VINSE Cleanroom Safety Plan & Conduct of Operations

VANDERBILT INSTITUTE OF NANOSCALE SCIENCE AND ENGINEERING

VINSE

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DISCLOSURE STATEMENT
The VINSE cleanroom team is committed to providing a safe working environment for all users. The goal of this manual is to provide information and guidance to the certified users of the cleanroom on how to conduct their work in a safe manner. While this document attempts to cover all acceptable operating and safety policies of the cleanroom, it is impossible to define a policy for every conceivable situation. Users should bring any safety questions or concerns to the attention of cleanroom staff and use a common sense approach when working in the cleanroom. SAFETY IS EVERYONE'S RESPONSIBILITY! *The use of this document is for the Vanderbilt VINSE cleanroom users; any other uses are strictly prohibited without written consent. All Rights Reserved.*

Revision Table

REV	RELEASE DATE	REV BY	PAGES AFFECTED (DESCRIPTION)	ECO NO.
0.0	24-April-2017	KWH	Initial Release – ESB Startup	**N/A**
0.1	07-May-2020	WMM	Updated to include details on new tool safety requirements (PicoSun ALD), new training requirements, and new chemical storage locations (cabinets inside cleanroom)	
0.2	10-July-2022	SMR	Updated the VEHS/OCRS transition, onboarding steps, cleanroom age requirements	
0.3	XXX-2023	BWS	Updated OCRS to VU EHS transition, Section 3.5.5, Section 4.2.2	

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1. Introduction

1.1. Purpose

The Vanderbilt Institute for Nanoscale Science and Engineering (VINSE) cleanroom is a state-of-the-art research facility where trained and authorized users can perform a wide variety of nanofabrication activities under controlled environmental conditions - i.e. temperature, relative humidity and airborne particulate contamination. The cleanroom user community represents a diverse range of academic backgrounds and research experiences, ranging from students exploring the facility for the first time to nanofabrication professionals with expertise in semiconductor processes. Many of the processing activities performed inside the cleanroom involve the use of hazardous materials and/or equipment utilizing potentially dangerous energy sources – e.g. electrical, mechanical, thermal. The information in this manual provides an umbrella under which users can safely and effectively utilize cleanroom resources. It is the framework for all cleanroom-based activities.

1.2. Scope

This manual covers all operations inside the VINSE cleanroom located on the first floor (i.e. main floor) of the Vanderbilt University (VU) Engineering and Science Building (ESB). Activities in this facility will be performed in accordance with this manual and associated training requirements along with equipment and/or process specific procedures. Furthermore, this manual does not replace but shall be used in conjunction with the safety requirements and guidance provided by VU Environmental Health and Safety (VU EHS) documents and in the VU Chemical Hygiene Plan (CHP), which is the governing document for the University as a whole. Additional safety information can be found on the VU EHS website at https://www.vanderbilt.edu/ehs/ or by contacting VU EHS directly at ehs@vanderbilt.edu or 615-322-4551.

1.3. Enforcement

Failure to follow the policies in this manual can potentially cause damage to equipment or facilities and threaten the health and safety of anyone in the cleanroom or in the ESB under extreme circumstances. Depending on their nature, frequency and severity, violations of these policies may be referred directly to the **VINSE Director** for review and may result in loss of all cleanroom privileges up to and including permanent revocation of access and the possibility of repair costs being passed on to the user and/or the user's principal investigator (PI).

1.4. References

The following materials were used to create this document or are referenced in it:

1.4.1. Regulatory and Industry Codes, Standards & Guidance

DOCUMENT NUMBER	DOCUMENT TITLE
29 CFR 1910.1200	Hazard Communication
29 CFR 1910.1450	Occupational Exposure to Hazardous Chemicals in Laboratories
CGA G-13 Guide	Storage and Handling of Silane and Silane Mixtures
SEMI "S" and "F" Guidelines	Selected Safety and Facility Guidelines
NFPA 318	Standard for Protection of Semiconductor Fabrication Facilities

1.4.2. Vanderbilt University Environmental Health and Safety (VU EHS)

DOCUMENT NUMBER	DOCUMENT TITLE
None	**VU "Chemical Hygiene Plan," Rev. 1, dated 4/21/20**
None	**OCRS "Laboratory Guide for Managing Chemical Waste," Rev. 1, dated 2/22**
None	**OCRS "Managing Particularly Hazardous Substances (PHS) in Your Laboratory"**
None	**OCRS "General Work Practices for Laboratory Hoods," Rev. 0**
None	**OCRS "Managing Chemical Retention and Storage in Your Laboratory"**
None	**VU EHS "Chemical and Physical Safety for Research Labs"**

1.4.3. Other

DOCUMENT NUMBER	DOCUMENT TITLE
None.	N/A

1.5. Document Nomenclature

Throughout this manual along with other procedures and documents used in the VINSE cleanroom, various conventions have been adopted to specify how statements shall be applied by users. These conventions are as follows:

Numbered or lettered lists: perform ALL items in the ORDER SPECIFIED

Lists using a closed circle ("•"): perform ALL items in ANY ORDER or ALL APPLY

Lists using an open circle ("o"): perform APPLICABLE items only in ANY ORDER or only APPLICABLE items APPLY

2. Facilities Description

The VINSE cleanroom is a bay and chase design totaling approximately 10,000 sqft of floor space: 4500 sqft of process space under filter, 3200 sqft of utility chase and 2300 sqft of hazardous process material (HPM) support corridors and storage rooms. Total floor space in the two Class 100 (ISO 5) lithography bays is approximately 1000 sqft with an additional 250 sqft Class 1000 (ISO 6) dedicated E-Beam enclosure designed to noise criterion (NC) 25. The remaining cleanroom area is Class 1000 (ISO 6) deposition, chemical vapor deposition (CVD), etch and metrology areas, clean corridor and Gown rooms. At the rear/south-end of the cleanroom are isolated corrosive and flammable storage rooms.

Air inside the cleanroom is extensively conditioned to meet stringent particulate, temperature and relative humidity criteria. Four fans inside the cleanroom make-up air unit (MAU) direct building-conditioned air over heating coils followed by cooling coils and desiccator wheels to remove as much moisture as possible from the air. The temperature and moisture level in the air is then adjusted to meet cleanroom requirements of 68$\pm$2ºF and 44$\pm$4% relative humidity (RH). Make-up air is then added to the cleanroom at the second floor ceiling (i.e. utility deck ceiling), which is the very top of the cleanroom envelope. Twelve recirculation air-handling units (RAHUs) on the utility deck force air down through high-efficiency particulate air (HEPA) and ultra-low particulate air (ULPA) filters mounted in the ceiling for the main floor of the cleanroom so that air is pushed continuously via pressure differentials from clean to less-clean areas. It is important to note that unlike the majority of laboratories on the VU campus, the VINSE cleanroom is under positive pressure relative to the adjacent building spaces. As a result, any chemical vapor releases from spills or gas leaks could be conveyed to adjacent ESB areas outside the cleanroom.

Central utilities for house and high-purity nitrogen, compressed dry air (CDA), process vacuum, process cooling water and type E-1 ASTM electronics and semiconductor grade water are provided along with solvent and corrosive exhaust systems that utilize point-of-

use (POU) scrubbers for specialty gases. Flammable, toxic and corrosive gases are distributed from gas cabinets in the storage rooms to cleanroom-mounted valve manifold boxes (VMBs), which dispense the gases to individual tools. Simple asphyxiant gases are distributed directly from wall-mounted gas panels in the flammable storage room directly to the tools they service.

3. General Facility Policies

3.1. Access

All access to the VINSE cleanroom is strictly controlled given the nature and number of safety hazards present. Depending upon the needs of individuals or groups requiring entry, access can be either unescorted or escorted by qualified VINSE staff.

3.1.1. Unescorted Access

Unescorted VINSE cleanroom users must first compete all training requirements prior to being granted access to the facility. Entry to the cleanroom is provided using a VU-issued identification badge that has a RFID tag uniquely identifying a person and recognized by the facility's door locks. Requirements for using identification badges in the cleanroom are as follows:

- An identification badge is for the sole use of the person to whom it has been issued – i.e. NEVER share or loan your identification badge to someone else.
- "Tailgating" is not allowed except during an emergency when immediate access to or from the facility is necessary. "Tailgating" in the context of lock-controlled cleanroom doors means a person enters through an opened door without first swiping their individual badge. In other words each person must swipe the card reader controlling a door even if the door is open – e.g. person in front of a group opens the door with their individual badge and holds the door open for the people following.

In addition to using identification badges for checking into the cleanroom through entry doors, all unescorted users must also check in/out of the computer-based system used for tracking re-charge hours as well as computers controlling individual pieces of equipment.

3.1.2. Escorted Access

Visitors, tour groups, vendor service engineers, VU leadership, VU support personnel and other individuals who require limited or one-time access to the cleanroom can be escorted by authorized personnel at the discretion of the **VINSE Cleanroom Manager or Director**. Must be 12 or older to enter the cleanroom facility. The level of oversight provided will be dependent on the previous experience of the individual(s) involved, location(s) visited in the cleanroom, activities performed, potential risks involved, and the professional judgement of the **VINSE Cleanroom Manager or Director**. All escorted

individuals shall receive a safety briefing appropriate for the nature of the visit and will be monitored by their escort(s). In the event of a cleanroom emergency, it is the responsibility of VINSE personnel to ensure the safety of all escorted individuals.

3.1.3. Restricted Areas

For safety reasons, the following areas inside the cleanroom are restricted to authorized VINSE staff only:

- HPM corridor
- Corrosives storage room
- Flammables storage room
- Utilities/Fan deck – i.e. second floor of cleanroom
- Access ladder to the utilities/fan deck
- Equipment chases between bays with the exception of users trained to operate tools located with these areas

3.2. Professional Behavior

Anyone granted access to the VINSE cleanroom shall demonstrate professional behavior at all times by observing the following general rules:

- No "horseplay" or practical jokes
- NEVER assume an unexpected situation is safe – e.g. unknown spills
- If in doubt, consult VINSE staff before proceeding with work activities
- Ask for assistance from VINSE staff when unsure
- Obey all cleanroom signs and postings
- NEVER work in the cleanroom when you are sick, intoxicated, tired or under the influence of a medication or a controlled substance
- Read and understand the material in this manual along with equipment procedures and material safety information necessary for performing your work

3.3. Particulate Contamination Control

The VINSE cleanroom is designed to Class 100 (ISO 5) and Class 1000 (ISO 6) particulate control standards meeting the criteria specified in the table below:

Table 1 Cleanroom classification standards

Class	Maximum Number of Particles / m^3					
	≥ 0.1um	≥ 0.2um	≥ 0.3um	≥ 0.5um	≥ 1um	≥ 5um
100 (ISO 5)	100,000	23,700	10,200	3,520	832	29
1000 (ISO 6)	1,000,000	237,000	100,200	35,200	8,320	293

In order to achieve these criteria, HEPA and ULPA filters are used to continuously remove particulates from the cleanroom air. HEPA filters remove particles sized 0.3μm and larger with an efficiency of 99.99% and ULPA filters remove particles sized 0.12μm and larger with an efficiency of 99.9995%. To maintain cleanliness standards and prevent unnecessary replacement of the high-efficiency filters, entrants to the cleanroom shall observe the following practices at a minimum:

- Wear approved cleanroom garments in accordance with VINSE procedures
- No personal items (e.g. necklaces, identification badge holders) are allowed outside approved cleanroom garments
- No facial makeup, body fragrances and similar items that generate particles are allowed
- Store jackets, backpacks and similar items outside Pre-Gown and Gown rooms
- All personal clothing including shoes should be dry and clean
- Do not wear clothing that sheds fibers
- Items covered by cleanroom garments shall NOT be accessed in the cleanroom (e.g. unzip cleanroom coveralls) but must be removed from underneath garments in the Gown room – i.e. go out to the Gown room to open cleanroom garments
- Only approved paper manufactured specifically for cleanrooms shall be used
- No cardboard, wood fiber products and other particle-producing packaging are allowed
- No pencils, markers and retractable pens are allowed
- Only VINSE supplied and approved cleaning materials shall be used
- Wipe down with isopropanol (IPA) and cleanroom wipes all approved materials brought into the cleanroom from outside
- No dust or particle producing activities may be performed in the cleanroom (e.g. scoring and breaking substrates into small pieces) unless specified in procedures
- Change disposable gloves frequently to prevent contamination spread

3.4. "Buddy Rule"

Working alone in the cleanroom is prohibited at all times. A second user authorized for unescorted access shall always be present whenever another person is working in the cleanroom. During normal working hours, this requirement is typically met by VINSE staff. When staff are not present, this requirement can be met in one of two ways:

- During the academic year, undergraduates are hired to provide safety "buddy" support.
- A second VINSE cleanroom user authorized for unescorted access can be a safety "buddy" for another user.

