UL PureSafety

OSHA 10 Semiconductor Industry Complete Job Aid

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This job aid provides reminders about information covered in UL online training courses. Always abide by local rules, regulations, equipment instructions, and your company's health and safety policies and procedures.

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Introduction to OSHA

The Occupational Safety and Health Act of 1970 was passed by Congress “to assure so far as possible every working man and woman in the nation safe and healthful working conditions and to preserve our human resources.”

The Occupational Safety and Health Administration (OSHA) is a division of the United States Department of Labor.

Since its creation in 1971, OSHA has had a big impact on worker health and safety.

Employer Responsibilities

The mission of OSHA is to save lives, prevent injuries and protect the health of America’s workers. Employers must:

- Meet their responsibility to provide a workplace free from recognized hazards
- Keep workers informed about OSHA and safety and health matters with which they are involved
- Comply, in a responsible manner, with standards, rules and regulations issued under the OSH Act
- Be familiar with mandatory OSHA standards
- Make copies of standards available to employees for review upon request
- Evaluate workplace conditions
- Minimize or eliminate potential hazards
- Provide safe, properly maintained tools and equipment and ensure that employees use them
- Warn employees of potential hazards
- Establish or update operating procedures and communicate them to employees
- Provide medical examinations when required
- Provide training required by OSHA standards
- Report a fatality, hospitalization, amputation or loss of an eye
- Keep OSHA-required records of work-related injuries and illnesses and post them appropriately
- Avoid discriminating against employees who properly exercise their rights under the OSH Act
- Provide access to employee medical records and exposure records to workers and others as required by law
- Determine if personal protective equipment (PPE) should be used to protect workers
- Pay for most required PPE

Employer Rights

- Seek free advice and on-site consultation from OSHA
- Be involved in job safety and health through industry associations
- Take an active role in developing safety and health programs
- Be assured of the confidentiality of any trade secrets
- Submit a written request to the National Institute for Occupational Safety and Health (NIOSH) for information on whether any substance in a workplace has potentially toxic effects in the concentrations being used
- Submit information or comments to OSHA on the issuance, modification or revocation of OSHA standards and request a public hearing

Employee Responsibilities

- Read the OSHA “It’s the law!” poster (OSHA 3165) at the jobsite
- Comply with all applicable OSHA standards
- Follow all employer safety and health rules and regulations, and wear or use prescribed protective equipment while engaged in work
- Report hazardous conditions to their supervisor
- Report any job-related injury or illness to their employer, and seek treatment promptly
- Cooperate with the OSHA compliance officer conducting an inspection
- Exercise their rights under the OSH Act in a responsible manner

Employee Rights

- Receive adequate training and information
- Request information from their employer on safety and health hazards, precautions and emergency procedures
- Review copies of appropriate OSHA standards, rules, regulations and requirements that the employer should have available at the workplace
- Request that OSHA investigate if employees believe hazardous conditions or violations of standards exist in their workplace
- Observe any monitoring or measuring of hazardous materials and see any related monitoring or medical records
- Object to the abatement period set in a citation issued to their employer
- Participate in hearings conducted by the Occupational Safety and Health Review Commission
- Submit information or comments to OSHA on the issuance, modification or revocation of OSHA standards and request a public hearing
- Seek safety and health on the job without fear of punishment
- Refuse to do a job if they believe in good faith that they are exposed to imminent danger

OSHA's Recordkeeping Requirements

As set out in the OSH Act, OSHA established an effective, centralized, nationwide system for monitoring occupational safety and health problems – a vital requirement for gauging problems and solving them.

Keeping records allows OSHA to compile survey material, helps identify high-hazard industries, and informs employees about their employers' workplace safety record. These records also help employers identify potential sources of injuries and illnesses at their worksites – and hopefully then correct or mitigate them.

Inspections

Inspections may be conducted by OSHA compliance safety and health officers. A typical on-site inspection includes the presentation of inspector credentials, an opening conference, an inspection walk-around and a closing conference. **Inspection priorities, in order, are:**

1. **Imminent Danger:** Inspecting a workplace where a danger exists that can be expected to cause death or serious physical harm is the highest priority.
2. **Fatalities/Catastrophes:** Fatalities as well as catastrophes that result in hospitalization, amputation or loss of an eye must be reported by the employer to OSHA.
3. **Complaints/Referrals:** A worker or worker representative can file a complaint about a safety or health hazard in the workplace.
4. **Programmed Inspections:** These inspections cover industries and employers with high injury and illness rates, specific hazards or other exposures.
5. **Follow-up Inspections:** OSHA also conducts follow-up and monitoring inspections. These inspections are made as needed and take priority over programmed inspections.

Citations and Penalties

Citations inform the employer and employees of the regulations and standards allegedly violated and of the proposed time for abatement. The employer must post a copy of each citation at or near the place where the violation occurred, for 3 days or until the violation is corrected, whichever is longer.

Under the OSH Act, OSHA may cite the following violations and propose the following penalties. Note that the threshold for penalties changes annually. You can find more information on the OSHA website.

- **Other-than-Serious:** A violation that has a direct relationship to job safety and health, but probably would not cause death or serious physical harm. OSHA may propose penalties for each other-than-serious violation
- **Serious:** A violation where there is substantial probability that death or serious physical harm could result and that the employer knew, or should have known, of the hazard. OSHA may propose a mandatory penalties for each serious violation
- **Willful:** A violation that the employer intentionally and knowingly commits, or a violation that the employer commits with plain indifference to the law. OSHA may propose large penalties for each willful violation, and there is a minimum penalty for each violation

Other penalties are **Repeated** and **Failure-to-Abate**. If an employer chooses to appeal a decision, it must be done formally in writing within 15 working days of receiving the citation.

General Duty Clause

What if there is no specific standard forbidding a particular activity, but that activity can easily be identified as being dangerous and potentially harmful to a worker? Can the employer be cited? The answer is YES!

The company or employer can be cited under the “General Duty Clause” found in the OSH Act.

Resources

There are many resources available to you if you want to find out more information about a safety or health issue in your workplace.

These include:

- Your employer, supervisor and co-workers
- Safety Data Sheets (SDSs)
- Labels and warning signs
- Employee orientation manuals and other training materials
- Written procedures
- OSHA’s hotline at **1-800-321-OSHA (6742)**
- The OSHA website: **http://www.osha.gov**
- Your local area or regional OSHA office
- Compliance Assistance Specialist training sessions/materials
- Health Hazard Evaluations (HHEs) conducted by the National Institute for Occupational Safety and Health (NIOSH)
- OSHA Training Institute Education Centers (OTIEC) and other university occupational and environmental health programs
- Doctors, nurses and other healthcare providers
- Public libraries

Semiconductor Fabrication Worker Safety Part 1

Semiconductor Fabrication Factory (Fab) Areas

Fabs vary from site to site. However, most fabs have 4 areas in common.

Office and Administrative Areas
- Some space for these purposes will be integrated into the building

Clean Rooms
- All wafer processing and handling occurs here, where the level of contamination can be controlled and damage from particulate avoided

Chemical and Gas Storage Areas
- Bulk chemicals and hazardous gases are usually stored in an area outside of the clean room because of the hazards involved

Facilities and Support Equipment Areas
- Facilities and support equipment is required for ventilation, fire protection, waste treatment systems, electricity, and heating and air conditioning

Hazards and Controls

Office and Administrative Areas
- The hazards and controls are not unlike other office areas
- Do not share clean room and production area ventilation systems
- Gas and liquid release alarms may not activate in these areas
- Fire alarms always activate throughout the entire fab

Chemical and Gas Storage Areas
- Bulk chemicals and hazardous gases are usually stored in an area outside of the clean room because:
  - Specialized safety controls minimize the risk of exposure and injury from chemicals
  - Clean rooms have limited storage so that laminar airflow can be maintained
- Chemical and gas technicians manage the areas, which require specialized skills and training to access

Facilities and Support Equipment Areas

- Chemical hazards include storage of hazardous gas, liquids and solids materials
  - Use and disposal of hazardous liquids and solids materials may also pose hazards
- Physical hazards include:
  - Electricity (50 to more than 600 V)
  - Mechanical systems
  - Pneumatics and high pressure
  - Fire and explosion hazards
  - Work at heights, confined spaces
- Controls include:
  - Ventilation
  - Chemical release detectors and alarms
  - Area access restrictions
  - Hazardous energy control
  - Work procedures and training

Clean Rooms

- Chemical hazards include gases, liquids and solids
- Physical hazards include:
  - Electricity that can reach more than 600 volts
  - Robots and other moving parts
  - Pneumatics and high-pressure piping and lines
  - Fire and explosion from chemicals and pressure
  - Work at heights
- Controls include:
  - Air filtering/ventilation to remove contaminants from the air
  - Human (administrative), requiring personnel to wear clean room suits
  - Material (particulate) to control contamination via materials brought into the clean room

Responding to Clean Room Emergencies

In Case of Gas Release

- All hazardous gases are plumbed with stringent controls, including gas sensors that detect releases and shut off gases when levels exceed acceptable exposure
- An alarm will sound before unsafe levels are reached
- Be sure you can recognize the alarm
- Evacuate to the assembly area if the alarm activates

In Case of Fire

- All clean rooms have fire protection systems, including sprinklers, smoke alarms and pull stations
- Audible and visual alarms are automatically activated when needed
- Evacuate to the assembly area for the site if the alarm activates
- Report any information to the evacuation monitors

In Case of Earthquake

- Fabs located in seismically active areas, such as earthquake zones, are built with earthquake bracing and equipment restraints
- They may also have earthquake sensors that shut down gas flow and equipment operation when activated
- Stay clear of overhead tiles, lights and any unsecured equipment
- Move to a safe area or duck and take cover once significant shaking starts
- Hold on while shaking continues

In Case of Medical Incidents

- Typically, emergency response teams are on-site to help personnel who suffer injuries, illnesses and exposures
- If you witness an injury or a person needing help, call your site's emergency number and help the victim if it is safe to do so
- Avoid contact with blood and bodily fluids
- Have someone escort the emergency team to the victim

Semiconductor Manufacturing Process

Semiconductor manufacturing is a complex process that produces computer or microchips. The front-end process involves building numerous very small electronic circuits on a flat wafer (covered in Part 1 and Part 2 of the training). Also be aware that there is a back-end process that involves cutting wafers into dies and packaging them.

1. Start with a polycrystalline wafer
2. For this device, the first step is epitaxial, or epi, to provide a high-quality starting layer
3. An oxide insulating layer is deposited
4. The following 3 steps are photolithography, starting with a coating of photoresist
5. Alignment and exposure set the pattern onto the wafer
6. The remaining pattern is developed leaving coated and uncoated regions
7. The wafer is etched to remove the oxide layer where there is no photoresist
8. The remaining photoresist is stripped away
9. Polysilicon is deposited atop the wafer
10. Another photolithography and etch sequence is performed to leave regions of polysilicon in the same layer with oxide
11. The wafer is implanted with dopants to make the silicon layer semi-conductive
12. An insulating nitride layer is deposited over the wafer
13. Another photolithography and etch sequence occurs to create channels through the nitride layer
14. Metal conductor is deposited into the channel
15. A chemical mechanical polish (CMP) flattens out the top of the wafer

Silicon Wafer Production

- The semiconductor manufacturing process begins with the manufacturing of the wafer, which is usually silicon. The most important advantage of silicon is that it can be grown into large, uniform crystals to produce silicon ingots
- Wafers are typically not made in fabs, but in clean rooms at wafer manufacturers
- The first step in the silicon wafer production process is to heat the silicon to a temperature of more than 2,192 °F (1,200 °C). This produces cylindrical ingots, which are sliced into wafers. Finally, wafers will be processed into integrated circuits
- Chemical hazards and controls: Silicon dioxide, the source material, generates silica dust. Inhalation can lead to chronic, accelerated or acute lung disease and is associated with bronchitis and tuberculosis. Fabs use local exhaust ventilation and personal protective equipment (PPE) to protect workers
- **Wafer production equipment hazards and controls**:
    - **Heat and molten silicon** – Reactor enclosures, enclosure interlocks and over-temperature protection are in place to keep workers safe. In addition, user training and procedures and safety eyewear and thermal protective gloves are provided
    - **Hazardous voltage** – Over-current protection and lockout/tagout maintenance and procedures are in place to keep workers safe. Additionally, safety eyewear and insulating gloves and materials are provided
    - **Lifting and ergonomics** – Lifting equipment and user training and procedures are provided to help prevent ergonomic injuries

Deposition and Diffusion: Epitaxial Deposition

- In the deposition and diffusion process, epitaxial deposition is the first sub process
- Epitaxial deposition, also referred to as epitaxy or epi, is a chemical vapor deposition (layering) process that occurs in a high-temperature reaction (epi) chamber at atmospheric or reduced pressure
- Steps: The bare silicon wafer is placed on the susceptor in the process chamber. Process gases are combined with dopant gases to flow across the wafer surface to form the crystalline structure. The resultant layer is a high-quality crystalline structure that can be doped with metal sources to form a semi-conductive doped layer
- The process uses highly toxic, corrosive and flammable gases to deposit a doped single crystal structure on a wafer. The highly toxic gas flows are low; the corrosive & flammable flows are high
- **Epi equipment hazards and controls**:
    - **Hazardous chemicals** – Ventilated gas distribution panel, gas leak detection, ventilated reactor enclosure, enclosure interlocks and abatement equipment are in place to keep workers safe. In addition, user training and procedures and safety eyewear and respiratory protection (for cleaning) are provided
    - **By-product reaction** – Hazardous chemical controls, over-pressure detection and over-temperature protection are in place to keep workers safe. Additionally, parts cleaning training and procedures and maintenance procedures are provided. PPE includes face shield, respiratory protection and chemical resistant gloves
    - **Hazardous voltage** – Over-current protection and lockout/tagout procedures are in place to keep workers safe. Additionally, safety eyewear and insulating gloves and materials are provided
    - **Lifting and ergonomics** – Lifting equipment, maintenance procedures and steel-toed shoes are provided to help prevent ergonomic injuries

Semiconductor Fabrication Worker Safety Part 2

The Process

There are 6 main steps in the process. In Part 1 of the curriculum, steps 1 and 2a were covered. Part 2 covers the remaining steps.

- Step 1: Silicon wafer production
- Step 2: Deposition and diffusion
  - Step 2a: Epitaxial deposition
  - Step 2b: Chemical vapor deposition (CVD)
  - Step 2c: Physical vapor deposition (PVD)
  - Step 2d: Diffusion
- Step 3: Patterning and lithography
- Step 4: Etching
- Step 5: Ion implantation
- Step 6: Chemical Mechanical Polish (CMP)

Vapor Deposition

Metal and dielectric layers are deposited onto the underlying layers using chemical or physical vapor deposition.

- Chemical vapor deposition (CVD) uses controlled chemical reactions to create oxide, nitride, silicon or metal layers on the wafer. Two common types of CVD are low-pressure and plasma-enhanced
- Physical vapor deposition (PVD) uses solid targets and high voltage to deposit metals on wafers

CVD Chemical Hazards

– CVD uses highly toxic, corrosive, flammable and oxidizing gases to deposit conductive, semi-conductive and insulating materials on wafers

PVD Chemical Hazards

– Solid targets do not pose a significant health hazard from chemical exposure
– The primary health concern is particulate and dust generated during cleaning operations from any of the metals used

CVD Equipment Hazards

- Hazardous chemicals: CVD may use silicon source gases that produce a reactive by-product in exhaust lines
  - Controls: Ventilated gas distribution panel, gas leak detection, ventilated reactor enclosure, enclosure interlocks and abatement equipment, user training and procedures, and safety eyewear
- Off-gassing
- Radio frequency (RF) energy
- Hazardous voltage
- Lifting and ergonomics

PVD Equipment Hazards

- Hazardous voltage: The primary hazard for PVD systems is electrical
- Vacuum: PVD uses only inert gases or vacuum
- Metal dust: Maintenance and cleaning of chambers generate metal dusts that can be flammable or explosive
- Lifting and ergonomics (metal target handling): This requires some lifting and carrying of parts

Diffusion

Diffusion is used for oxide and nitride layers as well as dopant and silicon deposition.Wafers are loaded into a long quartz tube surrounded by radiant heaters. The tube is sealed so process gases can flow through it and around the wafers. Then the tube is heated to allow the surrounding process gases to diffuse into the wafer surface.

Diffusion Chemical Hazards

- Diffusion is much like CVD in terms of process gases used
- The hazardous gas flows are usually higher than in CVD because the reaction tube is much bigger, creating more significant risks

Diffusion Equipment Hazards

- Hazardous chemical exposure
- Tube breakage or explosion
- By-product reaction
- Hazardous voltage
- High temperature tube and wafers
- Lifting and ergonomics

Photolithography

Photolithography involves a number of steps, much like a photographic process.

1. Apply an adhesion promoter to ensure the photoresists coat wafer surfaces properly.
2. Apply a photoresist to the wafer in a liquid state in small quantities.
3. Expose light through a mask and a lens to expose an image of the microelectronic circuit onto the photoresist-coated wafer.

Photolithography Chemical Hazards

– The steps in the photolithography process use different chemicals, which may be flammable, toxic or corrosive
– Some photolithography chemicals are reproductive toxins

Photolithography Equipment Hazards

– Liquid chemicals
– Ultraviolet light and lasers
– Heater for soft bake
– Hazardous voltage
– Lifting and ergonomics

Etching

The etch process removes selected materials from the wafer and shapes the profile and critical dimensions of the remaining materials.

