FACT SHEET

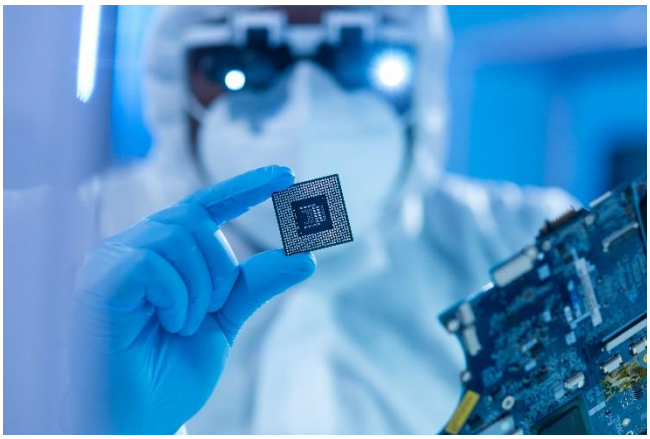
Safety in Semiconductor Manufacturing

OSHA Occupational Safety and Health Administration

Semiconductors are used in a variety of devices that support everyday life including personal computers, smartphones, and cars. The semiconductor manufacturing industry has greatly expanded and changed over the last 70 years, implementing many technological advancements. The rapid pace of change in the industry, including the manufacturing processes, means that hazards change in the workplace periodically. While many of the historic health risks are addressed by specific OSHA standards, the pace of change in this industry requires vigilance to keep hazard assessments and workplace controls current.

Safety by Design

Designing manufacturing processes to avoid or reduce workplace hazards early in a process adoption or a process change is one of the best ways to prevent injuries and illnesses. It is critical for controls to be addressed in the initial design and construction phases and implemented through a change management process as manufacturing processes and technology evolve. See the NIOSH webpage Prevention through Design for additional information.



Safety and Health Management Systems

Establishing a safety and health management system (SHMS) (sometimes referred to as a safety program) a safety program) is an effective way to protect workers by assessing hazards, implementing controls that result in reducing the risk of injury and illness. A SHMS can prevent workplace injuries and illnesses by finding and fixing workplace hazards before they cause injury and illness to workers. To be effective, a SHMS must have meaningful employer and worker engagement and participation. In many workplaces, worker participation may include a safety committee that can be used to bring workers and management together to identify issues and find solutions. When contractors are working in the facility, it is important the employer and contractor consider how their work and safety activities can affect the safety of other employers and workers. See the Recommended Practices for Safety and Health Programs webpage for additional information on implementing a successful SHMS.

Industry Hazards

A wide range of hazards are present in the semiconductor industry. Different types of hazards may occur during research and development, facility construction, facility operations, front-end processes (wafer processing), and back-end processing (assembly and test), and equipment maintenance. Additional information can be found in the OSHA Safety and Health Topic Pages for several of the industry hazards.

- Hazardous Energy
- Robotics
- Radiation
- Ergonomics
- Lasers
- Electrical
- Slips/Falls
- Falls from Heights
- Confined Spaces
- Noise
- Powered Industrial Trucks - Forklifts
- Hazardous Waste
- Hand and Power Tools
- Extended or Irregular Shifts
- Moving Machine Parts

Chemical Hazards

The semiconductor industry uses hundreds of chemicals, many in significant quantities. The chemicals used can pose a wide range of health hazards (such as carcinogenic, reproductive, and sensitization) as well as physical hazards (such as flammability, corrosivity, reactivity, pyrophoricity). Proper storage, use, handling, and disposal is necessary to control the physical and health hazards. Workers should be properly trained, and information about the chemical hazards must be made available as required by OSHA's Hazard Communication standard. A comprehensive management program integrating technologies, procedures, and management practices may be required by the Process Safety Management of Highly Hazardous Chemicals standard. Byproducts of the semiconductor manufacturing process can create a complex mixture of wastes including possible combustible dust hazards. Additional information can be found in the OSHA Safety and Health Topic Pages for several of the chemical hazards commonly encountered in the industry.

