ECHA REACH PFAS restriction response Hitachi Energy Semiconductors

Hitachi Energy response to ECHA PFAS restriction dossier

Summary

Hitachi Energy Switzerland Ltd. Semiconductors (Hitachi Energy) produces high-power semiconductors which support the global energy generation and distribution, industrial applications, and e-mobility. Hitachi Energy´s high voltage semiconductors are key in the production, transmission, and distribution of energy. Additionally, the semiconductors and chips from Hitachi Energy enable the operation and control of high-power electric motors in industrial applications and e-vehicles, including personal and public transportation and transportation of goods, on the road, rail, and water.

Hitachi Energy recognizes the need to avoid emissions of substances with known toxicological concerns to best protect human health and the environment. This goal needs to be achieved by employing a risk-based regulatory approach in a sustainable manner, ensuring product reliability and achieving critical targets such as the green energy transition. Therefore, Hitachi Energy acknowledges the opportunity to submit a response to the public consultation of the PFAS (Per- and polyfluorinated alkyl substances) proposed restriction and has prepared this report to provide information on PFAS used in its manufacturing processes, their products containing PFAS, and wherever available, the estimated volumes used. Additionally, this report provides information on the collective efforts of the semiconductor industry to identify non-PFAS alternatives and the challenges to find suitable alternatives, and information on the risk reduction measures for PFAS emission during manufacturing and at end of life of the PFAS containing products.

It is important to note that the group of PFAS is a large and inhomogeneous group of substances with very different physical and chemical properties, coming with vastly different levels of hazards. The human health and environmental implications of those substances are also different and depend on the nature and level of control of their use. Thus, sustainable regulation of PFAS should identify differentiated risk management measures in consideration of the risk of a specific substance in a specific use with its relevance for society. More than 96% of globally used fluoropolymers, including PTFE, PFA and fluorinated elastomers, fulfill the widely accepted criteria for polymers of low concern as per OECD definitions.

PFAS are used in several steps of the semiconductor's productions processes and are in many cases an irreplaceable part of the production machines or the final products. In the semiconductor manufacturing process, hazardous, toxic, flammable, corrosive and highly reactive chemicals are typically used at high temperatures and in high vacuum conditions. In many cases only PFAS can be used due to the combination of their chemical inertness, mechanical resistance, thermal resistance and because they do not release contaminant substances by evaporation.

Hitachi Energy is actively replacing PFAS with known toxicological concerns in any use where alternatives exist and are available, such as in some uses on heat transfer applications. Unfortunately, in many cases, alternatives without PFAS or alternative technologies are, as of the preparation of this response, not available. Research for finding alternatives is ongoing and may take decades without a guarantee of success. If and when alternatives are identified, the

replacement of the existing processes and substances used in those processes may take an additional 10 or more years of implementation upon identification of alternatives.

The emissions of harmful substances during the production processes are being actively managed and minimized. Hitachi Energy is actively measuring possible emission sources to effectively control emissions and detect and mitigate any risk of release of such to the environment. Additionally, Hitachi Energy has set up a take back scheme, to recycle and appropriate dispose of its products at the end of life.

High-power semiconductors are key elements and enablers of the several strategies of the EU, for example the EU Green Deal and the EU Digital Strategy and play a key role in the implementation of several policies such as the EU Chips Act, the EU's Net-Zero Industry Act, The Digitalization of the European Energy System, and the EU Circular Economy Action Plan.

In conclusion, due to the high and wide socioeconomic impact of the use of these products and downstream applications, the current lack of alternatives for most uses of PFAS in the semiconductor production processes and final products, and the fact that the annual PFAS volumes used in the production are relatively low, and emissions are being controlled, managed and reduced at the production and end of life phases, it is recommended:

- "**The use fluoropolymers and fluoroelastomers considered as "polymers of low concern" to be excluded from the scope of a PFAS restriction**, and
- **a derogation for the uses of PFAS in the semiconductor manufacturing process, all required upstream processes for components and production equipment and all downstream applications, for an unlimited time period with appropriate review periods to review the developments and availability of new alternatives.**"

1. Information on the stakeholder

Hitachi Energy produces high-power semiconductors which support the global energy generation, distribution, and e-mobility. These semiconductor products include, for example, insulated gate bipolar transistors (IGBT), diodes, Thyristors, chips used in e-mobility in the interphase between the batteries and the motors, and assemblies for high-power applications. Additionally, Hitachi Energy produces internal test systems to secure the quality of the high-power semiconductors. The overall production facilities are in closed clean room facilities wherewith the exposure of any substances to the environment is minimized and/or controlled.