- Dry chemical etching and ashing removes materials through exposure to plasma and a highly reactive chemical species created in an etch reactor
    - A reacted gas flows into the process chamber
    - Heat or RF energy allows the process gas to etch the wafer surface
    - Dry etch processes allow for very precise etching and prevent undercutting of the photoresist
- Wet chemical etching uses baths of corrosive and oxidizing liquids to remove material
    - Effective for etching relatively large amounts of material without the need for very high precision
    - Much of the work with chemicals takes place at large "wet benches" where special solutions are prepared for specific tasks
    - Many etchant baths are mixed at the ventilated wet bench and are highly reactive when mixing. The baths may be heated or agitated, are open and typically hold 1-3 gallons (4-12 liters) each
    - Systems may be manual or automated

Dry Etching Chemical Hazards

– The processing system uses various gases
– Gases that pose corrosion hazards are:
    - Chlorine
    - Boron trichloride
    - Hydrogen bromide
– Nitrogen trifluoride (NF3) gas is oxidizing

Wet Etching Chemical Hazards

– The processing system uses various chemicals, all of which are corrosive
    - Buffered oxide etch (BOE)
    - Hydrofluoric acid (HF)
    - Tetramethylammonium hydroxide (TMAH)
    - Piranha etch
    - Potassium hydroxide (KOH)
– Piranha etch is also oxidizing

Dry Etching Equipment Hazards
- Hazardous chemical exposure
- Off-gassing
- RF energy
- Hazardous voltage
- Lifting and ergonomics

Wet Etching Equipment Hazards
- Hazardous liquids and vapors
- Heated baths
- Chemical pouring and mixing
- Robots and automated systems
- Hazardous voltage
- Lifting and ergonomics

Ion Implantation

An ion beam is accelerated through the ion implanter to embed small amounts of conductive metals into wafer surfaces.

- To alter the conducting properties, dopants are added to silicon
- Dopant molecules are implanted under vacuum into the surface of the silicon by an accelerated ion beam
- Ion implantation is used to precisely position dopants in several different areas of the wafer, typically with different source dopants – solids and gases – in each area

Implantation includes some of the most dangerous chemicals and physical hazards in the semiconductor manufacturing process.

Implantation Chemical Hazards
- The solids and gases used for dopants in the ion implantation process are hazardous
- Process gases are toxic, pyrophoric, flammable and corrosive

Implantation Equipment Hazards
- Hazardous chemical exposure
- By-product reaction
- Radiation
- Hazardous voltage
- Lifting and ergonomics
- Toxic chemical exposure during cleaning operations

Chemical Mechanical Polish (CMP)

CMP is a process used to smooth the wafer surface to allow accurate photolithography of the subsequent layer. A rotating head spins abrasive slurry across a wafer to polish the surface and remove surface imperfections.

CMP Chemical Hazards

- A slurry is a very thick liquid that contains fine, abrasive particulates, such as silica
- All are irritants and may require special treatment and disposal methods

CMP Equipment Hazards

- Slurries
- Moving parts
- Hazardous voltage
- Oxygen-deficient atmosphere
- Lifting and ergonomics

Semiconductor Environmental, Health and Safety at Work Part 1

Precautions

Communication between you and your employer regarding safety matters can prevent illness, injury or even death. Your input is welcome, and no disciplinary action or retaliation will occur.

- Safety is everyone's concern and responsibility
- Report any EHS concerns regarding security and workplace hazards to your supervisor, HR or EHS department immediately
- Be proactive to report issues right away
- Realize that taking no action could result in an accident, injury or illness

Security and Safety

A comprehensive safety plan may include safe work practices, administrative controls, medical responses, engineering controls and procedures to track corrective actions.

Prevent Loss

Loss is the result of any event that deprives your company of an asset (e.g., employees, equipment, property or reputation). Loss can result from accidents, environmental waste or theft of company resources.

Common costs from loss include:

- Pain and suffering of employees and their dependents
- Loss of company resources
- Additional management and employee time
- Negative company publicity/image
- Late or missed deliveries/orders
- Property damage
- Increased repairs and maintenance

Prevent loss with prompt accident reporting and effective incident investigation.

Security: Wear and Check Identification

All employees, contractors and visitors should wear name badges displayed at all times. Control chemical and equipment access to deter theft.

Security: Confidential Information

Keep company information confidential. Even through casual conversation, it is possible for other businesses to extract critical, sensitive information about the development of future projects.

Documents
- Mark your documents as “Confidential” or “Proprietary” to deter readers who should not see the information
- Dispose of confidential papers in a paper shredder or locked disposal box

Electronic Devices
- Secure your electronic devices with complex passwords to stop anyone from unauthorized access
- Shield confidential material while working or traveling to stop others from reading over your shoulder

Security: Prohibited Practices

Weapons and illegal substances are prohibited on company property, at sponsored events, or at any related workplace event or occasion. Illegal items found on company property will be confiscated and local law enforcement will be notified. An investigation will be conducted with disciplinary actions up to and including termination.

Security: Violence

A violent act is almost always preceded by changes in behavior and must be reported to your supervisor. Watch for potential warning signs like threatening harm to others or displaying intimidating, harassing, bullying or aggressive behavior. Report all inappropriate references to guns and/or bringing weapons to work to your supervisor or EHS department.

Workplace Hazards

Conduct safety inspections to identify potential hazards and consult workers about any safety problems they have encountered. Perform scheduled preventive maintenance on all equipment and tools. Conduct near miss/accident investigations and root cause analysis, and implement corrective actions.

Extension Cords

Use extension cords as temporary power to equipment such as power tools or mobile lights. Remove them when finished. Tape long cords to the floor to prevent trips and falls. Install a permanent solution if a temporary extension cord is needed for a long period of time. Ensure power cords are rated for industrial use and have surge protection. Connecting extension cords to each other is strictly prohibited.

Identify and Fix Hazards

Be aware of and prevent hazards in your work area. Seemingly small hazards like spilled chemicals and poor lighting can cause a really big accident.

Accidents and Investigations

Accidents happen. Learn how to handle each accident by category to save lives.

Minor Accident

Report within 24 hours to site, local and regional managers and your local EHS Coordinator.

- Minor first aid injuries
- Near misses
- Hazardous practices or conditions
- Short term illness

Serious Accident

Report immediately to site and local management and EHS Department.

- Lost time accidents
- Medical treatment (serious injury but no lost time)
- High-potential near misses (with potentially serious implications)
- Long-term occupational illnesses
- Environmental accidents (below the level of a major accident)

Major Accident

Report to local management and EHS Department immediately.

- Fatalities or permanent disabling injuries
- Major fires, explosions or property damage
- Major product, process or environment accidents
- Major spills or environmental accidents

Accident Investigations

- Collect all incident facts and details
- Develop a corrective plan
- Prevent the incident again
- Do not place blame
- Ensure that the same accident does not reoccur

Emergency Response

Bloodborne Pathogens
- Don't clean up blood unless you've been trained
- Report it to your emergency response personnel as soon as possible
- Exposure could lead to disease or death

Chemicals
- Protect for your own safety first before helping others
- Never assume liquid on the ground is water
- Do not approach a spill or release unless you know the material, hazards, precautions and are trained in spill procedures
- Keep others away from the affected area
- Call for help if needed

Evacuations
- Promptly evacuate on any alarm
- Take the nearest safe exit; your exit route for an evacuation may not be the one you normally use
- Report to your assembly point and wait for instructions
- Do not re-enter the building until an "All Clear" is given by emergency personnel
- Always cooperate with emergency responders

Housekeeping

Good housekeeping goes a long way in preventing workplace hazards.

- Keep a tidy, orderly work area
- Put trash in appropriate containers as you work
- Clean up all spills within the scope of your job immediately. Report spills of unknown or dangerous substances unless you are trained to clean them up
- Never block access to a fire extinguisher
- Never block a fire escape or path

Resource and Energy Conservation

Wherever possible, encourage efforts that lead to water conservation, recycling programs and energy conservation across your company. Practice the three conservation techniques described to achieve your waste reduction and money saving goals.

Prevent

Prevention can include minimizing material use. Use fewer solvents, soaps or other products if possible. Substitute environmentally safe products where available. And avoid fuel waste by shutting off the engine on forklifts and other vehicles when idling.

Reuse

Reuse semiconductor-grade solvents as technical-grade solvents such as sulfuric acid when possible. Be imaginative as to possible reusable options and save your company needless expenses.

Recycle

Disassemble cardboard boxes for recycling. Collect and recycle machine shop waste, metal or electronic parts, and purify wastewater for cooling needs.

Semiconductor Environmental, Health and Safety at Work Part 2

Ergonomics

Ergonomics is the science of designing the job to fit the worker, rather than forcing the worker's body to conform to the job.

Ergonomic injuries, or musculoskeletal disorders (MSDs), are the most frequently occurring injuries in the semiconductor industry. They are a leading cause of illness and lost time at work. Understanding some of the common ergonomic risk factors and learning to minimize them will help prevent injury.

- **Force** is exerting the body over and over, which pushes the muscles beyond their capacity and causes strains and sprains. Repeating actions, such as lifting a process chamber lid or gripping a hand tool, are examples of force that may cause injury
- **Frequency** is too much repetition or too little movement. Prolonged periods of using a hand tool can damage nerves and tendons. Sitting without taking a break to stand and move about can restrict blood flow and damage muscles
- **Posture** can be compromised by leaning over a chamber, climbing under a tool, kneeling and twisting to access parts, or reaching overhead. Over-stretched or twisted joints and tendons can damage nerves and tendons

If MSDs are not treated and allowed to get worse over time, they become harder to treat. Report your work-related symptoms to your EHS department and physician promptly.

Material Handling

You may be required to lift, carry and move materials while performing your job. You should learn and use proper lifting techniques to reduce stresses that can lead to a back injury or other MSD.

- **Weight** – You may be required to lift relatively light objects or extremely heavy parts, such as a turbo pump. The body experiences stress regardless of the weight. NIOSH recommends lifting no more than 35 pounds (16 kg)
- **Devices** – Whenever possible, avoid manual lifting by using an adjustable height table or a mechanical assist for heavy equipment. Use carts to move parts and equipment
- **Risk factors** – As a general rule, avoid activities that are repetitive or require twisting or lifting above the shoulders or below the knees

Computer Workstation Ergonomics

Chair:

- Sit upright! Use an adjustable chair with lumbar support
- Keep your hips and knees at a 90° angle and your feet flat on the floor or on a footrest
- Be sure your forearms are parallel with the floor and lightly touch the armrest when your shoulders are relaxed
- Change positions every 45 to 60 minutes

Monitor:

- Sit directly in front of your monitor, with the top line of the display at or slightly below your working eye height to maintain neutral posture

- Position yourself an extended arms-length away from your monitor

Keyboard:

- Sit directly in front of your keyboard, keeping it close to you to avoid reaching
- Position your elbows close to your body and your forearms parallel to the floor
- Rest your arms at your sides between tasks
- Use a neutral wrist and finger position and rest wrists on work surface edge

Noise

Occupational noise-induced hearing loss typically develops slowly over several years of exposure to continuous or intermittent noise. Damage can occur more quickly with exposure to continuous noise.

For employees' protection, noise monitoring is conducted during typical work situations. It must be repeated whenever there is a change in production, process, equipment or controls that may increase noise exposure.

- **Dosimeters**, or personal sound exposure meters, measure and store sound pressure levels. Integrated over time, these measurements provide a cumulative noise-exposure reading for a given period such as an 8-hour workday
- **Sound level meters** are used to measure sound level readings throughout the work area, with results expressed as decibels (dB). This type of meter is commonly used in noise pollution studies to quantify different kinds of noise in industry or the environment

Hearing Conservation Program

If the noise cannot be reduced to safe levels, your company must develop and implement a hearing conservation program.

If you cannot carry on a normal conversation because of the noise level, an assessment should be made. In addition, your company must identify employees whose noise exposure equals or exceed 85 dB, averaged over 8 working hours for inclusion in the program.

The program provides both audiometric testing and audiograms.

- Audiometric tests include baseline audiograms, annual audiograms, training and follow-up procedures
- Audiograms show the softest sounds a person can hear at different pitches or frequencies

Employers must provide employees with a selection of hearing protection based on the noise hazards present in their work environment. Devices may include:

- **Earplugs** can be either disposable or reusable and are made of a variety of materials such as waxed cotton, foam, silicone rubber or fiberglass wool. Most earplugs are designed to expand and conform to the shape of your ear canal
- **Earmuffs** come in many models and provide different levels of protection. They require a perfect seal around the ear. Glasses, facial hair and facial movements can reduce their protective value

Personal Protective Equipment

Personal protective equipment (PPE) refers to protective clothing, goggles, or other garments or equipment designed to protect you from injury while at work.

Your employer must conduct an assessment to determine the health and physical hazards that may be present in your work area. After the area is assessed to determine if PPE is required, your employer must provide it, at no cost to you, and must also provide training.

Before wearing your PPE, inspect it for any damage such as tears, rips or cracks. Ensure that it fits correctly. After use, clean the PPE and store it in the appropriate space.

Working Alone

On occasion, you may be required to work alone. Working alone can be dangerous. It can be even more dangerous in safety-critical work environments, such as these:

- Some areas contain **hazardous materials** such as chemicals, radioactive materials, cryogenics and explosives. The quantities may be large enough that you could be injured in an accident or prevented from escaping
- Some areas have **high-pressure systems**, equipment and machinery. They may have moving parts or pinch-point hazards without protective barriers and functional interlocks, making them extremely dangerous
- Beware of areas **energized** by electrical systems that do not have protective barriers and functional interlocks. Locations with **dangerous heights** and any **unfamiliar** work assignment present dangers too

When working alone, discuss the potential hazards and the specific procedures with your supervisor and always follow your company's policy regarding working alone.

Chemicals

Companies are responsible for communicating the hazards of hazardous chemical products to all workers. One chemical may have several hazards so it's important to read the SDS and label.

Topics addressed in your company’s hazard communication program include chemical hazard determination and labeling, employee information and training, and SDSs.

Labels:

- All chemical containers must be labeled with specific information to minimize risk during storage, transportation or use. If you see chemical containers without labels, notify your supervisor and do not use them until the contents are positively identified
- On hazardous substance containers you can find information such as hazard and precautionary statements, identity of the chemical, pictograms and signal words, and supplier contact information

SDSs:

- Are written by the chemical manufacturer and delivered when the chemicals arrive
- Communicate detailed hazard information about a chemical, including how to respond to chemical emergencies. An SDS is required for each chemical used at your company.
- Should be filed for quick and easy access when chemicals are delivered. They must be readily available to all employees. Ask your supervisor where to find the Safety Data Sheets at your workplace

Chemical Routes of Entry into the Body

Chemicals can enter or affect our bodies in several ways. Any chemical in the eye or on the face near the eye should be rinsed in the eyewash. The patient should rinse for 15 minutes unless told to stop by medically trained personnel. For all chemical exposures, call for emergency services to have the patient assessed and transported if necessary.

Inhalation

- The most common entry route is breathing in an airborne chemical substance in fumes or vapors
- Inhalation of a toxic or corrosive gas or vapor can be life-threatening
- If safe to do so, the patient must be removed to fresh air while emergency services are called

Absorption

- Exposure to the skin may result in localized burning or irritation
- Some chemicals may be absorbed through the skin into the bloodstream and cause health effects in other parts of the body
- If you have skin contact with a chemical, rinse in the safety shower for 15 minutes

Ingestion

- Ingestion usually occurs from eating or smoking with contaminants on the hands, or from accidentally swallowing a chemical

Injection

- Injection of chemicals may occur when handling sharp objects such as broken glass, ceramics or other materials that may be contaminated with a chemical

Identifying New Hazards

To develop and produce new products, your company may periodically purchase new chemicals, processes and/or equipment. These items may introduce additional hazards into the workplace. Be aware of any special company procedures for ensuring that safety and the environment are considered in the process of acquiring and installing these items.

Any new chemical or equipment in the facility must be assessed for its impact in your work area. Before purchasing or bringing new chemicals on-site, review your company's chemical purchasing policy.

Your supervisor or manager can give you specific information about the procurement process. If you have any concerns or questions regarding new purchases or want more information, please contact your supervisor.

Hazardous Waste Handling

Government regulations require hazardous waste to be managed safely from the moment it is generated to the time when it is ultimately disposed of. This "cradle to grave" system is designed to protect human health and the environment through effective management.

Items found in a semiconductor fabrication facility that are considered to be chemical waste include:

- Contaminated gloves and wipes
- Empty containers with chemical residues
- Expired chemicals
- Spent process chemical
- Spill cleanup materials

Semiconductor Environmental, Health and Safety (EHS) at Work: Part 3

All types of hazardous energy may be stored in stopped equipment during maintenance and released when the equipment is re-energized. Serious physical harm or death may occur if hazardous energy is not properly controlled.

Hazardous Energy Types

Electrical

The most common source of energy is electrical. Electrical energy powers devices such as motors, switches, heaters, magnets and lasers. The unexpected movement or operation of these devices can cause damage or injury. Hazards also exist when working on power supplies and UPS systems, relays, contactors, fuses, switches or other electrical components.

Mechanical

Energy used for moving mechanical parts can be hazardous, especially when cutting, crushing, trapping or snagging occurs. Mechanical energy can be found in items such as springs or hinges under tension, in wafer handlers, robots, gate valves, chamber lids and belt drives. Mechanical hazards exist around wafer handlers, robots, chamber lids, lifters and slit valves.

Pneumatic

Pneumatic energy is used to drive air tools and open pistons and valves. The valves may enable chemical energy in piping systems, as well as mechanical energy. Examples are clean, dry air used to power gate valves, solenoids, and cryogenic and normally closed pneumatic valves.

Hydraulic

Hydraulic energy uses controlled circulation of pressurized fluid to power pistons and other devices. Hazards exist around pressurized liquid chemical lines in a waste treatment system, plant chilled-water supply and return system and equipment chiller units.

Thermal

Thermal energy is found in the form of very hot or very cold temperatures. Thermal energies include chamber surfaces, heater blocks, lamps used to heat process chambers, cryogenic pumps and chillers. This job aid is intended to provide you with supplemental information associated with UL courseware.

Chemical

Chemicals may be reactive, explosive, toxic, corrosive, flammable or oxidizing. They can be solids, liquids or gases in the form of raw materials, by-products or waste. Chemical energy is used in

processes such as etching, cleaning, diffusion, deposition, ion implantation and photolithography. Look for chemical energy in piping, vacuum forelines, residues in process chambers and vacuum pumps. Hazards exist when changing mass flow controllers, valves and in-line filters and cleaning exhaust lines.

Radiation

It's important that you recognize the hazards from the three types of radiation likely found in semiconductor fabrication facilities as they may produce skin burns or cancers.