- Chemicals
- Solvents
- Carcinogens
- Reproductive Toxins
- Combustible Dusts
- Arsenic
- Dermal Exposures
- Lead
- Toxic Metals
- Process Safety Management

Chemical Exposures

Many of the chemicals used in the industry have been introduced relatively recently. For these chemicals, there may be limited toxicological information available and no established OSHA permissible exposure limit (PEL). For chemicals with an established PEL, the PEL may be outdated and inadequate for ensuring protection of worker health. In these cases, employers are encouraged to adhere to more protective alternative occupational exposure limits that are developed by technical, professional, industrial, and/or government organizations, some of which appear in the OSHA Permissible Exposure Limits – Annotated Tables.

For chemicals without occupational exposure limits, Occupational Exposure Banding and Control Banding can be used in conjunction with the Hierarchy of Controls to manage risks and prevent exposures to hazardous chemicals.

Adverse Reproductive Effects

Historically, the industry had a statistically significant association between fabrication workers and adverse reproductive health effects.[1] [2] While the exposure environment in a modern fabrication plant is different, due to changes in the chemicals and manufacturing processes, reproductive toxins are still present and exposures should be minimized through the Hierarchy of Controls.

Hazard Controls

Controls should be implemented according to the Hierarchy of Controls. Manufacturing processes can be designed to avoid or limit chemical hazards by choosing safer chemicals when available. OSHA's Transitioning to Safer Chemicals Toolkit is a step-by-step resource with information, methods, tools, and guidance for employers and workers to proactively eliminate or reduce chemical hazards at the source through informed substitution. When a manufacturing process does involve hazardous chemicals, the most effective method to eliminate or reduce hazards to workers is to control the hazards at the source, for example through engineering controls such as those described above. Personal Protective Equipment (PPE) such as respirators and dermal protection may also be necessary in some processes.

The semiconductor industry implements a wide variety of industry-specific controls, often required by building and/or fire codes (e.g., National Fire Protection Association (NFPA) 318 Standard for the Protection of Semiconductor Fabrication Facilities, International Fire Code (IFC) Chapter 27 Semiconductor Fabrication Facilities). Common engineering controls often designed into and used in the industry include:

- Process automation
- Process enclosures
- Lockout-tagout (LOTO) / emergency machine off (EMO)
- Radiation shielding/encapsulation
- Continuous gas detection
- Liquid leak detection
- Emergency power
- Exhaust/waste treatment and segregation
- Automated and exhausted gas dispensing cabinets
- Localized/point of use incineration of pyrophoric chemical exhaust
- Coaxial piping of toxic/highly toxic gasses
- Chemical use area ventilation
- Designation of Hazardous Production Material and emergency exit access corridors
- Fire detection/suppression systems
- Emergency shower and/or shower facilities
- Automatic sprinkler in exhaust ducts
- Emergency alarm systems
- Automatic gas supply shut offs (based on continuous gas detection)
- Separate chemical storage areas, designated transportation corridors
- Effluent process exhaust scrubbers
- Fire resistance rating
- Subatmospheric gas sources

Training

Education and training are important tools for informing workers, managers, temporary employees, and contractors about workplace hazards and controls. Training requirements vary in the semiconductor industry, depending on the work being performed. Training may be required by OSHA standards. Information about training requirements and training resources for specific hazards can be found on OSHA's website.

- Hazard Communication
- Personal Protective Equipment

[1] Choi KH, Kim H, Kim MH, Kwon HJ. Semiconductor Work and Adverse Pregnancy Outcomes Associated with Male Workers: A Retrospective Cohort Study. *Ann Work Expo Health*. 2019;63(8):870-880. doi:10.1093/annweh/wxz061

[2] Kim H, Kwon HJ, Rhie J, et al. The relationship between spontaneous abortion and female workers in the semiconductor industry. *Ann Occup Environ Med*. 2017;29:49. Published 2017 Oct 9. doi:10.1186/s40557-017-0204-x

- Respiratory Protection
- Powered Industrial Truck
- Substance-specific health standards (example: Arsenic, Lead)
- Fall Protection
- Hazardous Waste Operations and Emergency Response (HAZWOPER)
- Emergency Action Plan
- First-Aid/Bloodborne pathogens
- Electrical Safety
- Control of Hazardous Energy (Lockout/Tagout)
- Ergonomics
- Confined Space Entry
- Radiation Safety
- Fire Prevention

The OSHA publication Training Requirements in OSHA Standards provides a general overview of the training requirements in specific OSHA standards.