Application of the VINSE "Buddy Rule" means the following:

- A minimum of two cleanroom users authorized for unescorted access by VINSE are physically in the cleanroom at the same time and can assist each other at any time in case of an accident or emergency.

- Authorized cleanroom users who agree to be safety "buddies" check on each other frequently and NEVER leave the cleanroom without informing the other person.
- Just because a second person is in the cleanroom does not automatically mean they are your safety "buddy." Both individuals must agree to be safety "buddies" for each other before beginning work in the cleanroom.
- In the event one of two "buddies" must leave the cleanroom, the second person must safely secure whatever they are working on and leave the cleanroom at the same time unless another person agrees to be their safety "buddy."

When first entering the cleanroom even during normal working hours, never assume a second person is available to meet the safety "buddy" requirements. Always check for staff or another person and let them know where you will be working. If there is a sign posted at the entrance to the cleanroom stating no staff is present, do NOT enter without a "buddy." When working through close of office hours into after hours, always verify undergraduate "buddy" availability on arrival and, if unavailable, ensure cleanroom user "buddy" arrives BEFORE staff departure to ensure work is uninterrupted.

3.5. Personal Protective Equipment

Personal attire and protective equipment are not only important for safety reasons inside the cleanroom but are also critical for controlling the spread of particulates and contamination that can adversely affect cleanliness standards. Personal protective equipment (PPE) includes all equipment used by an individual to protect the respiratory system, eyes, face, head, ears and auditory system, hands, arms, torso, skin, legs and feet from exposure to hazards.

3.5.1. Attire

Only shoes with a hard sole and covering the entire top of the foot shall be worn in combination with socks – e.g. NO sandals, open-toe shoes, high heel shoes, minimalist running shoes, bare feet, etc. Shirts shall be worn and must extend from shoulders to pants. Hooded sweatshirts are not permitted in the cleanroom. Although long pants are recommended as an additional layer of protection underneath cleanroom garments, shorts may be worn with re-usable (i.e. launderable) cleanroom garments. On occasions where disposable cleanroom garments are utilized, long pants shall be worn.

3.5.2. Eye Protection

Safety glasses with side-shields that meet the American National Safety Institute (ANSI) Z87.1-2003 standard shall be worn at all times and may only be removed in the Gown room or when using optical microscopes. For individuals wearing prescription glasses, prescription SAFETY glasses with side-shields meeting this standard may be worn or goggles worn over prescription glasses. Safety glasses with side-shields are not a substitute for face-shields used when working with chemicals or other specialized protective eyewear – e.g. additional protection for working with ultraviolet (UV) light.

3.5.3. Gloves

All gloves required for cleanroom activities are stocked by VINSE. Individuals may not bring their own gloves into the cleanroom unless prior approval has been given by the **Cleanroom Manager or designee**.

Standard Gloves

The thin gloves that users put on in the Pre-Gown and Gown rooms and that are commonly used throughout the cleanroom provide minimal protection against heat, cold, burns and most chemicals. The primary purpose of these gloves is to protect cleanroom surfaces from oils, salts and other minute particles normally present on bare hands and to prevent inadvertent transfer of minor contamination that may be picked up while working in the cleanroom. As a result, these gloves should be changed frequently to prevent cross-contaminating items in the cleanroom. Standard gloves are dispensed in the Pre-Gown and Gown rooms as well as locations inside the cleanroom. CHANGE STANDARD GLOVES OFTEN TO PREVENT TRANSFER OF PARTICULATE AND LIQUID CONTAMINATION INSIDE THE CLEANROOM!

Chemical-Resistant Gloves

Chemically-rated gloves shall be worn whenever working with acids, bases, etchants, corrosives, solvents and other toxic or highly toxic materials as specified by the **Cleanroom Manager or designee**. These gloves are normally stocked near the process hoods where they are to be worn and shall be worn over the top of standard cleanroom gloves. NEVER touch surfaces outside the process hood with these gloves including the controls for the hood –e.g. touchscreen.

Extreme Temperature-Resistant Gloves

Gloves for handling extremely hot or cold surfaces (e.g. liquid nitrogen dewars, tube-furnace components) are kept near the locations where they are used and shall be worn over the top of standard cleanroom gloves. NEVER touch other surfaces inside the cleanroom with these gloves to prevent the spread of contamination.

If you cannot find the gloves needed for the processes and/or equipment you are attempting to operate in the cleanroom contact, VINSE staff for assistance.

3.5.4. Chemical-Resistant Aprons and Face-Shields

Aprons

Chemical-resistant aprons shall be worn whenever working inside process hoods with acids, bases, etchants, corrosives, solvents and other toxic or highly toxic materials in accordance with approved procedures and/or as specified by the **Cleanroom Manager or designee**. If an apron becomes contaminated with chemicals, do NOT attempt to clean it by yourself. Contact VINSE staff for assistance and to obtain a replacement apron.

Face-shield

A face-shield shall be worn whenever working inside a process hood. A face-shield is customarily worn when pouring and dispensing chemicals or performing other activities where there is a danger for chemical splashes. Users should only handle a face-shield from the top to prevent contamination of the clear portion of the shield that could obstruct visibility.

3.5.5. Gowning

Only VINSE approved and supplied cleanroom garments may be worn. The gowning protocol for entering the cleanroom is as follows:

1. Vacuum and scrub shoes in the PRE-GOWN vacuum shoe cleaner
2. PUT-ON the following items in the PRE-GOWN room:
   - Disposable face mask
   - Disposable bouffant ENSURING all hair is tucked into bouffant
   - Disposable shoe covers WHILE stepping over step-over bench
   - Nitrile or latex gloves
3. SWIPE door lock with identification badge
4. ENTER cleanroom GOWN room ONLY if you receive a **GREEN** light on the door lock
5. PUT-ON cleanroom hood
6. PUT-ON cleanroom coverall WITHOUT dragging on floor
7. VERIFY cleanroom hood is tucked UNDERNEATH coverall
8. SIT DOWN on step-over bench across cleanroom door entrance
9. PUT-ON first cleanroom boot WITHOUT touching floor on the GOWN room side of the step-over bench
10. PLACE foot covered with cleanroom boot on the cleanroom side of the step-over bench
11. REPEAT process for second foot
12. PLACE hand in front of motion detector until the door opens
13. ENTER cleanroom
14. CONFIRM Toxic Gas Monitoring System (TGMS) light is **GREEN** before commencing work in the cleanroom

On exiting the cleanroom, simply reverse the process for removing cleanroom garments:

1. REMOVE cleanroom boots BEFORE placing feet on GOWN side of the step-over bench
2. REMOVE cleanroom coverall WITHOUT dragging on floor
3. REMOVE cleanroom hood
4. HANG all garments on one hanger on the provided racks
5. EXIT the cleanroom GOWN room
6. DISPOSE of the following:
   - Face mask

- Bouffant
- Shoe covers
- Nitrile or latex gloves

7. WASH hands with soap and water at nearest restroom
8. RETRIEVE personal items

3.5.6. Respirators

Process (i.e. fume) hoods as well as a sophisticated glovebox arrangement are installed in the cleanroom for all approved chemical processes, and along with equipment interlocks and the TGMS, are the preferred engineered safety features for preventing inhalation of harmful gases or process-generated fumes. A VINSE cleanroom user requiring a respirator shall first consult with VU EHS. Specific regulatory requirements must be met for using respirators including training and device-fitting. VINSE staff members are not qualified to perform these services and rely upon VU EHS or other qualified, outside resources to provide these tests and training functions as well as for determining the necessity of using a respirator.

3.6. Training Requirements

Training is not only important for safety reasons but also for ensuring the availability of equipment, preventing the spread of contamination and maintaining process capabilities and reproducibility. There are two stages of training in the VINSE cleanroom: (1) training for unescorted access to the cleanroom followed by (2) tool and process specific training.

3.6.1. Unescorted Access Training

In order to gain unescorted access to the VINSE cleanroom, the following requirements shall be met by all perspective users:

1. Complete all required on-line VU EHS training modules and provide evidence of completion (i.e. copies of course completion certificates) to the VINSE staff
2. Watch the online cleanroom orientation video
3. Read VINSE Safety Plan & Conduct of Operations manual (VOP No. 0.0.0rev0.3) and submit the online acknowledgement form
4. Complete a cleanroom safety and operations tour with the Cleanroom Manager or designee.

After these requirements have been successfully completed, the user's VU identification badge will be authorized for unescorted entry into the cleanroom - i.e. the user's badge will open the entry door to the Gown room. However, this authorization only grants the user unescorted access to the cleanroom.

3.6.2. Equipment & Process Hood Training

Before using any cleanroom equipment including process hoods, users must first be trained by authorized VINSE staff or Cleanroom Manager designee. Users cannot be trained by other users or VINSE staff not authorized to train on a piece of equipment or process hood. Furthermore, experience and/or training on the same or similar piece of equipment at another facility or laboratory does not meet VINSE cleanroom training requirements. On occasion it may be necessary to re-train all authorized users if there is a major modification to a piece of equipment or a significant change to its process capabilities. Any uncertainties or questions about these requirements shall be brought to the attention of the **Cleanroom Manager**.

Equipment and process hood training will cover the following topics at a minimum:

- Layout and operation including procedures
- Risks associated with operation along with design features and actions taken to limit those risks
- Restrictions on use – e.g. approved materials
- Actions taken to safely abort a process
- Location of any EMO/EPO and its use to protect users and equipment

Equipment and process hood training is based on the on-the-job training (OJT) model where users are first shown how to operate equipment or perform processes by qualified VINSE trainers and then demonstrate their ability to perform the task independent of prompting by the trainer. Training is tailored to the process requirements of each user. Users are expected to arrive for training equipped with knowledge of their desired process flow and, as necessary, samples for such a process.

3.7. Personal Electronics

Personal electronics may be used in the cleanroom as long as they do not distract other users, prevent individuals from responding promptly and appropriately to alarms, create an unnecessary distraction that inhibits the ability of a user to actively monitor equipment and/or processes in use, or have the potential to create particulate contamination in the cleanroom. General guidelines for using personal electronics are the following:

- Wipe down all surfaces of the electronics exposed to the cleanroom environment with IPA and wipes prior to bringing into the cleanroom
- NEVER remove electronics from underneath garments inside the cleanroom – e.g. you must exit into the Gown room to answer your cell phone if it is in a pocket of your personal clothes
- NEVER touch electronics underneath your cleanroom garments with gloves
- NO cell phone use (i.e. talking or texting) while actively operating equipment or performing processes, including monitoring

- Ear buds that fit completely underneath your cleanroom hood are allowed but head phones are NOT allowed

Enforcement on the use of electronics in the cleanroom is at the complete discretion of VINSE staff. If it is felt that the use of electronics is distracting or creating another problem, VINSE staff members are expected to immediately stop the activity.

