[confidential, refer to confidential attachment] We create innovative products that provide the highest levels of precision through intensive research and development processes, unique expertise, and a broad network of collaborative operations, which are essential for such high performance measurement systems that provide our clients with a genuine competitive advantage. The company is located in the EEA and is therefore directly affected by the proposed restriction. [confidential, refer to confidential attachment]. [confidential, refer to confidential attachment] This document shall provide valuable information to the ECHA committees during the consultation period for the Restriction Proposal Annex XV: Restriction of Per- and Polyfluoroalkyl Substances (PFAS) under REACH (Restriction Proposal may be referred to as Dossier in the following text).

The following elaboration can be assigned to Annex XV Report Consultation ***Category 6: Missing Uses, Analysis of Alternatives and Socio-Economic Analysis***. It contains arguments and expert knowledge from our engineers as well as product- and chemical stewardship task force. While we aim to provide an unbiased notion of conclusive arguments, our view is in general consistent with the Orgalim (federation, representing Europe's technology industries) *Position Paper on the restriction of PFAS*.[1]

Although there is a wide variety of electronic applications, the Restriction Proposal submitters summarize the cost-benefit assessment in the *Electronics* sector as follows:[2]

> *"As long as no further information is available, the information suggests that the use of PFAS enhances safety and durability of articles and facilitates a more efficient energy consumption. The Dossier Submitters received limited information on alternatives, however, does not fully understand whether these alternatives have the potential to be used broadly or can only be utilized in niche applications. It is the Dossier Submitters' understanding that alternatives are available for some uses in which fluorinated polymers are used currently. No information on cost-effectiveness and affordability of the alternatives is available, making it impossible to justify a general derogation for all PFAS- uses in electronics. It is also not possible to identify sub-uses for which a derogation is justified as the available information basis is mostly weak or inconclusive."*

It is not clear to us why equipment needed for semiconductor production should (in contrast to processing media) not be included in the proposed derogation for the use in the semiconductor industry (according to a dossier submitter's information note, equipment is not planned to be included in the semiconductor industry)[3]. Nevertheless, the Dossier submitters assess the costs and benefits in the *Semiconductors* industry as follows:[4]

> *"A cost-effectiveness estimate cannot be derived considering the scarce information on impacts of a PFAS ban on this sector. The Dossier Submitters conclude that information on the availability of alternatives is insufficient and therefore characterize it as 'weak' (…). Not being able to manufacture, use, import or export these articles would lead to high producer surplus losses for manufacturers and employment losses due to business closures and to high socioeconomic costs to customers due to the unavailability of an unknown number of articles.(…)"*

While the Dossier submitters explicitly mention a time-unlimited derogation for PFAS e.g. used as active substances in biocidal products and human medicinal products (as they are addressed under their own directives), this is not proposed for electronics although being addressed in Directive 2011/65/EU (RoHS; Restriction of the use of certain hazardous substances in electrical and electronic equipment).[5] Due to the importance of electronics for the functioning of society (e.g. when used in semiconductor production, see European Chips Act[6]; or as an indispensable component in any industrial production) and the responsible reduction of dependence on suppliers outside the EEA (such as Asia), we cannot understand the currently proposed extremely limited derogations and timelines. Therefore, we do not understand why for some use sectors such as lubricants or fluoropolymers in petroleum industry,[7] the Dossier authors state that the socio-economic costs of a total ban are expected to be high, with a strong supporting evidence, while for others such as electronics and semiconductors, this is not stated, although the importance is given and the potential "unavailability of an unknown number of articles" is explicitly mentioned. Stated in the chapters describing these use sectors are the non-existence of alternatives and substantial functionality loss when applied in harsh environments, e.g. in terms of performance level and lifetime – which should affect an unknown number of industries and end-users. It was also mentioned that it would take a long time (several years to several decades) to the transition towards the use of alternatives that can achieve the same level of performance. To our knowledge, by research of stakeholder transmissions that was submitted already prior to filing of the Annex XV Restriction Proposal, at least analogue information was also submitted for a variety of electronics and semiconductor-related uses. Regarding the Restriction Proposal, we consider the argumentation regarding the proposed derogation periods and clear distinction made by the Dossier authors between weak, inconclusive, and (sufficiently) strong evidence to be unclear or at least highly non-transparent. We also find it inconsistent that the authors of the Dossier conclude on numerous occasions that the evidence was weak due to communication by too few stakeholders, while at the same time advocating for a joint submission of arguments (according to the FAQ provided by the authors during the consultation period, “Joint submissions are strongly encouraged”).[8] The latter, in turn, would limit the number of perceived voices and arguments.