- **Ionizing**: Ionizing radiation includes X-rays and gamma rays, which have enough energy to change cell matter. X-rays can be produced by high-voltage equipment like ion implanters or electron microscopes. Gamma rays are typically emitted from radioactive material, such as cobalt-60 or krypton-85
- **Non-ionizing**: Non-ionizing radiation includes the spectrum of ultraviolet, visible light, infrared, microwave, radio frequency and lasers. UV light can cause redness of the skin (sunburn) or eyes (welders flash)
- **Microwave**: Microwave and RF radiation can cause heating of the skin or body. It can be found in the plasma electron flood (PEF) system in an ion implanter and also in plasma ashers, sputters or microwave ovens. Most types of non-ionizing radiation are contained in the equipment by enclosures

Regulations

Most jurisdictions have their own regulations covering hazardous energy. Consult your supervisor about the hazardous energy control regulations for your workplace.
For workers in the United States, Occupational Safety and Health Administration (OSHA) regulations, including lockout/tagout requirements, explain company expectations for controlling hazardous energy.

Lockout/Tagout

The lockout/tagout (LOTO) process involves, in part, shutting down the equipment and preventing the release of hazardous energy. The release is prevented through the use of energy-isolating devices, such as circuit breakers, disconnect switches and line valves.

In **lockout**, employees attach their own locks to prevent the opening of isolation devices and energization of the equipment. Only the person attaching a lock should have a key to remove it.

In **tagout**, employees attach their own warning tags to alert others that the equipment is off and should not be operated. Tags also identify the person performing maintenance on the equipment. Unlike lockout, tagout is not a physical restraint. This job aid is intended to provide you with supplemental information associated with UL courseware.

Electrical Safety

Electrical current travels through insulated conductors. **Conductors**, wrapped in insulators, are the wires and cables that carry electricity to an energized object. **Insulators** are electricity-resistant materials such as rubber, plastic and glass that keep the electric current on its path and prevent accidents. You should never use a cord that is frayed or missing wire insulation!

Grounding provides a path for the current to travel to a safe place in the event of an electrical fault and helps protect against shock. Most electrical equipment is grounded with metal frames and covers and/or 3-pronged plugs.

In outdoor or potentially wet areas, special electric outlets called ground fault circuit interrupters (GFCIs) provide added protection. GFCIs monitor current and are designed to shut power off if the current leaks to ground through either your body or another conductor.

Shock occurs when you provide a ground path by touching a live wire or poorly insulated tool. Injuries that may occur when electric current surges through your body include:

- Pain
- Loss of muscle control that can lead to falls or contact with powered equipment
- Nerve, muscle, or tissue damage
- Internal bleeding
- Cardiac arrest
- Death

To prevent accidents:

- Don't bend or cut off 3-pronged plugs or try to force them into 2-pronged outlets
- Use only spark- and explosion-proof tools and equipment in flammable atmospheres
- Inspect equipment before each use, and remove from service any equipment with frayed wires or other signs of damage or overheating
- Observe warning signs and barriers designed for protection from energized parts
- Don't work on energized equipment unless you're specially trained as an authorized worker
- Be sure electrical equipment is properly locked and tagged out before any testing, repair or maintenance is done

Egress and Emergency Action Plans Awareness

Egress Basics

"Egress" refers to a place or means of getting out or an exit. Safety regulations refer to a "means of egress" as a continuous and unobstructed way of exit travel from any point in a building or structure to a public way. A means of egress has three parts:

1. Exit access – the portion of "means of egress" that leads to an exit
2. Exit – the portion separated from all other spaces by construction or equipment that provides a protected way of travel to the exit discharge
3. Exit discharge – the portion between the termination of an exit and a public way

Requirements

The first fundamental requirement is that a building will have a sufficient number of exits. Every building or structure, new or old, designed for human occupancy shall be provided with exits sufficient to permit the prompt escape of occupants in case of fire or other emergency.

Another fundamental requirement is that the design of exits and other safeguards shall be such that reliance for safety to life in case of fire or other emergency will not depend solely on any single safeguard:

- An exit sign must be illuminated, so it can be seen if the lights in a building fail
- Buildings also have safety lights that turn on in the event of a power loss
- Buildings should have more than one exit – all with exit signs

Detailed Elements

Exits must be clearly identified. Every exit must be clearly visible and marked and access to exits must be conspicuously and unmistakably identified. Doorways or passageways that do not lead outside must be arranged or marked to minimize their possible confusion with real exits.

Exits must be illuminated:

- Adequate and reliable illumination should be provided for all exit facilities: both exit access and exits
- Every required sign designating an exit or way of exit access should be readily visible
- No decorations, furnishings or equipment should impair visibility of an exit sign
- No other distracting displays or signs should be put near or in the line of vision to a required exit sign

There must be **free and unobstructed egress** from all parts of the building at all times when it is occupied. No lock or fastening to prevent free escape from the inside of any building may be installed (exceptions include mental, penal or corrective institutions).

Configuration

- When more than one exit is required from a story, at least two of them must be remote from each other
- Doors leading to exits or exit access must be side-hinged
- Exit access must not pass through a bathroom or other room subject to locking unless the exit is required to serve only the locked room
- Exit accesses must have smooth, solid, substantially level floors and guards on the unenclosed sides
- Stairs must be arranged to make clear the direction of egress to the street
- Exit stairs that continue beyond the floor of discharge must "force" persons to make the right choice when presented with a right and wrong way to the street
- If snow and ice are possible, the area must be covered or cleared regularly
- Travel paths must be permanent, unobstructed and reasonably straight
- Exits must discharge directly to an open space that gives safe access to a public way
- Open areas must be of adequate width and size to accommodate evacuees

Emergency Action Plans

An emergency action plan is a plan for a workplace describing procedures employer and employees must take to ensure employee safety from fire or other emergencies. An emergency action plan should include at a minimum:

1. Procedures for reporting a fire or other emergency
   - Telephone number to call to report any emergency
   - Remember, stay calm and answer all questions that are asked by emergency services
   - Know the nearest manual fire-alarm pull station

2. Procedures for emergency evacuation
   - Type of evacuation and exit route assignments

3. Procedures to be followed by employees who remain to operate critical plant operations before they evacuate

4. Accounting for all employees after evacuation

5. Procedures to be followed by employees performing rescue and medical duties
   - These employees should receive special training and instruction

6. The names and job titles of every employee who may be contacted by employees who need more information about the plan or an explanation of their duties under the plan
   - Employees with questions need to be able to get answers

Fire Prevention Awareness

Elements of Fire

Three elements must be present to start a fire: **oxygen**, **heat** and **fuel**.

Workplace Fires

Oxygen is in every workplace since it is in the air we breathe.

Some sources of **fuel** in the workplace include:

- Paper
- Wood
- Cloth
- Flammable liquids and gases

Sources of **heat** in the workplace include:

- Smoking
- Electrical hazards
- Overheating/malfunctioning equipment
- Friction
- Sparks
- Molten substances
- Lightning

Workplace Fire Prevention Tools and Practices

Housekeeping

Good housekeeping includes:

- Making sure combustibles are collected and stored metal cans or bins with self-closing covers
- Regularly removing dust from machines, pipes and overhead beams
- Keeping passageways and exits free from storage and waste
- Promptly removing waste paper, packaging, old rags and other fire hazards
- Depositing oil-soaked or paint-soaked rags, clothing or waste in noncombustible containers with self-closing covers that are emptied daily
- Storing large quantities of waste in fire-resistant rooms with fire doors and automatic sprinklers
- Scheduling regular collection and removal of combustible waste and garbage

Make sure you:

- Smoke only in designated locations
- Dispose of smoking materials and waste in designated containers
- Keep portable heaters at least 1 meter (3 feet) from combustibles
- Verify heaters have tip-over safety features certified by an independent testing laboratory, such as UL
- Do NOT weld or cut near flammable liquids, vapors or dusts

Keep in mind that **sparks and hot particles** can travel as far as 10.7 meters (35 feet)!

To prevent fires involving **flammable liquids**:

- Bond or ground containers when transferring flammables from drums to small containers or transferring large quantities of flammables
    - **Bonding** is when you connect two flammable liquid containers to each other by an electrical conductor
    - Do NOT transfer flammable liquids from a metal to a plastic container

To prevent **electrical equipment** fires:

- Ground all electrical equipment
- Use surge protectors, when possible
- Immediately turn off, unplug and report equipment that begins to smell or give off smoke

When it comes to electrical equipment:

- Do NOT run electrical cords across doorways or walkways, or pinch them behind furniture or equipment
- Do NOT overload outlets or extension cords

Fire detectors and alarms:

- May detect heat, smoke, flames and/or gas
- Give an early warning to allow occupants to escape the building
- Start fire extinguishing procedures

Alarms must be:

- Clearly and immediately distinguishable from other signals and alarms
- In good working order and tested at least monthly

Alarms should be located so everyone can hear them (or see them if they are hearing-impaired).

To make sure **sprinklers** and **extinguishers** are effective, your company must:

- Inspect and test sprinkler systems and their water supplies regularly
- Train any workers who are expected to use fire extinguishers
- Inspect extinguishers as required
- Make sure extinguishers are easy to see and access
- Replace used or damaged fire extinguishers immediately

Personal Protective Equipment (PPE) Overview – General Guidelines

OSHA's PPE standard (29 CFR 1910.132-138) requires employers to set up and administer an effective PPE program.

According to the standard:

- Employers must have written hazard identification and evaluation of hazards, including a determination of whether PPE is an appropriate control measure
- If employees use PPE, the program must also state how they should select, maintain and evaluate PPE
- Employers must also train employees about how to properly use PPE

PPE Fit

PPE shouldn't move around or fall off while you work, and shouldn't be too tight or constricting. To get a good fit:

- Choose a size that fits snugly but not tight
- Check for a good seal when fitting:
  - Respirators
  - Goggles
  - Hearing protection

Too-loose PPE could:

- Snag on something, tear and become ineffective
- Get caught in machinery – and draw you in as well
- Provide an inadequate seal to block out the hazards

Find a balance between having enough comfort and enough protection. Safety comes first.

Cleaning and Storing PPE

Keeping PPE clean, dry and damage-free helps increase the lasting quality of it.
Clean PPE:

- After checking with your employer for cleaning procedures
- After reading the manufacturer's label
- Before and after each use
- With soap and water (alcohol, thinners and strong cleaning agents can degrade materials)

Inspecting PPE

After cleaning PPE, inspect it for:

- Signs of excessive wear (i.e., holes, cracks, tears)
- Broken fittings

- Elastic straps that are slack, worn or twisted
- Modifications or changes to the equipment's structure

After visually inspecting the PPE, you may also need to:

- Conduct an air or water test to check for leaks
- Send PPE out for testing, repair and recertification by a qualified professional

***Never use ineffective PPE*.** Instead, replace or repair it. Be sure to label it as "out of service" so no one else will use it. PPE requirements vary depending on which part of your body might be exposed to hazards:

PPE for the Head

Wear head protection anytime you may be exposed to the hazards that typically cause head injuries such as:

- Being exposed to falling objects
- Bumping your head against a fixed object
- Working near exposed electrical conductors

PPE for the Eyes and Face

Wear eye protection anytime you may be exposed to the hazards that typically cause eye and face injuries such as:

- Splashes of toxic or corrosive chemicals
- Hot liquids and molten metal
- Flying objects
- Fumes
- Gases and mists of toxic or corrosive chemicals
- Intense light
- Optical radiation

PPE for the Ears

Wear PPE for your ears to conserve your hearing.

- Your employer may require it based on the level or intensity of noise and exposure time
- If you ever notice signs of hearing damage or loss, be sure to wear hearing protection regardless of whether your employer requires it or not

PPE for the Hands

Wear hand protection anytime you may be exposed to the hazards that typically cause hand injuries. Examples of such hazards include:

- Corrosive or toxic chemicals
- Dangerous chemicals
- Electrical sources
- Objects that can strike, cut or pinch
- Extremely cold or hot objects

Choose gloves made of an appropriate material:

- Canvas and leather gloves protect against dust and abrasions
- Cut-resistant gloves are made from synthetic fibers
- Chemical and electrical gloves are made from a variety of natural and synthetic rubbers

PPE for the Body

Jeans and long-sleeve shirts are often adequate against minor hazards like dirt, dust, minor abrasions and sun exposure. Other types of body protection may include:

- Full-body suits
- Gowns
- Jackets
- Vests
- Aprons

Choose body PPE made of material that is appropriate for each hazard.

- Treated wool and cotton for changing temperatures, dust and abrasions
- Insulated and tightly woven cotton protects for cuts, bruises, extreme temperatures
- Leather and welding aprons for hot work
- Paper-like synthetic fibers for liquid, puncture, tear and abrasion resistance
- Synthetic rubber and plastic materials for chemicals and other harmful substances

PPE for the Feet and Legs

Wear foot and leg PPE anytime you may be exposed to the hazards that typically cause foot or leg injuries. These hazards may include:

- Heavy/sharp objects
- Electricity
- Extreme heat/moisture
- Slippery surfaces
- Liquids (acids, caustics and molten metal)

Common foot PPE includes:

- Steel-toed boots
- Foundry shoes
- Conductive (CD-rated) shoes
- Static-dissipating (SD-rated) shoes
- EH-rated (electrical hazard) shoes

Respiratory Protection

Wear respiratory protection anytime you may be exposed to hazards that may damage your respiratory system. These hazards include:

- Dust
- Fumes
- Temperature extremes
- Gases
- Vapors

Respiratory protection may include:

- Air-purifying respirators (APRs) that remove contaminants from the air
- Air-supplying respirators (ASRs) that supply clean air from a source other

You must go through fit-testing, medical clearance and special training before using a respirator. Inspect your respirator before using it and have it repaired or replaced if you find anything wrong with it. After using your respirator, you should clean and disinfect it. Store respirators in a sealable bag away from:

- Dust
- Sunlight
- Heat
- Extreme cold
- Moisture
- Damaging chemicals

Semiconductor Chemical Safety Part 1a: Introduction to the GHS

Workers in the semiconductor industry work with hazardous chemicals every day. The purpose of the Globally Harmonized System of Classification and Labelling of Chemicals (GHS) is to define and classify the hazards of chemical products, and to communicate health and safety information on labels and Safety Data Sheets. The goal is to reduce confusion and worker injury and illness.

Responsibilities

As an employee, you:

- Have a right to a safe and healthful workplace by understanding the hazards of chemicals you work with and following all safety controls put in place to protect you
- Are responsible for your own well-being and that of your co-workers
- Should know, understand and follow safety procedures
- Should report injuries, accidents and unsafe conditions to Environmental Health and Safety (EHS) or your supervisor
- Should never take risks or shortcuts
- Should participate in safety and health training offered by your employer
- Need to properly use machinery, tools, substances and personal protective equipment (PPE)
- Need to immediately evacuate during an emergency

Employers should:

- Develop a chemical safety management program that includes processes, equipment and hazard control measures
- Identify all the hazardous chemicals in the workplace (hazardous chemical inventory)
- Communicate chemical hazards via Safety Data Sheets (SDSs), signs and labels
    - The SDS has a specific format with 16 sections

Hazardous Materials Characteristics

Physical states include:

- Liquid: Is not a gas and has a melting point of 112°F (20°C) or less
- Gas: At 122°F (50°C), has a vapor pressure greater than 43.5 pounds per square inch (psi) or 300 kilopascals (kPa)
- Solid: Does not meet the definition of the other two substances

Pictograms

A pictogram is a symbol plus other graphic elements, such as a border, background pattern or color, that is intended to convey specific information about the hazards of a chemical. Each pictogram consists of a black hazard symbol on a white background within a red square frame set on a point (red diamond).

Physical Hazards

- **Flammable liquids** are chemicals that give off flammable vapors that can ignite at a temperature less than 73°F (22.8°C). This temperature is known as the flash point.
- **Flammable solids** are readily combustible, or may cause or contribute to fire through friction. They ignite by flame, friction or reaction with water.
- **Flammable gases**, like hydrogen, methane and acetylene, must mix with an oxidizer, like air, to ignite. Flammable gases have an ignitable flammability range.
- A **pyrophoric liquid or gas**, even in small quantities, is able to ignite or explode simply by coming into contact with air – no flame or other ignition source is required.
- **Self-heating chemicals** are solids or liquids, other than pyrophoric substances, that heat up upon contact with air. Self-heating materials react slower than pyrophoric substances.
- **Gases under pressure** are gases that are contained in a cylinder at a pressure not less than 40.6 psi (280 kPa) at 68°F (20°C) or as a refrigerated liquid. Compressed gases may be flammable, toxic, corrosive, oxidizing, pyrophoric, cryogenic or inert.
- **Oxidizers** are required to ignite a fuel. They do not burn, but they make fuel burn better.

Health Hazards

- **Toxic chemicals** may produce acute (short-term) or chronic (long-term) health effects in exposed employees. They can even cause death!
- **Corrosive chemicals** can cause irritation or damage to the skin, eyes, nose, throat and respiratory tract. Corrosiveness to metal makes some chemicals useful for etching and cleaning processes in semiconductor fabrication. A corrosive chemical is an acid or a base.
    - Chemicals with a pH of 2 or below are acids
    - A pH of 7 is neutral
    - Chemicals with a pH of 12.5 or above are bases or alkalis
- **Hydrofluoric (HF) acid** is an extremely corrosive chemical commonly used for etching, chamber cleaning and dissolving silicon compounds. Exposure can cause extreme respiratory irritation, immediate and severe eye damage, and pulmonary edema. After exposure, rinse with water for 5 minutes and seek immediate medical attention.
- **Carcinogens** are chemicals that may cause cancer.
- **Mutagens** are substances that may alter or mutate DNA.
- **Reproductive toxins** may adversely affect sexual function, fertility and offspring.
- **Respiratory sensitizers** produce an allergy-like reaction upon inhalation that worsens with repeated exposure.
- **Aspiration toxins** cause severe health effects including chemical pneumonia and lung injuries, while **target organ toxins** may cause damage to bodily organs.
- **Skin or eye irritants** cause discomfort.
- **Skin sensitizers** induce an allergic response that may get worse with successive contact.
- Narcotic effects and respiratory tract irritation following a single exposure are considered **target organ systemic effects**.

Environmental Hazards

Environmental toxins are chemicals that may cause damage to the aquatic environment. The effects may be short-term (acute) or long-term (chronic).