Figure 1 High-power Semiconductors from Hitachi Energy

Figure 2 Downstream applications of Hitachi Energy products

In the following chapters Hitachi Energy Semiconductors provides as much evidence and technical background information as possible. Since PFAS are used in several processes and the difficulty of obtaining all the relevant information within our company and from all our suppliers we provide information, particularly on the PFAS uses and alternatives available, referring to publicly available publications about PFAS and complete it with any internal information we have collected until now.

2. Uses of PFAS in the Semiconductor Manufacturing Process – Description of Most Important Uses

2.1 Use in the Photolithography, wet etching of silicon dioxide coatings and plasma etching processes

The production of circuits on the semiconductor wafers is done using several sequential steps where layers are selectively added and carved from the starting material and subsequent added layers.

Photolithography is the process of patterning parts on the wafer substrate. During the photolithography a film of photoresist (light sensitive polymer) is applied to the substrate material. The photoresist is altered on exposure to light making it easier or harder to remove (depending on the properties of the film and the desired effect on the many different layers applied). In this manner, selected parts of the substrate material or subsequent added layers are removed (etched). In this process PFAS as part of the photoresist itself, act as a photoacid generator or act as photosensitizers. PFAS are also used as antireflective coatings between the different layers, to improve the photoetching process. For review on the different PFAS used in the photolithography process refer to Glüge et al. (2020)[1], and references therein.

PFAS are also used as surfactants in the wet etching of silicon dioxide coatings. The PFAS not only facilitate wetting of the area to help produce sharp detail, but also reduce the reflection of the etching solution, achieving accuracy and precision that would not be possible without their use.

Additionally, another process known as plasma etching is also used in the manufacture of semiconductors. In this case, PFAS in oxygen plasma generates a variety of reactive species that break down chemical layers and deposits, selectively removing them.

PFAS are also widely used in the intermediate cleaning steps during the semiconductor production processes. These cleaning steps are either oxidative and etching steps or a combination of the two. Several PFAS substances are used in these cleaning steps.

2.2 Use in Cleaning of the plasma deposition chambers

In general, PFAS are used between semiconductor manufacturing steps to clean the plasma enhanced chemical vapor deposition chamber (PECVD). At Hitachi Energy, hexafluoroethane (C_2F_6, CAS 76-16-4) is used in a cleaning step between processes in PECVD deposition of silicon oxide and silicon nitride. The cleaning step is a plasma etching of the film deposited in the chamber after the wafer photolithography. For this cleaning step, C_2F_6 is used as fluorine source. This is the most state-of-the art process since it allows accurate end point detection as the educts and

[1] Juliane Gluge, Martin Scheringer, Ian T. Cousins, Jamie C. DeWitt, Gretta Goldenman, Dorte Herzke, Rainer Lohmann, Carla A. Ng, Xenia Trieri and Zhanyun Wangj. (2020). An overview of the uses of per- and polyfluoroalkyl substances (PFAS). Environ Sci Process Impacts1;22(12):2345-2373. doi: 10.1039/d0em00291g.

products show very distinctive plasma spectra and, thus, only the absolute minimum amount of process gases is consumed.

2.3 Use in Working fluid for vacuum pumps

During all the production processes, PFAS containing fluids are used as working fluids in high performance vacuum pumps. These pumps are essential, for example, for the operation of the PECVD chambers.

2.4 Use in Lubricants

Solid and liquid lubricants are used to reduce friction and wear between surfaces, corrosion protection and sealing. The lubricants used in the manufacture of semiconductors are high-performance materials that need to be stable at both changing temperatures and changing pressure. Among other critical properties, PFAS -containing lubricants are inert and resistant to harsh chemicals. This use should be covered by the proposed derogation 5. S. “lubricants where the use takes place under harsh conditions, or the use is needed for safe functioning and safety of equipment until 13.5 years after EIF”

2.5 Use in Manufacturing equipment

Perfluoro elastomers are used where the processing equipment is in direct contact with the chemicals used in the photolithography process as well as in contact with wet aggressive chemical environment or dry plasma etching gases.

