The U.S. Semiconductor Industry's Environment, Health, and Safety Practices

U.S. semiconductor manufacturing is projected to triple from 2022 to 2032, the highest rate of growth in the world during that period.[1] More domestic chip production will address urgent supply chain vulnerabilities and strengthen America's national security and economy. As the U.S. semiconductor footprint grows, the industry is committed to maintaining its strong record of protecting workers and the environment.

Trained industrial hygienists, safety experts, and environmental teams in the semiconductor industry work on continuous improvement of health and safety practices in the industry to ensure all risks to workers and the environment are minimized.

WORKER HEALTH & SAFETY

Semiconductor workers today are subject to minimal workplace risks. Advanced fabrication techniques and automation, enhanced safety standards and engineering controls, and robust personal protective equipment all promote the safety of facility technicians and operators. Modern fab equipment uses enclosed systems which physically separate workers from the production process. More information is in Appendix A.

CHEMICAL EXPOSURE

- A 2010 study by Vanderbilt University evaluated historical air monitoring data from semiconductor manufacturers, including 60,000 measurements of more than 60 chemicals. The authors found that over 98% of the results were below the then-current most stringent occupational exposure limits.[2]
- In 2024, the Environmental Protection Agency (EPA) characterized the semiconductor industry as a model industry with "stringent controls in place that reduce workplace exposures."[3]

RISK OF ILLNESS:

- A 2010 study by Vanderbilt University, of over 100,000 semiconductor workers found "work in the U.S. semiconductor industry, including semiconductor wafer fabrication in cleanrooms, was not associated with increased cancer mortality."[4]
- A 2022 meta-analysis on semiconductor worker occupational disease found semiconductor work was not significantly associated with leukemia, lymphoma, or cancer.[5]
- A 2017 study of over 2,200 female semiconductor workers across roughly 4,000 pregnancies found the risk for spontaneous abortion in female semiconductor workers who became pregnant after 2009 was not significantly higher for fabrication and packaging process workers than for clerical workers.[6]

RISK OF INJURY:

- Bureau of Labor Statistics data on injury and illness rates demonstrate there are very few, if any, large U.S. manufacturing sectors with a lower incidence rate than semiconductors. In 2022, the U.S. semiconductor industry's injury or illness incidence rate per 100 workers was 1.1, compared to 3.2 for all manufacturing sectors and 3.0 for all sectors.[7]

[1] SIA/BCG, "Emerging Resilience in the Semiconductor Supply Chain," May 2024. https://www.semiconductors.org/wp-content/uploads/2024/05/Report_Emerging-Resilience-in-the-Semiconductor-Supply-Chain.pdf

[2] Journal of Occupational and Environmental Medicine, "Exposure assessment among US workers employed in semiconductor wafer fabrication," Nov. 2010, DOI: 10.1097/JOM.0b013e3181f6ee1d.

[3] Proposed Regulation of NMP Under the Toxic Substances Control Act, June 2024. https://www.federalregister.gov/d/2024-12643.

[4] Journal of Occupational and Environmental Medicine, "Cancer Mortality Among US Workers Employed in Semiconductor Wafer Fabrication," Nov. 2010. SIA commissioned Vanderbilt to conduct this study. DOI: 10.1097/JOM.0b013e3181f7e520.

[5] International Journal of Environmental Research and Public Health, "Semiconductor Work, Leukemia, and Cancer Risk: A Systematic Review and Meta-Analysis," Nov. 2022 DOI: 10.3390/ijerph192214733.

[6] Annals of Occupational and Environmental Medicine. "The relationship between spontaneous abortion and female workers in the semiconductor industry," Oct. 2017. DOI: 10.1186/s40557-017-0204-x.

[7] Bureau of Labor Statistics, Table 1. Incidence rates of nonfatal occupational injuries and illnesses by industry and case types, 2022. https://www.bls.gov/web/osh/table-1-industry-rates-national.htm

ENVIRONMENTAL STEWARDSHIP

The semiconductor industry is a global leader in promoting environmental sustainability in the design, manufacture, and use of its products. The industry strives to address environmental challenges and drive sustainable solutions.

Chemicals of Concern: Data available in the EPA Toxics Release Inventory show the semiconductor manufacturing sector represents only 0.17% of all releases for relevant substances.[7] The semiconductor industry has also been a leader in phasing out and eliminating chemicals of concern in response to evolving science on chemical risks, eliminating substances such as TCE, EGEs, and TCA, which are the chemicals cited as chemicals of concern in industry health studies from the 1980s and 1990s.

