electrolyte diffusion along the tantalum anode wire.
- resist distortion during the oxidation and impregnation process.
- binder for electrodes – similar application as PFAS in batteries

Gnonhoue et al. (2021) have identified various fluoropolymers that are used in passive components/capacitors as dielectric films, and occasionally as liquid impregnates. They are used for their low dissipation factor, high dielectric strength, good stability, water repellent characteristics, high heat resistance, as well as the ability to be produced into thin films (easy processing & smaller form factors). Perfluorocarbons are effective liquid impregnates for capacitors (Banks et al. 1994). Relevant PFAS for capacitors are shown in Table 1.0.

Table 1.0 – PFAS used as liquid impregnates for capacitors

	Molecular formula	Specification of chemical(s)	CAS No.	Type	Reference
Aliphatic perfluoroalkane[1a]	C_nF_{2n+2}	n = 6	355-42-0	U	(R. E. Banks, Smart, and Tatlow 1994)
Perfluoromethylcycloalkane[1b]	C_nF_{2n+2}	n = 6, 7	1805-22-7, 355-02-2	U	(R. E. Banks, Smart, and Tatlow 1994)
Perfluoro-1,3-dimethylcycloalkane[1c]	C_nF_{2n}	n = 8	335-27-3	U	(R. E. Banks, Smart, and Tatlow 1994)
Perfluorotrialkyl amine[1d]	$N(C_nF_{2n+1})_3$	n = 4	311-89-7	U	(R. E. Banks, Smart, and Tatlow 1994)
Perfluorinated cyclic ethers	-	-	-	U	(R. E. Banks, Smart, and Tatlow 1994)

In addition, it is important to note that PFAS is part of capacitors' material properties (ceramic element). In these elements PFAS is used as a polymeric material and fluorinated surfactant. The functions imparted by PFAS with these ceramic elements are:

1. Help reduce cure shrinkage (JP59128240, 1984). This is due to high temperature stability of PFAS and ability to preserve material properties over a large temperature range.
2. Fluorinated surfactants promote the flow of coatings and prevent cracks in the coating during drying.
3. Some fluorinated surfactants functions also as corrosion inhibitor.
4. Fluorinated surfactants can be used to disperse various particles. For example, ferromagnetic metal oxide particles have been dispersed with potassium N-ethyl perfluoroalkane sulfonamidoacetate (CAS No. 2991-50-6) to help disperse particles.

<u>Suitability of Dossier Submitter Proposed Non-PFAS Alternatives</u>

For electrical cables/connectors, fluoropolymers provide all of the properties and characteristics needed to generate robust products utilising one substance. By heavily restricting or indeed banning the use of fluoropolymers, the electronics industry will need to conduct a substantial level of research and development to identify and qualify non-PFAS alternatives to undertake the function fluoropolymers perform today. The Dossier Submitters proposed alternatives for wire insulation. These non-PFAS alternatives are PEEK, PC and EDPM. A review was conducted to ascertain their feasibility as viable non-PFAS alternatives, focusing upon several prominent properties.

<u>Dielectric Constant</u>

Most fluoropolymers have a dielectric constant of ~ 2.0 (Matweb 2023). This is extremely critical as the size of electronic devices continues to shrink, which introduces new obstacles such as signal crosstalk, power consumption and time delays, as a result, fluoropolymers with low dielectric constants are needed to achieve faster and stable signal transmission (Dong et al. 2023). Such dielectric characteristics are the result of the fluoropolymers' symmetrical molecular structure $(C_2F_4)n$ and the short distance between the carbon and fluorine (Daikin 2023).

The three proposed non-PFAS alternatives have much higher dielectric constants ranging from 2.7 – 4.5 (Matweb 2023 and Gunaskaran et al. 2008), which will result in much slower and unstable signal transmission. This will greatly affect the functioning, safety and quality of the electronic product for which these cables/connectors are utilised. Consequently, on this critical property alone, none of the proposed non-PFAS alternatives are suitable for the intended use in wire insulation.