Originally as we understood it, to avoid outright bans and regrettable restrictions or substitutions, the implementation of the REACH SVHC (Substances of Very High Concern) key concept was established to allow a phased approach to limiting substances of concern with the aim of creating awareness and knowledge among industries, consumers, and authorities. This, in turn, should encourage the adoption of safer alternatives and promote the development of innovative and sustainable technologies. This approach will provide industries with the time, motivation and supply chain information to find suitable alternatives or solutions, thereby promoting the development and implementation of safer products and processes. SVHC should strengthen the exchange of information in supply chains, leading to increased transparency and responsible chemicals management. We do not understand why the SVHC concept was not applied in the case of a PFAS restriction such as the currently proposed. In the case of the restriction of PFAS in fire-fighting foams, the European Commission and ECHA commissioned a detailed study on possible regulatory management options to address the risks associated with the use – and concluded prior to the Restriction Proposal that fluorine-free products are generally available, technically feasible, and have been successfully used in most of the identified sectors.

Like many stakeholders, we conclude that the complexity and consequences of banning the substance class of PFAS have not been adequately addressed and therefore advocate for a balanced, thorough and (where possible) globally coordinated review of the PFAS challenge. While focused on the United States of America, the U.S. Environmental Protection Agency (EPA) has developed a roadmap that it regularly reviews and discusses as new data is received from the public, the scientific community, and industry. Extended consultation periods and the avoidance of industry-wide bans combined with a time-independent *essential use* categorization, enable stakeholders to find, test and verify suitable alternatives to the use of PFAS without risking market loss and ineffective shifts in the country of production. In this context, we want to emphasize that **as an industry leader in the field of high-performance sensor applications, we were not contacted during the previous stakeholder consultations**. We believe it is illusionary to expect that a variety of complex supply chains (including component manufacturing and the socio-economic impact of a ban at the end-user level) of electronic devices can be thoroughly evaluated within a few months or years. Typically contracts exist neither for disclosure of the final use of an article, nor for a disposal strategy, nor for a risk-assessment for substitution of PFAS contents to different materials, nor for intentionally added PFAS in articles. On the contrary, contracts often contain mandatory obligations to communicate and evaluate any significant change in production processes with the customer. The electronics and semiconductor industries are, as also the Dossier submitters argue, difficult to distinguish as they are naturally interdependent. While we understand that the distinction between specific uses, such as high-precision sensor applications, when considering derogation periods may be considered exhaustive, we strongly advocate for a more holistic approach. We believe that an ideal approach should address PFAS materials throughout the entire value chain and carefully address restrictions on precursors, processing aids, or production equipment necessary to provide e.g. semi-finished products.

Our experts are working intensively and across the entire company group in special teams to evaluate, develop and qualify substitutes for PFASs currently in use. Due to the vast number of products we offer (more than 1000 different products), we judge we were not yet able to identify every use of PFAS in the articles, the performance upon substitution of PFAS parts, the availability of alternative parts, and to communicate the impact of substitution to our customers. Therefore, we estimate that we could cover approximately 70 % of our product sub-articles, and the key functions provided by PFAS for the corresponding complex products. This explicitly covers the (lack of more detail on) later mentioned sub-article categories *sealings* and *various other*. As mentioned above, our expertise is the development and production of high-performance displacement and temperature sensors with unsurpassed characteristics providing a significant competitive advantage on the market. While the use sectors of PFASs were established in recent years, for example in the publication *An overview of the uses of per- and polyfluoroalkyl substances (PFAS)* from 2020,[9] we see that the sector of electronic sensor equipment in general, or in particular high-performance displacement and temperature sensors, is underrepresented or even not mentioned. We could not find a specific use sector or derogation for our products in the Restriction Dossier.

We therefore request that the following sub-use sector be added to the electronics use sector: high-performance displacement and temperature sensors. This includes necessary peripheral articles such as cables or cable connectors, which are often required to separate the (e.g. signal processing) electronics or the controller, which typically cannot withstand very harsh conditions, from the sensor. A sensor is defined as a device that detects or measures physical properties or changes in the environment and converts them into electrical signals or other forms of output that can be interpreted by electronic systems. Key characteristics of sensors are transduction (sensors use transducers to convert physical properties, e.g., temperature, pressure, light, motion, into electrical signals), sensitivity (sensors are designed to be sensitive to specific physical phenomena, allowing them to detect small changes in the environment), output (sensors generate electrical signals or data that represent the measured parameter), and interaction with the environment (sensors must be in direct contact or close proximity to the physical property they are designed to sense).

