Review of the SIA PFAS Consortium Paper:
"The Impact of a Potential PFAS Restriction on the Semiconductor Sector"
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"The Impact of a Potential PFAS Restriction on the Semiconductor Sector," published by the Semiconductor Industry Association [SIA] PFAS Consortium in April 2023, makes a strong case that it would difficult and take years to remove Per- and Polyfluorinated Substances (PFAS) from semiconductor processing and products. That's because the industry has introduced a large variety of PFAS into production and products over several decades, without ever proving their safety to humans and the environment. This SIA paper summarizes the technical papers released by the Consortium this year.

In this paper, the SIA claims, "The semiconductor industry has a history of proactively adopting voluntary elimination and reduction strategies, as a result of new information on the environmental concerns of the substances it uses." (p. 3) It gives as an example its elimination of long-chain PFOS (perfluorooctane sulfonic acid), without mentioning—as reported in the technical papers—that other PFAS, such as short-chain perfluorobutane sulfonate (PFBS), were substituted.

The paper contains the first estimates that I've seen of PFAS use and discharge by the industry:

> Worldwide, a total of 33,745 kg of PFAS are used by semiconductor manufacturers in photolithography annually based on SIA's members survey of 2021 sales capturing well over 90% of the materials market, as shown in Table 4-5 below. TARCs [Top antireflective coatings] are the largest single product type, accounting for over 50% of total PFAS use in photolithography. The total PFAS use for photolithography in Europe is estimated to be **2,248 kg** annually, or about 6.7% of the worldwide semiconductor use. (p. 41)
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> The total worldwide PFAS discharges from photolithography range between **1,282 to 17,433 kg/year** (of which the EU is estimated at 6.7%, or 86 to 1,168 kg/year), depending on the amount of spin bowl waste collection. SIA estimates from previous surveys that about 50-60% of TARC users collect and properly dispose of the waste so the emissions are expected to be on the lower end of this scale. With full TARC spin bowl waste collection, the **estimated amount discharged to wastewater in the European Union is 56 kg per year**. (p. 42)

I am attaching that table, "Total PFAS Use in Photolithography." (p. 42) I cannot vouch for the completeness of the survey. It appears that the greatest releases are through wastewater (WW). The authors explain:

> Most PFAS are not regulated pollutants and therefore unless company specific provisions are in place, the wastewater from processes that use aqueous wet chemical formulations that contain PFAS would likely be discharged to the publicly owned treatment works without substantive removal of the PFAS. The industry is actively researching PFAS wastewater releases and treatment technologies. (p. 90)

That almost sounds like an invitation to strengthen regulation, but that is not SIA's intent. Of course, wastewater treatment simply transfers the PFAS to filtering media. It does not destroy the PFAS.

Table 4-5 Results of SIA 2021 sales survey and an example release mass balance.[44]

Total PFAS Used in Litho (2021 SIA Survey)					Split Organic Polymer by type					
PFAS (kg/yr)	Aq non-polymer	Aq polymer (TARC disp to WW)	Aq polymer (TARC disp collected)	Org non-polymer	Org Poly Immersion Top Coat	Org Poly Solv Dev PB/PI	Org Poly Aqeous PB/PI	Org Poly Resist	Total w/o TARC collection	Total w/ TARC collection
Total PFAS used in photolithography (kg/y)	**229**	**17,182**	**17,182**	**9,726**	1652	2147.6	2147.6	660.8	33,745	33,745
Disposition in the materials balance model:	**(kg/y)**	**(kg/y)**	**(kg/y)**	**(kg/y)**	**(kg/y)**	**(kg/y)**	**(kg/yr)**	**(kg/yr)**	**(kg/yr)**	**(kg/yr)**
pfas collected at dispense for disposal	215	0	16,151	9,142	**1,553**	2,019	**2,019**	**621**	15,569	31,720
pfas in dispense step to ww	0	16,151	0	0	**0**	**0**	**0**	**0**	16,151	0
pfas in developer ww	11	859	859	243	83	0	54	17	1,267	1,267
pfas to plasma strip	0	0	0	156	0	0	34	11	201	201
pfas to wt strip ww	0	0	0	12	0	0	3	1	16	16
pfas to solv strip waste	0	0	0	75	0	107	17	5	205	205
pfas to solid waste	1	43	43	24	4	5	5	2	84	84
pfas collected as solvent waste in tool cleans	2	129	129	73	12	16	16	5	253	253
Total pfas waste & efl:	229	17,182	17,182	9,726	1,652	2,148	2,148	661	33,745	33,745
Total dispensed	229	17,182	17,182	9,726	1,652	2,148	2,148	661	33,745	33,745
Total release to to the environment (WW) :	**11**	**17,010**	**859**	**255**	**83**	**0**	**56**	**17**	**17,433**	**1,282**
% of use discharged to the env:	5.0%	99.0%	5.0%	2.6%	5.0%	0.0%	2.6%	2.6%	51.7%	3.8%
Total PFAS used in Europe for photolithography[kg/y]	0	598	598	531	130	169	169	52	2,248	2,248
Total release to to the EU environment (WW) :	0	592	30	14	7	0	4	1	618	56
% of use discharged to the EU environment:	0.0%	99.0%	5.0%	2.6%	5.0%	0.0%	2.6%	2.6%	51.7%	3.8%

This SIA paper asserts that there are minimal air releases of PFAS in production: "The chemistries used in photolithography have relatively low vapour pressure and as outlined in Section 4.6 the quantities of emissions from photolithography are extremely small." (p. 89)

Some wastes are incinerated off site, in my view likely forming products of incomplete combustion: "Organic waste, including organic liquids containing PFAS, is typically segregated, collected, and containerised to be treated at an offsite licensed treatment and disposal facility, as a blended fuel by high temperature incineration or reprocessing." (p. 90)

The paper also recognizes that the PFAS embedded in products remain at the end of product life: "At the end-of-life of the product containing the semiconductor, or any parts replaced during the manufacture of semiconductors, would enter waste disposal streams where any PFAS contained therein could enter the environment." (p. 90)

The SIA warns: "**Elimination or substitution of a whole class of chemicals, like PFAS, is unprecedented and will add a significant amount of time to identify and implement each alternative …" (p. 30)** That may be true, but I believe, given the vast number of PFAS used by chipmakers, it is essential to monitor and regulate them as a class to set a goal of reducing the use and release of fluorine compounds.

It appears that the characteristics of PFAS—particularly their stability or persistence—that make them useful in the semiconductor industry make them particularly hazardous to human health and the environment. That creates an additional challenge: Any chemicals that replace PFAS and provide the same benefits may also pose a risk to human health and the environment.

The SIA PFAS Consortium is made up of chipmakers and their suppliers of equipment and materials. To sign up to receive their technical papers, go to
https://www.semiconductors.org/pfas/