3.8. Food & Beverages

NO food or beverages are allowed inside the cleanroom or any adjacent areas, including Pre-Gown and Gown rooms, HPM corridor, and corrosive and flammable storage rooms. Furthermore, never use lab-ware for handling food, and do not store food or beverages in any laboratory refrigerator or freezer.

3.9. Cleanroom Computers & Telephones

Cleanroom computers and telephones shall only be used for authorized activities. Under no circumstances shall users access the internet for personal use (e.g. checking headlines, game playing) nor make personal phone calls using the cleanroom telephones. Furthermore, VINSE does not archive data on computers in the cleanroom. It is up to the individual users to make copies of their data and keep their own lab notebook records.

4. Safety Hazards

The VINSE cleanroom has been designed and constructed to provide a safe work environment. However, knowledge of the potential safety hazards that exist is important to maintaining safety and ensuring any concerns are quickly addressed before they can cause any problems.

4.1. Chemicals

Chemicals in gaseous, liquid and solid forms are used in almost every cleanroom-based activity. Understanding how to safely work with chemicals is critical to maintaining a safe work environment in the cleanroom for all users.

4.1.1. Chemical Safety Information

The Safety Data Sheet (SDS) is a federally mandated document that must be supplied for any chemical provided by a manufacturer or distributor. This document is a detailed source of information that includes the following material: identification of the chemical, its constituents and hazards; properties of the chemical such as physical and chemical attributes, stability, reactivity, toxicology, ecological impact and disposal considerations; emergency response actions including fire-fighting, first-aid and accidental release measures; personal protection and exposure controls; and handling, storage, transport and regulatory information. ALL cleanroom users shall read and maintain familiarity with the SDS for every chemical they handle and/or is present with any equipment they operate.

SDSs are available in the VINSE Cleanroom Manager's office, the cleanroom Pre-Gown room, inside the cleanroom near the entrance door, on VINSE computers inside the cleanroom and on the VINSE website.

4.1.2. Chemical Hazard Types

Corrosives

A corrosive chemical causes visible destruction or irreversible alterations in living tissue by chemical action at the site of contact. For example eye splashes can cause blindness and inhalation can destroy lung tissue leading to life-threatening fluid build-up. Generally, strong acids and strong bases are corrosives.

Oxidizers

An oxidizer (i.e. oxidizing agent) is a substance that can oxidize another substance or cause it to lose electrons. Common oxidizers include oxygen (O_2), hydrogen peroxide (H_2O_2) and halogens (e.g. Cl^-, F^-, Br^-). Some materials can be both an oxidizer and a corrosive – i.e. nitric acid (HNO_3). When oxidizers are mixed with materials that can act as reducing agents (i.e. electron donors), violent and sometimes explosive reactions can occur. Oxidizers shall be kept segregated away from flammable chemicals, such as solvents that can act as reducing agents, and any combustible materials, such as cleanroom wipes.

Reactives

Reactive materials can cause damage through the release of gases that burn, explode or produce high pressure. In addition, the released substances may be considerably more toxic than the original, unreacted components. Water-reactive materials, such as concentrated acids and bases (e.g. sulfuric acid, piranha etch), rapidly generate heat and/or gas upon mixing with water, potentially creating superheated conditions and explosions. As a result, water-reactive mixtures shall never be poured directly into water.

Toxics

Toxic or highly toxic materials have harmful or deadly effects on humans. Quantified definitions for toxics and for the toxicity level vary based on experimental data.

Pyrophorics

Pyrophoric materials can spontaneously ignite on contact with air, oxygen or water. These materials can also be corrosive and/or toxic.

Flammables

Flammable materials are fuel sources for fire and explosion if mixed with an oxidant – e.g. oxygen in air – and an ignition source – e.g. flame, electric spark, static discharge, hot surface such as a hot plate. Liquids with sufficiently high vapor pressures can be flammables.

Simple Asphyxiants

Simple asphyxiants are gases that displace oxygen in the ambient atmosphere. If adequate ventilation is not available, oxygen deprivation can result leading to unconsciousness and death. Examples include inert gases such as helium (He), argon (Ar) and nitrogen (N_2).

4.1.3. New Chemical Authorization

NO new chemicals may be brought into the VINSE cleanroom without first being reviewed and approved by the **Cleanroom Manager or designee**. In order to facilitate this review process, the following information shall be provided at a minimum:

- Requestor Name
- Principal Investigator or Vanderbilt Sponsor
- SDS
- Quantity Required
- Brief Usage Description – e.g. heating/cooling, mixture, reactions, etc.
- Explanation of Need – i.e. why existing capabilities are inadequate
- Usage Duration – e.g. permanent cleanroom addition, one-time experiment, etc.

This information shall be submitted to the **Cleanroom Manager or designee** either via email or in writing at least two weeks prior to need. In some cases, it may take longer to complete the review process if additional input is needed from outside sources such as VU EHS, a safety consultant, an engineering firm, tool manufacturer, etc. Every effort will be made to complete the VINSE review as soon as possible.

Unless previous arrangements have been made with the **VINSE Director**, the following items shall be the responsibility of the requestor:

- Costs associated with introducing a new chemical into the cleanroom – e.g. additional TGMS sensor capabilities, modifications to equipment or the cleanroom, VINSE-external engineering or consulting fees, etc.
- Disposal of any chemical or waste by-products that cannot be handled by existing cleanroom facilities or place an unreasonable burden on VINSE
- Purchase of the new chemical and other associated costs (e.g. rental of compressed gas cylinder, shipping, etc.) unless these purchases are made for the entire VINSE cleanroom user community

4.2. Wet Chemical Hazards

Wet or liquid chemicals are “hands-on” hazards and are hard to control using engineered safety features, such as real-time monitoring and machine interlocks. Improperly used wet chemicals can cause fires, explosions and harm to individuals – e.g. severe burns, tissue and organ damage, asphyxiation, genetic damage and death. Exposure routes can be through inhalation, ingestion and absorption either through skin or improper glove material usage. Users are expected to be aware of the hazards involved with the

chemicals and processes they utilize and to ask questions of VINSE staff whenever there are any uncertainties or concern.

4.2.1. General Liquid Chemical Guidelines

At a minimum the following guidelines shall be followed whenever any chemical is used in the VINSE cleanroom:

- No chemical may be left unattended outside its labeled container unless it is being used as part of a process approved by VINSE staff
- Any approved, unattended chemical shall be labeled with the user's printed full name and contact information, chemical name, date, and expected time of return
- ALWAYS avoid skin contact with chemicals – i.e. wear appropriate gloves, sleeves and aprons as appropriate
- Wash hands with soap and water after exiting the cleanroom
- NEVER pipette chemicals by mouth
- All chemical processes shall be performed inside process hoods unless a VINSE authorized procedure is in use
- ALWAYS assume an unknown toxicity is produced during a chemical reaction
- Clean up after completing work in the lab – e.g. follow waste disposal guidelines, wash glassware, put away lab equipment
- Maintain clean and unclutter lab areas – e.g. process hoods, tables, chairs
- Ask VINSE staff to obtain chemicals from storage
- NEVER use damaged glassware, plastic containers or other hand tools

4.2.2. Process Hoods

A number of different types of process hoods are installed in the cleanroom in order to protect users from the fumes and other dangers generated by chemical processes. Stainless steel hoods are used for solvent-based processes (e.g. lithography processes, lift-off techniques) whereas polypropylene/plastic hoods are used for corrosive-based chemical processes – e.g. BOE etches, Piranha cleans, acid etches, base etches. With the exception of incidental cleaning using solvents (e.g. acetone, isopropanol or methanol squeeze bottle and cleanroom wipes) or procedure-specific processes, ALL chemical processing shall occur inside process hoods.

PPE

The minimum personal protective equipment (PPE) required in the cleanroom at ALL TIMES consists of the personal attire standards previously described: OSHA-approved safety glasses with side-shields or googles, disposable gloves and VINSE-supplied cleanroom garments. Additional PPE requirements for handling chemicals are specified by wet bench and process procedures. The table below summarizes additional PPE requirements in the absence of specific guidance:

Table 2 Additional PPE requirements for handling chemicals

Chemical/Activity	Additional PPE Requirements
Pouring any bulk chemical	Face-shield, Apron, Chemical-Resistant Sleeves, Chemical-Resistant Gloves
Corrosives (acids, bases, etchants), oxidizers, bulk solvents	Face-shield, Apron, Chemical-Resistant Sleeves, Chemical-Resistant Gloves
Standard lithography activities – photoresists, developers	Chemical-Resistant Gloves
General/light general solvent usage (e.g. cleaning with acetone, isopropanol and methanol)	Chemical-Resistant Gloves

Users shall change their standard, disposable gloves frequently to prevent the spread of contamination (e.g. solvent residue, particulates) to cleanroom surfaces.

Chemical-Resistant Lab-ware

Lab-ware (e.g. containers, holders, tweezers) shall NOT be moved from one process hood to another. Only VINSE-supplied lab-ware supplied for each hood may be used unless other arrangements have been made with VINSE staff. These restrictions are in place to control not only the spread of contamination across hoods and processes but also to prevent the use of incompatible materials with chemicals that could create safety hazards. For example hydrofluoric acid (HF) processes should only be performed in compatible plastic containers since HF chemically attacks glass.

Mixing Chemicals

Many processes, along with disposal activities involve mixing different types and sources of chemicals together. Combining chemicals can create unanticipated hazards if not performed properly. The table below illustrates the general risks created when incompatible chemicals are mixed together:

Table 3 Prohibited chemical combinations to prevent creating safety hazards

Chemical Types Mixed Together		Potential Result
Flammables (e.g. solvents)	Oxidizers (e.g. hydrogen peroxide, nitric acid, halogens)	Explosion/Fire
Flammables (e.g. solvents)	Corrosives (e.g. acids, bases, etchants)	Explosion/Fire
Toxics/Poisons	Corrosives (e.g. acids, bases, etchants)	Toxic/Poison Gas
Acids	Bases	Corrosive Fumes/Heat

General rules that shall be followed to prevent creating unexpected safety hazards when chemicals are mixed as either part of a process or for waste disposal:

- Follow approved procedures and processes
- NEVER change the ratios of chemicals combined outside those specified in approved procedures and processes
- NEVER mix acids and solvents since an explosion can result
- NEVER Add Water to acid (NAW) since it can splatter violently – i.e. Always Add Acid to water (AAA)
- Only perform specified processes in the appropriate process hoods – e.g. no acid or etch based process in solvent hoods, no solvent cleans in acid/base hoods

4.2.3. Wet Chemical Storage

Chemical storage (e.g. quantities, types, locations) is strictly controlled by codes, safety considerations and the underlying design assumptions for the cleanroom design. Excess chemicals shall be appropriately separated and stored in flammable, acid, base and oxidizer storage cabinets in the corrosive and flammable storage rooms adjacent to the HPM corridor. Operating quantities of chemicals can be maintained either inside the process hoods where they are used in accordance with approved procedures or in the flammable, acid and base cabinets inside the cleanroom. Temperature sensitive chemicals shall be stored in the appropriate refrigerator or freezer – e.g. explosion-proof refrigerators for storing flammable chemicals. ONLY authorized VINSE staff are allowed to store and retrieve chemicals from the cleanroom storage areas.

4.2.4. Lab-Specific Wet Chemical Hazards

The following overview of wet chemical hazards in the VINSE cleanroom is not exhaustive and does not replace the requirements for reviewing chemical SDS(s) and for receiving the appropriate VINSE training on cleanroom processes and equipment.

Flammable Solvents

Common solvents in the cleanroom such as acetone, isopropanol (IPA) and methanol are considered flammables due to their low flash points. Because the vapors can travel considerable distances, the source of ignition (e.g. hot plate, electric spark) can be far away from the flammable source. A one-gallon spill of acetone can cause a significant fire or explosion hazard. Flammable solvents can react explosively with oxidizers such as hydrogen peroxide (H_2O_2) and nitric acid (HNO_3).