As a definition to distinguish our high-performance displacement and temperature sensor products from generic sensors or generic measuring devices, we propose: Displacement and temperature sensors are based on electromagnetic principals (such as eddy current, inductive, capacitive, and optical). They perform a precise continuous displacement/distance/position or temperature measurement, characterized by parameters such as range, linearity, or resolution. *High-performance* is thereby characterized by a combination of (one or more of) the following features:

- The ability to operate at high temperatures (typically above 105 °C and up to 260 °C)
- The ability to operate at low temperatures (typically below -150 °C and down to -270 °C)
- Outstanding tightness / resistance against chemicals, e.g. various liquids and gases
- Sensor (long-term) signal stability
- Suitable peripheral properties of attached articles, such as physical properties like cable diameter and/or cable bending properties (good handling and low influence on electrical parameters during movement and bending), tightness between sensor and sensor cable plug, or suitable electrical properties like an outstanding low dielectric constant of a cable.
- Outstanding outgassing requirements meeting clients' application requirements. Max. outgassing in the range of 10^{-13} mbar L/s/cm², available e.g. *via* VACOM purity classes – see footnote 10
- High vacuum tightness with a leak rate of less than 10^{-8} mbar l s^{-1}
- High resolution, i.e. ≤ 0.05 % of measuring range (FSO)
- High sensor bandwidth/frequency response, i.e. 250 Hz to 100 kHz

External factors such as high temperatures, device movement, or the influence of various chemicals may be summarized as *harsh environment* or *harsh conditions*. Exemplary combinations that justify the need for PFAS materials (such as but not limited to FKM, FFKM, or PTFE) are listed below. The following list is not exhaustive:

- 1 High-performance sensors for ultra-clean vacuum environments in lithography machines for the semiconductor industry are often sealed to guarantee a high-level vacuum tightness. This type of sealing can be used to prevent internal outgassing of the sensor or to separate the vacuum from the atmospheric environment. The sealing itself also must meet the high outgassing requirements.
- 2 Sensors in lithography machines for the semiconductor industry must fulfill a demanding list of performance requirements such as high resolution, high sensor bandwidth/frequency repsonse, and suitable peripheral properties. They must provide (long-term) signal stability at various (including elevated) temperatures and meet high outgassing requirements for ultra-clean vacuum environments of the lithography machines.
- 3 Electromagnetic high-performance sensors with a cable connection between sensor head and signal-processing electronics must fulfill a demanding list of requirements including high resolution, high sensor bandwidth/frequency response, sensor (long-term) signal stability at various (including elevated) temperatures. To achieve those requirements, a high-frequency signal (250 kHz to 3 MHz) is used to excite the sensor head. The sensor cable is, with its electrical properties such as cable capacitance, part of the impedance of the sensor head. The electrical properties of the cable must be state-of-the-art and very stable (over time at various temperatures)

to reduce the influence on the sensor impedance at the given frequency range. The stability of the signal and reliability of electrical properties of the cable must be ensured during bending and movement.

- 4 High-performance sensors (and peripherals such as cables or plugs) applied under harsh conditions require a suitable material to withstand these conditions. The sensor signal must be long-term stable and, in addition, the influence of temperature changes or bending/vibrations on the electrical parameters of the cable must be as small as possible. It is also important to have suitable (small) cable dimensions. When PFAS are applied, the thin insulation of the individual wires and the cable outer layer results in significantly smaller outer diameters for the same inner copper strand thickness. Silicone cables, which may potentially be suitable at (a single key requirement such as the) application temperature, have significantly higher insulation thicknesses, both for the strands and the cable sheath. As peripheral articles, such as cables, may be directly connected to the sensor housing, the material combination must be compatible for an outstanding pressure-tight connection (which is ensured by a complex, specially designed process) under harsh conditions. The explicit need for PFAS (and comparison with potential, but unsuitable substitution materials) is further outlined in one of the following sections.
- 5 Temperature sensors such as infrared pyrometers are rated for use at 180 °C. To withstand these temperatures PTFE cables are used. These kind of sensors transduce unamplified, analog, direct current signals in microvolt range over four strands to an electronic unit in the lower temperature area. To fulfill the requirements of typical applications in industrial environments, the cables must be flexible while mounting, but also need to be robust enough to ensure, that there is no further movement afterwards. Any movement of the cable during the measurement will affect the measurement signal in an inappropriate manner. PTFE cables offer a compromise between flexibility and robustness. Silicone cables as an alternative regarding the temperature range are not robust enough at the required small diameters to ensure a stable signal in industrial environments. On the other hand, cables with PEEK sheath are not flexible enough to be mounted in the given applications.

Sub-level articles of the sensors where PFAS are integral are as follows:

- Cables: [confidential, refer to confidential attachment]
- Sealings: [confidential, refer to confidential attachment]
- Various other: [confidential, refer to confidential attachment]
  Emissions at our site are estimated with [confidential, refer to confidential attachment]

Examples of high-performance displacement sensors include: [confidential, refer to confidential attachment]. Our products are for example applied in the fields of measurement and testing technology, manufacturing automation, semiconductor production, aerospace industry, machine control or monitoring, quality assurance, and experimentation. This highlights the large interconnectivity of the use sectors mentioned in the Annex XV Restriction Proposal. We think the presented Restriction Proposal does not convincingly consider these interconnections, which are vital for e.g. transfer of the energy and transport sector towards a sustainable future, or the European Chips Act.