PFAS

- As the scientific community identifies risks associated with PFAS, the semiconductor industry is making a significant effort to address these concerns. Over the past two decades, the semiconductor industry successfully phased out, PFOS[8] and PFOA,[9] two "long-chain" PFAS identified by the scientific community as presenting environmental and health concerns.
- The industry formed the Semiconductor PFAS Consortium[10], a technical effort to improve our understanding of PFAS use in the semiconductor industry, quantify and reduce releases to the environment, assess the availability of alternatives, optimize the use of PFAS in the manufacturing process, and drive adoption of abatement and treatment technologies.
- The semiconductor industry uses and releases a small fraction of the total PFAS in the environment. Precise data is unavailable, but available use data indicates that the semiconductor uses comprise a fraction of 1% of the overall PFAS market. An article in the journal Nature calculates the amount of PFAS used in different industry sectors in Europe and concludes that the electronics sector as a whole uses a very small amount of overall PFAS, and the semiconductor industry is just a portion of this small amount.[11]

GREENHOUSE GASES

- Semiconductor manufacturing in the U.S. represents about 0.068% of all greenhouse gas (GHG) emissions and about 0.29% of industrial sector emissions. The industry's GHG emissions have been virtually flat since 2005, despite increasing output and process complexity.[12]
- The industry has also worked for decades to reduce emissions of fluorinated greenhouse gases. The semiconductor industry was the first industry to establish a voluntary, global GHG reduction goal, and, in 1998, the EPA recognized the World Semiconductor Council (WSC) as part of its first Climate Protection Award in honor of the semiconductor industry's efforts to commit to a 10% reduction in emissions of perfluorocarbons (PFCs). In 2011, the WSC announced it surpassed its goal and achieved a 32% reduction in absolute PFC emissions compared with the baseline.
- While the semiconductor industry constantly seeks to reduce its own GHG emissions, innovation and growth of the semiconductor industry enables substantial GHG emissions reductions in other sectors and throughout the economy. For every unit of emissions generated by the semiconductor industry on a Scope 1-2 basis, it has helped avoid 5 times more emissions for end-customers.[13]

All U.S. semiconductor manufacturing facilities must comply with existing laws and regulations at the federal, state, and local level, including permits required for construction and operation, such as those under the Clean Air Act, Clean Water Act, and the Resource Conservation and Recovery Act, as well as applicable state or local environmental reviews.

[7] EPA Toxics Release Inventory (TRI) Program, 2023. https://www.epa.gov/toxics-release-inventory-tri-program
[8] Semiconductor Industry Statement to the UN Stockholm Convention POP-Review Committee on Phase-Out of PFOS, Feb. 2018. https://www.semiconductors.org/wp-content/uploads/2018/06/Semiconductor-Industry-PFOS-Statement-to-POP-RC-Feb-15-2018.pdf
[9] Semiconductor Industry Statement to the UN Stockholm Convention POP-Review Committee on Phase-Out of PFOA, July 2024. https://www.semiconductors.org/wp-content/uploads/2024/07/Semiconductor-Industry-Statement-on-Phaseout-of-PFOA-July-2024.pdf
[10] Semiconductor PFAS Consortium. https://semiconductors.org/pfas.
[11] Nature, "Could the world go PFAS-free? Proposal to ban 'forever chemicals' fuels debate," Aug. 2023. DOI: 10.1038/d41586-023-02444-5
[12] EPA, "Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2022." https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2022
[13] Goldman Sachs Asset Management, "Green Capex Capturing the Opportunities," 2022. https://www.gsam.com/content/gsam/us/en/institutions/market-insights/gsam-connect/2022/Green_Capex_Capturing_the_Opportunities.html]

APPENDIX A: CHEMICALS AND INDUSTRIAL HYGIENE PRACTICES IN THE SEMICONDUCTOR INDUSTRY

Chipmakers closely adhere to the hierarchy of controls, adopting robust engineering controls, administrative controls, and personal protective equipment (PPE), minimizing worker exposure to chemicals to near-zero and, in most cases, below detectable analytical limits. The entire fabrication process is conducted in a tightly controlled clean room environment, where highly specialized manufacturing tools and processes deliver exactly the right amount of a particular chemical, in exactly the right place, at exactly the right time. Processes that use these chemicals and materials are also subject to significant and often redundant controls and safety measures. This exceptional level of control is necessary to build chips with features at the nanoscale, and, as a result, also enables the highest possible protection for workers. This collection of practices provides the semiconductor industry significantly greater workplace control compared to other manufacturing industries. Semiconductor manufacturers and their safety and industrial hygiene staff take action daily to ensure the safety of their workplace and workforce.