Semiconductor Chemical Safety Part 1b: Communication, Controls and Emergency Procedures

Employees in the semiconductor industry work with and around hazardous chemicals every day. “Hazardous materials” include liquid chemicals, liquefied and pressurized gases, and solid substances.

Safety Data Sheets (SDSs)

Safety Data Sheets (SDSs) contain 16 sections that cover four broad categories of information about a chemical: Identification, Emergency/exposure, Properties and Additional Information.

SDSs must:

- Be created and provided by the chemical manufacturer, importer or distributor
- Be obtained before chemicals are used
- Be easy for employees to access (YOU are responsible for knowing where they are!)
- Be in English or the official language(s) of the country
- Include the chemical identity and common names
- Include contact information for the people who prepared the SDS

Labels

You can learn about the general hazardous properties of a specific chemical by checking its label. Labels must be: legible, in English or the official language(s) of the country (may be in other languages as well), and prominently displayed. Labels include:

- The product **name**, with hazardous ingredients in parentheses, where appropriate
- **Pictograms** that convey hazard classes, transportation requirements or toxicity
- The **signal word** to indicate the severity of the hazard; remember that Danger is more severe than Warning
- **Supplemental information** that may be required by different authorities
- **Precautionary statements**, including *prevention*, *response*, *storage* and *disposal*
- The supplier's **address and phone number**

Classifications

The GHS classification system rates hazards from 1 (highest) to 5 (lowest). This is the OPPOSITE of the National Fire Protection Association (NFPA) hazard rating system, which goes from 0 (no hazard) to 4 (high hazard). The NFPA codes are:

- Blue = Health
- Red = Flammability
- Yellow = Instability (reactive)
- White = Special hazards
- ~~W~~ = Water reactive
- OX = Oxidizing agents

Hazard Controls and Precautions

There are five general methods, in descending order of effectiveness, for controlling hazards:

- ELIMINATE IT by redesigning the process
- SUBSTITUTE with a safer process or product
- Provide an ENGINEERING CONTROL at the source
- REDUCE exposure through administration

- USE PPE as a last line of defense

Engineering controls include designs or modifications to equipment, ventilation systems and processes that reduce the source of exposure. **Administrative controls** alter the way people work to reduce exposure to a hazard. These controls may include altering work schedules, implementing work practices and writing standard operating procedures. **Safe handling practices** reduce the risk of chemical exposure, lessen the risk of fire and prevent accidental mixing of incompatible chemicals. **PPE** includes items such as respirators and protective clothing like gloves, face shields, eye protection and footwear that serve to provide a barrier between the wearer and the chemical or material. Only rely on PPE when other control methods are inadequate to minimize the risk to the employee or use it with other hazard control methods as an added layer of protection.

Chemical Storage

When not in use, chemicals should be stored in approved storage cabinets. Store incompatible chemicals in separate cabinets or areas.

Emergencies

In the event of a chemical accident, protect your own safety first. Do not approach a spill or release unless you know the material, hazards and precautions and are trained in spill procedures. Keep others away from the affected area. Call for help, if needed.

Immediate steps you should take include:

- If a chemical may be in the face or eye, rinse in an eyewash for 15 minutes
- If skin is exposed to a corrosive or toxic chemical, rinse in a safety shower for 15 minutes
- Anyone who inhales toxic or corrosive gases or vapors should leave the affected location and breathe fresh air
- For hazardous gas releases, evacuate when toxic gas alarms are activated
- For uncontrolled inert gas releases, call for internal emergency response

Clean up small spills ONLY if all these conditions are met:

- The spill is within allowable cleanup limits for your facility
- Personnel know the chemical and the hazards
- The area is secure and safe to perform the cleanup
- Personnel are trained to perform cleanup
- Appropriate cleanup materials are available
- Proper disposal receptacles are available

For large spills (over 1 pint), get away from the spill, prevent others from approaching and call the local emergency number.

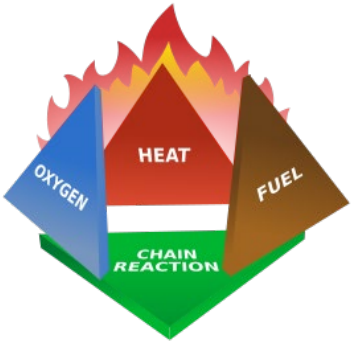
Disposal

Hazardous wastes are subject to strict regulation and handling/management practices because MISHANDLING them can pose a threat to employees and the environment. The generating company must manage the waste from the moment it is generated to

the time it is ultimately disposed of. Use appropriately labeled hazardous waste containers.

Semiconductor Chemical Safety Part 2: Hazards, Controls and Emergency Actions

Flammable Chemical Hazards



To ignite, a fire requires fuel, oxygen and heat. Flammable chemicals are the **fuel** for a fire. Air provides oxygen for most fires. To prevent fires in semiconductor fabrication facilities, we control the ignition source. To sustain burning, a fire needs a chemical chain reaction.

The **flash point** is the minimum temperature at which a flammable liquid will evaporate enough vapor to ignite and flash in the presence of an ignition source.

The **flammable range** is the range at which fuel can mix with air and burn. Different gases have different flammable ranges.

Hazard	Description	Examples	Controls
Flammable liquids	When a flammable liquid mixes with air, it creates a flammable vapor that can fuel a fire.	• Isopropyl alcohol • Acetone • Methyl alcohol • Photoresists • Photodevelopers	• Prevent flammable vapors from evaporating in open areas • Prevent open ignition sources • Use ventilation to remove and dilute vapors • Keep flammable liquid containers in chemical storage cabinets
Flammable gases	Flammable gases must mix with air in a specific concentration range to ignite.	• Hydrogen • Ethane • Propane • Acetylene	• Avoid ignition sources near flammable gases • Install explosion-proof facilities and equipment • Ensure high ventilation rates • Flow flammable gases in closed systems that are not open to air
Flammable solids	Solids that will ignite or explode upon contact with water, air, spark or friction.	• Sodium metal • White phosphorus • Yellow phosphorus • Dichlor and trichlorsilane by-products in epi and poly depositions	• Use flammable solids in closed systems

Combustible Chemicals

Combustible chemicals:

- Do NOT release flammable vapors at room temperature/pressure
    - Combustible liquids will release ignitable vapors if they are heated
- May be liquid or solid
- Ignite upon contact with heat or flame

Oils and diesel are common semiconductor combustible liquids. Furniture, plastics and cardboard are combustible solids.

Controls to prevent combustible materials from igniting:

- Store combustible liquids in sealed containers in flammable storage cabinets
- Keep combustible solids away from heat sources and open flames
- Flammable and combustible liquids may be stored together, but these should NOT be stored with flammable SOLIDS as solids can become an ignition source

Pyrophoric Chemicals

A pyrophoric chemical is a solid, liquid or gas that will spontaneously ignite in air – possibly in an explosive manner – at or below 130°F (54.5°C). Examples in the semiconductor industry include silane (gas), organometallics such as trimethyl and dimethyl aluminum hydride (DMAH) (liquid), yellow phosphorus (solid), and solid residues in exhaust lines and ducts.

Pyrophoric chemical hazard controls are stringent and include: closed systems and storage and use procedures.

Oxidizing Chemicals

Oxidizing chemicals can make normally non-combustible materials very combustible. Some oxidizing chemicals can start a fire without an ignition source. In addition, many oxidizers can burn skin or mucous membranes on contact. Examples of strong oxidizers in semiconductor fabrication facilities are nitric acid, hydrogen peroxide, chlorine, 100% oxygen, nitrous oxide, nitric oxide and fluorine.

To control oxidizing chemical fire hazards, keep oxidizers and flammables separated and keep ignition sources away from oxidizers and flammables.

Corrosive Chemicals

Corrosive chemicals may be used in etching, cleaning, photolithography processes, and equipment and facility maintenance operations. Examples include hydrofluoric acid (HF), sulfuric acid, nitric acid and sodium hydroxide.

To control corrosive chemical hazards:

- Control vapors
- Use corrosion-resistant materials and containers
- Avoid mixing incompatible materials
- Wear corrosion-resistant personal protective equipment

Toxic Chemicals

ANY chemical or substance can be toxic at a certain level – even water! We need controls to prevent exposure or limit it to an acceptable level – the **permissible exposure limit (PEL)**.

How toxic a chemical is to specific people may depend on:

- How they were exposed (ingestion, absorption, injection or inhalation)
- Their age and gender
- Their overall health (including their immune system)

Examples of toxic chemicals in the semiconductor fabrication industry include ammonia, arsenic, arsenide, diborane, germane and phosphine.

Control measures include ventilated chemical hoods, closed systems, supplied-air respirators, gloves and protective clothing.

Exposure Limit Acronyms

- PEL: permissible exposure limit
- TLV: threshold limit value
- TWA: time weighted average (usually over 8 hours)
- (C) or Ceiling: exposure limit that cannot be exceeded for any period of time
- STEL: short term exposure level (allowable exposure for 15 minutes)
- IDLH: immediately dangerous to life and health (irreversible adverse health effects if exposed for 30 minutes or more)
- LD_{50}: dose at which 50% of the test population died when exposed by ingestion, absorption or injection
- LC_{50}: dose at which 50% of the test population died when exposed by inhalation

Chemical Storage and Handling

Hazard Class	Storage
Flammable liquids	Store flammable liquids in a flammable chemical cabinet when not in use.
Flammable gases	Store flammable gases in a chemical cabinet or well-ventilated area according to code requirements.
Flammable solids	Store flammable solids in a chemical cabinet when not in use. Do NOT store them in the same cabinet with flammable liquids!
Pyrophoric substances	Store pyrophoric gases in an approved gas cabinet. Store pyrophoric liquids and solids the same way you store flammable solids.
Combustibles	Store combustible liquids in a flammable chemical cabinet when not in use.
Oxidizers	Store oxidizers in a chemical cabinet when not in use. Separate them from flammable and combustible materials.
Corrosive liquids and solids	Store corrosive liquids and solids in a corrosive chemical cabinet when not in use. Do NOT store acids and bases on the same shelf!
Corrosive gases	Store corrosive gases in an approved gas cabinet.
Toxic liquids	Store toxic liquids in a chemical cabinet when not in use.
Toxic gases	Store toxic gases in an approved gas cabinet.

Personal Protective Equipment (PPE)
Choose the appropriate PPE for the chemical, the operation and the individual.

Item	Recommendation
Eyewear	Use appropriately rated safety glasses, goggles and face shields.
Gloves	Use appropriately rated safety hand protection. Check the manufacturer's glove chart for chemical resistance rating.
Respirators	Chemical respirators may require a specialized program, medical exams, equipment fit testing and training prior to use.
Clothing	Check the manufacturers' ratings to ensure aprons, sleeves and chemical-protective clothing are rated for the chemical used.
Footwear	Wear closed-toe shoes when handling chemicals.

Compatibility

	Flammable	Oxidizer	Acid	Base	Toxic
Flammable	OK	No	No	No	OK
Oxidizer	No	OK	OK	No	No
Acid	No	OK	OK	No	No
Base	No	No	No	OK	No
Toxic	OK	No	No	No	OK

Initial Actions During a Hazardous Chemical Emergency

Flammable Chemicals
If there is a fire involving **flammable liquid**, leave the area. If you get a flammable liquid on your skin or clothes, remove the clothing and rinse the affected area. In the event of a **flammable gas** release, alarms will activate and you must leave the area. Only trained personnel should attempt to extinguish **flammable solid** fires. Everyone else should leave the area. Handle emergencies with **pyrophoric chemicals** through remote means, such as an emergency off button or closing the chemical in a chemical hood. If there is a pyrophoric chemical fire, move away and call for help. Do not use an extinguisher!

Corrosives and Oxidizers

If…	Then…
Your skin is exposed	Rinse in water immediately
You inhale vapors and experience more symptoms than minor coughing	Seek immediate medical attention
Any patient is contaminated	Decontaminate the patient BEFORE transporting elsewhere

Hydrofluoric acid (HF) causes deep penetrating burns. If you are exposed to HF:
1. Rinse under a safety shower for at least 5 minutes.
2. Remove all contaminated clothing while in the shower.
3. Using a gloved hand, apply **calcium gluconate gel** to the burn.

4. Contact emergency services.

Toxic Chemicals

Look at the Safety Data Sheet (SDS) for specific emergency response instructions.

Exposure Route	Procedure
Inhalation	Go to fresh air and call for emergency services
Absorption	Rinse with water and call for emergency services
Ingestion	Call a poison control center and induce vomiting, if necessary; then, call for emergency services
Injection	Control bleeding and call for emergency services

Semiconductor Chemical Safety Part 3: Extremely Hazardous Chemicals

In the semiconductor fabrication industry, there are numerous extremely hazardous chemicals and by-products. For this course, we've divided them into nine extremely hazardous chemical categories:

Chemical Type	Primary Hazard	Secondary Hazard
Toxic hydride gases		
Corrosive gases		
Oxidizing gases		
Pyrophoric gases		
Silane		
Flammable gases		
Highly energetic materials		
Corrosive liquids		
Pyrophoric liquids		
Hazardous by-products	Varies	

IMPORTANT: There may be other extremely hazardous chemical categories in your workplace; your employer will educate you about specific hazards.

Emergencies

A release of any extremely hazardous chemical is a very serious event. If there is an alarm:

1. Evacuate to the designated assembly area.
2. If it is safe to do so:
    - Activate the fire alarm if you see smoke or flames
    - Use remote means to shut down gas
3. To help people who may have been exposed:
    - Take anyone who has inhaled chemicals to fresh air
    - Place anyone with chemical burns in a safety shower
4. Report any relevant information about the event to responders.
5. Follow any directions from the responders.

The information in these data sheets is **NOT COMPREHENSIVE**. For detailed information about the chemicals with which you work, please consult the Chemical Safety Handbook for the Semiconductor, Electronics and Photovoltaic Industries.

Toxic Hydride Gases

Examples:

- Arsine
- Diborane
- Germanium tetrahydride
- Hydrogen selenide
- Hydrogen sulfide
- Phosphine

Uses

Gases are often used as in diffusion, implant or deposition

Hazards

- Ignites on contact with air
- Primary hazard: **flammable**
- Secondary hazard: may be **toxic**
- Compressed gas is under pressure and can explode if the cylinder is heated
- By-products will form and coat exhaust lines and process pumps

Precautions

Requires pyrophoric (or toxic) gas controls that may include:

- Alarms that activate upon gas release
- Exhausted and monitored enclosures for the cylinder and any fittings
- Handling and cleaning procedures for opening delivery lines, chambers and exhaust lines

Key Information

TLVs (ppm)	IDLHs (ppm)	LC50s (ppm)	LELs (% in air)	UELs (% in air)	Odor

Under 10	Under 100	Under 200	0-4	75-100	Odors are detectable at levels over the exposure threshold.

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Corrosive Gases

Examples:

- Ammonia
- Boron trifluoride
- Hydrogen bromide
- Hydrogen chloride
- Tungsten hexafluoride

Uses

Gases used to:

- Etch silicon in etch processes
- Clean chambers in numerous processes

Hazards

- Primary hazard: **toxic**
- Secondary hazard: **corrosive**
- Compressed gas is under pressure and can explode if the cylinder is heated
- Fluorinated and chlorinated radicals hydrolyze with moisture in air to form hydrofluoric acid (HF) or hydrochloric acid (HCl) vapors

Precautions

Corrosive gas controls may include:

- Alarms that activate at occupational exposure limits
- Exhausted and monitored enclosures for the cylinder and any fittings
- Double contained piping or specially treated piping
- Handling and cleaning procedures for opening delivery lines, chambers and exhaust lines

Key Information

The information in these data sheets is **NOT COMPREHENSIVE**. For detailed information about the chemicals with which you work, please consult the Chemical Safety Handbook for the Semiconductor, Electronics and Photovoltaic Industries.

TLVs (ppm)	IDLHs (ppm)	LC50s (ppm)	LELs (% in air)	UELs (% in air)	Odor
Under 10	Under 100	Under 200	N/A	N/A	Odors are usually pungent or acrid. Many cause olfactory fatigue.

Oxidizing Gases

Examples:

- Chlorine
- Chlorine trifluoride
- Fluorine
- Nitric oxide
- Nitrogen dioxide
- Ozone

Uses

Gases used for:

- Nitride deposition
- Chamber cleaning

Hazards

- Primary hazard: may be **toxic** or an **oxidizer**
- Compressed gas is under pressure and can explode if the cylinder is heated

Precautions

Oxidizing gas controls may include:

- Alarms that activate at occupational exposure limits
- Exhausted and monitored enclosures for the cylinder and any fittings
- Double containment piping
- Handling and cleaning procedures for opening delivery lines, chambers and exhaust lines

Key Information

TLVs (ppm)	IDLHs (ppm)	LC50s (ppm)	LELs (% in air)	UELs (% in air)	Odor
0.1 to 25	5 - 100	Under 500	N/A	N/A	Odors are detectable at levels just below or at the exposure threshold. Odor quality varies, most are sharp and pungent.

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Pyrophoric Gases

Examples:

- Silane
- Phosphine
- Germanium tetrahydride
- Disilane

Uses

Gases are often used as in diffusion, implant or deposition

Hazards

- Ignites on contact with air
- Primary hazard: **flammable**
- Secondary hazard: may be **toxic**
- Compressed gas is under pressure and can explode if the cylinder is heated
- By-products will form and coat exhaust lines and process pumps

Precautions

Requires pyrophoric (or toxic) gas controls that may include:

- Alarms that activate upon gas release
- Exhausted and monitored enclosures for the cylinder and any fittings
- Handling and cleaning procedures for opening delivery lines, chambers and exhaust lines

Key Information

TLVs (ppm)	IDLHs (ppm)	LC50s (ppm)	LELs (% in air)	UELs (% in air)	Odor
0.2 to 5	Not available	9600 (4 hr rat)	1	100	Minor gas leaks of silane will generally react and form silicon by-products at the leak point.

The information in these data sheets is **NOT COMPREHENSIVE**. For detailed information about the chemicals with which you work, please consult the Chemical Safety Handbook for the Semiconductor, Electronics and Photovoltaic Industries.