An overview by the government-funded international organization ChemSec on the use of PFAS in the electronics industry also reveals that there are still many data gaps regarding the application of this substance class.[11] The article states that manufacturing processes and formulations of final products are typically not disclosed to the public, which means that the full extent of PFAS use remains unclear. It is important to note that suggested alternatives may not be suitable for all situations due to the specific physical and chemical properties required to fulfill the current function of PFAS. The industry acknowledges that finding a perfect substitute for PFAS is often not feasible. For instance, substituting a PFAS-containing product with a new compound may require additional changes to accommodate differences in size, resistance, or other factors between the alternative and the PFAS compound. Furthermore, some suggested alternatives might themselves contain PFAS, either intentionally added without disclosure or as impurities. The publication is also a good common example of how the “ease of substitution” is justified by listing a variety of substances for e.g. cables that can substitute PFASs, whereby we want to emphasize that the references are largely based on information gathered from web pages rather than (significantly more) reliable peer-reviewed or weighed information from stakeholder associations / stakeholders. This is all the more important, as research on material datasheets alone can lead to wrong conclusions. We are aware of numerous examples where articles consist of a mixture of chemical compounds and contain less than 20 % PFAS (added to achieve certain key functionalities), which is not declared on any datasheet and may lead to a (wrong) “example that non-PFAS materials can achieve similar properties as PFAS”.

Publications such as the Organization for Economic Co-operation and Development (OECD) information on the effectiveness of PFASs and their alternatives in coatings[12] states “(…) fluorinated polymers (FP) would be the consistent choice for use in cable and wire coating materials. However, because the majority of cable and wire applications do not require such a wide range of high performance, alternative materials are sufficient.” The source of the evidence given is a general statement “information from stakeholder consultations”, whereby [confidential, refer to confidential attachment] was not considered to have been contacted. To maintain market access, we rely on our products having excellent mechanical and electronic properties that are state-of-the-art and beyond. **We therefore conclude with a contrary statement: for our high-performance sensor devices, non-PFAS materials are largely insufficient.** During our investigations, we generally found significantly lower performance of alternatives compared to the use of PFAS in the products, as discussed in more detail in the following sections. We share the opinion of the Dossier submitter highlighted in Annex F to Annex XV, table F.2.17 (moderate risk of uncertainty on extent non-PFAS alternatives perform to the required level), but conclude with a high risk. Many applications and products we provide are part of non-disclosure agreements and patents, and extensive research combined with the attempt of substituting materials, extensive qualification (at our end and the customer’s end), and risk assessment with the customer’s help has to show whether the products align with specified performance levels.

A unique selling point for our sophisticated displacement and temperature sensors is high performance (which includes high precision), i.e. we must provide displacement measurement with lower noise and higher stability than typical products available on the market. Stability in displacement measurement means that the measurement does not change over time and is independent of environmental conditions. Changing temperature or the presence of lubricants, humidity or dirt, as well as perturbations such as shock or vibration on the sensor must not affect the measurement or cause an additional measurement error. For applications where dimensions are critical, such as where the sensors must be very small, this is only possible by attaching a coaxial cable with very small outer diameters to the sensors. For these small sensors, coaxial cables with outer diameters as small as 0.5 mm are applied. Low dimensions may be necessary due to limited space at the mounting location and thus limited space for the routing of the cable from the sensor to the electronic unit/controller. In the semiconductor industry, e.g. where sensors are used in lithography machines in a high vacuum, low outgassing of the components used is essential and required by our customers – please refer to footnote 10 for literature data and explicit values. It is important to note that specific customer specifications beyond these publicly available values are likely and may evolve / become more stringent for future high-end technologies. Outgassing is typically investigated on single-part / single-supplier level and is not (only) evident by material selection, but is associated with a significantly higher chance for compliance through the selection of suitable materials such as a polymeric PFAS.

Almost all of our eddy current displacement sensors use a cable between the sensor and the electronic unit/controller. In most cases, we use a coaxial cable. Our displacement sensors use the sensor coil in an LC resonator. The sensor cable is an integral part of this resonant circuit and will be discussed in the following.