Glycol Ether Solvents

Commercial photoresists use a wide variety of casting solvents that include different types of glycol ethers – e.g. methyl cellosolve, PGMEA (1-methoxy-2-propanol acetate), 2-ethoxyethanol (2EE). Experiments with laboratory animals using extremely high concentrations of these materials have demonstrated adverse reproductive effects as well as other health problems. It is important for these materials to be used with adequate ventilation such as inside a process hood.

Peroxides

All peroxides are oxidizers and can release significant amounts of energy when undergoing reactions. The hydrogen peroxide (H_2O_2) concentration used in cleanroom processes is 30% in water, which is ten times the concentration of drugstore-available hydrogen peroxide commonly used for treating cuts. Extreme care should be taken when mixing peroxide solutions in accordance with approved procedures due to the amount of energy released. Peroxides are incompatible with all forms of organic solvents and flammable materials.

Piranha Etch

Piranha etch is an aggressive oxidizing solution made by combining concentrated sulfuric acid (H_2SO_4) and 30% hydrogen peroxide (H_2O_2). It is commonly used for removing organics (e.g. photoresist residue), heavy metals and other contaminants from substrates. The solution is made by slowly adding hydrogen peroxide to sulfuric acid, which generates a great deal of heat when the two components are combined and creates a corrosive vapor. Piranha etch will destroy human flesh, cleanroom wipes, vinyl or latex gloves and any other organic material it contacts. It should only be used in the appropriate process hood and mixed in the proportion specified by procedure to prevent a dangerous heat build-up when the components are mixed. NEVER attempt to cool piranha etch by adding water to it since sulfuric acid is water reactive and an explosion could result.

Hydrofluoric Acid

Hydrofluoric acid (HF) is a significant laboratory hazard in both its concentrated and dilute forms. HF is a major component in buffered oxide etch (BOE), which is used for removing silicon dioxide. It is more dangerous than other acids due to its effects on human skin and tissue. Typically HF is used at relatively low concentrations such that skin contamination is initially relatively painless. HF is both a small molecule and a weak acid allowing it to penetrate deeply through skin and into tissue. The dissociated fluorine ions bind with calcium and magnesium ions resulting in severe electrolytic imbalance that disrupts normal cellular function. Deaths from cardiac arrest have been reported from concentrated HF burns with exposures as low as 2.5% of the body surface area.

It is absolutely critical that any HF exposure, no matter how small or seemingly insignificant be treated quickly and properly. After rinsing with water, a gel containing calcium gluconate must be spread over the exposed area. The calcium ions in this gel scavenge free fluorine ions before they can penetrate skin and damage tissue. Immediate medical attention is also necessary to evaluate further treatment needs – e.g. intravenous calcium gluconate treatment.

Nitric Acid

Nitric acid (HNO_3) is a water-reactive hazard as well as being a corrosive hazard and an oxidizer. Typically, nitric acid, along with acetic acid, is a component of pre-mixed

aluminum etchants. Similar to the precautions taken with other oxidizers, nitric acid should be kept away from solvents, bases and flammable materials.

Tetramethylammonium Hydroxide

Tetramethylammonium hydroxide (TMAH) affects nerves and muscles causing difficulties in breathing, muscular paralysis and possibly death. TMAH concentrations used in the cleanroom range from 2-3% in photoresist developer solutions to 25% in water heated to 70-90°C for anisotropic etching of silicon. TMAH in the concentrated form is significantly more hazardous than the dilute solutions used for developing photoresists. In addition to its corrosiveness, concentrated TMAH is toxic. Therefore, it is very important for users to treat concentrated TMAH with extreme caution and not simply view it as a more concentrated version of photoresist developer.

Photoresist Removers and Strippers

Various organic base mixtures are used for removing photoresists from substrates during lift-off processes or after plasma etching when the photoresist is used as an etch mask. These strippers are not water-based and can be combustible. They should only be used in the appropriate process hood due to the vapors that are generated and the waste handling needs. Removers and strippers should never be mixed with oxidizers.

4.3. Hazardous Gases

4.3.1. Compressed Gas Storage & Distribution

A number of compressed gas cylinders support a wide variety of processes inside the VINSE cleanroom. These cylinders are stored in the corrosive and flammable storage rooms accessed through the HPM corridor. Gases are distributed to various cleanroom tools via a sophisticated network of stainless steel piping, gas cabinets, valve manifold boxes (VMBs) and gas panels which, along with the cleanroom atmosphere, are continuously monitored by the TGMS. Toxic, corrosive, pyrophoric and flammable gas cylinders are stored inside gas cabinets, and gases are distributed to tools via dedicated coaxial piping running from gas cabinets and VMBs. Oxidizers and simple asphyxiants (e.g. Freons, SF_6, He, Ar, N_2, N_2O) are stored and distributed from the flammable storage room via header-based networks of single-walled stainless steel piping.

4.3.2. Compressed Gas Cylinders

The internal pressure of a gas cylinder can be as high as 2500 psig making cylinders missile hazards capable of penetrating walls if improperly handled and/or dropped, resulting in catastrophic damage to the cylinders – e.g. cylinder valve sheared off when dropped. Given the number of safety hazards associated with gas cylinders, the following requirements shall be met for their safe handling, installation and maintenance:

- Only trained and authorized VINSE staff members may handle, install and perform any actions to compressed gas cylinders.

- All cylinders shall be secured with restraints.
- All toxic, corrosive, pyrophoric, flammable and oxidizing gas cylinders shall be equipped with safety caps and gas-tight dust caps to prevent gas leaks through the cylinder outlet connection and associated cylinder valve.
- Valve-protection caps and cylinder caps shall be left in place until the cylinder is secured in position and connected to piping for use.
- Only Compressed Gas Association (CGA) valves and fittings shall be used in compressed gas installations.
- Cylinders shall be clearly marked with their content names.
- Cylinders shall only be moved using a suitable gas cylinder hand cart – i.e. never drag, roll or slide cylinders.
- Pressure regulators shall be used to control gas flow from cylinders.
- No repairs shall be made to damaged cylinders – i.e. return all compromised cylinders to the appropriate vendor for replacement.

4.3.3. Toxic Gas Monitoring System

The cleanroom toxic gas monitoring system (TGMS) is a sophisticated computer-controlled system that detects a multitude of potential problems with the process gas storage and distribution system and automatically activates corrective actions (e.g. isolating gas cylinders) as well as generating various levels of alarms up to and including complete ESB evacuation via the building fire alarm system. The TGMS uses various sensors and electrical contacts to detect gas leaks, exhaust-loss problems and other equipment issues applicable to the various gases used in the VINSE cleanroom.

4.3.4. Lab-Specific Gas Hazards

Gases are not stored in the cleanroom but are remotely distributed from the corrosive and flammable storage rooms. As previously stated, cleanroom users are expected to review the SDS(s) for any processes or equipment that utilize chemicals, which includes process gases. The following overview is not a substitute for this requirement.

Silane

Silane (SiH_4) is used for the deposition of silicon, silicon nitride and silicon dioxide thin films in the PECVD. It is a pyrophoric gas meaning it may spontaneously ignite if exposed to air at concentrations of approximately 4-90%. The silane cylinder concentration used in the VINSE cleanroom is 10%. Silane risks are managed via engineered safety features – e.g. locally-exhausted gas cabinet & VMB distribution equipped with automatic shutoff capabilities, double-wall gas piping, local UVIR sensors, TGMS monitoring.

Flammable Gases

Multiple flammable gases (i.e. hydrogen (H_2), methane (CH_4), ethylene (C_2H_4), acetylene (C_2H_2)) are used by several pieces of cleanroom equipment including the tube furnaces,

MW-CVD and PECVD. Although these gases are dangerous as simple asphyxiants, if released uncontrollably within a confined environment, their primary hazard is as a fuel source for fire and explosion if mixed with an oxidant (e.g. oxygen in air) in the presence of an ignition source – e.g. flame, electric spark, static discharge. Risks for flammable gases are managed via engineered safety features – e.g. locally-exhausted gas cabinet & VMB distribution equipped with automatic shutoff capabilities, TGMS monitoring and user adherence to operating procedures.

Chlorine & Boron Trichloride

Chlorine (Cl_2) and boron trichloride (BCl_3) are used in the plasma etching tools. These gases are extremely corrosive and in particular are very dangerous if inhaled. The chlorine ions form hydrochloric acid (HCl) in the lungs causing irreversible tissue damage that can be fatal. Medical attention should be sought immediately after exposure since the onset of symptoms is typically delayed. In addition leaks of these gases can cause significant damage to cleanroom facilities and equipment. Risks are managed via engineered safety features – e.g. locally-exhausted gas cabinet & VMB distribution equipped with automatic shutoff capabilities, double-wall gas piping, TGMS monitoring. Chlorine and boron trichloride have low concentration thresholds for odor detection.

Anhydrous Ammonia

Anhydrous ammonia (NH_3) is a severely corrosive alkaline vapor with a pungent odor (i.e. low concentration threshold for odor detection) that is used in the PECVD for growing nitride thin films and in the photolithography vapor prime oven for image reversal processes. Hazards and risk management are similar to those for chlorine.

Trimethylboron

Trimethylboron (TMB) is a toxic gas used as a dopant in PECVD processes. TMB may cause thermal burns and reacts violently with water, oxidizers and halogens. To mediate toxicity, VINSE uses a diluted concentration of TMB in hydrogen, however, this makes it a flammable hazard as well. Protection in the cleanroom is provided by extensive engineered safety features – e.g. locally-exhausted gas cabinet & VMB distribution equipped with automatic shutoff capabilities, double-wall gas piping, TGMS monitoring.

Phosphine

Phosphine (PH_3) is a highly toxic gas used as a dopant in PECVD processes. It is a pulmonary irritant and acute systematic poison that can cause sudden or delayed death due to lung destruction. Odor is a poor indication of phosphine since its toxic threshold concentration is near the level at which it can be smelled by humans. Protection in the cleanroom is provided by using a diluted concentration of PH3 in He as well as extensive engineered safety features – e.g. locally-exhausted gas cabinet & VMB distribution equipped with automatic shutoff capabilities, TGMS monitoring.

Plasma Gases

Carbon tetrafluoride (CF_4), trifluoromethane (CHF_3, Freon 23), octafluorocyclobutane (C_4F_8, Freon C 318), sulfur hexafluoride (SF_6) and nitrous oxide (N_2O) are used in plasma-producing equipment such as reactive ion etchers (RIEs) and the PECVD. In their unreacted forms, these gases are primarily simple asphyxiant hazards if released into a confined, unventilated space. When exposed to plasmas, the resulting by-products should be considered very hazardous making it critical to follow proper operating procedures for pumping down and purging plasma vacuum chambers during processing.

Liquid Nitrogen

Even though nitrogen (N_2) is an inert gas, it is considered a significant safety hazard due to the number of people that die from N_2-asphyxiation every year. N_2 is used in the VINSE cleanroom for a wide variety of needs and is supplied as "House-Nitrogen" via a 6500 gallon tank on the south side of the ESB. Liquid nitrogen (LN2) represents a significant hazard as an uncontrolled release can quickly create an oxygen-deficient atmosphere. The greatest risk of such a release is improper operation of the LN2 fill stations that draw directly from the 6500 gallon supply tank. Although oxygen monitors are located near these fill stations, any corrective actions must be manual since there are no automatic shut-off valves or mechanisms. Only trained and authorized individuals in continual attendance may operate the LN2 fill stations.

Non-Toxic Gases

Cylinder-supplied inert gases such as helium (He), argon (Ar) and nitrogen (N_2), are simple asphyxiants used in the cleanroom.