Dissipation Factor

The dissipation factor can also be used to assess the characteristics or quality of an insulating material in applications such as cables, connectors, terminations, joints etc. The lower the value, the better the dissipation factor. Fluoropolymers have a low value of 2.0 (Omnexus 2023) which provides a highly efficient insulator. EPDM also performs well with this quality with a dissipation factor of 2.5 (Thorne & Derrick 2023), however, the other proposed non-PFAS alternatives PC and PEEK have dissipation factors of 9 and 30 (Omnexus 2023) respectively which are not best suited for cables/connectors.

Coefficient of Friction

Fluoropolymers have a Coefficient of Friction (COF) in the range of 0.02 - 0.08 (Matweb 2023) which are effectively the lowest of any known solid material. Such properties have proven to be invaluable to the electronics industry in providing sustained durability. PC has the closest COF with a range of 0.05-0.18 (Matweb 2023) to that of the fluoropolymers. PEEK has higher values of 0.15-0.40 (Matweb 2023) while EPDM has very high values of 1.36 - 2.76 (Mukhopadhyay 2014) which are not suitable for cables/connectors.

Flame Retardancy

In terms of flame retardancy, a primary safety function, fluoropolymers are unique with their extremely high Limiting Oxygen Index (LOI) of ~95% (Omnexus 2023) which inherently means they are non-flammable. The proposed alternatives have LOI values ranging from 19.5 - 24 (Omnexus 2023). Taking EPDM with the lowest LOI value of 19.5, implies that it is a highly flammable substance that restricts its further application and development particularly within the electronics industry (Tang et al. 2013). PC and PEEK also have low LOI values which would require flame retardant additives to be employed. However, the "Regulatory Strategy for Flame Retardants" published by the European Chemicals Agency in March 2023, which stated that "the substances in scope of this strategy are in principle all flame retardants.", places a very high degree of uncertainty on the future availability of flame retardants that would be required for the non-PFAS alternatives proposed by the Dossier Submitters.

In essence, the proposed non-PFAS alternatives have some of the necessary properties required for use in cables/connectors. However, they all have inappropriate characteristics that would require in some cases, the addition of supplemental chemical substances to render them functional which are also on a roadmap to be regulated under the REACH regulation. Others such as EPDM with its flammability properties precludes them on safety grounds from undertaking a meaningful function with cables/connectors.

The Dossier Submitters did not propose any non-PFAS alternatives for the PFAS utilised in capacitors, so a review was not conducted. It may be assumed that the Dossier Submitters could not find non-PFAS alternatives for the function they provide with capacitors.

<u>Non-PFAS Alternatives Identified Through the Supply Chain or Research</u>

The electronics industry has a very deep and complicated supply chain which operates on a global basis. Ascertaining data on feasible non-PFAS alternatives for cables and connectors has yielded no drop-in replacements to date. Intel contacted its suppliers to understand their ability to provide non-PFAS cables and connectors. Table 2.0 illustrates their responses and demonstrates the scale of the problem in ascertaining non-PFAS cables, connectors and capacitors for electronics products.

Table 2.0 – Intel supplier survey on non-PFAS cables, connectors and capacitors

Supplier	PFAS Function	Ability to Provide Equivalent Non-PFAS Cables, Connectors & Capacitors	Component Type	Availability of Alternatives
#1	High temperature resistance: Teflon wire has very high temperature resistance and can be stable in the temperature range of -40℃ to +260℃. This makes it an ideal insulating material for high temperature environments. In the manufacturing process such as soldering, the temperature may reach 300℃, FEP insulation will not deform after soldering. 2. FEP has low dielectric constant (DK) which can support higher speed data	No, since PFAS contains 10,000 materials, some supplier even didn't arrange to test it. They don't want to shoulder the cost alone. Some supplier starts to find new material, but they don't dare to guarantee the performance since it has to undergo many test for a long time. If this derogation (exemption) is not successful, we will not	Cables	Based on supplier feedback, we cannot start alternative timelines since supplier cannot recommend new material to us.