A change in the cable capacitance directly translates into an error in the distance measurement. It is crucial for a stable measurement that the cable capacitance is as low and as stable as possible. The higher the cable capacitance, the higher is the ratio of the cable capacitance to the total capacitance, so a relative change in cable capacitance will cause a greater measurement error. The cable capacitance varies when the cable changes its geometry due to mechanical stress such as bending or torsion of the cable or a temperature change. In particular, a change in the cable temperature not only influences its geometry due to thermal expansion but also affects the electrical properties of the coaxial cable materials, such as the electrical resistance of the inner conductor, the electrical resistance of the outer screen and the dielectric properties of the insulator between the inner conductor and the screen, which directly causes a change in capacitance. Almost all coaxial cables we use for our high-performance displacement sensors as a sensor cable, include PTFE, FEP, PFA, ETFE or FKM. We have evaluated materials to substitute the PFAS compounds in these peripherals (*in this case,* cables) but have not been able to find suitable materials. Substitution materials typically meet some of the requirements and fail in many others.

When used as a dielectric inside the coaxial cable, the low dielectric constant (relative permittivity) of PTFE and the possibility to manufacture a foamed (also called expanded or porous) form of PTFE is a key factor for using it. PTFE, PFA and FEP already have a low dielectric constant of only 2.1; in its foamed form, it is possible to reduce the dielectric constant to 1.3. A low dielectric constant is mandatory to lower the capacitance of the coaxial cable to the ultimately needed levels, as a low cable capacitance is important for the accuracy and stability of a highly precise measurement.

The capacitance of a coaxial cable of length l is calculated using the following formula, where d_a is the diameter and ε_r the relative permittivity of the dielectric insulation, and d_i is the diameter of the inner conductor ($\varepsilon_0 = 8.854 \cdot 10^{-12} \frac{As}{Vm}$):

$C = 2\pi\varepsilon_0\varepsilon_r \frac{l}{\ln\frac{d_a}{d_i}}$ Equation 1

Replacing a foamed PTFE dielectric with a dielectric constant of $\varepsilon_{r_1} = 1.3$ with a material with a dielectric constant of $\varepsilon_{r_2} = 3.2$, increases the cable capacitance by a factor of 2.46. If the cable with the PTFE dielectric has a capacitance of 40 pF/m, the new cable would have a capacitance of 98 pF/m. Assuming the sensor is excited at 1 MHz and the total capacitance of the LC resonator is 750 pF, the percentage of the cable capacitance to the total capacitance (sum of the capacitance inside the electronics and the cable capacitance) increases from 32 % to 78 % for 6 m cable length. This increases the measurement error, because the cable capacitance is not as constant as a discrete C0G capacitor at the electronic unit. In addition, in most applications the cable is exposed to a larger temperature change during the measurement. The higher the ratio of the cable capacitance to the total capacitance of the sensor system, the higher is the measurement error due to changes in cable capacitance during bending or vibrations. The only way to overcome this increase in cable capacitance is to alter the geometry of the cable. According to Equation 1, the ratio of the outer to the inner diameter of the dielectric $\frac{d_a}{d_i}$ of the cable must increase from 6.1 to 85.7 by a factor of 14. One option is to increase the outer diameter of the dielectric. For this particular cable, which has an outer diameter of 3 mm, the diameter of the dielectric insulation must increase from 1.7 mm to 23.8 mm. The outer diameter of the cable (including the shielding and the outer jacket) would therefore be more than 24 mm. A cable with a diameter increased by a factor of 8 has a much larger bending radius, is much heavier and it would be practically impossible to connect to most of our sensors (because its diameter is larger than the sensor itself). The second option would be to reduce the diameter of the inner conductor from 0.3 mm to 0.02 mm. Aside from the technical feasibility of such a thin inner conductor, the electrical resistance of the cable would increase drastically by a factor of $\left(\frac{0.3\text{ mm}}{0.02\text{ mm}}\right)^2 = 225$, which also drastically decreases the sensitivity of the measurement and increases the noise of the distance measurement. In addition, the electrical resistance of the conductor depends on the temperature of the cable and so the temperature dependency of the measurement will increase. The dielectric losses, described by the dielectric loss factor $\tan\delta = \frac{G}{\omega C}$, of PFAS materials are very low; for example, for solid PTFE dielectric losses are in the range of $2 \cdot 10^{-4}$, and for foamed PTFE in the range of $5 \cdot 10^{-5}$. Compared to the losses due to the electrical resistance of the conductor, these losses - and therefore also the temperature dependence - are negligible. This is not the case for other materials like polyimide, which has a loss factor of 0.01 to 0.03, which is more than 200 times higher.