4.4. Temperature-Related Hazards

4.4.1. Cryogenic Fluids

Liquid nitrogen (LN2) exists at extremely low temperatures (-196ºC; 77K; -320ºF) and can cause burns to unprotected skin and eyes. In addition LN2 released rapidly to the open atmosphere quickly vaporizes and can create an oxygen-deficient environment in the immediate vicinity of the leak. Operation of LN2-associated equipment such as fill stations, dewars, valves and hoses shall only be carried out subject to the following restrictions:

- Only users trained and authorized by VINSE staff shall handle LN2 and operate associated equipment
- Wear protective equipment (i.e. thermally insulated gloves and face shields) when handling LN2 equipment
- Only operate equipment in accordance with approved procedures
- NEVER leave LN2 fill stations alone while in operation
- Monitor equipment for leaks and immediately cease operations if there is any indication of a leak

4.4.2. Hot Plates

While commonly used inside the cleanroom, hot plates are a significant risk for causing fire in the laboratory as well as generating potentially harmful fumes. Observe the following precautions whenever using hot plates:

- NEVER leave hot plates unattended unless the process is well understood and documented in a procedure and the hot plate is checked periodically per procedure
- Turn off hot plates after finishing activities in the cleanroom at the end of the day
- Only VINSE-approved hot plates may be used for approved processes
- Discuss new processes requiring hot plates with VINSE staff before implementing
- Hot plates shall be used only in exhausted enclosures (e.g. process hoods) unless used as part of a VINSE-approved procedure
- Hardware-based over-temperature interlocks should be used whenever possible unless approved procedural controls are in place and being followed

4.4.3. Hot Equipment Surfaces

A number of equipment surfaces are hot or become hot during use. Always pay attention to all labels on equipment as well as processing conditions used when operating tools and take appropriate actions to avoid touching hot surfaces or use appropriate means to avoid burns:

- If a process involves heating inside a vacuum chamber, such as the AJA sputter, ALD or PECVD tool, do not touch the wafer carrier until it has cooled off.
- Heat can be generated when chemicals are combined – e.g. Piranha etch. Consult procedures for guidance and use appropriate precautions for handling the containers without burning your hands or spilling.
- Pay attention to warning labels on tools and precautions inside procedures.
- Never check the temperature of a surface with your hand. Use a contact or non-contact thermometer, as appropriate.
- Inform VINSE staff of unexpected hot surfaces as this observation may indicate a problem.

4.5. Metal & Other Process-Generated Particulates

Thin film deposition tools, such as the PECVD, ALD, Angstrom deposition chambers and AJA sputter tool, can create films that flake when exposed to atmosphere, that undergo thermal cycling (e.g. heating during deposition followed by post-process cool-down to ambient conditions) or when deposited over the top of dissimilar films in the same vacuum chamber. Any dust or particles created during a cleanroom process should always be treated as a potential health hazard. Precautions to take when working with sources of metal or other thin film processes include the following:

- NEVER place your head inside a vacuum chamber or in the path of air blowing over a particle-generating surface

- NEVER use a nitrogen gun or other pressurized source for removing or blowing off thin film particles
- NEVER scrub or use a dry abrasive tool that generates airborne particles outside a controlled and isolated environment for cleaning
- Use a VINSE-supplied HEPA vacuum and/or IPA-wetted cleanroom wipes for cleaning up metal and other thin film particles
- Any process that has the potential to generate airborne particles shall only be performed inside the appropriate process hood
- Contact VINSE staff for assistance with any concerns or uncertainties regarding removal of particulates

4.6. Electrical Hazards

Electrical shock hazards are always present wherever electricity is used. Although equipment interlocks, enclosures and ground-fault circuit-interrupters (GFCIs) are used to protect tool users, it is important to become familiar with the electrical hazards present in the cleanroom. Whenever a circuit connecting a power source to ground is established through the body, injury can result ranging from a simple tingling sensation to severe burns or death. The amount of current necessary to kill a person is small and can easily be exceeded if the proper precautions are not taken. General electrical safety guidelines are as follows:

- Extension cords and expansion bars shall only be used as authorized by VINSE staff
- All tools and instruments shall have grounded plugs
- Do not unplug extension cords or equipment while under load
- Bring any electrical safety concern to the attention of VINSE staff including any sensation of electric shock such as a tingling sensation, unexpected electric arcing during equipment operation, unexpected loss of electric power
- Observe all lock-out tag-out (LOTO) restrictions in place for out-of-service (OOS) equipment

4.7. Fire Hazards

Fires can be caused by the ignition of flammable gases and solvents as well as by solid materials such as paper. Guidelines for fire prevention are the following:

- No open flames are allowed
- Procedures and processing protocols approved by VINSE staff must be followed when heating materials
- Do NOT heat flammable solvents unless following a VINSE-approved procedure inside a hood equipped with appropriate controls to prevent overheating (e.g. high-temperature control interlock) and with a fire suppression system.

4.8. Vacuum Hazards

In vacuum systems, the higher pressure is on the outside of the contained volume so any vessel failure can cause an implosion resulting in debris/shrapnel being expelled with significant force. General guidelines are as follows:

- Only apply a vacuum to items that are approved by VINSE staff and are qualified to withstand a vacuum environment
- Inspect equipment for flaws before applying a vacuum
- Never use glassware for vacuum operations unless specifically designed for low pressure operation
- Avoid creating any stresses on equipment exposed to vacuum

4.9. Other Considerations

4.9.1. Allergens

Allergens or chemical sensitizers are typically harmless substances that cause the immune system in some individuals to trigger an allergic response – e.g. skin rash, eye irritation, hives. A sensitizer causes little or no reaction on first exposure, but on subsequent exposures a marked immunological response occurs. Common allergens are the latex found in gloves and nickel compounds. Consult with VINSE staff if you believe you have experienced an allergic response while working in the cleanroom.

4.9.2. Irritants

An irritant is a chemical not classified as a corrosive that causes reversible inflammatory effects on living tissue by chemical action at the site of contact. With irritants, the inflammatory reaction can be reversed, whereas with corrosive damage, it is permanent or irreparable. Examples of irritants are acetic acid, ammonia and isopropyl alcohol. Wear required PPE (e.g. gloves) to prevent unexpected exposures to chemical irritants.

4.9.3. Pacemakers

Certain pieces of equipment such as reactive ion etchers and deposition tools utilize electromagnetic wave frequencies (e.g. RF, MW) that could interfere with pacemakers. It is recommended that users with pacemakers consult their physicians prior to working in the VINSE cleanroom.

4.9.4. Pregnancy

While every effort is made to control risks in the cleanroom, it is recommended that you and your health care provider discuss the potential risks present and precautions to take if you are pregnant or planning to become pregnant.

5. Cleanroom Equipment

Unrestricted access to the VINSE cleanroom does not permit use of any tool or process hood. Users must be trained on tool-specific procedures and policies to prevent safety issues and/or damage that could result from improper operation. Violation of these training requirements or carelessness on the part of a user could result in damage to equipment or facilities, extensive down-time affecting other researchers, considerable expense for repairs, and safety issues that threaten the health of facility users.

5.1. Equipment Malfunctions

All equipment problems or malfunctions shall IMMEDIATELY be reported to VINSE staff. Under no circumstances should a user attempt any repairs or recovery actions beyond what is specified in the operating instructions. If a tool stalls and is unresponsive to actions specified in procedures, verify the tool is in a safe condition and contact VINSE staff without taking any further actions. If the malfunction occurs after-hours when no VINSE staff is present, notify VINSE staff via the after-hours notification number for further instructions and place a handwritten note on the tool informing other users the tool is not available.

5.2. Equipment Maintenance

Tool maintenance shall only be performed by authorized VINSE staff. Users are not allowed to perform any maintenance no matter how minor the activity.

5.3. Equipment Availability

Any equipment that is identified as being unavailable (i.e. LOTO, OOS) shall not be operated under any circumstance. Attempting to use out of service equipment could cause injury to people and/or damage to the equipment.

5.4. Equipment Enclosures, Cabinets & Circuit Breakers

Circuit breakers shall only be manipulated by authorized VINSE staff. Under no circumstances shall any cleanroom user access and operate a circuit breaker. Furthermore, only authorized VINSE staff can open electrical enclosures or cabinets on tools even when power has been removed. Never stick hands, fingers or conductive tools inside equipment. If you feel an electrical “tingle” when touching a piece of equipment, stop using the tool and immediately notify VINSE staff. Potential electrical hazards shall be brought to the immediate attention of VINSE staff to protect all users of the cleanroom.

5.5. New Equipment

Any equipment or instrumentation that is not supplied or previously authorized by VINSE can NOT be brought into the cleanroom until it has been reviewed and approved

by the **Cleanroom Manager or designee**. User-supplied equipment shall only be allowed in the cleanroom at the discretion of VINSE management and shall only be used in accordance with any VINSE-specified limitations.

6. Waste Disposal

Only authorized VINSE staff are allowed to dispose of the following waste types in accordance with policies specified by VU EHS:

- Empty chemical bottles and containers
- Solid chemical waste
- Mercury-contaminated waste
- Unused chemicals
- Materials that users are uncertain about the appropriate disposal requirements

6.1. Liquid Waste

Liquid waste in the cleanroom can be disposed of or collected for disposal in three ways depending upon the type or lack of hazard(s) involved.

6.1.1. Acid Waste Neutralization System

Acid/base and water drains discharge to the ESB acid waste neutralization system (AWNS) where the combined effluents from the entire building are collected, pH neutralized and discharged to the city of Nashville's sanitary sewer. Liquid waste streams discharged to the AWNS are controlled by procedures to prevent discharge of materials that would violate local, state and federal laws. NEVER pour a chemical down a drain if you are uncertain whether it is appropriate. ALWAYS ask for guidance from VINSE staff if you are unsure.

6.1.2. Process Hood Integrated Carboys

Any liquid chemical waste that cannot be poured down the AWNS must be segregated into the appropriate carboys for collection and disposal by VU EHS. For certain waste streams associated with hood-specific processes, carboys are integrated into the process hood systems. The types of chemicals that can be poured down these integrated drain systems are strictly controlled by hood-specific procedures to prevent mixing incompatible waste streams that could create a serious safety hazard.

6.1.3. Localized Carboy Collection

Certain liquid waste streams must be collected in carboys that are not integrated into process hood drains but are handled as standalone collection units – i.e. waste containers are emptied directly into these carboys. This type of collection is controlled via procedures and/or the labeling on the carboy. NEVER pour waste into a localized carboy without first checking the carboy's label. If no carboy exists for the waste created, contact VINSE staff. When in doubt, do not proceed.

6.2. Solid Waste

Solid waste contaminated with chemicals or falling into specific categories is segregated by waste type and shall only be disposed of in the appropriately labeled container.

6.2.1. Solvent, Acid and Base Contaminated Waste

These waste streams are segregated by contamination type and collected in the appropriately labeled white, 5-gallon pails located near points of expected waste generation in the cleanroom

6.2.2. Sharps

Razor blades, syringe needles and other sharp objects shall be disposed of in the labeled red sharps containers.

6.2.3. Glass

Broken glassware, glass slides and glass wafers shall be disposed of in the labeled glass containers.

6.2.4. Metals

Metals are collected in the appropriately labeled container near the metal deposition tools.

6.2.5. Wafers and Other Substrates

Contact VINSE staff during normal business hours for wafer disposal.

6.2.6. General Waste Disposal

Solid waste uncontaminated with chemicals or not involving another hazard can be disposed of in the regular cleanroom waste baskets.

7. Emergency Response

From an emergency response standpoint, the primary goal is to prevent emergencies from developing through the use of engineered safety features (e.g. TGMS, equipment interlocks, locally-exhausted enclosures, construction material selection), administrative controls (e.g. procedures, material inventories and restrictions, codes, best practice guidance) and training. Unfortunately, experience has consistently shown that it is not possible to completely eliminate the possibility of emergencies that can threaten the health and safety of people or cause damage to equipment and facilities. Furthermore, most emergencies that do arise are unique in nature, making it impossible to plan for specific scenarios. From that perspective, it is important for cleanroom users to understand the operation of safety features available and the general response guidelines for addressing emergencies.