Silane

Examples:

- Silicon tetrahydride (SiH_4)

Uses

Gas used as a silicon source in deposition and diffusion

Hazards

- Pyrophoric gas, highly ignitable or explosive in air
- Compressed gas is under pressure and can explode if the cylinder is heated

Precautions

Requires pyrophoric (or toxic) gas controls that may include:

- Alarms that activate at occupational exposure limits
- Exhausted and monitored enclosures for the cylinder and any fittings
- Double containment piping
- Only specially trained personnel can perform cylinder changes

Key Information

TLV (ppm)	LEL (% in air)	UEL (% in air)	Odor
5	1	100	Repulsive odor

Flammable Gases

Examples:

- Acetylene
- Carbon monoxide
- Hydrogen
- Methane
- Propane

Uses

Used as:

- Carrier gases in deposition and implant
- Diffusion and as fuel in abatement and anneal

Hazards

- Primary hazard: **flammable**
- Compressed gas is under pressure and can explode if the cylinder is heated

Precautions

Requires hazardous gas controls that may include:

- Alarms that are set at 25% of the lower explosive level to activate alarms and shutoff gas flow
- Quantities above threshold levels must be in exhausted and monitored enclosures

Key Information

TLVs (ppm)	IDLHs (ppm)	LC50s (ppm)	LELs (% in air)	UELs (% in air)	Odor
N/A	N/A	N/A	4-10	75-100	Varies

The information in these data sheets is **NOT COMPREHENSIVE**. For detailed information about the chemicals with which you work, please consult the Chemical Safety Handbook for the Semiconductor, Electronics and Photovoltaic Industries.

Highly Energetic Materials

Examples:

- Organometallic materials (OM)
- Diethylzinc
- Trimethylaluminum
- Trimethylgallium
- Trimethylindium

Uses

- Highly energetic source materials are solids and liquids
- Vapors are evaporated from source materials and used to deposit metals on substrates

Hazards

- Primary hazards:
  - **Flammable**
  - **Highly reactive to water or air**
- Secondary hazard: **corrosive**

Precautions

Requires stringent controls that may include:

- Highly energetic materials should be used in closed systems
- Installation and operation review using a process hazard analysis or other system safety approach
- Handling and cleaning procedures for opening delivery lines, chambers and exhaust lines

Key Information

- Due to air and moisture reactivity, low-level exposure is not considered a main hazard
- Fire and explosion risks due to spontaneous ignition is the hazard to control

The information in these data sheets is **NOT COMPREHENSIVE**. For detailed information about the chemicals with which you work, please consult the Chemical Safety Handbook for the Semiconductor, Electronics and Photovoltaic Industries.

Corrosive Liquids

Examples:

- Hydrochloric acid (hydrogen chloride)
- Hydrofluoric acid (hydrogen fluoride)
- Sulfuric acid
- Nitric acid
- Phosphoric acid

Uses

Liquids used to:

- Etch silicon
- Strip photoresist from wafers
- Clean parts

Hazards

- Primary hazard: **corrosive**
- Secondary hazard: **toxic**
- Contact with skin will cause burns
- Inhalation or vapors can cause irritation and burning (significant inhalation of vapors can lead to chemical pneumonia)
- Mixing corrosives with incompatible materials, such as flammables, can lead to violent reactions (fire and explosion)

Precautions

Requires controls that may include:

- Ventilated hoods for any open use
- Handling and use procedures
- Safety eye and face wear, gloves and protective clothing
- Readily accessible safety shower

Key Information

TLVs (ppm)	IDLHs (ppm)	Odor
0.1 to 2	15 to 50	Sharp pungent odors, many with the ability to cause olfactory fatigue.

The information in these data sheets is **NOT COMPREHENSIVE**. For detailed information about the chemicals with which you work, please consult the Chemical Safety Handbook for the Semiconductor, Electronics and Photovoltaic Industries.

By-products

Uses

Solids and **liquids** that form in chambers, exhaust lines and exhaust system equipment from deposition, diffusion and implant processes



Hazards

- Hazards are similar to the hazards from the original material
- Primary hazard: usually **toxic** from off-gassing when exposed to air
- Secondary hazard: **flammable**
- Can combine to form additional hazards:
  - Water-reactive
  - Toxic
  - Corrosive
  - Violent reactions (fire and explosion)

Precautions

Requires specialized controls that may include:

- Ventilation, monitoring and alarms to maintain exposure below limits
- Transportation, handling and cleaning procedures for opening chambers and exhaust lines
- Personal respirator, eye and face wear, gloves and protective clothing

Key Information

Assume all by-products have the same hazards as source materials and are reactive

Semiconductor Chemical Safety Part 4: Hazardous Gases and Control Systems

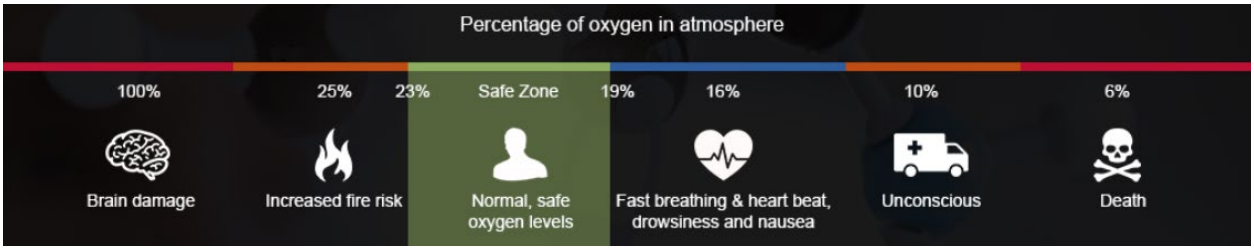
Chemical Hazard Categories Review

- **Corrosive** – poses inhalation risk as well as a risk for burns to eyes and mucous membranes
- **Flammable** – ignites if there is sufficient oxygen (or other oxidizer) and there is an ignition source
- **Oxidizing** – does not burn itself but will make another fuel burn more readily
- **Pyrophoric** – ignites or explodes on contact with air
- **Toxic** – can have harmful health effects at low doses

Characteristics of Inert Gases

Inert gases are found throughout the fab. Examples include compressed nitrogen, argon and sulfur hexafluoride.

An inert gas does not pose any chemical or physical hazards aside from being a simple asphyxiant. Simple asphyxiants are harmful only when they become so concentrated that they reduce the oxygen in the air to dangerous levels.



% Oxygen in Air	Health Effects
23.5 - 19.5	None; safe level
19.5 - 10	Fast to intermittent breathing, fast heartbeat, impaired attention, thinking and coordination, and exhaustion
10 - 6	Nausea, vomiting, lethargic movements and possible unconsciousness
< 6	Convulsions followed by stopped breathing and heartbeat, resulting in death

Characteristics of Cryogenic Gases

Cryogenic cylinders, referred to as dewars, store cryogenic liquids, such as nitrogen, argon, hydrogen and oxygen.

Transition of Liquid to Gas

- The liquid will evaporate slowly, generating gas
- The evaporation continues and the gas phase builds up pressure. The pressure can be drawn off as a gas source
- If the gas pressure builds up above a level of concern, it will be slowly vented to the surrounding environment through a pressure-relief device. This automatic venting is slow enough that the gas will not affect the surrounding environment
- The venting will cause the moisture in the air near the pressure relief device to freeze. This will cause ice to build up on the dewar, but not enough to be of concern

Safe Generation of Gas

The key to safe generation of gas from cryogenic liquids is slow evaporation. Rapid evaporation will generate a lot of gas due to thermal expansion, or the dense liquid expanding into the less-dense gas form.

Preventing Sudden Releases of Cryogenic Gases

- Always wear the appropriate PPE when handling cryogenic liquids. This includes a face shield, insulated gloves and an apron
- Large dewars should be seismically restrained in areas where there is risk of earthquakes
- The facility should consider placing oxygen level sensors in spaces where cryogenic liquids are stored

Physical Hazards and Safety Precautions for Compressed Gases

Pressures inside a full compressed gas cylinder may exceed 2,000 pounds per square inch (psi). Those high pressures pose hazards such as gas discharge and pinhole leaks, and a damaged cylinder can become a pressurized projectile.

Use the proper precautions when working with compressed gas cylinders. You need to:

- Wear eye protection when connecting gas lines
- Keep cylinder caps on when not in use
- Transport cylinders using a cylinder cart and wear safety shoes, if required by your facility
- Always secure the cylinders to prevent damage from falling

Common Semiconductor Gases by Primary Hazard Category

Toxic Hydrides	Corrosive Gases	Oxidizing Gases	Pyrophoric Gases	Flammable Gases	Inert Gases
Arsine	Ammonia	Chlorine	Disilane	Hydrogen	Argon
Diborane	Boron Trifluoride	Chlorine Trifluorine	Silane	Methane	Carbon Dioxide
Germane	Germanium Tetrafluoride	Fluorine		Propane	Helium
Hydrogen Selenide	Hydrogen Bromide	Nitric Oxide			Nitrogen
Hydrogen Sulfide	Hydrogen Chloride	Nitrogen Dioxide			Sulfur Hexafluoride
Phosphine	Phosgene	Nitrogen Trifluoride			
	Tungsten Hexafluoride	Nitrous Oxide			
		Oxygen			
		Ozone			

Common Controls

Controls for Compressed Gas Cylinders

- Security/protection
  - Compressed gas cylinders must be secured to avoid damage
  - A compressed gas cylinder's neck and valve must be protected by a valve cap when not in use
- Storage
  - Cylinders must be stored in ventilated areas
  - Gases and gas storage areas must have signs and labeling

Controls for Gas Delivery Systems

- Systems are usually equipped with emergency shutdown systems, pressure-monitoring devices and pressure-relief devices
- Piping and components are made of materials that are compatible with the gas they carry
- Systems and piping areas have signs and labeling

Review of NFPA Rankings

The NFPA ranks chemicals from 0 (least hazardous) to 4 (most hazardous). Hazardous gas controls are more stringent for gases that have a 3 or 4 in any of the NFPA diamond fields.

Hazardous gas controls depend on the amount of gas used and the hazard level of the gas.

Hazardous Gas Control System: Source

1. Start with a source gas cylinder.
2. Place an RFO in the valve outlet.
3. Place the cylinder in an enclosure.
4. Install a shutoff valve at the cylinder outlet.
5. Connect the enclosure to exhaust.
6. Install a flow sensor.
7. Install a gas release sensor.
8. Connect flow and release sensors to a monitoring station.
9. Connect fire alarm and seismic activation signals to the monitoring station.
10. Connect monitoring station shutdown signal to shutoff valve on cylinder.
11. Connect a regulator to the cylinder.
12. Connect the regulator to a gas control panel.
13. Verify the presence of an excess flow device in the control panel.

Common Hazardous Gas Controls

- Alarms
- Connection to fire alarm
- Double piping
- Emergency shutoff valve
- Gas enclosure
- Leak protection sensors
- Restrictive flow orifice (RFO)
- Seismic sensor
- Ventilation

Emergency Procedures

Fabs and clean rooms are equipped with hazardous gas alarms that are set to activate at levels LOWER than allowable exposure levels.

Personnel will have time to evacuate the area before they become overexposed to hazardous gas. Always evacuate the area whenever you hear an alarm.

If you see a problem with a hazardous gas or a system running a hazardous gas, use the emergency off, or EMO, button. This will shut down the equipment and stop any release.

Semiconductor Electrical Safety Part 1 – Basics of Electrical Safety

Characteristics of Electricity

Electricity is the flow of moving electrons, which carry electrical energy from one place to another. Electricity flows from higher potential energy to lower potential energy and can be measured in numerous ways and exhibits various characteristics.

- **Power**, measured in watts (W) and kilowatts (kW), is the ability of electricity to perform work and is proportional to current and voltage
- **Voltage**, measured in volts (V), is the difference in electricity flow potentials. Any voltage greater than 50 V is considered hazardous
- **Current**, measured in amperes (A) or milliamps (mA), is the flow rate of electricity. The amount of current is related to the amount of resistance it meets in the circuit. There are 2 types of current:
    - Direct current (DC), which moves at a steady rate
    - Alternating current (AC), which moves in a wave
- **Resistance**, measured in ohms (Ω), is the property of a material that opposes current flow. The degree of resistance depends on the type of material and the distance the current has to travel. As resistance increases, current flow decreases

Ohm's Law expresses the relationship between voltage, current and resistance as: **V (voltage) = I (current) x R (resistance)**. A change in one factor can affect the others and increase or decrease the hazard.

Conductors and Insulators

Conductors are materials through which electricity flows with relative ease. Examples include: metal pipes, copper wire and water (or wet skin). Conversely, insulators are materials that have high resistance to current flow. Examples include: ceramics, glass and rubber.

Hazards of Electricity

Electric Shock

Electric shock can be caused by:

- **Current**. Electricity can flow from the energized circuit through the body to a grounded object. Just 16 mA of current entering your body causes your muscles to contract involuntarily and make it impossible to let go ("Let Go Threshold")
- **Skin resistance**. Perspiration, wet clothes, high humidity and cuts in the skin can reduce skin's resistance dramatically
- **High voltage**. High voltage (greater than 600 V) can result in burns, entry and exit wounds, and other effects of electrical shock depending on the current of the high voltage discharge
- **Hazardous voltage**. There are very few equipment components that operate between 24 V and 50 V. Therefore, you can treat any voltage greater than 24 V as a hazardous voltage. These voltages will require electrical safe work practices

Arc Flash

Arc flash is an intense electrical fault condition usually caused by:

- Malfunction of an electrical disconnect or circuit breaker
- Removal or replacement of an electrical panel cover
- Contact of conductive or grounded tools with electrical contacts
- Corrosion or environmental conditions affecting the equipment

An arc flash can:

- Produce intense light and heat
- Propel molten metal at high velocities over great distances
- Cause injuries such as severe burns; loss of limbs/hearing/sight/life
- Result in the vaporization of metal conductors and an accompanying pressure wave, called an arc blast

In semiconductor fabrication facilities, arc flash and arc blast can result from very high fault currents in electrical distribution panels or within the main power distribution panels of semiconductor equipment.

Warning Signs

Hazardous and high voltage warning signs and labels are good indicators of potential hazards. Typically, an electrical bolt symbol indicates voltage danger.

Recognizing and Avoiding Hazards

There are a number of environmental conditions that could increase the hazards of working on electrical systems.

- Wet conditions
- Dimly lit conditions
- Conductors close to electricity
- Cramped conditions
- Atmospheric conditions

Before working on electrical systems, visually inspect the work area for potential electrical hazards. Examine equipment and circuitry for conditions that pose hazards, such as cuts, frays, burns and stains; improperly taped or spliced wiring; or damage to outer protective covers on equipment.

If frayed or damaged wiring or equipment is found, the equipment should be de-energized, locked out and placed out of service until the damaged components are replaced or repaired. Electricity cannot be seen, heard or smelled. NEVER assume exposed conductors are de-energized until 0 voltage has been confirmed by a qualified person using a properly rated meter!

Semiconductor Electrical Safety Part 2 – Developing a Risk-Based Approach to Electrical Safety

Employers' Obligation to Provide a Safe Work Environment

Regulations require that employers implement safety-related work practices to prevent electrical shock or other injuries resulting from electrical contact. *NFPA 70E®: Standard for Electrical Safety in the Workplace®* is a tool that all employers can use to meet this obligation.

NFPA 70E®:

- Guides the employer in identifying electrical hazards and assessing risk in the facility
- Directs activity appropriate for mitigating risk and safeguarding those employees who are exposed to electrical hazards

NFPA 70E® Requirements

1. Identify a qualified person who has demonstrated skills and knowledge
2. Determine the hazard potential for arc-flash and electrical shock during job planning
3. Determine appropriate PPE for arc-flash and electrical shock hazards
4. Establish work boundaries and install barriers
5. Determine procedures for achieving and verifying a zero-energy state
6. Determine safe work procedures based on the risk associated with employee exposure to electrical hazards
    - Example: Assigning a dedicated observer to ensure the qualified person performs the work safely

Electrical Hazard Risk Assessment

Employers conduct an electrical hazard risk assessment to ensure a safe work environment. This information must be included in the assessment:

- Identification and analysis of electrical hazards
- Identification of electrical work tasks to be performed near hazards
- Documentation of hazards and potential hazards associated with each task
- Estimate of the risk of each task
- Identification of protective measures, which include:
    - Establishing electrically safe work conditions
    - Implementing safe work practices and procedures
    - Ensuring maintenance of electrical equipment and systems
    - Conducting employee training and qualification
    - Instituting an energized electrical work (EEW) permit process
    - Conducting job briefings
    - Providing shock and arc-flash PPE

Electrically Safe Work Conditions

The most effective method of risk control is elimination. Eliminating the electrical energy when working on energized conductors or circuit parts is referred to as de-energizing the circuit.

The steps required to establish an electrically safe working condition are:

- DE-ENERGIZE
- VERIFY disconnection
- IMPLEMENT hazardous energy control (lockout/tagout)
    - The shock and arc-flash hazard assessments must be completed **before** starting electrical lockout/tagout to establish the appropriate approach limits and determine the required shock and arc-rated PPE
- TEST for de-energization
- APPLY GROUND, if necessary

NFPA establishes minimum distances from which workers need to remain clear from exposed and energized circuits. If the worker breaches these minimum distances, the conductor circuit part must be put into an electrically safe work condition.

There are 4 exceptions to the requirement for placing electrical conductors or circuit parts into an electrically safe work condition. This is referred to as authorized energized work and it is only permitted when:

- De-energizing the electrical conductor or circuit part introduces additional hazards
- The task to be performed is infeasible in a de-energized state
- Energized electrical conductors and circuit parts operate at less than 50 volts with no increased exposure to electrical burns or arcs
- Operating electrical disconnect and other interrupting devices

Examples of work tasks that are permitted to be performed while energized include:

- Voltage measurements as part of diagnostics and testing
- Work on a hazardous-substance-control exhaust ventilation system
- Work on a toxic-gas monitoring system

Qualified Persons

It is your company's responsibility to designate, train and ensure the demonstrated competence of qualified persons. Qualified persons must be:

- Trained and knowledgeable in the construction and operation of equipment or a specific work method
- Trained to identify and avoid the electrical hazards that might be present with respect to that equipment or work method
- Familiar with the proper use of techniques, policies, PPE, materials and insulated equipment

Additionally, qualified persons need to be trained in:

- Skills and techniques necessary to distinguish exposed energized electrical conductors and circuit parts from other parts of electrical equipment
- Skills and techniques necessary to determine the nominal voltage of exposed energized electrical conductors and circuit parts
- Approach distances and the corresponding voltages to which the qualified person will be exposed
- Decision-making process necessary to:
    - Perform the job safety planning
    - Identify electrical hazards and assess the associated risks
    - Select the appropriate risk control methods

A qualified person for certain equipment may be an unqualified person for other equipment, or even for different tasks on the same piece of equipment.