In addition, fluoropolymers are used in the semiconductor manufacturing process due to their excellent resistance to the harsh chemical conditions of the manufacturing process, together with their resistance to temperature and pressure and their overall durability and resistance to abrasion and mechanical stress. Typical applications in laboratory and production equipment include:

- Linings in pipes, valves, tanks, and containers
- Sealing equipment in pipe connections, valves, and pumps (e.g., O-rings, fittings, seals)
- Low-friction bearings and housing
- Coating of equipment parts

For example, PFA-coated stainless-steel casts are used in the manufacturing process to avoid aggressive chemicals degrading the cast and / or to facilitate the removal of the molded part, without tearing it and without contamination from substances present in the cast. This cast is used to produce rubber rings used in high-power semiconductors.

2.6 Use in Wafer containers

During the production process, semiconductors are contained and transported to the different processing equipment on fluoropolymer-made containers, because of the fluoropolymers’ inertness and resistance to chemically and physically aggressive environments. Without these containers the transfer and processing of the semiconductor wafers would not be possible or lead to a critical loss of product quality.

Use in Heat transfer fluids

Several semiconductor manufacturing processes entail physical and chemical processes that require precisely controlled temperatures, and thus are highly reliant on fluorinated heat transfer fluids (F-HTFs) and fluorinated refrigerants. In both cooling and heating applications, F-HTFs help ensure the ability to provide the precise temperature control required in specific manufacturing operations.

Refrigerant gases in chillers and AHU/HVAC-units are needed to maintain the clean-room temperature and humidity under all weather conditions.

Additionally, cooling machines with PFAS refrigerants provide cooling water for the semiconductor production equipment.

2.7 Use as dielectric medium in electronic microscopes used for quality control

A PFAS dielectric medium is also used in the electronic microscopes that are used for quality control. A dielectric medium is required to withstand the high potential (voltage) differences within the voltage probe. An alternative containing C-H instead of C-F bonds, is more likely to form plasma, leading to a flashover, as the medium would suddenly conduct current while losing its insulating properties. In plasma, some H-atoms would be separated from the C-atom, leading to charged ions that conduct electricity. Thus, PFAS-free dielectric media inherently cannot fulfill the technical requirements of this application.

2.8 Use of PFAS in the finished semiconductors *Confidential*

Although there are no residual PFAS in the semiconductors form the production processes, there are PFAS containing materials that are part of the assembly, packaging, and final semiconductors products, and are necessary for the downstream applications of the semiconductors.

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A detailed overview of all the different assembly, packaging and substrates that are also generally used with semiconductors that might contain PFAS, including possible alternatives that are being developed has thoroughly been described by the SIA in their relevant white paper[2]

3. VOLUMES OF PFAS IN SEMICONDUCTOR MANUFACTURING PROCESSES

In general, the volumes of PFAS used in the semiconductor manufacturing are very low compared to volumes used by other industries. It should be noted that the amount of PFAS used in high energy semiconductors, is lower than the annual quantities used in the production of other semiconductors used in the production of chips because the annual quantities of high energy semiconductors produced is much lower.

Total PFAS volumes for all uses are difficult to estimate because, at the moment, suppliers are not obliged to disclose PFAS content in their products. The estimated total amount of PFAS used in the production processes of semiconductors by Hitachi Energy is around 4 t/year.

No reliable data is available on the PFAS-containing articles that are part of the production machines since they are not inventoried separately and might never be exchanged during the service life of the machines.

[2] See. SIA Whitepaper: PFAS-Containing Materials Used in Semiconductor Manufacturing Assembly Test Packaging and Substrate Processes Semiconductor PFAS Consortium Assembly, Test, Packaging and Substrates Working Group, June 2, 2023

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4. EMISSIONS

4.1 Production process

All exhaust gases from the plasma etching process that contain PFAS or other hazardous gases pass through a two-stage abatement system.

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General waste management: Hitachi Energy has contracts in place where the suppliers of chemicals are obliged to take back the empty or half-empty containers to correctly dispose of the chemicals without harming the environment.