7.1. Assembly Locations

During an emergency that necessitates evacuation of the cleanroom, occupants shall assemble at the following locations to ensure everyone from the cleanroom is properly accounted for and to gather any information pertaining to the emergency situation:

Table 4 Assembly locations for cleanroom evacuation in order of evacuation priority

Evacuation Type	Assembly Location	Initiating Event
General ESB evacuation (ALWAYS includes the VINSE cleanroom)	Second/ground floor of 25th Avenue parking garage	ESB Fire Alarm
Local cleanroom evacuation ONLY (General ESB evacuation NOT required)	Gown or Pre-Gown Room outside VINSE Analytical Lab	Any event causing CLEANROOM evacuation ONLY – NO ESB fire alarm

7.2. Contact Information

Table 5 Important contact information for the VINSE cleanroom

Contact	Phone Number
EMERGENCY (From any VU phone)	911
EMERGENCY (From non-VU phone - e.g. personal cell phone)	615-421-1911
VINSE cleanroom cell phone	615-961-5157
VU EHS	615-322-4551
VU EHS 24/7 Emergency (VU Office of Public Safety)	615-421-1911

7.3. Response to Cleanroom Alarms

There are four systems that generate visual and audible alarms inside the VINSE cleanroom: (1) TGMS; (2) standalone fire alarm and suppression systems dedicated to each individual stainless-steel solvent hood; (3) emergency shower and eye wash stations; and (4) the general ESB fire alarm system. In addition there are several stacks of different colored lights or light towers that provide information on the operational condition of the TGMS and its interconnected components in the gas distribution and exhaust systems. Prior to discussing the expected responses to the various visual and audible alarms and indications, several general observations concerning the interrelationships among these systems need to be clarified:

- The general ESB fire alarm system does NOT initiate any visual or audible signal in any other cleanroom system.

- Certain conditions detected by the TGMS in the absence of a fire can actuate the general ESB fire alarm system in order to evacuate the entire ESB – e.g. large gas release that could create a danger outside the cleanroom.
- The discrete fire alarm and suppression systems integrated with each stainless-steel solvent hood will actuate the general ESB fire alarm system.

7.3.1. ESB Fire Alarm – General Building Evacuation

The general ESB fire alarm consists of a white flashing strobe and an audible notification. Inputs that initiate the general building fire alarm system are the following:

- Fire detected anywhere in the ESB including the cleanroom
- Manual actuation of the system at a building fire alarm pull-station
- Cleanroom TGMS high-level gas alarm for ambient environment
- Manual actuation of a cleanroom Emergency Gas Off (EGO) pull-station

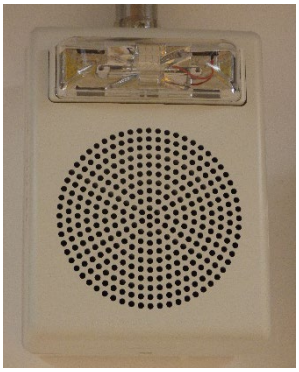

Figure 1 ESB Fire Alarm Light & Horn Combination

In all cases actuation of the ESB fire alarm system will result in complete evacuation of the building. Cleanroom occupants shall immediately exit the building without stopping to remove their cleanroom garments and assemble on the second/ground floor of the 25th Avenue parking garage.

7.3.2. Solvent Hood Fire Alarm – General Building Evacuation

Each stainless-steel solvent hood is equipped with a dedicated fire detection and suppression system consisting of an ultra-violet infrared (UVIR) sensor that can detect a localized fire in the hood, horn and strobe alarm combination mounted to a red box directly above the solvent hood, manual actuation pull-station and two CO_2 cylinders. When a UVIR sensor detects a flame inside a hood, a white strobe and audible alarm are actuated and two CO_2 cylinders are automatically released into the hood. For a localized solvent hood fire alarm actuation (i.e. fire entirely contained inside a stainless-steel solvent hood), a general ESB fire alarm will be actuated and occupants shall immediately exit the building without stopping to remove their cleanroom garments and assemble on the second/ground floor of the 25th Avenue parking garage.

Figure 2 Solvent Fume Hood Fire Alarm Light & Horn Combination

7.3.3. TGMS Alarms

The TGMS alarm system is made up of a blue flashing light and horn. Unless instructed otherwise by VINSE cleanroom staff, exit the cleanroom immediately if the TGMS blue light starts flashing with or without the horn and wait for further instructions in either the Gown or Pre-Gown room. If the general ESB fire alarm system actuates, exit the building immediately and assemble on the second/ground floor of the 25th Avenue parking garage.

Figure 3 TGMS Alarm Light & Horn Combination

7.3.4. TGMS Informational Light Stacks

In addition to the TGMS alarm system, there are two TGMS informational light stacks located at the main cleanroom exit to the Gown room and at the double-door exit to the HPM corridor at the rear of the bay and chase area. A third light stack is located in the second floor office suite where VINSE staff is located. Conditions corresponding to the different light colors are summarized in the table below.

Figure 4 TGMS Informational Light Stack

Table 6 TGMS light stack condition-response summary

Light Color	Label	Description
Green (Steady)	OK	TGMS and gas distribution & exhaust systems functioning properly with no gas release detected
White (Flashing)	Trouble	EGO manually actuated (Note: fire alarm will be actuated as well) --- OR --- Equipment malfunction (no fire alarm): o TGMS component o Part of the gas distribution system o Problem with exhaust system
Amber (Flashing)	Exhaust	Gas detection in an enclosure that is connected to a cleanroom exhaust system
Blue (Flashing)	Ambient	Gas detection --- OR --- Low oxygen concentration in open cleanroom environment

The TGMS light stacks provide information on the status of the system and its interconnected components in the gas distribution and exhaust systems. Users should always check the light stack upon entry to the cleanroom as well as periodically while working in the cleanroom. For a non-green condition seek clarification from VINSE staff before starting or continuing any work. If a VINSE staff member is not present, contact the after-hours phone IMMEDIATELY. NEVER try to diagnose the cause of a non-green light condition or ignore it.

7.4. Emergency Equipment

7.4.1. Safety Showers and Eyewash Stations

Safety showers and eyewash stations are located throughout the cleanroom at the front and rear of each bay and chase. To start the flow of water during an emergency, simply pull down the handle of the safety shower or push back the paddle on the eyewash. A flow sensor at each station will send an alarm to the VU BSC indicating the location of the actuation, resulting in VUPD being dispatched to investigate. Always be aware of the nearest safety shower and eyewash station when working in the cleanroom.

Figure 5 Typical Fire Alarm Pull-Station

7.4.2. ESB Sprinkler System

The cleanroom is equipped with a standard building sprinkler system that will actuate to release water when exposed to flame and heat. The individual sprinkler heads are equipped with fusible links that break from the heat produced by a fire or other source. A building-wide fire alarm is generated as a result of this actuation, causing evacuation of the ESB and dispatch of the fire department.

7.4.3. Manually-Actuated Emergency Devices

Fire Alarm Pull-Stations

Manual fire alarm pull stations should be actuated in the event of a fire or major event that, in the judgement of the observer, could threaten the life and safety of cleanroom or ESB occupants, such as a major chemical spill.

Emergency Gas Off Push-Buttons

Yellow Emergency Gas Off (EGO) stations are located near the exits from the cleanroom. They should be actuated when it becomes apparent that an uncontrolled process gas leak is in progress or has the potential to be initiated such as a mechanical accident shearing off gas piping that would result in uncontrolled gas release. NOTE: The EGO stations isolate toxic/corrosive and flammable gases that are distributed from

Figure 6 Emergency Gas Off (EGO) Push-Button

gas cabinets in the corrosives and flammable storage rooms to VMBs in the cleanroom. They do not isolate gases distributed from wall mounted panels in the flammable storage room.

Process Hood CO_2 Actuation Pull-Stations

Each stainless-steel solvent process hood has a red, fire-suppression actuation pull station on the front, left-hand side. These pull-stations actuate the localized release of two CO_2 cylinders inside the hood. Examples

- An uncontrolled fire has developed in the hood and the integrated UVIR sensor did not actuate the automatic release of CO_2
- A small fire has developed that cannot be put out safely and is in danger of spreading

Tool-Specific Devices

All major tools and instruments as well as most process hoods are equipped with large, red emergency machine off (EMO) or emergency power off (EPO) switches. Unless stated explicitly in the tool-specific procedure, these devices are to be used only during emergency situations when normal abort features associated with the equipment (e.g. software "stop" radio-buttons) are inadequate, unresponsive or non-existent. NEVER use an EMO for non-emergencies, such as flickering plasma, abnormally long pump down times, process instabilities that do not threaten the tool, software freezing tool operation, unexpected halting of tools in the middle of a process with no indication of impending damage, wrong process recipe selected, etc. Recovery from an EMO/EPO actuation can only be performed by an authorized VINSE staff member. Examples of emergencies that require EMO/EPO actuation include:

- Fire or smoke from the tool
- Injury or protection of the health and safety of individuals using the equipment
- Spill that could create a fire, electrical short or other hazard
- Electrical arcing
- Uncontrollable equipment function that could cause damage – e.g. impending crash of a robot arm
- Unexpected/abnormal grinding or other loud mechanical noises

7.5. First-Aid & Medical Attention

For handling minor cuts and burns, first-aid kits are located in the Pre-Gown room, mounted to the wall near the HPM double-door exit and mounted to the wall near the process hoods in the chase. Calcium gluconate gel is available in the first-aid kits mounted to the walls of the cleanroom, close to where hydrofluoric acid (HF) is authorized for use. The ESB has one automatic external defibrillator (AED) unit located on each floor. The nearest AED to the cleanroom is located just outside the Pre-Gown room.

7.6. Chemical Exposure

Chemicals used in the cleanroom have the highest potential for creating emergency situations given the "hands-on" nature of their use, wide variety of processes they are used in, and difficulty of controlling via engineering means. Furthermore, many users tend to develop a complacent attitude when repeatedly performing the same or similar wet chemical procedures. It is critical for all cleanroom users to understand the appropriate actions to take in response to different types of chemical exposure scenarios. This understanding is important not only for cleanroom users to protect themselves but also to allow them to lend assistance to fellow cleanroom users.

7.6.1. Skin: Non-corrosive Chemical Exposure

Chemicals that are not classified as corrosives and do not cause skin burns include the following:

- Acetone
- Isopropanol (IPA)
- Methanol
- Ethanol
- Uncontaminated oils and greases
- Photoresist

Skin exposure of these chemicals may be handled as follows:

1. REMOVE any contaminated clothing;
2. WASH the affected area(s) thoroughly with soap and water for 15 minutes;
3. REPORT the incident to VINSE staff;
4. CONSULT the appropriate SDS for further actions.

7.6.2. Skin: Corrosive Chemical Exposure - NO Hydrofluoric Acid

VICTIM actions:

1. CALL loudly for help while proceeding to the nearest safety shower;
    - Keep calling for help until someone is able to offer assistance
2. PULL the lever at the safety shower to initiate water flow;
3. REMOVE all contaminated clothing under the safety shower;
    - Pull clothing away from body to prevent additional contamination from chemicals that may have saturated clothing
    - Tear or cut with a scissors clothing that cannot be removed from body without spreading chemical(s) – e.g. do NOT pull shirts over your head
    - Do NOT worry about preserving your clothing since the chemicals that have saturated it cannot be cleaned out
    - Be aware of secondary contamination caused by water washing chemicals into initially uncontaminated clothing – if in doubt, REMOVE ALL CLOTHING!