In addition, dielectric losses (and the dielectric constant) in the cable are strongly influenced by absorbed moisture. Therefore, the used dielectric material itself, including connection setup, must prevent moisture absorption – and PTFE has a very low water absorption ratio (< 0.01 %). We use coaxial cables with an FKM outer jacket for applications where a high temperature resistivity in combination with pressure sealing is needed. It is not possible to use a cable gland with an additional rubber seal at the cable outlet of the sensor to pressure seal the outlet because of the small size of the eddy current sensors. The elastic properties of an outer jacket made of FKM make it possible to seal the cable outlet directly to the sensor housing. Part of the sensor housing is a cylindrical metal cable outlet, which is roll-formed on the outer jacket of the cable. This type of sealing uses minimal space and ensures pressure resistance of several bars. Like the other PFAS materials we use, FKM also withstand temperatures up to 200 °C and is only limited in the lower temperature range. For this special type of coaxial cable construction, the dielectric also utilizes PTFE and a PTFE foil is used between the FKM jacket and the braid. For displacement and temperature sensors, not using a coaxial cable, the temperature resistance and the small outer diameter of cables (resulting in a more flexible cable with smaller bending radius) are the key factors for using PFAS as insulator. In addition, the pressure sealing by roll forming on a FKM outer jacket, like described before is often used here.

In the following section, we attempt to provide insight to evaluating the advantages and disadvantages of some of the most promising PFAS alternatives for cables.

Plastics such as polyurethane or PVC are currently used only as materials for the outer jacket; these materials have a high dielectric constant ($\varepsilon_r \approx 4$ to 8) and high dielectric losses (tan$\delta \approx 0.1$), which makes them not an option as a dielectric insulator for a coaxial cable. Cables with outer jackets made from these materials also have limited maximum operating temperatures of typically not more than 100 °C.

Polyethylene has a low dielectric constant $\varepsilon_r = 2.3$ and also a small loss factor. When used as a dielectric insulator for a coaxial cable, it can be foamed to reduce the dielectric constant and losses. Evaluating dielectric properties, it is a viable alternative to PTFE at low temperatures and is readily used in coaxial cables. However, its limited maximum operating temperature is - even for specially designed cross-linked polyethylene (XLPE) - limited to 105 °C, making it unsuitable for many high-performance applications. In addition, the chemical resistance of PE materials against mineral oil at elevated temperatures is poor, as are their unfavorable outgassing properties.

EPDM has similar properties to FKM and can be used for an outer jacket but only up to a temperature of 150 °C. It is not resistant to mineral oil-based fluids, greases, and oils, which often prevents its use. As rubber material, it is not intended to meet outgassing requirements for high-end technologies.

Silicone rubber can be used up to a temperature of 180 °C (short-term up to 250 °C). It provides good flexibility, but low abrasion and tear resistance. Like EPDM, silicone is incompatible with hydrocarbon fuels and high temperature steam. It has an elevated dielectric constant of $\varepsilon_r = 3.2$ and higher losses than PFAS materials. A major disadvantage is the much higher moisture absorption capability of silicone (1 %) which will cause a change in the dielectric constant, and therefore a capacitance change of the cable. Finally, silicone releases volatile silicone oils, which excludes its use in high-performance applications in clean room, vacuum, automotive and other high-end applications.

Polyimide has a high upper temperature limit of 300 °C. However, the dielectric constant of $\varepsilon_r = 3.4$ to 3.6 and the high dielectric loss factor of tan$\delta \approx 0.005$ make it unsuitable as a dielectric insulator for a coaxial cable. Like silicone, it also has a higher water absorption ratio than PFAS materials. In addition, a major disadvantage is the stiffness of polyimide, due to its low elasticity (elastic modulus 5000 MPa).

PEEK has an adequate upper operating temperature limit of 180 °C. However, it cannot replace PFAS materials as a dielectric insulator in a coaxial cable due to its higher dielectric constant of $\varepsilon_r = 2.8$ to 3.2 and the high dielectric loss factor of tan$\delta \approx 0.003$. The elastic modulus of PEEK is about 3000 to 4000 MPa and thus much stiffer than the PFAS coaxial cables we currently use for many sensors. Currently, polyimide and PEEK are only applied where a combination of high temperature resistance and high radiation resistance (better radiation resistance than PFAS) is required, and therefore the disadvantages of these materials have to be accepted.

The following table contains parameter values that we know through research of multiple sources.[12,13] It is important to note, that we are aware of the fact that (secret, thus unmentioned and unknown) admixtures of PFAS to (main component) non-PFAS materials may improve their properties and lead to wrong conclusions regarding their suitability for substitution. Differentiation between short-term and long-term value stabilities and ranges is not considered – for example, short-term and long-term temperature stability can be fundamentally different.