In the case of the polymeric coating of the stainless steels' molds used in the production, the molds are coated at an external provider. After several use cycles, the molds are sent to the external provider, that removes the PFAS containing coating, and re-coats the mold. Disposal of the coating is done by the provider. Hitachi Energy is already in contact with the supplier to ensure no-emissions disposal for the used coating will be ensured.

4.2 Products end of life

The end of life of the semiconductor-containing products will depend on the downstream product.

For the final products of Hitachi Energy, there is a take back system in place where the costumers return them after their end of life (in average over 30 years) and they are recycled and properly disposed of, according to national legislation by a provider near the production site of Hitachi Energy.

The downstream products that are electronic waste, and are not returned, are disposed of or recycled depending on where the product was used. In the EU disposal has to be done following the directive of Waste from Electrical and Electronic Equipment WEEE. In the USA disposal has to follow the regulation issued by United States Environmental Protection Agency EPA.

5. ANALYSIS OF ALTERNATIVES

Currently, no alternatives have been identified for most of the PFAS uses in semiconductors.

In the semiconductor manufacturing process, hazardous, toxic, flammable, corrosive and highly reactive chemicals are typically used at high temperatures and in high vacuum conditions. In most cases only PFAS can be used due to the combination of their chemical inertness, mechanical resistance, thermal resistance and also because they do not release contaminant substances by evaporation.

The specific critical properties of the PFAS used vary depending on the specific use. Additionally, in most uses all the mentioned properties are important, and in specific uses materials lacking some of these properties could lead to safety issues (e.g., explosion risk), contamination of the semiconductors that severely interfere with their functioning or directly render them useless. Contamination may also lower the performance of the production process, which results in higher use of materials, increased energy, and water consumption, to mention some possible consequences of the replacement of PFAS in the affected process.

The Semiconductor Industry Association (SIA) has carried out an extensive investigation in order to find alternatives to PFAS substances used in the semiconductor manufacturing process. This assessment is described in detail in a series of white papers[3] where the technical challenges for replacing the PFAS in the semiconductor production processes are outlined, therefore they will not be reviewed here.

According to the information collected by the SIA, they estimate that in most cases, even if an alternative was available and could be implemented, the substitution would require between 4 to 10 years, which depends on what exactly in the process must be changed.

In cases where no alternatives are currently available, the time required to develop an alternative technology in semiconductor manufacturing processes would require more than 25 years, which includes R&D efforts, qualification and the final implementation of the new fabrication devices or adapted process of the existing ones.[4]

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6. SOCIOECONOMIC IMPACT ASSESSMENT

6.1 Market overview and downstream products

Semiconductors are used for transmission and distribution in high-power distribution lines, with lower energy loss. Power semiconductors help ensure stable grids and minimize reactive power. Additionally, they are key components

[3] SIA's white papers are published here –Semiconductor PFAS Consortium - Semiconductor Industry Association (semiconductors.org)

[4] See also The Impact of a Potential PFAS Restriction on the Semiconductor Sector - Semiconductor Industry Association, 2023

to control the power generation and connection of the network from renewable energy sources such as wind turbines and photovoltaic cells.

Power semiconductors are also used in locomotives from trains, metros and tramways in the traction converters that supply the current to the motors with variable frequency to adjust the motor speed and switch the motor current on and off to generate the desired voltage and current shape for the motor.

Power electronics also play an important role in electric mobility, as they handle the efficient power transmission from the battery to the motor. semiconductors typical applications are scalable current and power ratings support inverter platforms of various e-cars, e-trucks, public transport, aviation and are also key for enabling fast charging of electric vehicles.

Finally, semiconductors are widely used in the industry in variable speed drivers on motors for fans, pumps, winches, roller tables, and hoists.

6.2 Consequences of a limited derogation scenario

The wording of the currently considered derogation for use of PFAS in the semiconductor manufacturing process only refers to PFAS used in the manufacturing process specifically and it is unclear whether it also includes other essential uses of PFAS in the whole manufacturing process, such as fluoropolymers in components of manufacturing equipment and in the packaged semiconductors.

Considering these uncertainties, it is important to highlight that inability to use PFAS and fluoropolymers in any step and equipment of the semiconductor manufacturing process, including the final packaged semiconductors, would require the whole process to stop.