4. RINSE continuously for a **minimum of <u>15 minutes</u>**;
    - Do NOT rub areas exposed to chemicals but allow the water to thoroughly rinse these spots
    - Pay particular attention to allowing the water flow to rinse areas that are hard to reach such as underneath finger nails, skin folds, etc.
    -
5. INFORM people assisting you about the chemical(s) involved, spill location, and other details that may be important for your safety and follow-up response to the emergency.
6. GO TO a medical emergency room for evaluation and further assistance

ASSISTANT actions:

- Ensure victim stays in safety shower for a minimum of 15 minutes
- Assist victim without contaminating yourself
- Call the campus emergency number: 911 from any campus phone (615-421-1911 from any other phone)
- Get as much information as possible from the victim about the incident and provide all relevant information to emergency responders
    - Name of victim
    - Emergency contact for victim
    - SDS(s) for chemical(s) involved
    - Location of incident
    - Additional safety concerns
- Get a disposable set of cleanroom coveralls and shoe covers for the victim to wear after they have exited the emergency shower after 15 minutes
- Consult the appropriate SDS for further actions
- Evaluate if additional emergency response actions are necessary once the victim has been stabilized and additional help is available – e.g. chemical spill response
- Contact VINSE staff

7.6.3. Skin: Corrosive Chemical Exposure – Hydrofluoric Acid

VICTIM actions:

1. CALL loudly for help while proceeding to the nearest safety shower;
    - Keep calling for help until someone is able to offer assistance
2. PULL the lever at the safety shower to initiate water flow;
3. REMOVE all contaminated clothing under the safety shower;
    - Pull clothing away from body to prevent additional contamination from chemicals that may have saturated clothing
    - Tear or cut with a scissors clothing that cannot be removed from body without spreading chemical(s) – e.g. do NOT pull tee shirts over your head
    - Do NOT worry about preserving your clothing since the chemicals that have saturated it cannot be adequately cleaned

- Be aware of secondary contamination cause by water washing chemicals into initially uncontaminated clothing – if in doubt REMOVE ALL CLOTHING!

4. RINSE continuously for **5 minutes**;
    - Do NOT rub areas exposed to chemicals but allow the water flow to thoroughly rinse these spots
    - Pay particular attention to areas that are hard to rinse such as underneath finger nails, skin folds, etc.
5. APPLY **calcium gluconate gel** to contaminated skin locations;
    - Massage the gel into the skin while wearing gloves
    - Use gel generously over affected area(s) until told to stop by a qualified medical professional such as a doctor
    - Take the gel with you while being transported for medical attention
6. INFORM people assisting you that HF was involved, the spill location and other details that may be important for your safety and follow-up response to the emergency.
7. GO TO a medical emergency room for evaluation and further assistance

ASSISTANT actions:

- Ensure victim stays in safety shower for a maximum of 5 minutes
- Get calcium gluconate gel for victim along with clean gloves for applying to skin
- Assist victim without contaminating yourself
- Call the campus emergency number, 911 from any campus phone (615-421-1911 from any other phone)
- Get as much information as possible from the victim about the accident and provide all relevant information to emergency responders
    - Name of victim
    - Emergency contact for victim
    - SDS(s) for chemical(s) involved
    - Location of accident
    - Additional safety concerns
- Bring a disposable set of cleanroom coveralls and shoe covers to the victim
- Evaluate if additional emergency response actions are necessary once the victim has been stabilized and additional help is available – e.g. chemical spill response
- Contact VINSE staff

7.6.4. Eyes: Chemical Exposure – NO Hydrofluoric Acid

VICTIM actions:

1. CALL loudly for help while proceeding rapidly to the nearest eyewash station;
    - Keep calling for help until someone is able to offer assistance;
2. PUSH the lever at the eyewash station to initiate water flow;
3. RINSE eyes continuously in the eyewash for a **minimum of 15 minutes**;

- Hold eyes wide open and completely rinse eyes in water
- It may be necessary to physically hold your eye lids open to allow water to thoroughly flood your eyes
- Do NOT rub your eyes; allow the water flow to rinse chemicals out
- Do NOT use your gloved hand to pry your eyes open since the gloves may be contaminated with chemicals; remove your gloves or have someone assist you
- If you feel your bare hands may be contaminated with chemicals, do NOT put them anywhere near your eyes or other unprotected body parts – ASK FOR HELP!
- If you are wearing contact lenses, remove them while rinsing in the eyewash station. Do NOT try to remove contacts before using the eyewash station.
- GO TO a medical emergency room for evaluation and further assistance

4. INFORM people assisting you about the chemical(s) that splashed into your eyes and where you were working.

ASSISTANT actions:

- Ensure the victim holds eyes open in the eyewash station for a minimum of 15 minutes
- Assist the victim as necessary, such as by holding their eyes open in the eyewash station, without contaminating yourself
- Call the campus emergency number: 911 from any campus phone (615-421-1911 from any other phone)
- Get as much information as possible from the victim about the accident
    - Name of victim
    - Emergency contact for victim
    - SDS(s) for chemical(s) involved
    - Location of accident
    - Additional safety concerns
- Evaluate if additional emergency response actions are necessary once the victim has been stabilized
- Contact VINSE staff

7.6.5. Eyes: Chemical Exposure – Hydrofluoric Acid

VICTIM actions:

1. CALL loudly for help while proceeding rapidly to the nearest eyewash station;
    - Keep calling for help until someone is able to offer assistance;
2. PUSH the lever at the eyewash station to initiate water flow;
3. RINSE eyes continuously in the eyewash for **5 minutes**;
    - Hold eyes wide open and completely rinse eyes in water

- It may be necessary to physically hold your eye lids open to allow water to thoroughly flood your eyes
- Do NOT rub your eyes; allow the water flow to rinse chemicals out
- Do NOT use your gloved hand to pry your eyes open since the gloves may be contaminated with chemicals; remove your gloves or have someone assist you
- If you feel your bare hands may be contaminated with chemicals, do NOT put them anywhere near your eyes or other unprotected body parts – ASK FOR HELP!
- If you are wearing contact lenses, remove them while rinsing in the eyewash station. Do NOT try to remove contacts before using the eyewash station.

4. Apply calcium gluconate eyewash to eyes;
    - Drip sterile 1% calcium gluconate solution continuously into eyes
    - Do NOT use 2.5% calcium gluconate GEL on the eyes
    - Use eyewash generously in affected area(s) until told to stop by a qualified medical professional such as a doctor
    - Take the eyewash with you while being transported for medical attention
5. INFORM people assisting you about the chemical(s) that splashed into your eyes and where you were working, and that HF was involved.
6. GO TO medical emergency room for evaluation and further assistance.

ASSISTANT actions:

- Ensure the victim holds eyes open in the eyewash station for a 5 minutes
- Get calcium gluconate eyewash for victim along with clean gloves for applying to eyes
- Assist the victim as necessary, such as by holding their eyes open in the eyewash station, without contaminating yourself
- Call the campus emergency number: 911 from any campus phone (615-421-1911 from any other phone)
- Get as much information as possible from the victim about the accident
    - Name of victim
    - Emergency contact for victim
    - SDS(s) for chemical(s) involved
    - Location of accident
    - Additional safety concerns
- Evaluate if additional emergency response actions are necessary once the victim has been stabilized
- Contact VINSE staff

7.6.6. Inhalation

ACTIONS:

- REMOVE to fresh air to improve breathing
- CONSULT the appropriate SDS for further action
- CALL the campus emergency number if the victim is unconscious, having difficulty breathing or exhibiting other signs of distress: 911 from any campus phone (615-421-1911 from any other phone)
- Contact VINSE staff

7.7. Chemical Spills

The severity of a chemical spill can be greatly reduced by taking prompt action to limit its spread and potential effect on surrounding equipment. However, users should **NOT respond to chemical spills** under the following conditions:

- The spill involves HF or an HF-containing mixture, such as buffered oxide etch
- The nature of the chemical spilled is unknown – e.g. type, safety hazards, etc.
- The spill is outside of a process hood and fumes are present
- More than one chemical has been spilled
- You are not sure how to proceed
- You do not feel it is safe to clean up the spill
- You feel symptoms that could be attributed to the spill
- A secondary emergency – e.g. fire – is in progress
- The spill size exceeds the amount of absorbent material available

CONTINUOUSLY maintain situational awareness during spill response. If at any time you feel conditions have become unsafe or beyond your capabilities to handle safely:

1. NOTIFY ALL cleanroom occupants to exit the cleanroom
2. EXIT the cleanroom
3. CONTACT the appropriate emergency response personnel:
    - VINSE staff during normal working hours
    - VINSE phone after-hours (615-961-5157)
    - VU EHS 24/7 Emergency number if no response to VINSE phone within approximately 5 minutes or it is known VINSE staff members are unavailable
4. ACTUATE manual building fire alarm if at any time you feel the situation is a threat to the life and safety of anyone or has the potential to create such as a threat

Spill Response:

1. NOTIFY other users in the area about the hazard
2. RESPOND to any chemical contamination to personnel first – e.g. safety shower for skin contamination

3. CALL for assistance from a second user
4. IDENTIFY the chemical spilled to determine if you are capable of cleaning it up
5. CONSULT the appropriate SDS as necessary
6. PUT-ON protective gear
   - Chemical-resistant apron
   - Face-shield
   - Chemical-resistant gloves
7. OBTAIN absorbent materials:
   - Sufficient cleanroom wipes may be readily available for small spills
   - Absorbent pads are staged at the back of the cleanroom along with plastic bags and waste bucket
8. SURROUND spills that are spreading with absorbent pads or pillows
9. PLACE absorbent materials on top of spill working from the outside of the spill to the inside
10. PLACE all materials used for cleaning up spill into plastic bag or waste bucket and seal
11. CONTACT VINSE staff who will determine further required actions
12. SECURE area of spill until VINSE staff allow normal activities to resume

7.8. Water Flooding

In the event of a large and/or continuous WATER spill:

- Isolate the flow of water if possible or route it towards a drain
- Surround spill with materials to contain spread – e.g. cleanroom wipes – as necessary
- Clean-up the spill using VINSE-supplied wet vacuum cleaner and/or uncontaminated absorbent materials available in the cleanroom
- Contact VINSE staff to report the incident and/or for assistance

Do NOT attempt to clean up a water spill under the following conditions:

- The water has mixed or is in danger of combining with a chemical
- The water resulted from an emergency shower and/or eyewash station activation
- There is potential electrical shock hazard – e.g. water surrounding or flowing uncontrollably towards electric equipment
- Another emergency is in progress – e.g. fire alarm, gas release
- You are not comfortable addressing the situation or there are additional dangers present

7.9. Fire

In the event of a fire, the expected response for VINSE cleanroom users is R-A-C-E:

- **R** – REMOVE or RESCUE everyone from the cleanroom
- **A** – ACTIVATE the nearest fire alarm pull-station

- **C** – CONFINE the fire by closing cleanroom doors and, if applicable, lowering the sash on a process hood or activating the hood's fire suppression pull-station
- **E** – EVACUATE from the cleanroom and the ESB to the assembly area on the second/ground floor of the 25th Avenue parking garage

If your clothing catches on fire, extinguish it by any means possible:
- STOP-DROP-AND-ROLL on the ground to smother the flames
- Use a safety shower or eyewash station
- Use the water supply at a process hood
- Use cleanroom garments or other material to smother the flames

QUALIFIED individuals who are trained to use hand-held fire extinguishers as well as to understand the conditions under which they can be used may try to extinguish small cleanroom fires at their own risk. The cleanroom is equipped with wall-mounted Class ABC fire extinguishers that can be used to extinguish any type of fire except metal fires. When using a fire extinguisher, always start 8-10 feet away and walk towards the fire as you spray it with the fire extinguisher:

1. IDENTIFY a safe evacuation path from the fire
2. MAINTAIN your evacuation route behind you while approaching and extinguishing the fire
   - NEVER allow the fire, heat or smoke to come between you and your evacuation path
   - EVACUATE immediately if the extinguisher is empty and the fire is not out
   - EVACUATE immediately if the fire progresses beyond the incipient stage
3. EXTINGUISH the fire with fire extinguisher remembering P.A.S.S.
   a. **P** – PULL the pin to break the tamper seal
   b. **A** – AIM low pointing the extinguisher nozzle at the base of the fire
   c. **S** – SQUEEZE the handle to release the extinguishing agent
   d. **S** – SWEEP side-to-side at the base of the fire until it is put out

7.10. Broken Mercury-Containing Devices

Mercury (Hg) is toxic to the central and peripheral nervous system and if inhaled can damage the lungs, kidneys, and digestive, nervous and immune systems. Disposal of the resulting waste is strictly controlled from a regulatory standpoint. With these considerations, it is important that any Hg clean-up and disposal be handled only by qualified personnel.