Shock and Arc-Flash Risk Assessments

The type of information that is included in a shock risk assessment includes:

- Limited approach boundary distance
- PPE required
- Restricted approach boundary distance
- Training and safe work practices required
- Voltage exposure

The arc-flash risk assessment is conducted by 1 of 2 methods:

- PPE category method determines the arc-flash PPE category by using the arc-flash risk assessment table and criteria in *NFPA 70E®*
- Incident energy analysis method determines the arc-flash hazard through a review of the facility's electrical installation drawings and as-built conditions and application of established formulas to perform calculations

The shock and arc-flash risk assessments establish limits-of-approach boundaries (distances) from exposed energized electrical conductors or circuit parts. The boundaries are:

- **Arc-flash boundary**: distance from which persons could receive second-degree burns if an arc-flash were to occur
- **Limited approach boundary**: boundary that only qualified persons able to identify the hazards and associated risks with the tasks to be performed are allowed to cross
- **Restricted approach boundary**: boundary that only qualified persons with an authorized EEW permit are allowed to cross. They must use proper PPE, rated for the voltage and incident energy level involved, and insulated tools and equipment in this area

Semiconductor Electrical Safety Part 3 – Implementing Electrical Safety

Shock and Arc-Flash Risk Assessments

The safety of fabrication facility workers is of primary importance to the semiconductor industry, as illustrated by the industry's safety record. Many of the electrical safety measures implemented are a result of the risk assessments that are conducted.

Shock Risk Assessment

The assessment is conducted in accordance with the shock protection table and the approach boundary requirements established in *NFPA 70E*®. The Approach Boundaries table illustrates that you are exposed to shock hazards even if you aren't touching high voltage structures. It contains this information:

- **Voltage**: operating voltage of equipment
- **Limited approach boundary**: divided in 2 sections
    - **Exposed movable conductor**: pertains to work on outside power lines and is not applicable to work inside the fabrication facility
    - **Exposed fixed circuit part**: a barrier should be set up at this location and all personnel not working on the task should be kept beyond it
- **Restricted approach boundary**: The entire area within the restricted approach boundary is considered to be as hazardous as direct contact with exposed conductor. Only qualified persons wearing PPE should approach closer than 1 ft (0.3 m)

Arc-Flash Risk Assessment

There are 2 basic ways to conduct an arc-flash risk assessment: by PPE category or incident energy analysis.

PPE Category Method

- Determines the arc-flash PPE category
- Uses *NFPA 70E*® arc-flash risk assessment table and criteria
    - Arc-Flash Hazard Identification table indicates if an arc-flash hazard exists. It lists the task, equipment condition and arc-flash PPE required
    - Arc-Flash Hazard PPE Categories tables for AC or DC indicates the arc-flash PPE category. It lists equipment, arc-flash PPE category and arc-flash boundary
    - Personal Protective Equipment table indicates if arc-flash PPE is required for the task. It lists PPE category and types of PPE
- The appropriate level of PPE required for the work task is determined when the PPE category method is used. The arc-flash hazard label lists that category

Incident Energy Analysis Method

- Applies established formulas to perform calculations
- Determines the available incident energy (cal/cm^2), arc-rated PPE necessary and arc-flash boundary distance
- Requires that the entire electrical system be analyzed: from incoming source of power to the ultimate location of the work
- Includes review of site-specific information about the facility's electrical system, such as the installation drawings
- Results are used to provide labels that are placed on electrical equipment. Different label formats may be used, but all labels must include:
    - Nominal system voltage
    - Arc-flash boundary: distance at which an unprotected person could receive second degree burns. Barrier must be at least this distance from the work and all unprotected personnel, including unprotected qualified persons
    - Available incident energy and corresponding working distance: the level of energy that could be released at arms' length from the exposed conductor, or to the chest and face of a worker who inadvertently causes a fault
    - Minimum arc rating of clothing
    - Site-specific level of PPE

Lockout/Tagout Process

The basic steps of the process are:

1) Preparation for shutdown
    - Review the tool's normal shutdown procedures and then locate and identify all isolating devices
    - Gather written maintenance procedures, required tools, and appropriate locks and tags
    - Review the written lockout/tagout procedure
2) Notification: notify all affected employees prior to beginning work
3) Equipment shutdown: shut the machine or equipment down using the normal operating controls and procedures
4) Isolation and dissipation of hazardous energies
    - Use proper precautions to operate the energy isolating device and isolate the energy source
    - Dissipate or restrain any hazardous stored energy remaining in the equipment
5) Application of lockout and tagout devices: the authorized person working on the equipment will apply his or her personal lockout/tagout device to the energy isolating device
6) Verification of isolation: a qualified person, wearing appropriate PPE, will verify that the circuit elements and components to which employees will be exposed are de-energized. The test instrument should be verified operational immediately before and after this check
7) Performance of task: perform the service or maintenance

8) Release from lockout/tagout and restore to normal service
    - Visually verify the job is complete and remove tools, equipment and unused materials
    - Notify personnel affected to remain clear so you can perform necessary equipment and/or electrical supply checks
    - Notify affected employees that the tool is being returned to normal service and remove lockout/tagout devices

Energized Electrical Work (EEW) Permit

After implementing lockout/tagout, the EEW permit is completed. Regardless of the format of the EEW permit form used, it must contain at least these elements:

- A description of the circuit and equipment and their location
- Justification for why the work must be performed in an energized condition
- Results of the shock and arc-flash risk assessments
- Energized work approval signature or signatures from the authorizing or responsible manager, safety officer or owner, for example
- Means employed to restrict the access of unqualified persons from the area
    - Typically done using barricades and safety signs
        - Barricades can be no closer than the limited approach boundary
        - If the arc-flash boundary distance is greater than the limited approach boundary, the barricades must be placed at the arc-flash boundary
    - If signs and barricades do not provide sufficient warning, an attendant must be stationed to keep unqualified employees outside the boundary
- A description of the safe work practices to be employed
- Evidence of completion of a job briefing. Before work on a task begins, employees must be briefed about:
    - Any job-specific hazards
    - Work procedures involved
    - Special precautions needed
    - Energy source controls
    - PPE requirements
    - Other relevant information from the EEW permit

Semiconductor Electrical Safety Part 4 – Electrical Safety Program Components

Electrical Safety Program Components

The assessment and work practices need to be integrated within an overall employer electrical safety program.

The program directs activity appropriate to the risk associated with electrical hazards and must include these elements:

- Safety-related work practices
- Maintenance of electrical equipment
- Awareness and self-discipline
- Risk assessment procedure
- Electrical safety program principles, controls and procedures
- Job briefing requirement

Electrical Safe Work Practices

Electrical hazards result from electrical conductors or circuit parts that are or can become energized.

Some of the practices used to prevent injury from those hazards include:

- Job planning
- Shock protection and arc-rated PPE
- Control of stored electrical energy
- Proper positioning while opening disconnects
- Use of appropriate tools and ladders

Remember, the specific safe work practice must be consistent with the electrical hazards and the associated risk as determined by the shock risk and arc-flash risk assessments.

Job Planning

Before beginning any work task involving electrical hazards:

- Think it through
- Review documentation
- Obtain required permits
- Conduct a job briefing
- Inspect the work area
- Anticipate problems
- Only perform work for which you are qualified

In preparing to perform electrical work:

- Perform hazard assessments
- Establish boundaries and boundary controls
- Select PPE based on the assessments

Shock Protection and Arc-Rated PPE

Shock Protection PPE – A circuit is always considered energized until verified as de-energized. When exposed to an electrical shock hazard of less than 500 V, you should wear:

- Insulating gloves – Class 00 electrical insulating gloves must first be used within 1 year of manufacturing, and then for not longer than 6 months. Ensure the gloves have no punctures, abrasions or degradation of the rubber
- Hard hat – non-conductive
- Safety glasses – durable, non-conductive, heat-resistant and provide deflection qualities

Arc-Rated PPE – Selection of the PPE varies by the arc-flash risk assessment method used:

- When the PPE categories method is used, refer to the *NFPA 70E*® Personal Protective Equipment table
- When the incident energy analysis method is used, the *NFPA 70E*® Table H.3(a) applies. It lists:
    - Incident energy exposures and PPE required for that exposure
    - References to sections of *NFPA 70E*® that support the requirement

Positioning While Opening Disconnects

An arc-flash can occur while someone is opening or closing electrical disconnects, particularly if they are not well maintained or under load. Three actions can minimize exposure to an arc event:

- Inspect the disconnect
- Stand to the hinged side of the door or cover
- Wear appropriate PPE

Using Tools and Ladders

Insulated Hand Tools

– Have 2 layers of insulation of different colors: (1) the inner insulating layer and (2) the outer "wear" surface.

– Do NOT use tools with damaged insulation or attempt to make repairs with electrical tape

Power Tools

– Should be grounded (with a third prong) or double insulated

– Double-insulated tools have an outer insulated case and an inner insulated shell to protect workers from electrical shock in the event of a ground fault

Power Tool Inspection
- Check cases (insulated tools) and power cord/prongs (grounded tools)
- Tag damaged tools for repair or replacement
- Discontinue use immediately and tag as defective if you receive a shock/tingle

Ladders
- Must be made of non-conductive materials
- Semiconductor fabrication facilities often require only fiberglass ladders with rubber feet and end caps
- Metal ladders are never allowed

Control of Stored Electrical Energy

- **UPSs (uninterruptible power supplies)** are battery backup systems used to provide a continuous source of electricity to equipment, even during power loss. This allows the wafer(s) currently being processed to be completed and removed safely from the equipment
    - The UPS may provide a second power feed to the equipment that must also be isolated prior to performing work on electrical systems. Simply opening the main disconnect to a panel may not de-energize that panel or any equipment it feeds
- **Capacitors** are energy storage devices that remain charged even when the power is off. Energy is stored on 2 parallel plates that are insulated from each other. Capacitors may not be fully discharged unless a shorting jumper or bleeder circuit is in place
    - Ensure the structure is properly grounded to drain the capacitive discharge. Verify zero energy of drained capacitors using all appropriate PPE and tools
- **Inductors** are devices that store energy in a magnetic and electric field that can cause current to flow after the source of power is turned off. Common uses include electromagnets, motors, fluorescent lamp ballasts and relay coils
    - Follow the manufacturer's instructions for the methods to ensure the inductor is brought to and remains in a zero energy state throughout the duration of the work

Electrical Safety Responsibilities and Training Requirements

Training about company-specific electrical safe work practices and procedures is required for any employee who may be exposed to an electrical hazard. Retraining must be conducted at least every 3 years, or whenever:
- Non-compliance is indicated by the annual audit or employee's supervisor
- There is a change in safe work practices
- Safe work practices that are not normally used are employed

The host and contractor employers must agree on coordination of work responsibilities and methods prior to beginning any work. Other electrical safety responsibilities for these roles include:
- Host employer – must inform contract employees of site-specific hazards related to their work and provide information about the electrical installation needed by the contract employer in making electrical hazard risk assessments
- Contract employer – responsible for advising the host employer of any unique hazard presented by the contract employer's work and hazards identified during the course of work by the contract employer that were not communicated by the host employer

Responding during an Electrical Emergency

All sites where energized electrical work (EEW) is performed should have:

- Personnel trained in first aid and CPR available onsite
- Maximum 4-minute response time from trained personnel (a U.S. OSHA requirement)

It is preferable that these sites also have automated external defibrillators, or AEDs, and personnel trained in their use available.

Rescue

Signs that are indicative of electric shock include:

- Charred skin
- Deep reddening of the tissue
- Muscle paralysis
- No breathing or heartbeat/pulse
- Unconsciousness

Someone who has experienced an electric shock may have entry and exit wounds. The area of the wound may be small – entry wounds may be less than 5 mm while exit wounds may be 25 mm or larger. Common locations of wounds include hands, feet, elbows, knees and shoulders.

Employees exposed to shock hazards must be trained to safely release victims from contact with exposed energized electrical conductors or circuit parts.

- Don't rush in to help someone until you know the area is safe!
- Don't attempt the rescue if the power can't be turned off or the electrical current can’t be interrupted safely
- Do use a non-conductive device – such as a piece of wood, broom handle, or dry rope or clothing – to separate the victim from the current
- If it is safe to do so, turn off the power using an Emergency Off (EMO) button
- From a safe distance, check for a medical emergency or electrical or chemical hazards
- Immediately report the situation, following your company's emergency reporting procedures
- Keep others out of the hazard area

Fire

Never to attempt to extinguish an electrical fire unless you are trained and expected by your company to do so.

- Using fire extinguishers rated for electrical fires is the preferred method
- An alternative method is to remotely turn off the power and use a fire extinguisher rated for general combustible materials
- Never use water to extinguish an electrical fire

Semiconductor Hazardous Energy Control Part 1

Serious physical harm or death may occur if hazardous energy is not properly controlled. To ensure protection from harm, personnel working on or near serviced equipment must understand the different types and magnitudes of hazardous energies found in semiconductor fabrication facilities.

Hazardous Energies

The potential to cause injury is directly related to the magnitude of the energy. If an energy source has the potential to cause injury or death (for electricity, equal to or greater than 50 V), then it is considered hazardous energy that must be controlled.

During normal production operations, hazardous energy is controlled through equipment design and preventing access to the energy by enclosures, guards and interlocks.

Types of Hazardous Energy Found in Semiconductor Fabrication Facilities

Electrical
- Electrical energy powers equipment
- Unexpected movement of equipment can cause damage or injury
- Electrical energy can directly cause harm through shocks, arc-flash and fires

Chemical
- Chemical energy may be reactive, explosive, toxic, corrosive or flammable
- Chemicals may be solids, liquids or gases and may be in the form of raw materials, by-products or waste

Mechanical
- Moving mechanical parts can be hazardous, especially when cutting, crushing, trapping or snagging occurs

Pneumatic
- Pneumatic energy drives air tools and open pistons and valves

Hydraulic
- Hydraulic energy controls circulation of pressurized fluid to power pistons and other devices

Thermal
- Energy found in the form of very hot or very cold temperatures

Radiation

- Ionizing radiation, which may break chemical bonds:
  - X-ray
  - Radioisotopes
- Non-ionizing radiation, which may cause vibrations but not break bonds:
  - Ultraviolet, infrared and laser lights
- Microwave radiation

Stored

- Electrical energy stored in batteries, uninterruptable power supplies (UPS), capacitors, high voltage structures and inductors
- Chemical energy is stored until removed from the system
- Mechanical energy is stored by springs and in hinged loads and counter-weights
- Pneumatic and hydraulic systems store energy in their piping until pressure is released
- Thermal energy must be allowed to cool or warm until safe to handle

Lockout/Tagout Program

A lockout/tagout program helps prevent personnel from being injured or killed by the unexpected energization of equipment. Each person is 100% responsible for their **own** safety.

What Is Lockout/Tagout?

- A process to shut down devices, isolate energy, and attach a lock and tag to safeguard maintenance or service personnel who are working on a piece of equipment
- Prevents the opening of isolation devices and unexpected return of hazardous energy
- Tagout involves the use of prominent warning tags to alert others to not operate equipment, and to identify who is performing maintenance on the equipment
- Tag warnings such as “DO NOT ENERGIZE” and “DO NOT REMOVE” must be understood by all employees

When to Use Lockout/Tagout

- Whenever a guard or other safety device is removed
- Any time you are required to place any body part into an area where, if energy were to be unexpectedly returned, you would be injured (such as a “hazard zone”)
- During any service or maintenance where there is a risk of hazardous energy exposure

When Not to Use Lockout/Tagout

- The tool or equipment is on and used as intended (in normal production operation)
- Employees are performing minor adjustments, and are well-protected by machine guards

Removing Lockout/Tagout Devices

- Lockout/tagout devices must only be removed by their owner
- If, under special circumstances, a device is removed by a person other than its owner, the owner must be notified immediately
- Destroying or disregarding lockout/tagout devices will result in disciplinary actions that could include termination of employment

Employer Responsibilities

An employer's hazardous energy control program must define the purpose, authorization, rules and techniques used for the control of hazardous energy and the means to enforce compliance. Employers should:

- Clearly document procedures for each piece of equipment
- Perform periodic inspections to ensure equipment procedures are accurate
- Describe and implement employee training
- Evaluate and document that each employee uses correct procedures
- Identify a retraining process

Training and Retraining

- Ensure all employees understand the purpose and function of lockout/tagout procedures and can follow the steps safely
- Employers must retrain authorized and affected employees whenever there is a change:
    - In job assignments
    - In machines or equipment that presents a new hazard
    - In the energy control procedures

Inspections

- An authorized employee may inspect another employee's work to identify and correct deviations or inadequacies
- Inspection records must be documented and must identify the date of the inspection, the equipment and employees involved, and the person performing the inspection

Employee Responsibilities

- Everyone should follow lockout/tagout procedures
    - Violations can cause serious injury
- Only the person who applied a lockout/tagout device should remove it. Check your company policy for more information

Three Types of Employee Designations under Lockout/Tagout:

Authorized
- Fully trained employees who may perform maintenance on tools or equipment
- Are the only employees who may attach a lockout/tagout device on equipment

Affected
- Employees who use the tools or equipment being serviced, or who perform other job responsibilities in an area where such servicing is performed
- Must never remove a lockout/ tagout device
- Must never disturb or startle anyone working with hazardous energy

Other
- Employees who work around the equipment and who need to understand and respect lockout/tagout devices

Lockout/Tagout Devices

All lockout/tagout devices must be provided by your employer and used only for controlling energy. The devices must be:

- Durable
- Standardized
- Substantial

Tags are essentially warning devices. They do not provide a physical means of preventing activation of the energy isolation device. They are rarely used without locks.