ENGINEERING CONTROLS

Engineering controls are fundamental to the manufacturing process and worker safety. Semiconductor process equipment is located in the clean room where a stringent clean regime is maintained as a requirement for production, which also ensures no chemical releases. Some features of the manufacturing process include:

- Modern high-volume manufacturing fabs use enclosed, interlocked, ventilated, and automated manufacturing equipment (tools) which separate employees from the product wafer and process chemicals.
- Hazardous gases and chemicals are transferred to process tools in transfer lines that are contained (and sometimes double contained) as well as being equipped with leak detection.
- Chemicals are stored and delivered into the manufacturing area using secondary containment and methods to prevent personnel exposure and ensure limited human interface.
- Fail safe designs and packaging of chemicals improves safety throughout the full chemical life cycle, including through primary and secondary contained failure points, exhaust ventilation and monitoring, and leak detection.
- Prior to maintenance, tools are emptied of chemicals and purged prior to maintenance, and maintenance occurs at room temperature under local exhaust ventilation.

Contemporary equipment is also designed and fabricated to meet the requirements of SEMI S2 – Environmental, Health, and Safety Guideline for Semiconductor Manufacturing Equipment and SEMI S6 – Environmental, Health, and Safety Guideline for Exhaust Ventilation of Semiconductor Manufacturing Equipment.

The SEMI S2 guidelines specify that chemical emission to the workplace environment during normal equipment operation must result in ambient air concentrations that are less than 1% of the American Conference of Governmental Industrial Hygienists (ACGIH)[14] threshold limit value (TLV) or permissible exposure limit (PEL) during normal equipment operation. ACGIH TLVSs are consistently much lower than OSHA occupational exposure limits (OELs). The semiconductor industry is committed to adopting measures to ensure exposure is reduced to well below OSHA levels or other regulatory requirements. Chemical emissions do not exceed 25% of the TLV or PEL in the anticipated worst-case breathing zone during equipment failures and maintenance activities. The SEMI S2 guidelines also require a third-party validator to certify the tool's compliance.

[14] ACGIH is a trusted partner in the industrial hygiene community and its TLV development process is well understood by most IHs. ACGIH publishes new and revised limits annually, and the supporting documentation is invaluable in explaining how the limit was derived and what studies were considered in the limit's development. For example, ACGIH categorizes the data considered in TLV development and makes it clear how the limits are related to that data based on health factors. These categorizations help the IH community understand the type of controls necessary to protect workers against the chemical hazard.

ADMINISTRATIVE CONTROLS

Semiconductor fabrication facilities also feature a number of administrative controls that ensure minimal to no personnel exposure to chemicals. Some industry-wide practices include:

- Inspections of equipment and facilities at the start up stage
- Chemical evaluation programs
- Exposure assessment programs
- Industrial hygiene monitoring and testing programs
- Employee training programs
- Hazard communication programs
- Standard operating and maintenance procedures

PPE

PPE is treated as a last resort in the semiconductor industry, considering the extensive engineering and administrative controls deployed at fabs. In order to prevent exposure, often during maintenance activities, task-specific personal protective equipment is required, including:

- Goggles
- Face shields
- Chemical resistant gloves used for splash protection
- Chemical resistant aprons
- Chemicals resistant suits

There are no chemically intensive maintenance activities that result in skin exposure. All fabs also have training to ensure that employees are knowledgeable of:

- Hazards associated with their task
- When PPE is required
- What PPE is required
- Inspection and care of PPE
- Proper methods of donning/doffing PPE
- Proper disposal/maintenance requirements

In order to handle certain chemicals or perform certain maintenance activities, employees must first have received comprehensive chemical safety training that requires passing grades on written tests that are administrated in the location-specific language used at the manufacturing facility. Any PPE that comes in contact with the chemical is generally discarded or properly cleaned.