7.10.1. Mercury Arc Lamps

Pressurized Hg arc lamps are used in lithography exposure tools as a source of ultraviolet light. The lamp housings of these tools are vented to the cleanroom exhaust system. In the event that a lamp explodes, do NOT attempt to clean up the tool or to recover any process samples. Notify other cleanroom users in the area, exit the bay where the

exposure tool is located and contact VINSE staff to address the situation. The lamp housing exhaust should remove all Hg vapors generated while components cool down from their elevated operating temperatures. VINSE staff will clean up the tool and provide notification when activities can resume in the bay.

7.10.2. Thermometers & Other Sources

If any unheated Hg-containing device, such as a Hg thermometer, breaks, notify other users in the area and contact VINSE staff for assistance. Do NOT try to clean up the Hg spill. If there is any danger of the Hg spreading or becoming airborne, notify others in the area and exit the bay. Do NOT re-enter the bay until VINSE staff provide notification that activities can resume.

7.11. Reporting Requirements

Any response to an emergency involving one or more of the following events shall be immediately reported to VINSE staff and/or VU emergency response personnel (e.g. VU EHS, VUPD):

- Equipment abnormality that results in damage to equipment or actuation of an EMO/EPO pushbutton
- Accident involving chemicals, compressed gases, electricity, ultraviolet light or other safety hazard in the cleanroom
- Accident resulting in injury to an individual
- Actuation of any safety device such as eyewash station, safety shower, fire extinguisher

Reporting an incident shall occur as soon as possible due to legal reporting requirements with government agencies in some instances. A written summary of the details may be requested if a personal injury or safety system actuation is involved. Details to report are the following:

- Time and date of incident
- Individuals involved including victim(s), victim assistant(s) and/or witness(es)
- Personal injuries resulting from the incident
- Location of incident along with equipment, chemical(s) and process(es) involved
- Actions taken
- Status of incident (e.g. stabilized, safe condition, on-going, growing)
- Any other information that could be important for further corrective actions or clarifying the details of the incident – i.e. too much information is better than not enough or confusing information

Reporting forms are located on tables in every process bay as well as in the Pre-Gown room. When unable to inform VINSE staff directly, these reporting forms shall be completed and provided to the VINSE staff when available.

8. Acronyms

ACGIH	American Conference of Governmental Industrial Hygienists
AED	Automated External Defibrillator
ANSI	American National Standards Institute
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
AWNS	Acid Waste Neutralization System
BOE	Buffered Oxide Etch
BSC	Building Systems Control
CDA	Compressed Dry Air
CGA	Compressed Gas Association
CFR	Code of Federal Regulations
CHP	Chemical Hygiene Plan
CVD	Chemical Vapor Deposition
GFCI	Ground Fault Circuit Interrupter
EGO	Emergency Gas Off
EMO	Emergency Machine Off
EPO	Emergency Power Off
ESB	Engineering and Science Building
HEPA	High-Efficiency Particulate Air
HPM	Hazardous Process Materials
IARC	International Agency for Research on Cancer
IBC	International Building Code
IDLH	Immediately Dangerous to Life or Health
IFC	International Fire Code
LN2	Liquid Nitrogen
LOTO	Lock-Out Tag-Out
MSDS	Material Safety Data Sheet now referred to Safety Data Sheet (SDS)
NFPA	National Fire Protection Association
NIOSH	National Institute of Occupational Safety and Health
OCRS	Office of Clinical and Research Safety (formerly VEHS)
OJT	On-the-Job Training
OOS	Out-of-Service
OSHA	Occupational Safety and Health Administration
PCW	Process Chilled Water
PEL	Permissible Exposure Limit
POU	Point of Use
PPE	Personal Protective Equipment

PI	Principal Investigator
QDR	Quick Dump Rinse
RAHU	Recirculating Air Handling Unit
RFO	Restrictive Flow Orifice
RH	Relative Humidity
RO	Reverse Osmosis
SDS	Safety Data Sheet formerly referred to Material Safety Data Sheet (MSDS)
SEMI	Semiconductor Equipment and Materials International
SOP	Standard Operating Procedure
TGM	Toxic Gas Monitoring
TGMS	Toxic Gas Monitoring System
TLV	Threshold Limit Value
TOSHA	Tennessee Division of Occupational Safety and Health
ULPA	Ultra-Low Particulate Air
UV	Ultraviolet
UVIR	Ultraviolet Infrared
VINSE	Vanderbilt Institute of Nanoscale Science and Engineering
VMB	Valve Manifold Box
VOP	VINSE Operating Procedure
VU	Vanderbilt University
VUPD	Vanderbilt University Police Department
VU EHS	Vanderbilt University Environmental Health and Safety

9. Definitions

Automated External Defibrillator (AED)	A portable electronic device that automatically diagnoses the life-threatening cardiac arrhythmias of ventricular fibrillation and ventricular tachycardia in a patient and is able to treat them through defibrillation, which is the application of electrical therapy that stops the arrhythmia, allowing the heart to establish effective rhythm.
Chemical *(29 CFR 1910.1200)*	Any substance or mixture of substances.
Cleanroom	A defined building environment with a controlled level of contamination (e.g. dust, airborne microbes, aerosol particles, chemical vapors) that is specified by the number of particles at a specified size per unit of air volume.
Emergency	Any occurrence such as but not limited equipment failure, rupture of containers or failure of control equipment which results in an uncontrolled release of a "Hazardous Chemical" into the workplace.
Hazardous Chemical *(29 CFR 1910.1200)*	Any chemical which is classified as a "Physical Hazard" or a "Health Hazard," a "Simple Asphyxiant," "Combustible Dust," "Pyrophoric Gas" or "Hazard Not Otherwise Classified" (HNOC).
Hazard Not Otherwise Classified (HNOC) *(29 CFR 1910.1200)*	Adverse physical or health effect identified through evaluation of scientific evidence during the classification process that does not meet the specified criteria for the physical and hazard classes addressed in 29 CFR 1910.1200. This does not extend coverage to adverse physical and health effects for which there is a hazard class addressed in 29 CFR 1910.1200 but the effect either falls below the cut-off value/concentration limit of the hazard class or is under a GHS hazard category that has not been adopted by OSHA (e.g. Acute Toxicity Category 5).
Health Hazard	Chemical that is classified as posing one of the following hazardous effects: 1. Acute toxicity (any route of exposure) 2. Skin corrosion or irritation 3. Serious eye damage or eye irritation 4. Skin or respiratory sensitization 5. Germ cell mutagenicity 6. Carcinogenicity 7. Reproductive toxicity 8. Specific organ toxicity (single or repeated exposure) 9. Aspiration hazard

Laboratory	Facility where "Laboratory Use of Hazardous Chemicals" occurs; workplace where relatively small quantities of hazardous chemicals are used on a non-production basis.
Laboratory Scale	Work with substances in which the containers used for reactions, transfers and other handling substances are designed to be easily and safely manipulated by one person; excludes those workplaces whose function is to produce commercial quantities of materials.
Laboratory-Process/Fume Hood	Device located in a laboratory; enclosure on five sides with a moveable sash or fixed partial enclosed on the remaining side; constructed and maintained to draw air from the laboratory and to prevent or minimize the escape of air contaminants into the laboratory; and allows chemical manipulations to be conducted in the enclosure without insertion of any portion of the employee's body other than hands and arms.
Laboratory Use of Hazardous Chemicals	Handling or use of such chemicals in which all of the conditions are met: 1. Chemical manipulations are carried on a "Laboratory Scale;" 2. Multiple chemical procedures or chemicals are used; 3. Procedures used are not part of production process nor in any way simulate a production process; and 4. "Protective Laboratory Practices and Equipment" are available and in common use to minimize the potential for employee exposure to hazardous chemicals.
Mutagen	Chemicals that cause permanent changes in the amount or structure of the genetic material in a cell.
Physical Hazard	Chemical classified as posing one of the following hazardous effects: 1. Explosive 2. Flammable (gases, aerosols, liquids or solids) 3. Oxidizer (liquid, gas or solid) 4. Self-reactive 5. Pyrophoric (gas, liquid or solid) 6. Self-heating 7. Organic peroxide 8. Corrosive to metal 9. Gas under pressure 10. In contact with water emits flammable gas 11. "Combustible Dust" per 29 CFR 1910.1200 Criteria for determining whether a chemical is classified as a physical hazard are in Appendix B of the Hazard Communication Standard 29 CFR 1910.1200.

Protective Laboratory Practices and Equipment	Laboratory procedures, practices and equipment accepted by laboratory health and safety experts as effective or that the employer can show to be effective in minimizing the potential for employee exposure to hazardous chemicals.
Pyrophoric Gas *(29 CFR 1910.1200)*	Chemical in a gaseous state that will ignite spontaneously in air at a temperature of 130 degrees F (54.5 degrees C) or below.
Reproductive Toxins	Chemicals that affect the reproductive capabilities including adverse effects on sexual function and fertility in males and females as well as adverse effects on the development of the offspring. Chemicals classified as "Reproductive Toxins" in accordance with the "Hazard Communication Standard" (29 CFR 1910.1200) shall be considered reproductive toxins for purposes of 29 CFR 1910.1450.
Safety Data Sheet (SDS) *(29 CFR 1910.1200)*	Written or printed material concerning a hazardous chemical that is prepared in accordance with 29 CFR 1910.1200(g) and consists of 16 sections: 1. Identification; 2. Hazard(s) Identification; 3. Composition (Information on Ingredients); 4. First-Aid Measures; 5. Fire-Fighting Measures; 6. Accidental Release Measures; 7. Handling and Storage; 8. Exposure Controls/Personal Protection; 9. Physical and Chemical Properties; 10. Stability and Reactivity; 11. Toxicological Information; 12. Ecological Information; 13. Disposal Considerations; 14. Transport Information; 15. Regulatory Information; and 16. Other Information including date of preparation or last revision.
Select Carcinogen	Any substance which meets one of the following criteria: 1. Regulated by OSHA as a carcinogen; or 2. Listed under the category "Known To Be Carcinogens" in the annual report on carcinogens published by the National Toxicology Program (NTP) (latest edition); or 3. Listed under Group 1 ("Carcinogenic to Humans") by the International Agency for Research on Cancer monographs (IARC) (latest edition); or 4. Listed in either Group 2A or 2B by IARC or under the category "Reasonably Anticipated to be Carcinogens" by

	NTP and causes statistically significant tumor incidence in experimental animals in accordance with any of the following criteria: a. After inhalation exposure of 6-7 hours per day, five days per week, for a significant portion of a lifetime to dosages of less than 10 mg/m^3; or b. After repeated skin application of less than 300 (mg/kg of body weight) per week; or c. After oral dosages of less than 50 mg/kg of body weight per day.
Simple Asphyxiant	Substance or mixture that displaces oxygen in the ambient atmosphere and can thus cause oxygen deprivation in those who are exposed leading to unconsciousness and death