Semiconductor Hazardous Energy Control Part 2

Energy Isolation

One method for controlling energy is energy isolation. The best practice is to entirely disconnect the equipment from the energy source by:

- Placing a disconnect switch or breaker in the off position
- Unplugging the equipment
- Closing the supply valve and purging a chemical line
- Closing the supply valve and bleeding a pressure line

Devices

Energy isolating devices are used to de-energize or isolate the energy source. They do so by physically blocking the energy path and guarding against accidental start-up or unexpected re-energization of tools and equipment.

- **Energy isolating**: Mechanical devices that physically prevent the transmission or release of energy include circuit breakers, disconnect switches and line valves, which can be manually shut off and locked. Physical blocks can also be used to stop the flow of energy at the source
- **Not energy isolating**: Push buttons and selector switches and other control circuit type devices do not cut off energy at the source and cannot be locked. Therefore, they are not permissible for use as energy isolating devices

Lockout/Tagout (LOTO)

After isolating the energy source, the next step in hazardous energy control is to lock and tag out equipment in the isolated position. However, not all energy isolating devices can be locked out.

- **Devices that can be locked out** are designed with a hasp-locking or other attachment to which a lock can be affixed. Alternatively, they may have a built-in locking mechanism or can be locked without dismantling, rebuilding or replacing the device or permanently altering its energy control capability
- Some energy isolating devices **cannot be locked out** due to the physical design or configuration of the equipment. In such cases, tagout may be used. However, adapters are often available. Lockout is always the preferred method

Lockout is the physical placement of a lockout device on or over an energy isolating device. A lockout device uses a positive means to hold an energy isolating device in a safe position, which prevents re-energization.It is preferable that these devices are integrated into equipment components such as switches, circuit breakers and ball valves.
Following are some examples of lockout devices and the steps you should take to use them.

Electrical Disconnect Switch
- Pull down the lever to turn off downstream power
- Apply a padlock and identifying tag to lock it out
- This prevents someone from reopening the lock while it is being maintained and identifies you as the person performing the LOTO procedure

Chemical Valve
- Turn off the chemical valve to stop any chemical flow
- Lock the valve by directly applying a lock and tag or by using a lockout adapter

Pneumatic or Hydraulic Valve
- Turn off the valve to turn off any flow of air or fluid
- Lock the valve by directly applying a lock and tag or by using a lockout adapter
- You may also need to bleed the line to release stored energy. Some designs allow for the automatic bleed of pressure

Wall Outlet
- Unplug a cord-connected device to lock it out
- This is acceptable as long as the plug remains in your control while the equipment is being maintained. If not, the plug needs to be locked and tagged out using a lockable cover

If lockout and tagout devices are not available, LOTO adapters that attach to the equipment and can accept a lock and tag may be used. Adapters include covers for switches, circuit breakers and ball valves as well as blank flanges and bolted slip blinds.

Always follow established procedures for the piece of equipment that is being serviced. Always ensure there is a physical disconnection or mechanical block in the energy path.

SEMI S2

SEMI S2 (*Environmental, Health, and Safety Guideline for Semiconductor Manufacturing Equipment*) is not a government regulation, but provides guidance related to worker protection.

Safety Interlock Systems

Equipment should be designed with interlocks to protect personnel, facilities and the community from hazards inherent in the operation of the tool. While it may be tempting to rely on interlocks to protect you, remember that they DO NOT meet the requirements under hazardous energy control standards.

Interlocks:

- Should be fault-tolerant and fail-safe. When activated, they should bring the tool to a safe state and notify the operator
- Often rely on control circuits to place a tool in a safe state, even if the interlock is 100% electro-mechanical
- Should be designed to minimize the need to override or bypass them during maintenance activities. In certain situations, bypass of interlocks is allowed provided a tool is required to complete the bypass and the interlock is automatically restored when the task is completed
- Are intended to protect equipment operators from being exposed to hazardous energies during operation
- Can be bypassed to allow for troubleshooting
- DO NOT isolate the source of hazardous energy and DO NOT ensure that the equipment cannot be re-energized without your knowledge

Hazardous Energy Isolation

Lockable hazardous energy isolation points should be provided wherever exposure to hazardous energy may occur.

Equipment that contains stored energy should include provisions to isolate the energy source and remove the stored energy prior to maintenance or service work. Equipment manuals should identify the hazardous energies in the tool and provide specific instructions on properly preparing for and performing LOTO of the tool.

Where maintenance and service tasks are performed on subassemblies of equipment, provisions may be made to isolate all hazardous energies to the subassembly through the use of specific devices.

- **Energy isolation devices**: Energy isolation devices include lockable circuit breakers, disconnect switches and manual valves. Energy isolation devices should be in a readily accessible location and capable of being locked out only in the de-energized position
- **Full equipment LOTO**: In some cases, full LOTO for all hazardous energies in the equipment is required. The entire tool must be locked out and tagged out for maintenance
- **Full LOTO exception (subassembly LOTO)**: In other cases, only the hazardous energies accessible within a particular subassembly could result in a hazard to maintenance personnel. In these instances, it is not necessary to lock out and tag out the entire tool. It is permissible to lock out and tag out only the hazardous energies in the subassembly being maintained

Semiconductor Hazardous Energy Control Part 3

LOTO Procedural Steps

To protect against accidents and potential injury, LOTO procedures must be performed:

- By authorizing employees
- In a specific order

Step 1: Prepare

- **Read the procedure**. The specific piece of equipment you are working on has a written HEC (LOTO) procedure. All of the information you need to know is required to be contained in the procedure
- **Know Your Equipment**. In preparing to perform maintenance, you should know several facts about your equipment's energy:
    - **Type** of energy, such as electrical, and the **magnitude** of the energy – voltage and amperage, for example
    - **Hazards** of the energy to be controlled, such as electrical shock
    - Possibility of any **stored energy**
    - **Method of controlling the energy**, such as placing the lock and tag on the handle of the electrical disconnect

Step 2: Notify Affected Employees

Notify all affected employees that the equipment is going to be shut down and locked and tagged out. Affected employees are all those working in the service area and include all machine operators and other employees, such as supervisors.

Step 3: Shut Down Equipment

Follow the written HEC shutdown procedure for your specific equipment. This will avoid any additional or increased hazards to employees.

Step 4: Isolate Energy Source

Many pieces of equipment have more than one source of energy, For example, work on an ion implanter source requires controlling electrical AND pneumatic energy sources. Be sure to isolate **all** of the energy sources. Locate and enable all energy-isolation devices for those sources.

Step 5: Apply LOTO

All authorized employees must place their own LOTO devices on each energy-isolating device:

- Lockout – must be placed so that they can hold the energy-isolating devices in a safe or off position
- Tagout – must indicate that the operation or movement of the device from the safe or off position is prohibited

Step 6: Control Stored Energy

After the energy-isolating device has been locked or tagged out, any stored or residual energy must be relieved, disconnected, restrained or otherwise rendered safe.

Electrical
- Discharge capacitors that may have stored charges
- Discharge any hazardous static electricity that may have accumulated

Pressure
- Relieve trapped pressure and/or vent vacuum
- Bleed lines and leave vent valves open
- Support parts in hydraulic and pneumatic systems that could move from loss of pressure

Springs and Parts
- Release tension on springs or block movement of spring-driven parts
- For moving parts, inspect the system to make sure all parts have stopped moving
- Support suspended parts that could fall because of gravity

Chemicals
- Drain process pipes and close valves
- Purge process chambers and lines
- Hazardous chemical piping should be double-blocked: 2 valves closed between the chemical source and point of maintenance
- If the line must be blocked with no valve, use a blanking flange

Thermal
- Dissipate extreme cold or heat, or wear thermal protective equipment

Re-Accumulation
- If stored energy can re-accumulate, monitor it to be sure it stays below hazardous levels

- **Exception**. In some cases, the sequencing of the energy isolation may be important. The stored energy must be released before shutdown of the equipment (Step 3). For

example, gas lines may need to be pumped and purged using the equipment's control system prior to shutdown

Step 7: Attempt to Power Up Equipment

- **Basic**. The purpose of this step is to verify the effectiveness of the lockout by confirming zero energy. First, ensure that all employees are out of the hazard zone. Then, try to restart the equipment using its normal startup routine or program
- **Advanced**. For work on electrical conductors, additional training is required to become an electrically qualified person. Electrically qualified persons verify zero energy by testing exposed circuits with an electrical meter, not by operating machine controls

Step 8: Perform Maintenance

After the previous 7 steps are completed, you should perform maintenance using the procedures provided by the equipment manufacturer.

Post-Maintenance Procedures

After the maintenance procedure has been completed, there are several other procedures to perform before returning the equipment to service:

- **Inspect** the work area to ensure that all tools, spare parts and maintenance supplies have been removed and that all machine or equipment components are operationally intact. Ensure that all safety controls, such as interlocks, valves, guards and covers, have been reset
- **Remove devices**. The employee who applied the device must remove each LOTO device from the energy-isolating device
- **Notify** all affected employees that the lockout or tagout devices have been removed
- **Return to service**. Now that the equipment is safe to use, it can be returned to service. Use the equipment manufacturer's written startup procedure to safely restart the equipment

Group LOTO

While it is preferable that all authorized employees have their own lock and/or tag on the energy-isolation device, it's not always possible. In situations when individual LOTO is not possible, group LOTO can be used.

Requirements

Each company must develop and implement its own group LOTO procedures. Check with your supervisor to determine the procedures for your location.

General requirements include using multiple lockout devices that can be ganged or daisy-chained. Additionally, all authorized employees must place their personal LOTO device on the group lockout device or lockbox before work begins.

The primary responsibility for all employees working under group LOTO must be vested in a single authorized employee. This employee may be a supervisor or a designated individual of a work crew.

Special attention must be paid to group LOTO in the situations that involve certain circumstances.

Absent Employee
- In cases where maintenance has been completed and an employee has left the building with their locks and tags still in place, each company must have specific procedures for removal of the lock and tag

Outside Personnel/Contractors
- If contractors or other outside personnel are working with you, proper coordination of LOTO procedures must occur
- Everyone must understand and comply with all restrictions and/or prohibitions of one another's energy control program

Equipment Testing/Positioning
- You may need to temporarily restore energy to equipment or machinery during service and maintenance to test or reposition a piece of equipment
- LOTO devices may be removed temporarily to perform these tasks
- Ensure that all employees are out of the hazard zone before each test
- After the tasks are completed, the equipment should be returned to its fully locked-out state

Shift or Personnel Changes
- If maintenance activity will take longer than one shift, communication between shifts is important to ensure an orderly transfer of LOTO device protection and continuity of worker protection
- Incoming employees should always verify de-energization and then put their locks and tags on the energy-isolating device before outgoing employees remove theirs

Walking/Working Surfaces

Slips and falls on walking and working surfaces are a major source of workplace accidents. Elevated platforms, runways, ladder rungs, stairs, steps, scaffolds and outdoor areas are commonly overlooked walking and working surfaces. Wear shoes with soles suitable to working conditions.

Housekeeping

Housekeeping is an important factor in all work environments and plays a vital role in maintaining a safe workplace. Keeping walking and working surfaces tidy can prevent people from slipping, tripping or falling due to clutter or slick surfaces.

Walkways and Floors

Keep aisles clear and in good repair. Aisles should be sufficiently wide where mechanical handling equipment is used. Use covers or guardrails to protect personnel from the hazards of:

- Open pits
- Tanks
- Vats
- Ditches

Floor Loading Protection

Do not place a load on the floor or roof of a building or other structure if the load is heavier than the load rating limit. Check with your supervisor if you are concerned about heavy loads that you need to place in or carry through an area.

Ladders and Steps

Portable Ladders

Maintain ladders in good condition. Inspect ladders frequently and before each use, and withdraw them from service if they have defects.

- Tag or mark defective ladders as “Dangerous, Do Not Use”

Place ladders on level, solid ground unless you secure or stabilize them to prevent accidental displacement. Secure any ladder that must be placed on a slippery surface. If you use a ladder to access a roof or other area, make sure it extends at least 3 feet (0.9 meter) above the point of support.

When climbing or descending a ladder:

- Face the ladder
- Keep both hands on the ladder
- Do not carry objects that can interfere with your ability to grasp the ladder
- Remember that the top of a regular stepladder is not safe for standing

Fixed Ladders

It’s common to find cages and wells on tall ladders, but these protections are often ineffective at stopping falls. Newer ladders have systems that stop or prevent falls. A ladder safety device is any device, other than a cage or well, designed to eliminate or reduce accidental falls and

may incorporate such features as friction brakes and sliding attachments. Landing platforms provide a means of interrupting a free fall and serve as a resting place during long climbs.

Step Bolts and Manhole Steps

- Step bolts and manhole steps must be uniformly spaced and in good condition
- Do not exceed the maximum intended load
- Inspect each step visually before use; report any issues, such as a bent or missing step, or if you slip or lose your grip

Stairs and Steps

Standard stairs provide access from one walking-working surface to another when operations necessitate regular and routine travel between levels, including access to operating platforms for equipment. When using stairs and steps:

- Keep a clear view of your footing
- Make sure you have good lighting so you can easily see the next step
- Keep a hand free to grab the stair railing if you lose your footing
- Don't carry anything that keeps you from seeing the next steps
- Know that wet or slippery shoes are as dangerous as a wet or slippery surface

Scaffolds

- Follow the specific safety guidelines for the type of scaffold you use
- The footing or anchorage for scaffolds or planks must be sound, rigid and capable of carrying the maximum intended load without settling or displacement
- Maintain scaffolds in a safe condition; do not use damaged or weakened scaffolds
- Do not alter or move scaffolds while they are in use or occupied
- Install guardrails, midrails and toeboards on all open sides and ends of platforms more than 10 feet (3 meters) above the ground or floor; install wire mesh between the toeboard and the guardrail along the entire opening where persons are required to work or pass under the scaffolds

Dock boards and Ramps

- Secure loading ramps and dock boards (bridge plates) to prevent slipping
- Newer dock boards have raised edges on the sides to prevent accidental runoff
- Use handholds on portable dock boards to permit safe handling when the dock board must be repositioned or relocated

Falls and Falling Objects

Open-sided work platforms and surfaces present a risk of falls to lower levels or falls onto or into dangerous equipment. Prevent or stop falls with:

- Guardrails
- Work positioning
- Restraint systems
- Safety nets
- Personal fall arrest systems

Preventing Slips, Trips and Falls Awareness

Slips, trips and falls can cause everything from painful bumps or bruises to broken bones, concussions or even death! Everyone in your workplace must take responsibility for slip, trip and fall safety. Before using a ladder at work for the first time, you much receive ladder safety training.

Definitions

- **Slip**: a loss of balance caused by too little friction between a person's foot/feet and his/her walking surface
- **Trip**: a loss of balance caused by the interruption of the movement of a person's foot by an obstacle
- **Same-level fall**: a slip and fall, trip and fall, or a step and fall
- **Elevated fall**: a fall from any distance, such as from a ladder, down stairs, off equipment, or from docks, trees, roofs or other height

Same-level falls have a higher frequency, but are associated with lower damage. Elevated falls have a lower frequency, but are associated with higher damage.

Causes

Slip and fall injuries can be caused by a combination of slippery surfaces and the wrong footwear. Other causes include:

- Poor housekeeping
    - Items in aisles or on steps
    - Spilled liquids, puddles or water tracked in from outside
    - Poorly secured or anchored floor mats
- Inadequate lighting
    - Too dark
    - Glare
- Improper use of equipment
    - Ladders, scaffolds, vehicles, etc.
    - Makeshift ladders (climbing shelves, boxes or chairs)
- Bad habits
- Taking shortcuts

Solutions

There are simple steps you can take to make your work area a safer, more productive place:

- Keep work areas neat
- Keep work areas well-lit
- Use equipment correctly
- Develop good habits

Keep Work Areas Neat

- Eliminate clutter from aisles
- Keep floors clean, dry and uncluttered
- Use caution signs on wet floors
- Keep outdoor areas safe too
- Use secure, non-slip mats
- Eliminate protruding nails, splinters or loose boards
- Take care when using cords
- Block off or mark hazardous areas

Keep Work Areas Well-Lit

- Keep work areas, stairs and aisles well-lit
- Avoid wearing sunglasses indoors

Use Equipment Correctly

The improper use of equipment is a significant cause of slips, trips, and falls. Care is needed when using:

- Ladders
    - Use the right ladder for the job
    - Do not use makeshift ladders such as: shelves, boxes or chairs
    - If a ladder is required as part of your job, you must have ladder safety training
- Stairs
    - Look where you are going
    - Take one step at a time
    - Hold handrails
    - Keep steps clean, dry and uncluttered
- Loading docks
    - Use portable railings
    - Be aware of traffic patterns
    - Keep area as clear as possible
    - Stay alert

Shoes

- Slip and fall injuries are often caused by a combination of a slippery surface and the wrong footwear
- Check with your employer about the most suitable shoes to wear in your workplace

Fall Protection

A good precautionary measure is to use fall protection anytime you are working on an unprotected or elevated work surface from which you could fall. Good practices recommend using it whenever you are at least 4 to 6 feet above the ground.

Ask your manager or supervisor for guidance about using fall protection on your worksite.

Common Fall Hazards

Common fall hazards include:

- Floor holes
- Open-sided floors
- Roof edges
- Skylights
- Ladders
- Aerial lifts

Mistakes that may cause a fall include:

- Not respecting fall hazards
- Not paying attention
- Equipment/tool failure
- Slips
- Overreaching
- Complacency

Methods of Fall Protection

Consider using fall protection when:

- Guardrails are removed
- Guardrails/covers are not able to be installed
- You are working hands-free

Primary fall protection includes footing, balance, handholds, stable work surfaces, and positioning equipment.