Material	Temperature Range (°C)	Dielectric Constant ε_r	Dielectric Loss Factor $\tan\delta$	Dielectric strength (kV/mm)	Outgassing total mass loss in % according to NASA	Water Absorption % in 24 h ASTM D570	Elastic / Flexural Modulus (MPa)	Tensile Strength (MPa)
PFAS:								
PTFE	-200 to 260	2.1	$< 2 \cdot 10^{-4}$	50 to 80	0.02	< 0.01	/ 496	21 to 34
ETFE	-100 to 150	2.6		60 to 90		< 0.03	/ 1172	40 to 46
FEP	-65 to 165	2.1	$< 5 \cdot 10^{-4}$		0.02	< 0.01	/ 586	23
PFA	-80 to 200	2.1	$< 5 \cdot 10^{-4}$			< 0.03	/ 586	25
FKM	-20 to 200			20				3 to 20
non-PFAS alternatives:								
TPE, TPU, PUR	-40 to 85	6 to 7.5	0.1	25	0.3 to 0.48	1.4	250 /	25 to 65
PVC	-55 to 105	4 to 8	0.04 bis 0.16	12 to 18	2.73	0.2 to 1		
PE	-40 to 85	2.3	$(0.3 \text{ to } 5) \cdot 10^{-4}$		0.24 to 0.48	0.01	300 / 300	10 to 30
XLPE	-40 to 105	2.3				< 0.01		
EPDM	-50 to 150	~ 3	0.02 to 0.05		0.3 - 26		6 /	4 to 18
HNBR	-40 to 150	10 to 15			0.3 - 5			
Silicone rubber	-55 to 180	3.2	$1 \cdot 10^{-3}$	20	1.15	1		10
Polyimide	up to 300	3.4 to 3.6	$5 \cdot 10^{-3}$	118 to 236	1.12	0.6 to 4	5000 /	138 to 380
PEEK	-60 to 180	3.2	$3 \cdot 10^{-3}$	70	0.23 to 0.71	0.1 to 0.5	4000 / 4000	110
PPS		3 to 4	$8 \cdot 10^{-3}$	17 to 18		0.01 to 0.07	4000 /	33 to 90
Mica		3 to 6					hard, brittle	

Although we use cables specifically designed and tested for our sensor products, we rely on cable manufacturers and their technology available on the market. While we can check the feasibility of substitution materials, we depend on suppliers to judge practicality and possibility of construction. While the chapter above has a focus on cables, the need for PFAS (and non-suitability of non-PFAS alternative materials) in sub-level articles such as sealings is judged with analogue argumentation.

Without applying PFAS in our products, market access would be lost substantively. Thus we anticipate a loss of more than [confidential, refer to confidential attachment]. The time necessary for alternatives to be fully accepted and to pass all necessary certification processes is expected to be long (transition time of more than ten years once a satisfactory alternative had been identified). Substantial invention is required to develop suitable replacement materials. A timeline cannot be assigned to an invention process; however, once potential replacements are identified, some may take 10 years or more to evaluate, demonstrate, qualify, and implement in the full supply chain. Fittings, O-rings, valve seals, and various applications in electronics all fit into this category, as an alternative has not been invented which is suited to the use. It is not a given that non-PFAS alternatives which have all the salient properties of PFAS would be found. Considering the information on socio-economic influence given in the Dossier and scientific data available in the field of electronics and semiconductor industry, we conclude restriction option RO1 (restriction option 1, full ban within 18 months) described by the Dossier Submitters is not deemed proportionate to the risk. RO2 (RO1 plus twelve months derogation period when no suitable alternative has been found yet) is described a balanced option, while we feel the need for re-evaluation should be considered as substitution of materials will likely not be possible for all applications.

We believe phasing out products manufactured with PFAS under consideration of reasonable timeframes for the development and industrial scaling of substitutes provides a benefit for society compared to an immediate ban of these products. The proposed derogation periods are justified for R&D, extensive certification, and coordination along the whole supply chain of the final products to substitute PFASs due to the high degree of complexity in the application of our products in the sectors Electronics and Semiconductors, as functional alternatives are not yet readily available for many of our products. To our opinion, the presented Restriction Proposal does not convincingly consider the immediate shift of world market share of the many product chains dependent on specialized articles containing PFAS to outside EEA, where companies can continue to use PFAS-containing technology that would be restricted for EEA companies. We conclude a high uncertainty on how a ban of PFAS in the respective use sectors in EEA would lead to an important reduction of pollution in a global manner – or merely a shift of the challenging topic out-of-sight and thus not solving the issue for future generations. This is supported by a potentially substantial risk of illegal und uncontrolled imports from outside EEA and coherent long-term (in-) efficiency of EEA bans on the global emission of PFAS. Evaluations of enforceability typically conclude with “(…) enforceability required by the proposed restriction may be challenging for enforcement authorities but is considered feasible.”. Though, that is even questioned in recent announcements by the BUND which recently declared that imports of kid`s toys and other items obtained online remain largely uncontrolled.[14]

In our case, this targets the complex supply / production chains in the semiconductor and other industrial sections that heavily rely on high-performance displacement and temperature sensors. Due to the importance of the use of such high-performance equipment, we envisage such bans without derogation periods would shift the production to countries where restrictions do not apply and efforts for justification of use, collecting data on conditions of use, search for substitution of products, and disposal are not considered. We thus agree with the highly likely scenario mentioned in the Dossier that competitors outside the EEA (European Economic Area) would immediately gain world market share, and the gains for non-EEA competitors (eg. located in Asia) is due to the fact that they can continue to use technology using PFAS that would be restricted for EEA companies. We also agree with the Dossier statement that the uncontrolled release of PFAS anywhere on earth into the environment is challenging as the substance class “knows no boundaries”, has a long-range transport potential, and distributes globally.[15] Thus, it is our strong belief that a controlled substitution with suitable derogation periods inside the EEA is to prioritize compared to an immediate ban instead of shifting the challenging topic out of sight.