	transmission. 3. The thickness of Teflon can be as thin as 0.05mm, which can reduce wire OD and reduce the use space. 4. Teflon can produce smaller specifications of wire (up to 46AWG)	be able to provide equivalent parts to Intel		
#2	Not disclosed	No	Cables/ Connectors	No
#3	Not disclosed	No	Cables/ Connectors	No
#4	Not disclosed	No	Cables/ Connectors	No
#5	Not disclosed	No	Cables/ Connectors	No
#6	Not disclosed	No	Cables/ Connectors	No
#7	Not disclosed	No	Cables/ Connectors	No
#8	Not disclosed	No	Cables/ Connectors	No
#9	PFA FEP materials are specially developed for high speed extruded thin-wall wire molding and high electrical performance requirements. In terms of processing, the wall thickness of extremely thin coaxial cable has high physical requirements for materials (such as MRF, breaking strength and elongation). No other materials except PFA FEP have been found to meet the processing requirements.	No	Cables	After investigation of industry manufacturers, no alternative materials more superior than PFA\ FEP have been found. PE material was tried, but no sample could be obtained. Due to material reasons, the complete sample could not be obtained (insulation, broken skin, discontinuity).
#10	Materials that contain PFAS are extremely stable and tough, not very polarizable, inherently good with flame/ smoke performance, low friction, low outgassing, and absorb little to no moisture.	No	Cables	For our cable jackets there are no known alternatives at this time. We do have a team of people reviewing prospective materials, but they

				are only in the early stages of the investigation.
#11	Ceramic element with ferrite beads	No	Capacitors	Planning in progress
#12	Ceramic element with ferrite beads	No	Capacitors	Planning in progress

So currently, Intel's cables, connectors and capacitors suppliers have no line of sight to having PFAS alternative products.

Moving beyond the supply chain and focusing upon research into non-PFAS alternatives has required an extensive literature review to determine what if any non-PFAS alternatives are being considered for cables, connectors and capacitors. The on-line library search engine utilised for this review was Summon™.

Table 3.0 illustrates the keywords/phrases utilised in an effort to comprehend what research into non-PFAS alternatives for cables, connectors and capacitors has taken place or indeed is still on-going.

Table 3.0 – PFAS literature review for non-PFAS alternatives in cables, connectors and capacitors

Keyword or Phrase	# of Results	Results of Relevance to PFAS in Cables/Connectors/Capacitors
PFAS	68,857	Reviewed the first 1,000 results. None of them were relevant.
PFAS in electronics	1,791	None
Non PFAS alternatives in electronics	19	None
PFAS alternatives in electronics	78	None
Fluoropolymer alternatives in electronics	84	Most of the results focused upon fuel cells, membrane materials for alternative energy and sustainability applications. None were relevant for cables, connectors and capacitors.
PFAS in electrical cables	188	There were some relevant results, but the papers emphasised the benefits of fluoropolymers in cable products.
Fluoropolymer	10	None

alternatives in electrical cables		
PFAS in electrical connectors	8	None
Fluoropolymer alternatives in electrical connectors	0	None
PFAS in capacitors	62	There were some relevant results, but the papers emphasised the benefits of fluoropolymers in capacitors.
Fluoropolymer alternatives in capacitors	5	None

It is typical that research into any chemical alternatives will be represented in the mainstream academic journals. Based upon the findings in Table 3.0, it is apparent that if there is on-going research into non-PFAS alternatives for cables, connectors and capacitors, none of it is finding its way into the public domain. This scenario is more than likely a result of the lack of research into these electronic components/products.

The combined lack of data on non-PFAS alternatives from the supply chain in conjunction with the lack of research into these electronic components/products, surmises that there are no drop in alternatives currently available and the likelihood of such alternatives being available at the entry into force timeframe is unlikely. Consequently, it is requested that a derogation covering the uses of cables, connectors and capacitors consisting of tantalum and aluminium electrolytic is granted from the proposed REACH Restriction on PFAS. The requested timeframe for the derogation is 12-years.

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