Secondary fall protection is classified as active or passive:

- **Passive** systems include guardrails, covers and safety nets
- **Active** systems include:
  - **Work positioning**: Allows you to work hands-free
  - **Fall restraint**: Prevents you from falling off an edge or into an opening
  - **Fall arrest**: Catches your body after you have fallen

When planning to use personal fall protection, consider free fall, clearance and swing fall:

- **Free fall** is the distance traveled from the point where you start falling to the point where your fall protection system begins to slow you down
- **Clearance** is the distance required for your personal fall arrest equipment to activate, decelerate and then completely stop your fall
- **Swing fall** can occur when you walk away from under your anchor point. When you fall, you will swing back under your anchor point like a pendulum

Fall Protection Equipment

Personal fall protection includes the following components:

- **Body support** includes a full body harness
- **Connectors** may be lanyards, snap hooks or carabiners
- **Anchor points** are the points at which you attach your anchorage connector
  - Use anchor points that are as high as possible and located at least at D-ring level
  - Anchor to a structure that can handle 5,000-pound load or that a qualified person has identified for you
  - Make sure you have enough clearance so your fall protection system stops you before your body strikes an object below
- **Self-Retracting Lifelines (SRLs)** require much less clearance than a lanyard and allow more freedom of movement
- **Vertical** and **horizontal lifelines** are also used on some worksites

Inspecting and Maintaining Equipment

You should inspect fall protection equipment before every use

- Inspect body support more frequently when welding or working with chemicals or sharp edges
- Inspect connectors periodically throughout the day

A qualified person should also inspect equipment annually.

If equipment is ever involved in a fall, even if it does not show signs of damage, remove it from use and return it to your supervisor.

To keep your fall protection equipment working, you should:

- Store equipment properly
- Never throw it into a storage box
- Keep it dry and clean
- Keep it out of direct sunlight

Semiconductor Ergonomics for Maintenance and Service

You perform a variety of tasks in your semiconductor fabrication job, many of which have the potential to cause you pain and ergonomic injuries.

Injuries and Risk Factors

Musculoskeletal disorders (MSDs) are the most frequently occurring injuries, and strains and sprains are the most common MSD injuries, in the semiconductor industry.

- One cause of MSDs is using excessive **force** to move objects. Avoid injury by using proper techniques and mechanical assists.
- Working in awkward **postures** or the same posture for prolonged periods can create stress. To avoid injury, keep the body straight and strong in a neutral position.
- **Repetition** of motions can damage nerves and tendons. Varying the tasks you perform and taking short stretching breaks can reduce fatigue and strain on the body.
- **Static loading** occurs when you stay in the same position for too long. Varying your position and stretching every so often can help prevent injuries.
- **Contact stress**, or pressing body parts against hard or sharp objects (like a table edge), can harm blood flow, nerves, tendons and muscles. Using tools with specially designed handles and grips and wearing footwear with cushioned soles can help alleviate the stress.

Reporting Guidelines

Early reporting is critical so you can get early treatment, heal faster and correct the cause of the injury. Follow your employer's reporting guidelines as soon as you feel ANY symptoms.

Best Practices

Workstations

Depending on the tasks you perform, you may be required to sit or stand at your workstation, or you may be able to alternate between the two positions. There are adjustments you can make to be comfortable and prevent injury:

- Adjust the **chair** so that the backrest supports the small of your back, your feet are flat on the floor with your knees angled between 90 and 110 degrees, and your forearms are parallel with the floor and lightly touch the armrest when your shoulders are relaxed.
- If standing at a **command center**, align your legs, torso, neck and head vertically with your feet slightly separated. Position your forearms parallel to the floor and with a 90-degree angle at the elbow. If sitting, follow the best practices for chair adjustments. Also remember to change positions every 45 to 60 minutes.
- For a **mobile station**, adjust monitor height and angle so that the top line of the display is at or slightly below your working eye height to maintain neutral posture.
- For **input devices**, position the device close to you, position your elbows close to your body and forearms parallel to the floor, rest your arms at your sides between tasks, use a light touch or grip, and use a neutral wrist and finger position.

Manually Handling Materials

Good posture and techniques are critical to safe lifting. To avoid stressing your body by twisting or extending your reach, consider the object's weight, shape and size, and location. General ergonomic best practices include:

- Avoid making sudden movements
- Keep the object close to your body
- Lift with your legs
- Make sure the object is light enough to safely lift
- Make sure your path is clear

If you need assistance, you can have one other person help you. If the lift cannot be safely performed, a mechanical assist should be used. Using a cart allows you to optimize your posture and reduce some of the effort required to move materials.

Maintenance Tasks

- Only use the amount of **force** needed. Use good lifting techniques to minimize the force placed on your body. If the task is very repetitive and involves excessive force to complete, consider using power tools or a mechanical assist to reduce force.
- Consider your **posture**. Try to keep your work at elbow height and use step stools or platforms to avoid reaching overhead. Place all the items you use frequently within easy reach at your workstation.
- Minimize **repetitive** motions for safety and efficiency. Consider using power tools.
- To avoid **static loading**, change your posture frequently and avoid prolonged extended reaches. Alternate tasks, stretch and take rest breaks during your shift.
- Avoid **contact stress** by using padding when kneeling, leaning, or lying on hard or sharp surfaces. Alternate the hands and knees you use to support yourself.

Selecting Tools

For manual hand tools, the handle is the primary consideration when it comes to ergonomic risk. The length should extend beyond the palm to avoid contact stress. The diameter should enable your fingers and thumb to comfortably wrap around it and form a power grip. It should be padded to minimize pressure, prevent slipping and absorb vibration.

There are two types of hand tools to choose from: pistol grip and in-line grip. The choice depends on the location of the work and the work surface.

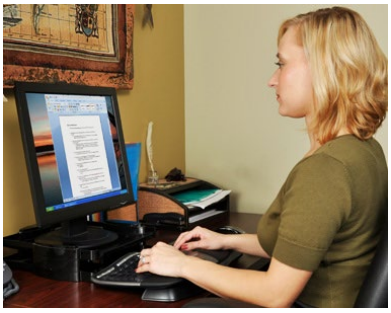
- Use a **pistol grip** for work: above the shoulder on a horizontal surface, between the shoulder and elbow on a vertical surface, or below the elbow on a horizontal surface.
- Use an **in-line grip** for tasks: above the shoulder on a vertical surface, between the shoulder and elbow on a horizontal surface, or below the elbow on a vertical surface.

Planning Considerations

it is important to develop a pre-task plan to ensure that ergonomic risks have been identified and appropriate controls are in place. Use these five questions as the basis of your plan:

- Are awkward postures required for extended periods of time?
- Are tools available to reduce forceful or repetitive hand motions?
- Can a task be performed without manually holding an object in place?
- If lifting or carrying is required, are the objects' weights known?
- Who is your site contact for ergonomic questions and concerns?

Office Ergonomics Awareness



Ergonomics is the science of designing the job to fit the worker, rather than physically forcing the worker's body to fit the job.

Adapting tasks, workstations, tools and equipment to fit the worker can help reduce physical stress on a worker's body. This, in turn, helps eliminate many potentially serious and disabling disorders, while promoting worker comfort and efficiency.

Ergonomic Risk Factors

There are a number of risk factors that can affect employee health, safety, comfort and efficiency. The greater the exposure to risk factors, the greater the risk potential.

Risk Factor - Repetition

Repetitive movements involve frequent use of the same joints and muscle groups in the same manner. Tasks associated with repetition are writing, typing and mouse use.

Risk Factor - Awkward Postures

An awkward posture occurs when you perform job tasks that force your body out of its natural (neutral) position. This applies to employees who perform both physical work and stationary activities.

- Examples of awkward postures include: Performing overhead work
- Bending and twisting the back or torso while lifting or moving heavy objects
- Bending the wrists during typing
- Squatting
- Cradling the phone against the shoulder

Risk Factor - Static Positions

A static position is a physical exertion in which you hold the same posture or position throughout the working task.

Other static positions include:

- Continuous gripping of computer input devices (mouse or trackball)
- Holding your arms out or up to perform tasks
- Standing in place or sitting improperly for prolonged periods
- Any other position that causes the body to be out of the neutral position for extended periods

Risk Factor - Contact Stress

Contact stress results from continuous contact or rubbing between hard or sharp objects/surfaces and sensitive body tissue. It creates localized pressure on that portion of the body, which can inhibit blood flow, nerve function or movement of tendons and muscles.

Examples of contact stress include:

- Your legs coming into contact with the edge of your chair
- Your wrists or forearms resting on the edge of your keyboard or desk
- Repetitive finger motion being performed with a bent wrist

Adjustments to Work Area Equipment

As you spend increasing time at your computer workstation, you need to be aware of how the design and arrangement of your equipment can impact your comfort, health and productivity.
By correctly adjusting and/or arranging key components, you can reduce your risk potential.

You can improve ergonomics in your work area by:

- Using a headset for lengthy or frequent telephone work
- Placing the items you use most frequently within your immediate work zone
- Removing items that clutter your work area
- Storing infrequently used items in file cabinets

Additionally, use these tips to avoid stress to the body and the discomfort that comes with it:

- **Chair**: Adjust your **chair** height and seat pan tilt so that you can sit comfortably with your knees bent around 90 degrees and your hips bent a little more than 90 degrees. Adjust your seat depth and backrest tension to support your back**.**
- **Monitor and lighting**: Position your monitor so that it sits directly in front of your keyboard, between 18 and 30 inches (46 and 76 cm) from your eyes, with the top of the screen at or below eye level. Keep the screen and glare filter clean, adjust brightness and contrast, position or close blinds to avoid glare, and place document holders at approximately the same height as the monitor.
- **Mouse, Trackball and Keyboard**: Place the mouse adjacent to the keyboard and at the same height to avoid extended reaching to the mouse. Test different models of input devices to determine your preference. Do not bend your wrist upward. Choose a different input device or consider a wrist or palm rest

Strategies for Reducing Ergonomic Risks

Working at a computer can be very fatiguing on your upper extremities as well as your eyes. Vary your work routine as much as possible.

- Use the 20/20/20 rule. Take a 20-second break, every 20 minutes, and look at least 20 feet (6 meters) away to help your eyes rest and recover
- Change positions periodically. Sitting in one position or leaning on your arms for an extended period of time can be uncomfortable and cause fatigue
- Stretch your muscles. Exercising your shoulders, wrists, hands and neck can reduce fatigue caused by static work

Hand, Wrist and Finger Safety

To prevent hand injuries, you need to be able to recognize hazards and know a few simple precautions.

Common Injuries and Causes

- **Wrist fractures:** Are most often caused by trying to break a fall with an outstretched hand. Fractures can also occur when the wrist is caught between objects

- **Hand and finger fractures:** Are generally caused by trapping or twisting the fingers suddenly. Accidentally hitting the finger with a heavy object like a hammer or pipe also can cause a finger fracture

- **Hand sprains:** Occur when the ligaments in the hand or wrist are stretched too far and tear. These injuries can be caused by handling heavy equipment without assistance

- **Fingertip injuries:** Fingertips are subject to many different types of injuries: the bones can be fractured, the fleshy part of the finger may be torn, or the fingernail may be damaged. Working with sharp-edged equipment increases the potential for these types of injuries

- **Lacerations:** Lacerations or cuts can cause severe bleeding and may also sever nerves, muscles or tendons. Lacerations can occur if you are not careful while handling sharp cutting tools, such as knives or saws

- **Nerve compression:** Results from a swelling of tissues that surround a nerve, causing a loss of feeling or sometimes a tingling sensation. Repetitive movements can cause the swelling of tissues

Identifying Potential Hazards

- **Mechanical hazards** shear, rotate, crush, puncture, etc.
- **Environmental hazards** include heat, sparks, cold, rough-edged materials, electricity, heavy objects, etc.
- **Contact hazards** can be chemicals, alkalis, acids, solvents, etc.
- **Poor housekeeping** increases your risk of injury and includes tools left out, substances not stored, a messy work area, etc.

Increase your awareness of the equipment, energy sources and simultaneous activities going on around you. Follow your organization’s procedures and job safety analyses (JSAs) without deviation.

More Potential Hazards

- **Jagged edges** require cut-resistant gloves to protect your hands from bruises, nicks and lacerations
- **Sharp and heavy tools/materials** can mean lacerations and severe cuts. Cut-resistant gloves work well here
- **Pinch points** are found where two metal objects come together, like when handling compressed gas cylinders or working around mesh gears, rollers and presses
- **Corrosive substances** can cause rashes, burns, chafed and chapped skin and chemical sensitivity. Rubber, vinyl or neoprene gloves provide protection
- **Bacteria** (especially during medical treatment): Disposable plastic gloves are effective
- **Tools and machines** can be especially dangerous because of moving parts
    - Make sure **machine guards** are in place where applicable
    - Make sure equipment is operating properly. Know your equipment!
    - Do not wear watches, jewelry, rings or loose clothing
    - Use good judgment and be prepared for anything

Identify "hidden" hazards that could lead to injuries:

- Repetition
- Strain from moving heavy equipment
- Pressure from hand tools
- Vibration from grinders, drills, jackhammers and other vibrating equipment

Avoid these four states of mind…

- Rushing
- Frustration
- Fatigue
- Complacency

…because they can cause critical errors like:

- Eyes not on task
- Mind not on task
- Line-of-fire
- Losing balance/traction/grip

Ergonomic Factors

Repetitive motion situations are common hazards on the job, placing stress on hands, fingers and wrists. Reduce the hazard by:

- Alternating different types of work
- Varying hand, wrist and finger movements
- Cutting down on unnecessary movement
- Keeping hands and wrists in a neutral position to help prevent fatigue
    - Keep them in a straight line as if you were shaking hands
- Avoiding positions that require you to flex or bend your wrist repeatedly
- Arranging your work environment to keep tools and materials within easy reach
- Stretching throughout the day to keep muscles loose and prevent muscle fatigue and ergonomic discomfort

Tool Use

- Be careful of handles that can pinch the hand and lead to compression injuries
    - Avoid using handles with sharp edges or grooves
    - Smooth or padded handles keep the wrist straight and are long enough to extend across the entire palm to avoid pinching nerves
- Tools that require a closed grip (e.g., hammers and files) should have a diameter no larger than 2 inches (5 centimeters) to distribute its weight across the entire palm
- With tools like wire-cutters and pliers, the handle spread should be no more than 4-5 inches (10-13 centimeters)
- Power tools should have trigger switches that allow you to use your middle finger or thumb (rather than your index finger)
- Avoid using tools that vibrate a lot because the rapid movement can lead to damaged circulation, pinched nerves and stressed tendons

Gloves

- Choose a glove that best protects against the hazards you expect (cut-resistant gloves may not be chemical-resistant, etc.)
- Gloves should be long enough to protect wrists and forearms
- Gloves must also fit properly:
    - Too large, they may get caught in moving parts
    - Too small, they will be uncomfortable and may wear out quickly
- Some machines can grab a glove and pull your hand into rotating parts
- Wash gloves regularly, or properly dispose of them, especially after contamination
    - Wash contaminated gloves separately from other items
- Inspect and test gloves for defects such as rips and tears. Exchange or repair them when damaged
- Store rubber and plastic gloves away from heat, sunlight and humidity
- Make sure gloves are kept soft and flexible

Preventing Back Injury

How the Back Works

- Spinal nerves carry motor, sensory and autonomic signals between the spinal cord and the body
- The spinal cord extends from the brain. It has three major functions:
    - Transporting motor information
    - Conducting sensory information
    - Coordinating certain reflexes
- The spine has interlocking bones called vertebrae
- Vertebrae are separated by discs, which act as cushions

Types of Injuries

Common injuries include:

- Strain and fatigue
- Fractured vertebrae
- Spinal cord nerve injury
- Pressure on nerves
- Tears in discs
- Disc fractures and ruptures

Risk Factors

Conditions that can increase the chance of an injury:

- Aging
- Poor physical fitness
- Physical stress
- Bad posture
- Poor diet
- Smoking

Aging

- Degeneration of the spine
- Inappropriate alignment
- Loss of strength

Physical Condition

- Strong muscles promote good physical condition, which reduces your risk of injury
- Weak muscles may cause discs to be susceptible to injury
- Strong stomach muscles will add extra support when handling objects
- Excess body weight puts extra strain on your back
- Excess body weight can cause damage because the back operates on a 10:1 ratio

Physical Stress

- Unwanted physical strain or pressure put on the body
- Stress may keep our muscles in a state of tension or contraction
    - Tension: muscles are in their stretched position
    - Contraction: shrinking or tightening of the muscles
    - Stressed muscles are more susceptible to strains, sprains and spasms

Bad Posture

Posture is the balance and alignment of your body.

- “S” or curved shape is the natural position of the spine
- Improper posture leads to musculoskeletal problems

Causes of Injuries

Identifying and understanding the following causes can be your best defense in preventing injury.

Overexertion

- Putting the body through extra strenuous effort
- Signs of overexertion include spasms and pain
- Don't ignore the physical limitations of the body

Improper Lifting

- Bending over
  - Using only your back muscles strains the back
- Unnatural body position, like reaching above shoulder height
  - Causes tension and overexertion
- Twisting
- Holding the object
- As the object moves farther from the body, the perceived weight of the object and necessary exertion increase

Poor Environmental Conditions

Environmental conditions are the physical surroundings and situations at your place of employment. Potential hazards include:

- Path of travel
  - Wet floors
  - Uneven surfaces
- Arrangement of workplace
  - Reaching above shoulders or below knees increases risk of injury

Prevention

The following can prevent a back injury from occurring.

Proper Lifting Techniques

1. Assess the situation: Is your path clear?
2. Test the weight of the object; if it’s too heavy, get help or use a mechanical device
3. Bend your knees
4. Get a good grip
5. Tighten the muscles in your arms, legs and abdomen
6. Look straight ahead
7. Hug the object
8. Turn with your feet; don’t twist at the waist

Proper Equipment

- Adjust your workplace to accommodate you
- Wear comfortable shoes with slip-resistant heels and soles
- Use mechanical aids when lifting heavy or bulky objects
- Get help from a co-worker

Personal Prevention Strategies

- Maintain good posture
  - Don’t slump, slouch or hunch over
- Outside work:
  - Exercise
- Sleeping:
  - Use a firm mattress with a pillow between or under your knees
  - Sleep on your side; avoid sleeping on your stomach
- Reduce stress
  - Take part in activities you enjoy
- Know the facts about back injuries
  - Injuries are cumulative
- Don’t ignore minor back pain

Strengthening the Back

- Exercises that stretch and strengthen the muscles of your spine can help prevent back problems
- If your back and abdominal muscles are strong, you can maintain good posture and keep your spine in its correct, most natural position
- Do exercises even if you’ve worked a long day

Injury Response

- Report the injury to your supervisor immediately
- Follow workplace policies regarding medical care and/or treatment
- Avoid devising your own treatment
- Follow medical advice about medications, treatment and physical activities