[confidential, refer to confidential attachment] clearly supports the move away from substances that are hazardous to the environment and to humans, which is integral part of our Code of Conduct.[16] We are confident to phasing out materials manufactured with PFAS wherever this is technically feasible with reasonable timeframes for the development and industrial scaling of substitutes. Thus, we advocate for a derogation period of a minimum of 12 years for high-performance displacement and temperature sensors that is not yet considered in the Dossier combined with establishment of a time-independent essential use concept for important applications where no substitution materials can be found – including the possibility for reviews towards the end of derogation periods. Feel welcome to contact us in any case you feel additional information is required or consultation is considered beneficial.

Management board

[confidential, refer to confidential attachment]

References

[1] ORGALIM publication *Paper on the restriction of PFAS*, 27 January 2022, accessible *via* https://orgalim.eu/position-papers/environment-orgalim-position-paper-restriction-pfas.

[2] See Annex XV Restriction Proposal, annex E, page 401

[3] Annex XV Restriction Dossier webinar, questions and answers part II - content of the proposed restriction, 28 June 2023, available *via*

https://echa.europa.eu/de/-/restriction-of-per-and-polyfluoroalkyl-substances-pfass-under-reach

[4] See Annex XV Restriction Proposal, annex E, page 402

[5] see https://environment.ec.europa.eu/topics/waste-and-recycling/rohs-directive_en

[6] European Chips Act to bolster Europe's competitiveness and resilience in semiconductor technologies and applications, see https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/europe-fit-digital-age/european-chips-act_en

[7] See Annex XV Restriction Proposal, page 138

[8] Annex XV Restriction Dossier webinar, questions and answers part I - consultation, opinion-making, process, 03 May 2023, available *via*

https://echa.europa.eu/de/-/restriction-of-per-and-polyfluoroalkyl-substances-pfass-under-reach

[9] *An overview of the uses of per- and polyfluoroalkyl substances (PFAS)*; *Environ. Sci.: Processes Impacts*, 2020, *22*, 2345-2373

[10] See Journal für Oberflächentechnik 7/2023, article *Sauberkeits-Anforderung der 2020er Jahre* (*Cleanliness requirements of the 2020s*): VACOM purity classes 4 or 5 (semiconductor or high-end technologies): outgassing of max. 10^{-10} for water, max. 10^{-12} for volatile hydrocarbons, max. 10^{-13} mbar·L/s/cm² for non-volatile hydrocarbons. Available *via* https://www.jot-oberflaeche.de/zeitschrift/heftarchiv/artikel/sauberkeits-anforderung-der-2020er-jahre-high-purity-3393956.html.

[11] Chemsec.org article *Check Your Tech: A guide to PFAS in electronics*, 25 April 2023, accessible *via* https://chemsec.org/reports/check-your-tech-a-guide-to-pfas-in-electronics/

[12] OECD: *Per- and Polyfluoroalkyl Substances and Alternatives in Coatings, Paints and Varnishes (CPVs)*, Report on the Commercial Availability and Current Uses, OECD Series on Risk Management, No. 70, Environment, Health and Safety, Environment Directorate, page 48, accessible *via*

https://oecd.org/chemicalsafety/portal-perfluorinated-chemicals/per-and-polyfluoroalkyl-substances-alternatives-in-coatings-paints-varnishes.pdf

[13] values obtained by publicly available data lists from product suppliers such as VEGA, SAB-Kabel, TELEDYNE, HUBER+SUHNER, ALLECRA, and many more. Outgassing data from https://outgassing.nasa.gov/.

[14] See BUND articles *The toys most frequently contaminated with banned pollutants in the EU*, accessible *via* https://www.bund.net/service/publikationen/detail/publication/toxfox-check-giftiges-spielzeug/, and *Legal opinion: Monitoring compliance with chemical and product safety legislation in online trading*, available at

https://www.bund.net/service/publikationen/detail/publication/rechtsgutachten-onlinehandel/

[15] See Annex XV Restriction Proposal: "(…) the emitted substances are transported across global borders (…)", page 51

[16] [confidential, refer to confidential attachment]