EPA Requirements and Consensus/ Industry Standards and Programs

EPA requirements as well as industry and consensus standards address hazards in the semiconductor industry:

- Semiconductor Manufacturing: National Emission Standards for Hazardous Air Pollutants (NESHAP) – EPA's final rule for hazardous air pollutants for semiconductor manufacturing. The pollutants covered by this rule include, but are not limited to, five chemicals that comprise over 90 percent of the total HAP emissions: hydrochloric acid (HCl), hydrogen fluoride (HF), glycol ethers, methanol, and xylene.
- National Fire Protection Association (NFPA) 318 Standard for the Protection of Semiconductor Fabrication Facilities – Provides recommended safeguards for the protection of semiconductor fabrication facilities and comparable research and development areas.
- International Fire Code (IFC) Chapter 27 – provides recognized good practices for life safety and property protection from hazardous materials used in semiconductor fabrication facilities.
- SEMI Safety Guidelines – SEMI is an industry association that has guidelines available for purchase that relate to the safe design, installation, use, and demolition of semiconductor equipment and facilities. These include: SEMI S2 Environmental, Health, and Safety Guideline for Semiconductor Manufacturing Equipment, S8 Safety Guideline for Ergonomics Engineering of Semiconductor Manufacturing Equipment, S10 Safety Guideline for Risk Assessment and Risk Evaluation Process, S12 Environmental Health and Safety Guideline for Manufacturing Equipment Decontamination, S16 Guide for Semiconductor Manufacturing Equipment Design for Reduction of Environmental Impact at End of Life, and S21 Safety Guideline for Worker Protection.
- Toward Zero Exposure – A commitment program from the Clean Electronics Production Network with signatory electronics companies taking action to protect workers from hazardous chemicals in the electronics supply chain by assessing the use of process chemicals, strengthening the organization's culture of worker safety and engagement, reducing worker exposures to identified priority process chemicals, and substituting them with safer alternatives within their own manufacturing processes.

OSHA Standards

While there is not a specific OSHA standard for semiconductor manufacturing, many of the OSHA general industry standards apply. These include, but are not limited to the following:

- 1910.95 Occupational Noise Exposure
- 1910.106 Flammable Liquids

- 1910.119 Process Safety Management of Highly Hazardous Chemicals
- 1910.124 General Requirements for Dipping and Coating Operations
- 1910.132 Personal Protective Equipment
- 1910.134 Respiratory Protection
- 1910.147 The Control of Hazardous Energy (Lockout/Tagout)
- 1910.178 Powered Industrial Trucks
- 1910.212 Machinery and Machine Guarding
- 1910.331-335 Electrical
- 1910.1000 Air Contaminants
- 1910.1018 Inorganic Arsenic
- 1910.1020 Access to employee exposure and medical records
- 1910.1025 Lead
- 1910.1200 Hazard Communication

Additionally, employers must comply with the General Duty Clause of the Occupational Safety and Health Act of 1970, which requires employers provide their employees with "employment and a place of employment which are free from recognized hazards that are causing or are likely to cause death or serious physical harm." 29 U.S.C. 654(a)(1).

OSHA's role is to ensure safe and healthy conditions for America's working people by setting and enforcing standards, and providing training, education, and assistance. For more information, visit www.osha.gov.

There are 22 OSHA-approved State Plans, covering both private sector and state and local government workers and seven State Plans covering only state and local government workers. State Plans are required to have standards and enforcement programs that are at least as effective as OSHA's and may have different or more stringent requirements.

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