European
Semiconductor
Industry
Association

The European Semiconductor Industry and PFAS

Summary paper

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Introduction

Semiconductors are a key enabler of low-carbon and energy-efficient solutions that reduce society's carbon footprint by optimizing energy usage in transportation, manufacturing, services, and consumer products. The European Chips Act envisages doubling the EU's current global market share from 10% to 20% by 2030. It is estimated that this will require a four-fold expansion of the semiconductor manufacturing capacity in the EU. Moreover, semiconductors will play a key role in achieving central targets of the EU Green Deal, in particular the goal to become carbon neutral by 2050.

The continued use of per- and polyfluoroalkyl substances (PFAS) by the European semiconductor industry will be essential to achieve these ambitious EU goals as both semiconductor manufacturing and semiconductor products rely on PFAS use at present. Therefore, the semiconductor industry is actively exploring non-PFAS alternatives as part of its commitment to sustainability. While the industry recognizes the importance of transitioning away from PFAS, the current technological limitations do not allow to manufacture semiconductors without their use. Hence, the industrial and societal transformation towards carbon neutrality will not be feasible without PFAS use.

Due to the extremely wide range of individual PFAS and their respective use cases in the semiconductor manufacturing process, time frames for finding and deploying alternatives can be very long, even in best-case scenarios. Depending on the use case, an alternative that has the same functionalities must first be invented and tools and/or process facilities must be adapted before said alternative could be qualified and deployed. Without a derogation to a restriction as currently listed in the Annex XV dossier, today's silicon-based semiconductors may no longer be produced or put on the market in the EU because an invention of novel compounds and/or new methods of producing semiconductor products that meet the requisite performance, may not be completed yet.

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PFAS: Critical for Semiconductor Manufacturing Process

The semiconductor industry is very reliant upon many applications of materials and chemical substances/formulations (solids, either articles or parts, liquids, and gases) falling under the definition of PFAS as set out in the PFAS restriction proposal (any substance that contains at least one fully fluorinated methyl (CF_3-) or methylene (-CF_2-) carbon atom without H/Cl/Br/I attached to it). In the semiconductor manufacturing industry, those materials are used in manufacturing process chemistries, in specific functional layers and packages, manufacturing equipment, manufacturing infrastructure, and support equipment in addition to the semiconductor device.

Many of those uses are very specific for the sector and are determined by the special physicochemical properties of PFAS, such as low surface tension, stability and chemical compatibility, inertness, polymer purity, chemical and permeation resistance, broad ranges of temperature stability, low coefficients of friction, special electrical properties, bacterial growth resistance, nonflammability, and a long service life (>25 years).

Lack of Existing PFAS Alternatives

Semiconductor technology development cycles often take a long time. Due to the complexity of the products and associated production processes, a major innovation can take several years/decades to bring to the market. Manufacturers of electronic devices, working in conjunction with their material and equipment suppliers, must typically proceed through multiple stages of research, technology integration, prototyping, and manufacturing ramp-up to achieve a process change effectively. One technology development cycle can take more than 25 years from fundamental research to production ramp-up.

Many materials are unique and have specific technical requirements making it extremely challenging to find a viable alternative. No known alternatives exist for many of the uses of PFAS-containing materials by the semiconductor manufacturing industry. Alternative substances need to be first invented and then qualified into mass production to represent a viable alternative.

It is possible that in some cases, after years of research, it is found that a PFAS-free alternative is not able to provide the required chemical function. Moreover, in some cases, the use of non-PFAS alternatives is simply prevented by the fundamental laws of chemistry and physics resulting in the loss of functionality of semiconductor products.

PFAS Emission Reductions (Water, Waste, Air)

Given its reliance on PFAS, the semiconductor manufacturing industry sector has implemented stringent risk management measures and safety practices to prevent the release of chemicals during all stages of the manufacturing process. There is no measurable release to the workplace environment during normal production due to the use of closed-system manufacturing equipment which is installed in a cleanroom environment. Automated chemical delivery systems create a barrier between workers and the manufacturing process and protect against chemical and physical hazards in the work environment.

As shown by Table E.130 of the Annex XV Restriction Report, an immediate ban of PFAS in the electronics and semiconductor sector would only have a very small impact on the resulting total emission reduction of PFAS compared to the maximum proposed time derogation (2025-2055: ~2.4%; 2025-2070: ~0.7%).[1] While there are limited releases to the environment, via wastewater, exhaust air, and waste, PFAS emissions from semiconductor manufacturing are well managed by the semiconductor industry.

Generally, spent PFAS-containing specialty chemicals are collected as separate waste streams and subjected to appropriate disposal or recycling methods, with only a very limited amount being emitted via wastewater. Emissions to air of gaseous perfluorinated compounds that fall under the EU PFAS definition are treated to low levels, for example by using point of use abatement systems (incineration). As a result, from 2010 to 2022, ESIA companies have reduced their emissions of gaseous perfluorinated compounds by 42%. There is also PFAS in solid waste, such as from manufacturing and facility equipment, but the industry continues to make efforts to minimize environmental releases.

Over the past two decades, the semiconductor industry has committed to and implemented a transition away from perfluorooctane sulfonic acid (PFOS) and perfluorooctanoic acid (PFOA) in the manufacturing process (where feasible) to short-chain PFAS. Short-chain PFAS were seen by the upstream chemical manufacturing industry as a less environmentally harmful alternative that exhibits the necessary technical performance properties. The industry continues to work on an industry-wide approach to PFAS.

Way Forward

PFAS possess numerous properties that enable unique functionalities across a wide spectrum of applications and in many situations, it is the combination of several properties that enable PFAS to satisfy multiple, overlapping performance requirements. Given the lack of alternatives for most applications of PFAS in the semiconductor industry and the long substitution timelines, it is not only imperative to grant the 12-year derogation proposed for the semiconductor manufacturing process and semiconductor products, but also to support research and development that would enable the semiconductor industry to collaborate globally with a view to effectively replace PFAS eventually. It will be crucial to fund and conduct research to where possible identify alternative chemistries that are preferable from an environmental point of view and to develop measurement, recycling, treatment, and abatement technologies to prevent environmental releases for uses to which no alternative can be found. For the strategic independence of the EU, it must be ensured that semiconductors can continue to be manufactured and put on the market in Europe and that stable and sustainable supply chains remain in place.

[1] Annex XV Restriction Report, Annex E, p. 398, Table E.130.

For further information:

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ABOUT ESIA

The European Semiconductor Industry Association (ESIA) is the voice of the semiconductor industry in Europe. Its mission is to represent and promote the common interests of the Europe-based semiconductor industry towards the European institutions and stakeholders in order to ensure a sustainable business environment and foster its global competitiveness. As a provider of key enabling technologies, the industry creates innovative solutions for industrial development, contributing to economic growth and responding to major societal challenges. Being ranked as the most R&D-intensive sector by the European Commission, the European semiconductor ecosystem supports approx. 200.000 jobs directly and up to 1.000.000 induced jobs in systems, applications and services in Europe. Overall, micro- and nano-electronics enable the generation of at least 10% of GDP in Europe and the world.