Wider socioeconomic impact

Without semiconductors, much of modern life would not be possible. The semiconductor industry has great strategic importance for the European strategy because semiconductors are widely used in strategic applications, and as seen on the wake of the Covid pandemic, critical in the value chain of telecommunications, electro-mobility and energy power generation, medical equipment, high-performance computers, computer peripherals, defense and security, and the emerging artificial intelligence. Therefore, semiconductors should be considered key for reaching the EU strategic objectives such as the EU Green Deal and the EU Digital Strategy.

The EU Is implementing several policies where semiconductors and energy production and distribution play a key role: the EU Chips Act, the EU's Net-Zero Industry Act, The Digitalization of the European Energy System, and the EU circular economy action plan.

6.2.1 EU Chips Act

The European Chips Act, adopted on 25 July 2023, should bolster Europe's competitiveness and resilience in semiconductor technologies and applications, and help achieve both the digital and green transition[5]. The World Economic Forum has estimated that scaling digital technologies could reduce up to 20% of carbon emissions by 2050, in the three highest emitting sectors (two of which, energy and mobility, rely on products from Hitachi Energy), contributing in this way to achieving the net zero trajectories of the International Energy Agency in the energy, materials and mobility industries[6]

The EU reacted with the Chip Act to the recent global semiconductor shortages in 2020-2021 that affected a range of sectors, from cars, such as the chips provided by Hitachi Energy, to healthcare equipment. The chips scarcities made also more evident the extreme global dependency of the semiconductor value chain. The EU Chips Act has set a goal to double the share of microchips produced in the EU to 20% by 2030, to reduce the EU's strategic dependencies to imports of semiconductors. This will be achieved strengthening the EU semiconductor industry through mobilizing more than €43 billion of public and private investments and setting measures to prepare, anticipate and swiftly respond to any future supply chain disruptions. It is estimated that more than €15 billion in private investment will build and reinforce capacity to innovate in the design, manufacturing, and packaging of advanced chips; develop an in-depth understanding of the global semiconductor supply chains. Thus, continued use of PFAS is necessary to allow the semiconductor industry to grow in the EU in the medium and long term.

6.2.2 EU's Net-Zero Industry Act – EU decarbonization goals

The Net-Zero Industry Act aims to help strengthen the European manufacturing capacity of net-zero technologies and overcome barriers to scaling up the manufacturing capacity in Europe[7]. The proposal sets a benchmark for the manufacturing capacity of strategic net-zero technologies of at least 40% of the EU's annual deployment needs by 2030 and sets a target of 50 million tons of annual CO2 storage capacity also by 2030.

The Net-zero technologies that are targeted by the Act include:

- Solar photovoltaic and solar thermal technologies
- Onshore and offshore renewable technologies
- Battery/storage technologies
- Heat pumps and geothermal energy technologies
- Electrolyzers and fuel cells
- Sustainable Biogas/Biomethane technologies
- Carbon Capture and Storage (CCS) technologies
- Grid technologies

semiconductors are key for most of these targeted Net-zero technologies as described in Section 6.1. and for the energy generation, transmission and use of renewable energy required to achieve the EU emission targets.

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[5] European Chips Act (europa.eu)

[6] Digital technologies can cut global emissions by 20%. Here's how | World Economic Forum (weforum.org)

[7] The Net-Zero Industry Act (europa.eu)

6.2.3 EU circular economy action plan

As a key part of the EU Green Deal, the EU has a circular economy action plan that paves the way for a cleaner and more competitive Europe. It aims to reduce pressure on natural resources and create sustainable growth and jobs. The action plan announces initiatives along the entire life cycle of products and aims to ensure that genera-tion of waste is prevented, and the resources used are kept in the EU economy for as long as possible. One of the objectives is to focus on the sectors that use the most resources and where the potential for circularity is high, including the electronics, ICT, batteries, and vehicle sectors.

As already discussed in Section 6.2, Hitachi Energy is setting up a take back system, where their products can be taken back for recycling, contributing in this way to the EU circular economy action plan. This would only re-main possible if the production of high energy semiconductors, that requires the use of PFAS, is still possible in the EU.